Switzerland's Eighth National Communication and Fifth Biennial Report under the UNFCCC

Fifth National Communication under the Kyoto Protocol to the UNFCCC

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Annex C Responses to recommendations and encouragements: Authors of the respective sections in the main text.

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Foreword

While Switzerland submits its eighth national communication and fifth biennial report, the synthesis report of the sixth assessment report of the Intergovernmental Panel on Climate Change is in the final phase of editing. Yet, the core statement is set out in the report of Working Group I, which was published more than a year ago: For global warming not to exceed the threshold of 1.5 degrees Celsius emissions of greenhouse gases need to be curbed drastically. Avoiding irreversible changes in many areas of the global atmosphere-biosphere-hydrosphere system becomes an increasingly challenging task. Tackling this task is essential if we want to preserve the greatest possible scope for future generations to shape their lives in a prosperous way. At the same time, we must also prepare for the inevitable impacts of climate change. For this purpose, the Swiss government adopted its second action plan for the implementation of the national adaptation strategy in 2020.

News headlines may have turned away from global warming recently. The challenge to reduce greenhouse gas emissions as much as possible remains. The potentials are well known: With more renewable energies and CO_2-neutral transport, less waste and more resource efficiency, Switzerland can reduce its greenhouse gas emissions far below today's levels. Suitable technologies are available and their implementation is economically viable. Moreover, recent geopolitical developments have given us even more reasons to reduce our heavy dependence on fossil fuels.

In April 2022, with the presentation of the greenhouse gas inventory 2020, Switzerland took stock of the achievement of its climate target under the second commitment period of the Kyoto Protocol. The balance sheet shows that the emissions target of minus 15.8 per cent compared to 1990 was achieved in the period from 2013 to 2020. Emission reductions from climate protection projects abroad also contributed to this positive result.

Now it is time to look ahead. By submitting its nationally determined contribution, Switzerland has committed to at least halving its greenhouse gas emissions by 2030 compared to 1990, which corresponds to an average reduction in greenhouse gas emissions of at least 35 per cent in the period from 2021 to 2030. To achieve the target, internationally transferred mitigation outcomes from cooperation under Article 6 of the Paris Agreement are to be used in part. In preparation for this, Switzerland has concluded several bilateral agreements with partner countries. The agreements set the framework conditions for cooperation and define the requirements for the recognition of internationally transferred mitigation outcomes in line with the high standards that Switzerland and the other members of the Environmental Integrity Group stand for.

Domestically, the transition to an energy system that relies more on renewable energy is underway. Considerable funding is being made available to expand and accelerate decarbonisation. The new version of the third CO_2 Act, which is currently under discussion, envisages supplementing the CO_2 levy with effective incentives, targeted support and subsidies. The debate on the future legal framework of Swiss climate policy is also shaped by the so-called 'Glacier Initiative', a popular initiative that seeks to stipulate the goal of reducing Switzerland's greenhouse gas emissions to net zero by 2050 in the Federal Constitution of the Swiss Confederation. The final decisions are expected in the course of the year 2023.

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September 2022

1 Executive summary

1.1 Introduction

Switzerland prepared its eighth national communication under the United Nations Framework Convention on Climate Change (UNFCCC) following the revision of the UNFCCC reporting guidelines on national communications for Parties included in Annex I to the Convention (see the annex to decision 6/CP.25).

Switzerland presents its fifth biennial report as an annex to the eighth national communication (Annex B), with detailed reporting of the information on the common topics in the main text of the national communication. The fifth biennial report was prepared based on the UNFCCC biennial reporting guidelines for developed country Parties (decision 2/CP.17). The accompanying tables correspond to the common tabular format (BR CTF tables, decision 19/CP.18). Switzerland took into consideration the methodologies for the reporting of financial information by Parties included in Annex I to the Convention (decision 9/CP.21), also implementing the revisions to the common tabular format. The supplementary information under Article 7, paragraph 2, of the Kyoto Protocol, as requested by decision 22/CP.7, is contained in different chapters and sections of Switzerland's eighth national communication and summarised in Annex A.

In preparation of the eighth national communication and the fifth biennial report, Switzerland took into account the issues raised by the expert review teams in the course of the reviews of the previous reports. To assist the review process, Annex C provides detailed answers to every recommendation and encouragement from the 'Report of the technical review of the seventh national communication of Switzerland' (FCCC/IDR.7/CHE) and the 'Report of the technical review of the fourth biennial report of Switzerland' (FCCC/TRR.4/CHE). The following sections provide a summary of the chapters contained in Switzerland's eighth national communication.

1.2 National circumstances relevant to greenhouse gas emissions and removals

Government structure

Switzerland is a confederation, subdivided into 26 cantons (states), each of which has its own government, parliament and cantonal courts. Responsibilities are shared between the federal authorities and the cantons, however, the principle of subsidiarity is of greatest importance. This is reflected in constitutional law, stipulating that unless legislative power is explicitly assigned to the Swiss Confederation (federal level), the cantons are sovereign, i.e. entitled to legislate in an area of policy. At the federal level, the following separation of powers is established: (i) the legislative authority at the federal level consists of a bicameral parliament, with the 200 members of the National Council representing the population of the country as a whole and the 46 members of the Council of States representing the cantons (together forming the Federal Assembly, i.e. the Swiss Parliament), (ii) the executive authority at the federal level is the Swiss Federal Council, consisting of seven members with equal power, and (iii) the highest judicative authority of the country is the Federal Supreme Court. However, according to the Federal Constitution of the Swiss Confederation, the Swiss people are sovereign and ultimately the supreme political authority. Consequently, virtually all important decisions have to be approved by the electorate (i.e. adults who are eligible to vote, about 63 per cent of the resident population). The most important formal instruments of Switzerland's direct democracy are (i) the optional referendum which allows citizens to veto decisions made by the Swiss Parliament, (ii) the mandatory referendum on each constitutional amendment passed by the Swiss Parliament, and (iii) the popular initiative by which citizens can propose amendments to the Federal Constitution of the Swiss Confederation.

Due to the very close economic ties of Switzerland with neighbouring states and the European Union, the relationship with the European Union is a high priority of Swiss foreign policy. Bilateral agreements are the legal basis of this close cooperation and most new laws or amendments to existing laws are made compatible with European Union legislation. Switzerland is a member of several international organisations (e.g. the OECD, the World Bank Group and all United Nations specialised agencies). Since September 2002, Switzerland has been a full member of the United Nations.

Population profile

At the end of 2020, Switzerland had a population of 8.670 million permanent residents with an average a density of 210 persons per square kilometre. Population is concentrated on the Central Plateau, the major alpine valleys and the Ticino, while the density is substantially lower in the hilly and alpine regions of the country. Population growth has been stable at around 0.75 per cent per year during the last years and mainly results from immigration and increasing life expectancy. It is expected that population growth will continue in the future, leading to 10.44 million permanent residents by 2050. Approximately 25.5 per cent of the permanent residential population are foreign nationals.

Economic profile

Switzerland's nominal gross domestic product was about 706 billion Swiss francs in 2020, corresponding to about 81 thousand Swiss francs per capita. With just a few exceptions in the early 1990s, in 2009 and in 2020, Switzerland's real gross domestic product increased annually by up to four per cent compared to the previous year over the period 1990 to 2020. Switzerland's economy largely depends on the services sector, which in 2020 not only employed 76.4 per cent of the total workforce, but also contributed 73.3 per cent to the gross value added.

The economy strongly depends on trade with other countries, as Switzerland imports bulk raw materials and exports processed high-quality goods. Switzerland's trade balance (exports minus imports) was about balanced between 1992 and the early 2000s. Since 2002, exports growth has been accelerating as compared to imports growth. During the last years, Switzerland's trade balance has remained between about four and five per cent of the gross domestic product. Among the most important traded goods in terms of monetary value are chemical and pharmaceutical products, noble metals, jewels and gemstones, machines, instruments and electronics, watches and precision instruments.

Geographical profile

Switzerland, located in the centre of Europe, covers an area of 41,285 square kilometres, comprising 25.1 per cent unproductive surface, 31.8 per cent forests and grove, 35.2 per cent utilised agricultural area, and 7.9 per cent built-up area. The topography is determined by the Central Plateau, the Jura mountains and the Alps. About half of Switzerland's surface area is located above 1,000 metres above sea level.

Climate profile

With the Alps acting as climatic divide, meteorological conditions such as average temperature and precipitation vary significantly across Switzerland. Variable winter temperatures are an important factor influencing energy consumption for heating and leave a strong imprint on annual CO_2 emissions. Long-term measurements indicate a marked shift towards a warmer climate (increase of the mean temperature by more than two degrees Celsius between 1864 and 2020, i.e. about twice the increase of the global mean temperature). Changes in mean precipitation are less clear, although there are robust indications for an increase in the frequency and intensity of heavy precipitation. Various climate indices document the ongoing climate change in Switzerland. For instance, over the Central Plateau, the average number of summer days has more than doubled over the last 60 years, the number of heating degree days has decreased by about 15 to 20 per cent in the same time period, the number of snow days has decreased and the number of sunny days has increased.

Energy

Switzerland's energy system largely depends on fossil energy imports, while it is almost self-sufficient regarding carbon-free electricity. In 2020, gross energy consumption amounted to just slightly over one million terajoules, composed as follows: (i) 287,010 terajoules were of domestic origin (50.9 per cent hydropower, 21.1 per cent waste, 15.0 per cent wood, 13.0 per cent other renewable energy sources), (ii) 872,180 terajoules were imported (45.0 per cent crude oil and oil products, 13.7 per cent gas, 28.8 per cent nuclear fuel, 11.1 per cent electricity, 1.0 per cent wood and other renewable energy resources, and 0.4 per cent coal), (iii) exports accounted for a total of 136,150 terajoules (86.1 per cent electricity, 13.9 per cent oil products, 0.1 per cent wood), and (iv) the remaining 20,930 terajoules corresponded to stock changes of mainly crude oil, but also oil products and coal. Due to the impact of meteorological conditions on heating demand, the final energy consumption shows strong year-to-year variations, however, a decreasing trend has become discernible since about a decade.

Transport

Switzerland's transport infrastructure provides for extensive road and rail networks serving individual and freight transport needs. This includes comprehensive public transportation services. The number of cars in Switzerland has increased from 3.0 million in 1990 to 4.7 million in 2020. Between 1980 and 2015, motorised private transport (total passenger kilometres) has increased by 43.9 per cent and public transport on road and rail (total passenger kilometres) has increased by 83.4 per cent, as a result of population growth as well as the increase in daily travel distance per person. By 2020, freight transport (in tonne-kilometres) has increased by 36 per cent since 1990, with the share of rail fluctuating around 40 per cent. However, transalpine freight transport in Switzerland is dominated by rail, inter alia, thanks to newly constructed railway tunnels. Given the relatively short distances and the dense and efficient road and railway networks, the share of domestic aviation is negligible.

Industry and services

The structure of Switzerland's industry sector clearly reflects the fact that the country is relatively poor in natural resources. Switzerland's industry is specialised in the production of mechanical devices and engines, data processing equipment, and high-precision instruments (watches and goods for medical uses). Of greatest importance are the food processing and chemical industries, in particular the production of pharmaceutical articles. However, Switzerland's economy is largely based on the highly diverse services sector, with the following most important branches (in descending order of gross value added): (i) wholesale trade, (ii) real estate activities, (iii) legal advice, architecture, consultancy, (iv) financial service activities, (v) human health activities, (vi) insurance, reinsurance and pension funding, and (vii) retail trade.

Waste

With regard to waste treatment, Switzerland has efficient infrastructure, high operating standards and clear legal stipulations in place. In concert with increasing prosperity and the steady growth of population, the total amount of municipal solid waste generated in Switzerland has increased by 49 per cent between 1990 and 2020 and accounted for about six million tonnes in 2020 (about 700 kilograms per person). Thereof, 2.9 million tonnes were incinerated and 3.2 million tonnes were recycled (landfilling of combustible waste is banned since the year 2000). In Switzerland, the wastewater of virtually the entire population (about 97 per cent) is sewered to a wastewater treatment plant.

Building stock and urban structure

At the end of 2020, the building stock in Switzerland consisted of 1.8 million buildings with at least partial residential use, corresponding to an increase of 37 per cent compared to 1990. Between 1990 and 2020, the energy reference area of buildings in the services sector has increased by 35 per cent, of buildings in the industry sector by 27 per cent, and of buildings for residential use by 50 per cent. In 2015, 63 per cent of all buildings were heated with fossil fuels. Heat pumps accounted for about 70 per cent of heating systems installed in newly constructed buildings during 2011–2015. Switzerland's urban structure may be best described by the term 'network city', i.e. a large number of interconnected 'nodes' with high densities of population, goods and information which have an extensive and efficient mutual exchange.

Agriculture

In 2020, Switzerland's utilised agricultural area (excluding alpine pastures) accounted for 25.3 per cent of the total land surface. When alpine pastures are included, the agricultural land surface covers more than a third of the total land surface. The number of farms has decreased by one third during the last about 20 years. A large share of farms keep ruminants. The number of cattle has decreased by 22 per cent between 1990 and 2020, while productivity per animal has been on the rise.

Forest

A third of Switzerland is covered by forests, with more than half of the forest being located above 1,000 metres above sea level. Of the 421 million cubic metres wood stocked in Swiss forests, 32 per cent arise from deciduous trees and 68 per cent arise from coniferous trees. Since 1983–1985, the forest area has increased by 11 per cent. Forest growth was significant in the Alps, while the forest area on the Central Plateau and in the Jura mountains remained about stable.

Relationship between national circumstances and greenhouse gas emissions

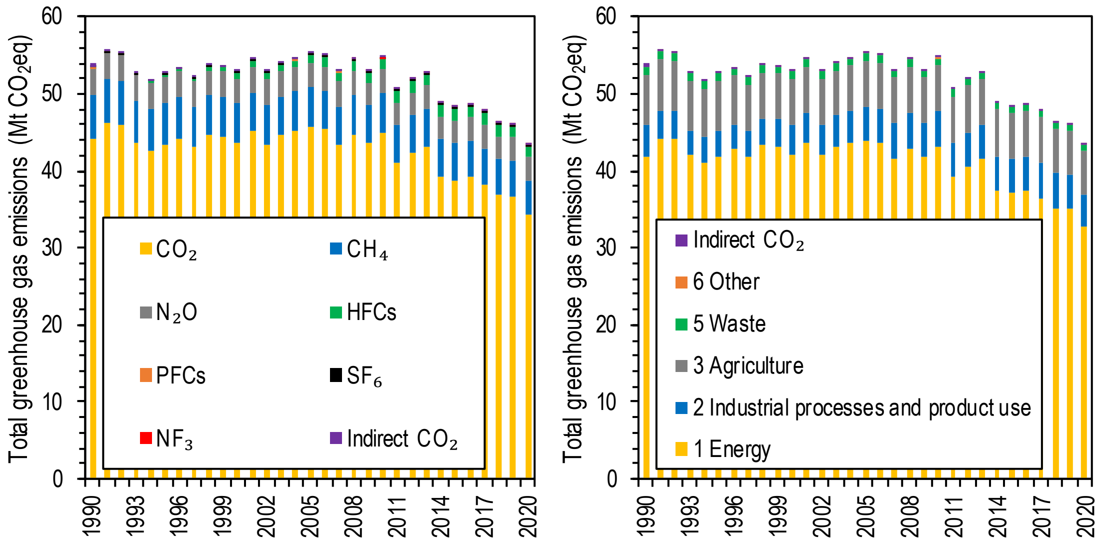
In line with the prospering economy and closely related to the increasing population, numerous key variables – such as the gross domestic product, industrial production, number of buildings, energy reference areas (in the services, industry, and buildings sectors), vehicle stock, passenger and tonne kilometres, foodstuff produced, amount of waste, etc. – have evolved, from 1990 to 2020, in a way as to provoke additional greenhouse gas emissions. In contrast, Switzerland's greenhouse gas emissions have shown a slightly decreasing trend over the same time interval, indicating a decoupling of greenhouse gas emissions from economic and population growth. Accordingly, Switzerland has managed to improve its greenhouse gas intensity substantially. Greenhouse gas emissions per capita and per gross domestic product have decreased by 38 and 49 per cent, respectively, between 1990 and 2020.

1.3 Greenhouse gas inventory information

Switzerland's greenhouse gas emissions

Switzerland's total greenhouse gas emissions (excluding LULUCF and international bunkers, including indirect CO_2) were 43.412 million tonnes of CO_2 equivalents in 2020 (Fig. 1), corresponding to 5.1 tonnes of CO_2 equivalents per capita. Between 1990 and 2020, total greenhouse gas emissions (excluding LULUCF) were mostly modulated by year-to-year changes in meteorological conditions which drive the amount of fuel needed for heating purposes. This resulted in minimum emissions of 80.4 per cent in 2020 and maximum emissions of 103.5 per cent in 1991, relative to 1990. However, since about ten years, a decreasing trend has superimposed the variations from meteorological conditions.

Fig. 1 > Switzerland's total greenhouse gas emissions (excluding LULUCF and international bunkers, including emissions from the sectors 1, 2, 3, 5, and 6, including indirect CO_2), 1990–2020. Left: Subdivided by gas. Right: Subdivided by sector.



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Regarding gases, CO_2 was the dominant contributor gas over the full time period (share of 78.9 per cent in total greenhouse gas emissions in 2020). CO_2 emissions primarily stem from fuel combustion activities, followed by emissions from industrial processes (mainly cement production). CH_4 emissions decreased by 20.8 per cent between 1990 and 2020, and accounted for a share of 10.6 per cent in total greenhouse gas emissions in 2020. The decrease is mainly attributable to reduced emissions from agriculture, but reduced CH_4 emissions from the energy and waste sectors also contributed to the observed trend. N_2O emissions decreased by 13.6 per cent between 1990 and 2020, and accounted for a share of 6.7 per cent in total greenhouse gas emissions in 2020. N_2O emissions from manure management and agricultural soils declined in concert with CH_4 emissions due to decreasing livestock populations and decreasing use of fertiliser. F-gas emissions (HFCs, PFCs, SF_6, and NF_3) increased their share in total greenhouse gas emissions from 0.5 per cent in 1990 to 3.6 per cent in 2020. Indirect CO_2 emissions play a minor role.

Regarding sectors, the major source of greenhouse gas emissions in Switzerland is sector 1 'Energy' (75.2 per cent of total emissions in 2020). In this sector, the overall emissions remained at a relatively constant level between 1990 and about 2010, with some fluctuations mainly caused by year-to-year variations in meteorological conditions. However, a decreasing trend has emerged since about ten years. A substantial decreased occurred in 2020 due to the measures to contain the corona virus pandemic. As in Switzerland electric power is mainly generated by hydroelectric and nuclear power plants, the main contributions to the emissions from sector 1 'Energy' stem from the source categories 1A3 'Transport', 1A4 'Other sectors' (residential and commercial buildings), and 1A2 'Manufacturing industries and construction'. Sector 2 'Industrial processes and product use' accounted for a share of 9.7 per cent in total greenhouse gas emissions in 2020. Sector 3 'Agriculture' accounted for a share of 13.3 per cent in total greenhouse gas emissions in 2020. Declining livestock (cattle and swine) and reduced fertiliser use have led to a decrease in CO_2 equivalents emissions from this sector until 2004, subsequently emissions remained relatively stable. In sector 4 'Land use, land-use change and forestry' (LULUCF), a reduction in net CO_2 removals is observed between 1990 and 2020, but wood harvesting is generally exceeded by the growth of the living biomass pool. Sector 5 'Waste' contributed 1.6 per cent to total greenhouse gas emissions in 2020. Emissions are mainly caused by solid waste disposal sites (inputs into solid waste disposal sites ceased in the year 2000, but emissions still occur) and wastewater treatment, and decreased by 39.8 per cent compared to the level in 1990. Emissions from sector 6 'Other' play a minor role.

National inventory arrangements

Switzerland's national greenhouse gas inventory system is developed and managed under the auspices of the Swiss Federal Department of the Environment, Transport, Energy and Communications, with the Swiss Federal Office for the Environment being responsible for the coordination. All institutional arrangements necessary to ensure the quality and timeliness of national submissions were put in place with regard to the first commitment period of the Kyoto Protocol, when the national system became fully operational. All arrangements have been maintained and adjusted as required ever since.

National registry

Switzerland's national registry conforms to the technical specifications of data exchange standards (DES) for registry systems under the Kyoto Protocol. It has been fully operational with the international transaction log (ITL) since 4 December 2007. The daily reconciliations confirm the integrity of the database.

1.4 Policies and measures

Switzerland has a wide spectrum of policies and measures in place. Many of them have been upheld for a long time and are scheduled to be strengthened in the future or supplemented by additional policies and measures (planned policies and measures). In its eighth national communication, Switzerland presents estimates of the mitigation impact of each policy and measure, discusses – in a more general way – the costs of policies and measures, and provides details regarding monitoring and evaluation. Also discussed are the economic and social consequences of response measures.

Policymaking process

The Federal Constitution of the Swiss Confederation forms the overarching framework for environmental and climate policy in Switzerland, making long-term preservation of natural resources one of the main aims (Article 74 of the Federal Constitution of the Swiss Confederation). The Swiss government established the 2030 Agenda steering committee that coordinates the efforts to achieve the 2030 agenda for sustainable development of the United Nations. The interdepartmental committee on climate of the federal authorities ('IDA-Klima') is responsible for the coordination between different policy areas and assures a coherent climate policy of the Swiss Confederation in compliance with the UNFCCC.

Deduced from the Federal Constitution of the Swiss Confederation, the principles and instruments of Switzerland's environmental policy are stipulated in the Federal Act on the Protection of the Environment, supported by various related acts (such as the CO_2 Act and the Energy Act) which define objectives, instruments, measures and general rules of implementation of climate policy at the needed level of detail.

By ratifying the UNFCCC in 1993, the Kyoto Protocol in 2003, the Doha Amendment to the Kyoto Protocol in 2015, and the Paris Agreement in 2017, Switzerland internationally committed to contribute to the stabilisation of greenhouse gas emissions at a level that prevents dangerous anthropogenic interference with the climate system.

Even if global warming is limited to two degrees Celsius or below, Switzerland will face major impacts (hitherto the warming in Switzerland exceeded the global warming by about a factor of two). Adapting to the effects of climate change is therefore becoming increasingly important. The Swiss government – entrusted to coordinate adaptation efforts – has implemented the Swiss adaptation strategy and the corresponding action plan, as well as various supporting measures.

Cross-sectoral policies and measures

While various policies and measures may have side effects beyond their specific policy domain, some policies and measures are clearly cross-sectoral in nature in that they impact several sectors at the same time. The CO_2 Act is the most fundamental of these cross-sectoral policies and measures, forming the legal framework for the implementation of Switzerland's wide spectrum of policies and measures tackling climate change. The first CO_2 Act entered into force in 2000 and was replaced by the second CO_2 Act in 2013. A third CO_2 Act that was supposed to replace the second CO_2 Act and to cover the period 2021–2030 was rejected in a popular vote on 13 June 2021. Following the rejection, the Swiss Parliament decided to extend the second CO_2 Act until 2024. For the period 2025–2030, the Swiss Federal Council sent a new version of the third CO_2 Act into public consultation in December 2021. The first, second and third CO_2 Acts stipulate the domestic reduction targets (aligned with Switzerland's international reduction commitments), define measures to set incentives for reducing emissions from fossil energy use in various sectors (buildings, transport, industry), and for increasing use of renewable energies and development of innovative technologies. Other cross-sectoral policies and measures are (i) the CO_2 levy on heating and process fuels which sets an incentive to use fossil fuels more efficiently, to invest in low carbon technologies and to switch to low-carbon or carbon-free energy sources, (ii) Switzerland's emissions trading scheme (cap and trade system) which gives participating companies the flexibility in contributing to CO_2 reduction goals under the same rules as their international competitors (the emissions trading schemes of Switzerland and the European Union have been linked since 2020, resulting in the inclusion of aircraft operators and gas-fired combined-cycle power plants in Switzerland's emissions trading scheme), and (iii) the negotiated reduction commitments (for exemption from the CO_2 levy) for companies of certain sectors with substantial CO_2 emissions, which are not participating in the emissions trading scheme; these companies may commit to individual emission reduction targets (taking into account the technological potential and economic viability of measures) in exchange for being exempt from the CO_2 levy on heating and process fuels.

Energy sector

In the energy sector, the Energy Strategy 2050 sets a number of priorities to assure the future energy supply, such as reduction in energy consumption, broadening of the portfolio of energy sources, expansion and restructuring of the electricity transmission grid as well as energy storage. Emphasis is placed on reduced energy and electricity consumption, increased energy savings (energy efficiency), the expansion of hydropower and implementation of new renewable energies. With regard to concrete policies and measures in the energy sector, the SwissEnergy programme represents a major policy instrument engaging cantons, municipalities, industry, as well as environmental and consumer associations for awareness raising, the promotion of increased energy efficiency and the enhanced use of renewable energy. The national buildings refurbishment programme increases the energy efficiency of buildings and promotes the use of renewable energies in the buildings sector, financed by one third of the revenues from the CO_2 levy on heating and process fuels. The building codes of the cantons, which were agreed on by the cantonal energy directors, provide a set of common energy and insulation standards (model provisions) aimed at reducing energy consumption of buildings. The feed-in tariff system and the investment aids support the increase of renewable power production according to the targets of the Energy Act. In the framework of the negotiated reduction commitment of municipal solid waste incineration plant operators, the Swiss Association of Municipal Solid Waste Incineration Plants committed to equip at least one plant with a unit for carbon capture and storage with a capacity of 100 thousand tonnes of CO_2 by 2030, and to continue its efforts to reduce its net CO_2 emissions (e.g. through the effective use of the heat generated or the recuperation of metals).

Transport sector

Within the transport sector, CO_2 emission regulations for newly registered vehicles ensure the steady decrease of specific fuel consumption of passenger cars and light commercial vehicles. The trend to more efficient vehicles is further supported by the energy label for new motor vehicles which informs potential buyers at the point of sale about specific fuel consumption and CO_2 emissions of the vehicles. The partial compensation of CO_2 emissions from motor fuel use has replaced the former climate cent. It obliges importers of fossil motor fuels to offset an increasing part of the resulting CO_2 emissions through investments in emission reduction projects, financed by a surcharge on the imported fuels. The heavy vehicle charge is applied to passenger and freight transport vehicles of more than 3.5 tonnes gross weight and aims at reducing tonne kilometres, in particular by shifting transalpine transport from road to rail. The mineral oil tax reduction on biofuels and natural gas sets an incentive to enhance the use of renewable motor fuels but also sets strict ecological and social requirements for their production. International exhaust gas regulations (NMVOC) limit emissions of air pollutants and, thus, indirect CO_2. Further policies and measures in the transport sector concern aviation: (i) the CO_2 emissions standard for aircraft, (ii) the carbon offsetting and reduction scheme for international civil aviation (CORSIA), (iii) the non-volatile particle matter emission regulation for aircraft engines, and (iv) the sustainable aviation fuel policy.

Industrial processes and product use sector

The main instruments affecting greenhouse gas emissions from industry are the CO_2 levy on heating and process fuels, the emissions trading scheme, and the negotiated reduction commitments (for exemption from the CO_2 levy). For emission of F-gases and precursor gases – such as NMVOC – specific policies and measures are in place. On the one hand, the provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3) regulate, inter alia, compressed gas containers, plastic foams, solvents containing HFCs, PFCs or HFEs, refrigerants, extinguishing agents, and SF_6 in electrical distribution equipment. On the other hand, the Ordinance on Air Pollution Control and the NMVOC incentive fee aim at reducing NMVOC emissions by setting emission limits for stationary installations and by using market-based instruments.

Agriculture sector

In the agriculture sector, the following policies and measures are in place: (i) the proof of ecological performance to receive direct payments, contingent on an appropriate soil nutrient balance, a suitable proportion of ecological compensation areas, a crop rotation system, soil protection measures, selective application of crop protection agents, and animal husbandry in line with legal provisions, (ii) the resource programme (subsidies for a more efficient use of natural resources), (iii) the climate strategy for agriculture, i.e. the declaration of intent to reduce greenhouse gas emissions from agriculture by at least one third by 2050 compared to 1990 with technical, operational and organisational measures and to further reduce emissions by influencing food production structures as well as consumption patterns, (iv) the agricultural policy 2014–2017 and 2018–2021, including, among other things, a further development of the direct payments system, and (v) the enhancement of label standards, which e.g. introduces a climate score system.

Land use, land-use change and forestry sector

In the land use, land-use change and forestry sector the climate-related goal of forest policy is to adapt forests by increasing resilience to climate change and – taking into account the high growing stock – to reduce CO_2 emissions by substituting other materials or fossil fuels rather than enhancing sink capacity. The following policies and measures aim at reaching these goals: (i) the Forest Act (sustainable forest management and forest area conservation), including a ban on clearcutting and deforestation, (ii) the Wood Action Plan (implementation of Swiss Wood Resource Policy), aiming at better use of the wood harvest potential (optimised cascaded use of wood, climate-appropriate building and refurbishment as well as communication, knowledge transfer and cooperation), (iii) the measures within Forest Policy (objectives and implementation), aiming at improving the conditions for an efficient and innovative forestry and wood industry, and (iv) the Forest Act (changes due to revision 2017), a renewal of legal provision aiming at, inter alia, increasing the adaptive capacity of Switzerland’s forests and the promotion of the use of sustainably produced timber (e.g. for the construction of federal buildings).

Waste sector

In the waste sector, two policies and measures are in place. First, the ban on landfilling of combustible waste ensures that all combustible waste is incinerated in waste incineration plants, using the combustion heat to generate electricity or to supply district heating networks and industrial facilities. Second, the Ordinance on the Avoidance and Management of Waste enforces the further optimisation of energy recovery by municipal solid waste incineration plants.

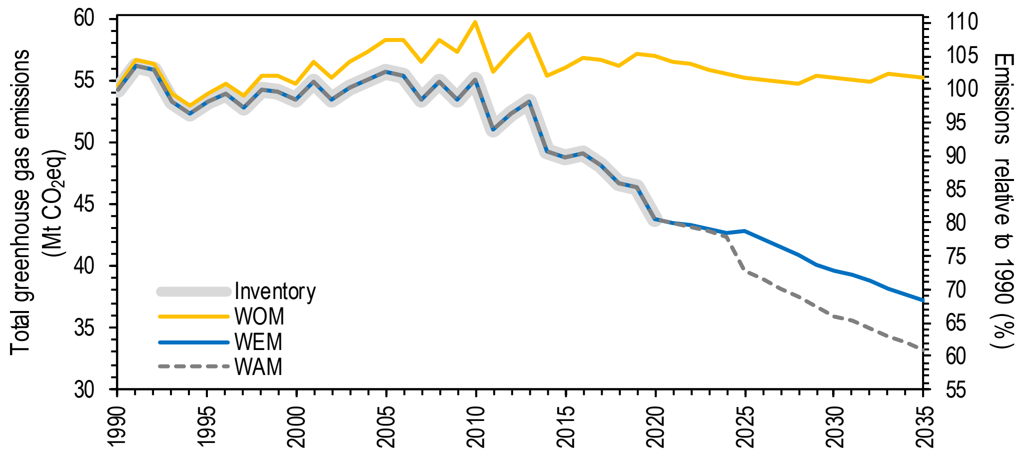
1.5 Projections and total effect of policies and measures

Switzerland reports updated greenhouse gas emission projections for the following three scenarios (see also Fig. 2): (i) ‘with existing measures’ (WEM), (ii) ‘without measures’ (WOM), and (iii) ‘with additional measures’ (WAM). The scenarios cover the time period from 1990 to 2035 (the WEM and WAM scenarios correspond to actual inventory data between 1990 and 2020). Regarding key underlying assumptions, population is assumed to increase considerably over the coming decades. This is also reflected in energy reference area and transport growth. Switzerland’s gross domestic product, another parameter strongly influencing energy consumption and greenhouse gas emissions, is also assumed to increase considerably over the coming decades. In brief, the three scenarios are characterised as follows:

- The WEM scenario reflects the current state of legislation and also takes into account the stipulated strengthening of existing policies and measures (i.e. any strengthening foreseen under current legislation). By 2025, 2030 and 2035, Switzerland’s total greenhouse gas emissions under the WEM scenario are projected to decrease to 78.6 per cent, 72.7 per cent and 68.2 per cent of the emissions in 1990, respectively. Emission reductions from the source categories covering residential and commercial/institutional buildings (1A4), transport (1A3), as well as manufacturing industries and construction (1A2) dominate the projected evolution of total greenhouse gas emissions under the WEM scenario. Emissions from other source categories remain about stable and/or are of minor importance, with the exception of the F-gases, where projections suggest the peaking of emissions before 2020 and a decline thereafter;

- Under the WOM scenario, climate-relevant policies and measures are excluded as early as 1990 (with a few exceptions). Consequently, emissions under the WOM scenario show an increasing tendency until around 2010, followed by a slow decrease to about the same emission level as in 1990 by 2030 and 2035. This decreasing trend after about 2010 is a result of autonomous technological progress improving the greenhouse gas efficiency also in the absence of policies and measures. Notably, under this scenario greenhouse gas emissions show a stepwise increase at the time when nuclear power plants are decommissioned and assumed to be replaced by gas-fired combined-cycle power plants (2029 and 2033). A continuously increasing trend is also projected for emissions from sector 2 'Industrial processes and product use', which, driven by emissions of HFCs, increase by 1.6 million tonnes of CO_2 equivalents by 2030 compared to 1990;
- The WAM scenario encompasses implemented, adopted and planned policies and measures. By 2030 and 2035, Switzerland's total greenhouse gas emissions under the WAM scenario are projected to decrease to 66.0 and 60.7 per cent of the emissions in 1990, respectively. Compared to the WEM scenario, emissions decrease faster, as new policies and measures are introduced and existing policies and measures are strengthened beyond the strengthening already stipulated under current legislation (i.e., under the WEM scenario).

Fig. 2 > Total greenhouse gas emissions under the WEM, WOM and WAM scenarios as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Also shown are actual inventory data for the years 1990 to 2020. The vertical axis to the right indicates emissions relative to 1990.



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The difference between the emissions under the WOM and WEM scenarios indicates that the total effect of currently implemented and adopted policies and measures is estimated at a reduction of 12.5 million tonnes of CO_2 equivalents for 2025 and 15.6 million tonnes of CO_2 equivalents for 2030 (annual reduction, not cumulative). In 2030, CO_2 contributes 78 per cent to the total reduction, and the energy sector accounts for 78 per cent of the total reduction. For 2030, the difference between the emissions under the WEM and WAM scenarios indicates that the total additional effect of planned policies and measures is estimated at 3.6 million tonnes of CO_2 equivalents (annual reduction, not cumulative).

The methodologies applied to establish Switzerland's greenhouse gas emission scenarios are tailored to the particular characteristics of each sector, always ensuring consistency with actual data of the greenhouse gas inventory. For the energy sector, the WEM and WAM scenarios are based on the newly established energy perspectives 2050+, while for the WOM scenario, the previously applied computable general equilibrium model is used. For the industrial processes and product use sector as well as for the waste sector, projections are calculated following exactly the same methodology as used for the greenhouse gas inventory, i.e. bottom-up estimates according to the 2006 IPCC guidelines for national greenhouse gas inventories. For the agriculture sector, scenarios are based on projected activity data, e.g. livestock numbers, crop production data (amount of crops harvested, area of crop cultures, meadows and pastures) and fertiliser use from different agricultural policy evaluation models. To project emissions from the land use, land-use change and forestry sector, a stochastic empirical single tree forest management scenario model (Massimo) is used. Switzerland also presents a sensitivity analysis to investigate the dependency of the projected emissions on the key underlying assumptions.

1.6 Vulnerability assessment, climate change impacts and adaptation measures

State of climate models and scenarios

In 2018, a new set of official scenarios on climate change for Switzerland was launched by the National Centre for Climate Services. These 'CH2018 scenarios' present a consolidated view on projected future climate change in Switzerland. Compared to the previous CH2011 scenarios, they further facilitate the use of climate scenario information and data in practice, with products aimed at both laypersons and experts. The scenarios are based on the RCP emission scenarios used for the fifth assessment report of the Intergovernmental Panel on Climate Change. They draw on a large number of state-of-the-art European-scale regional climate model experiments. Summarised results are available for five representative Swiss regions, three scenario time periods (represented by the reference points 2035, 2060 and 2085) and three emission scenarios. A major advancement with respect to the preceding CH2011 scenarios is the transient character of the data for impact applications. In 2021, the CH2018 scenarios were supplemented by the results of the Hydro-CH2018 project, which offers consistent bases for the hydrological domain.

Assessment of risks and opportunities and knowledge about climate change impacts

The nationwide assessment completed in 2017 documents the risks and opportunities of climate change for the 2060 time horizon and evaluates their relative importance from today's perspective. The assessment found that the level of knowledge is sufficient to justify the development and implementation of adaptation measures. In the meantime, two research projects were carried out to fill knowledge gaps on climate-related impacts abroad on Switzerland and on compound climate risks, respectively. Further insights for dealing with climate-relevant risks and opportunities are expected from a research programme led by the National Centre for Climate Services starting in 2022.

The CH2018 climate scenarios, together with the results of the Hydro-CH2018 project, provide an up-to-date basis for the assessment of the impacts of climate change on nature, society and the economy in Switzerland. In 2020, the current state of knowledge about the already observed impacts of climate change was also comprehensively documented in a report. Taken together, these sources open up far-reaching possibilities for classifying past developments and assessing future ones. Many projects investigating the impacts of climate change on Switzerland are now based on the latest scenario information, which leads to more reliable and detailed results and enables more targeted adaptation measures.

Adaptation policies and strategies and their implementation

The results of the nationwide assessment of climate-related risks and opportunities, together with the new CH2018 climate scenarios, formed the main basis for the development of the national adaptation strategy's action plan 2020–2025, adopted by the Swiss Federal Council in 2020. The new action plan contains 63 adaptation measures in 12 sectors. Another 12 cross-sectoral measures aim to improve the knowledge base for adaptation.

Important initiatives have been taken to support the implementation of the national adaptation strategy, in particular the National Centre for Climate Services and the pilot programme 'Adaptation to climate change' (the second phase of which is currently underway). Further, tools are being deployed to foster adaptation at regional and local level. At the same time, many cantons have made progress in developing strategies and measures to adapt to their specific challenges of climate change.

The federal authorities responsible for the measures included in the second action plan of the national adaptation strategy have continued the efforts begun under the first action plan. For example, the challenges of climate change for the integrated civil protection system in Switzerland and the resulting need for action were assessed. The national strategy on natural hazards was updated and now focuses more strongly on the challenges of climate change. New web-based platforms provide experts and the public with access to up-to-date information on natural hazards, a new warning system for mass movement hazards is under development, and the heat warning system has been revised. In the area of forest management, several measures are now being implemented under an Environmental Programme Agreement. In the health sector, the impact of recent heat waves was analysed and, based on this, recommendations for health services and the public were updated. Several projects addressed heat stress in cities and provided new information materials on ways to avoid overheating of urban areas.

Based on the provisions of Article 7, paragraphs 9, 10 and 11, and Decision 9/CMA.1, Switzerland submitted its First Adaptation Communication under the UNFCCC on 9 December 2020. The communication contains the national adaptation strategy and the two associated action plans.

1.7 Financial, technological and capacity-building support

The Federal Constitution of the Swiss Confederation stipulates that Switzerland is committed to the long term preservation of natural resources and to a just and peaceful international order. It further states that Switzerland shall assist in the alleviation of need and poverty in the world and promote respect for human rights and democracy, the peaceful co-existence of peoples as well as the conservation of natural resources. Support for international climate action – through a variety of channels and instruments, such as dedicated multilateral climate funds, specific multilateral and bilateral climate programmes and projects, as well as integrating low-carbon development and climate resilience into Switzerland's development assistance – has thus been a cornerstone of Switzerland's international engagement since the early 1990s. Regarding international climate financing, three government entities – the Swiss Agency for Development and Cooperation, the Swiss State Secretariat for Economic Affairs, and the Swiss Federal Office for the Environment – have specific roles and dedicated budgets. They cooperate closely to ensure the overall effectiveness and coherence of Swiss support for climate change adaptation and mitigation activities in developing countries and countries in transition.

Through its multilateral and bilateral cooperation and as a member of the main multilateral institutions (inter alia multilateral development banks, the Green Climate Fund, the Global Environment Facility, the Adaptation Fund and other United Nations agencies), Switzerland strives to ensure a more coherent implementation of policies and strategies and to promote synergies in international climate action. At the bilateral level, Switzerland supports mitigation and adaptation activities in a number of focal countries and/or regions.

Switzerland's public climate finance has seen a steady increase over the past years. Standing at 175 million US dollars in 2012 the amount grew to 411 million US dollars in 2020. The increase reflects the gradual shift of Switzerland's official development assistance towards a greater focus on climate change, increasingly mainstreaming it in development activities. This has led to a remarkable progression compared to previous efforts. The current effort is made in the context of ongoing budget constraints due to the consequences of the corona virus pandemic. It is considered adequate by the Swiss government pursuant to Article 4, paragraph 3, of the Convention.

Switzerland has made financial contributions to the UNFCCC secretariat, to the operating entities of the financial mechanism of the Convention, to other multilateral institutions and to international financial institutions such as the World Bank and other multilateral development banks that fund climate change adaptation, mitigation, capacity building and technology cooperation programmes in developing countries. Among the international financial institutions, the largest contribution goes to the International Development Association, a substantial share of which is allocated to finance climate change action. Switzerland's total contribution to the 19th replenishment of the International Development Association was 683 million Swiss francs. Moreover, many international organisations, such as the United Nations Development Programme and the Consultative Group on International Agricultural Research, whose operations are co-funded by Swiss core contributions, are increasingly generating important climate benefits. In total, Switzerland climate-specific contributions (public, grant-based) to multilateral institutions increased from 133 million US dollars in 2019 to 188 million US dollars in 2020 for mitigation and adaptation activities in developing country Parties.

Next to the important multilateral engagement, bilateral programmes and projects build a key element of Switzerland's climate change cooperation. Switzerland works closely with bilateral partners to deliver both effective global responses and tangible results on the ground. Almost all activities are implemented by one of the two Swiss development agencies – the Swiss Agency for Development and Cooperation or the Swiss State Secretariat for Economic Affairs – in close cooperation with government institutions, non-governmental organisations, private sector entities and research institutions. Switzerland's bilateral and regional climate-relevant activities are (i) the generation of new and relevant knowledge on climate policy, (ii) the support for technology development and implementation, (iii) the harnessing and replicating successful practices, (iv) the development of skills and capacities of partner countries for their engagement in the international debate on climate change issues, and (v) the implementation of climate action. Switzerland was able to increase its public bilateral climate-specific programmes and projects from 221 million US dollars in 2019 to 223 million US dollars in 2020 in developing country Parties. In 2019, Switzerland provided 55 per cent of its bilateral public climate finance for adaptation and 45 per cent for mitigation. In 2020, the share for adaptation rose to 58 per cent and the share for mitigation dropped to 42 per cent. In addition, Switzerland increased its bilateral private sector mobilisation from 71 million US dollars in 2019 to 106 million US dollars in 2020 through some of its public co-financing activities.

To foster mutual learning, various success stories for effective technology transfer and development as well as capacity building are highlighted in Switzerland's eighth national communication. Switzerland thereby stresses the integrated character of both technology transfer and capacity building in Swiss mitigation and/or adaptation support projects and programmes for developing country Parties.

1.8 Research and systematic observation

Research

In Switzerland, climate research is spread across many institutions and is funded by national and international funding agencies. Individual and programme research at the national level goes hand in hand with participation in international research programmes and cooperation with research centres and organisations abroad.

Climate research is mainly funded by the Swiss National Science Foundation (SNSF), the European Cooperation in Science and Technology COST and, until the year 2020, by the European Union Framework Programme for Research EU-FPR. Other sources of funding are the federal authorities with their research activities in the fields of environment, energy, agriculture, forestry as well as international development and cooperation.

Three Swiss research centres have a special focus on climate change and its impacts, namely the Oeschger Centre for Climate Change Research (OCCR) and the Centre for Development and Environment (CDE) at the University of Bern as well as the Centre for Climate Systems Modelling (C2SM) at the Swiss Federal Institute of Technology in Zurich (ETH Zurich). Many other research institutions contribute to climate research through individual projects and programmes.

At the international level, Switzerland participates in various research programmes (e.g. World Climate Research Programme, Future Earth) through individual research projects, research conducted at federal institutes and within coordinated programmes (Climate Research Centres). Switzerland also participates in the operation of climate monitoring stations and networks (in collaboration with the Global Climate Observing System, GCOS) and contributes to international projects by maintaining calibration and data centres. The Mountain Research Initiative (MRI), a multidisciplinary scientific organisation that addresses global change issues in mountain regions around the world, including developing countries, is hosted by the Centre for Development and Environment at the University of Bern and funded by the Swiss Academy of Sciences. Swiss researchers, many of them in leading positions, have repeatedly contributed to the preparation of the assessment reports of the Intergovernmental Panel on Climate Change.

Systematic observation

Switzerland has a long-standing tradition of climate observation. Temperature and precipitation records for more than 150 years, the world's longest total ozone series, glacier measurements dating back to the end of the 19th century and the 20-year anniversary of the Swiss Permafrost Monitoring Network form some of the highlights of the Swiss contribution to global climate monitoring. The national climate observing system (GCOS Switzerland) serves as the observation and monitoring pillar for the national implementation of the Global Framework for Climate Services.

The Swiss GCOS Office (now the Swiss GAW/GCOS Office) is responsible for the periodic compilation of an inventory report of climate observations and international data centres in Switzerland. The inventory was last updated in 2018 and currently includes 33 Essential Climate Variables (ECVs), two ancillary datasets and six international centres operated by Swiss institutions. Since 2018, around 30 project agreements have been signed, helping to secure systematic climate monitoring in Switzerland in the long term.

Switzerland actively supports capacity building in emerging and developing countries by participating in the GCOS Cooperation Mechanism. Through technical and/or financial support, Swiss institutions enable high-quality climate observations. Major contributions relate to glacier monitoring in Central Asia and South America. To support and improve the spatial coverage of atmospheric composition measurements globally, partnerships with station operators in various countries (e.g. Indonesia) are maintained, focussing on training, quality assurance, replacement of instruments and scientific support. In the framework of the Global Atmosphere Watch programme, MeteoSwiss supports weekly ozone soundings and associated training in Nairobi (Kenya).

1.9 Education, training and public awareness

According to recent surveys, the Swiss population ranks environmental protection and climate change among the biggest problems of our time. At the same time, the referendum on the third CO_2 Act in 2021 has shown that finding majorities for an ambitious emissions reduction policy remains challenging. Further efforts in the areas of education, training and public awareness are essential to gain the necessary support for the adoption and implementation of effective measures.

Compulsory education

Switzerland has a federal education system in which the education ministries of the 26 cantons have far-reaching competencies to decide about the school system on all levels, including curricula and learning methods. In recent years, efforts to harmonise curricula for compulsory education have led to the adoption of a common model curriculum by most German speaking and bilingual cantons. This curriculum defines goals at all levels of compulsory education. Education for sustainable development is acknowledged as a cross-disciplinary theme relevant to a wide range of subjects.

Building on the results of a nationwide assessment of climate education at primary and secondary school level, a research project was conducted between 2016 and 2019 in order to develop a teaching conception on climate topics. From this project, comprehensive teaching materials on climate change, climate protection and climate policy have emerged, which are now freely available for all levels of compulsory education. In addition, the ‘Climate Programme Training and Communication’ of the Swiss Federal Office for the Environment offers targeted support to institutions active in the domain of environmental education.

Vocational education and training

Education for sustainable development is part of the general studies curriculum for all apprentices in Switzerland. Additionally, in many of the decrees for each profession there is a reference to education for sustainable development.

The SwissEnergy programme of the Swiss Federal Office of Energy contains measures directed at professionals from various trades. One of its ambitions is to include new developments in energy technologies in vocational education, offering up-to-date training materials and accelerating knowledge transfer. In addition, the ‘Climate Programme Training and Communication’ has a special focus on professions with high relevance for greenhouse gas emissions.

Public awareness

In recent years, no public awareness-raising campaigns focussing specifically on climate change and directed at the general public have been conducted by the federal authorities. Climate change is widely recognised as one of the major long-term challenges for Switzerland. This is partly due to a committed scientific community, but also to an active scene of environmental non-governmental organisations, complemented by ecologically oriented business associations, both of which work to raise awareness and stimulate public debate about climate policy.

SwissEnergy is the major programme for conveying information related to energy efficiency and renewable energies to the general public. In 2020, the programme launched the nationwide awareness-raising and advisory campaign ‘erneuerbar heizen’ (‘heating with renewables’), which promotes the conversion from fossil to renewable energy sources in heating systems.

Participation in international education, training and awareness raising activities

In autumn 2021, Switzerland renewed its support to the One UN Climate Change Learning Partnership (UN CC:Learn) and its comprehensive knowledge-sharing platform. A particular focus of Switzerland’s contribution in this context are the Youth Climate Dialogues. These enable students from all over the world to engage with global challenges such as climate change and promote partnerships between educational institutions around the globe. Additional activities relevant to education, training and awareness raising at the international level include, inter alia, contributions to the organisation and implementation of regional workshops in the context of the Cluster Francophone of the Partnership on Transparency in the Paris Agreement (PATPA).

2 National circumstances relevant to greenhouse gas emissions and removals

Switzerland's national circumstances are presented in section 2.1 to 2.13, followed by a discussion of how the national circumstances affect greenhouse gas emissions and removals, and how the national circumstances and changes therein affect greenhouse gas emissions and removals over time (section 2.14).

2.1 Government structure

This section provides a general overview of Switzerland's government structure and political organisation. Specific information related to the policymaking process in the context of environmental and climate policy is presented in section 4.1.

Administrative structures

The following website depicts Switzerland's administrative structures: *https://www.ch.ch/en/demokratie*. The subsequent paragraphs provide a brief overview.

Switzerland is a confederation, subdivided into 26 cantons (states). The legislative authority consists of a bicameral parliament which, when in joint session, is known as the Federal Assembly, i.e. the Swiss Parliament. One chamber of the Swiss Parliament, the National Council, consists of 200 members, representing the population of the country as a whole. The other chamber, the Council of States, represents the cantons. 20 cantons are represented in the Council of States by two members and six half-cantons by one member (leading to a total of 46 members). The legislative system comprises several hierarchical levels and all legislation must ultimately comply with the Federal Constitution of the Swiss Confederation. Both chambers of the Swiss Parliament have equal power, meaning that federal acts or constitutional amendments can only enter into force once they passed both chambers. However, decisions by the Swiss Parliament are subject to optional referendums (federal acts) or mandatory referendums (constitutional amendments) by the Swiss population (see below). The members of the Swiss Parliament are directly elected by the Swiss population for a four-year term, while the Swiss Parliament then elects the Swiss Federal Council for a four-year term as well.

The executive authority at the federal level, the Swiss Federal Council, consists of seven members with equal power. The Swiss Federal Council is supported by the Swiss Federal Chancellery and seven federal departments (federal administration). While the Swiss Federal Council has the power to directly implement the contents of federal acts through ordinances, it proposes changes to the Federal Constitution of the Swiss Confederation or federal acts for parliamentary discussion and approval.

The highest judicative authority in Switzerland is the Federal Supreme Court, representing the final arbiter on disputes in the field of civil law (citizen-citizen), in the public arena (citizen-state), as well as in disputes between cantons or between cantons and the federal government.

In Switzerland, the principle of subsidiarity is of greatest importance, as ingrained in Article 3 and 5a of the Federal Constitution of the Swiss Confederation, stipulating that unless legislative power is explicitly assigned to the Swiss Confederation (federal level), the cantons are sovereign, i.e. entitled to legislate in an area of policy (*Swiss Confederation*, 1999a). This fundamental principle helps to protect minority interests, above all those of the French-, Italian- and Romansh-speaking parts of Switzerland. Accordingly, each canton has its own government, parliament and cantonal court, while responsibilities are shared between the federal authorities and the cantons. Each canton also has its own financial budget and sets its own level of direct taxation (fiscal federalism). Despite a system of fiscal equalisation amongst cantons, substantial differences between cantons remain in the level of taxation of both households and companies.

Relevant inter-ministerial decision-making processes or bodies

Cooperation is an important principle, both vertically across the hierarchic levels of authorities and horizontally within a level of authority. In matters where the federal authorities are responsible for legislation, the role of the cantons is to implement and enforce such legislation. Very often, the cantons have substantial leeway to take local or regional conditions into account. At a lower level, similar autonomy is granted to the municipalities by the cantons. At the same time, cantons cooperate horizontally and have agreements that facilitate harmonised and effective implementation of policies and measures.

The cantons and other interested parties (e.g. business, trade unions, non-governmental organisations etc.) are included in a consultation process whenever the Swiss Federal Council proposes a significant change to the Federal Constitution of the Swiss Confederation, to a federal act or an ordinance. This comprehensive consultation process is a very important phase in the legislative procedure in Switzerland. The aim is to include expert knowledge and to consider proposals of particular interest groups, where possible. This approach allows to estimate and improve the success chances of the proposals in an eventual referendum. Although the outcome of the consultation process is formally non-binding, it is of great importance and reflects an established principle of consensus, which is typical of policymaking and of political culture in Switzerland. However, this political participation process also leads to a relatively slow policymaking process. In particular, new legislation agreed upon by the Swiss Parliament (in a negotiation process that may take up to several years), may potentially be rejected by the Swiss population in case of a referendum (see below). This needs to be taken into account in the context of the policies and measures described in chapter 4.

Within the federal administration, interdepartmental exchange and consultation is an important pillar during the preparation phase of legal provisions or other business requiring a decision by the Swiss Federal Council. The leading federal offices, mandated by the respective member of the Swiss Federal Council, therefore conduct, as a matter of routine, an interdepartmental official consultation. Then, the received feedbacks are, to the extent possible, taken into account. In the forefront of the respective meeting of the Swiss Federal Council leading to the final decision on the business, all departments are invited to provide their agreement or reservations in a so-called joint reporting procedure.

Regarding environmental and climate policies, particular interdepartmental decision-making processes and bodies are established (see section 4.1 for further information).

Political organisation of Switzerland: The people, the supreme political authority

Switzerland is a representative democracy, with strong formal and informal elements of direct democracy. According to the Federal Constitution of the Swiss Confederation, the Swiss people are sovereign and ultimately the supreme political authority. Virtually all important decisions have to be approved by the electorate. This includes all Swiss adults who are eligible to vote – some 5.5 million citizens in 2020, i.e. around 63 per cent of the resident population. Those under the age of 18 years and foreign nationals have no political rights at federal level. Switzerland is virtually the only country in the world where the people have such extensive decision-making power. The long-standing democratic tradition, but also the comparatively small size of the population are crucial for the operation of this particular system of government. At federal level, Swiss nationals can elect, vote, request for popular initiatives and take a referendum. At cantonal and municipal level, similar rights exist; however, they are not uniform across Switzerland.

As mentioned above, the people elect the 200 members of the National Council and the 46 members of the Council of States every four years. All Swiss citizens over the age of 18 years may take part in elections, both actively and passively. In other words, they may cast their votes and stand for election themselves.

An important formal instrument of direct democracy is the referendum. The optional referendum allows citizens to veto decisions made by the Swiss Parliament. To request a popular vote on a decision by the Swiss Parliament, the collection of 50 thousand valid signatures within 100 days is needed. There is a mandatory referendum on each constitutional amendment passed by the Swiss Parliament. It is thus possible to have a referendum concerning regulations at the level of the Federal Constitution of the Swiss Confederation, formal laws, international treaties, and generally binding federal decrees that are put into effect as a matter of urgency. Both popular initiatives and referendums also exist at the cantonal level. The petition is an informal instrument of public participation and is non-binding.

By means of a popular initiative, which requires the collection of 100 thousand valid signatures within 18 months, citizens can propose amendments to the Federal Constitution of the Swiss Confederation (at the cantonal level also amendments to a law). Popular initiatives may comprise a general proposal or contain detailed regulations. A popular initiative needs to be accepted by a majority of both the electorate and the cantons to become part of the Federal Constitution of the Swiss Confederation. This requirement for a ‘double’ majority (population and cantons) mainly serves to protect the interests of sparsely populated rural cantons.

The ballots needed to implement the direct democracy in Switzerland generally take place four times a year and on average involve three to four proposals – in exceptional cases also up to twice that many – that may be adopted or rejected. Often, cantonal and communal ballots are held at the same time.

International relations

Switzerland is a member of several international organisations (e.g. the OECD, the World Bank Group and all specialised agencies of the United Nations). In March 2002, the Swiss population also voted for membership of the United Nations, and since September 2002, Switzerland has been a full member.

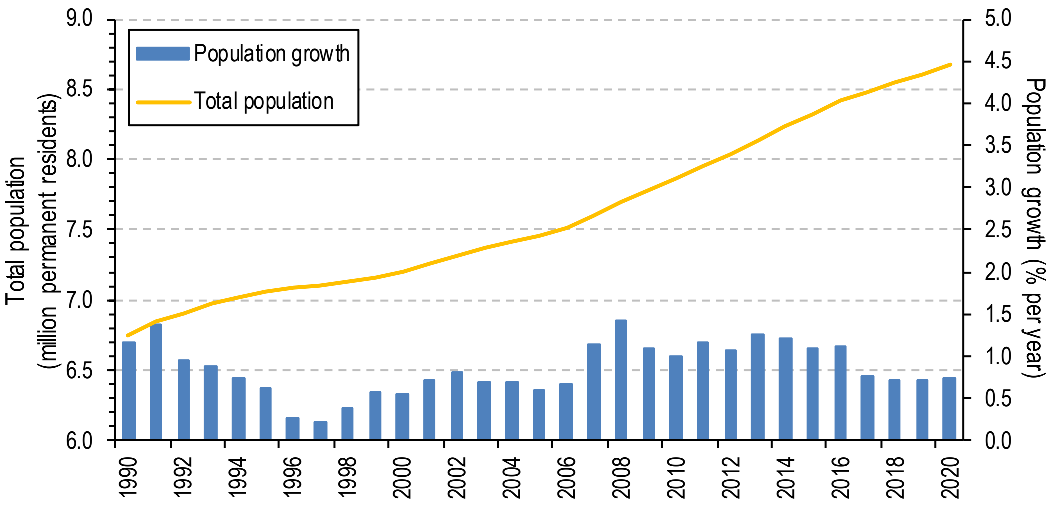
Although not a member state of the European Union, Switzerland has a strong relationship with the European Union and European policy is a high priority of Swiss foreign policy. The legal basis of this close cooperation is formed by bilateral agreements[2], and most Swiss laws have been made compatible with legislation of the European Union. Important stages of this policy have been assessed and approved by the people in referendums. Relations between Switzerland and the European Union have developed over decades. The bilateral agreements have been extended step by step. However, in 2021, the Swiss Federal Council took the decision not to sign the institutional framework agreement[3], as there remain substantial differences between Switzerland and the European Union on key aspects. The Swiss Federal Council nevertheless considers it to be in the shared interest of Switzerland and the European Union to safeguard their well-established cooperation and to systematically maintain the agreements already in force.

Since 2006, Switzerland is a member of the European Environmental Agency (EEA), one of the most important agencies for European cooperation in environmental issues. Concerning climate policy measures, Switzerland often adapts instruments of the European Union. Current examples are the CO_2 emission regulations for newly registered vehicles or the emissions trading scheme.

2.2 Population profile

At the end of 2020, Switzerland had a population of 8,670,300 permanent residents (*SFSO*, 2021a). Since the beginning of the 20th century, Switzerland's population has more than doubled, the increase of population from 1990 to the end of 2020 was 28 per cent. Between 2007 and 2016, population growth exceeded one per cent per year, and has now been stable at around 0.75 per cent per year during the last years (Fig. 3). Population growth mainly results from immigration and increasing life expectancy. It is expected that population growth will continue in the future, leading to 10.44 million permanent residents by 2050 (*SFSO*, 2020a).

Fig. 3 > Switzerland's total population (orange) and population growth (blue) between 1990 and 2020. At the end of 2020, Switzerland had 8.67 million permanent residents, of which 4.30 million men and 4.37 million women.



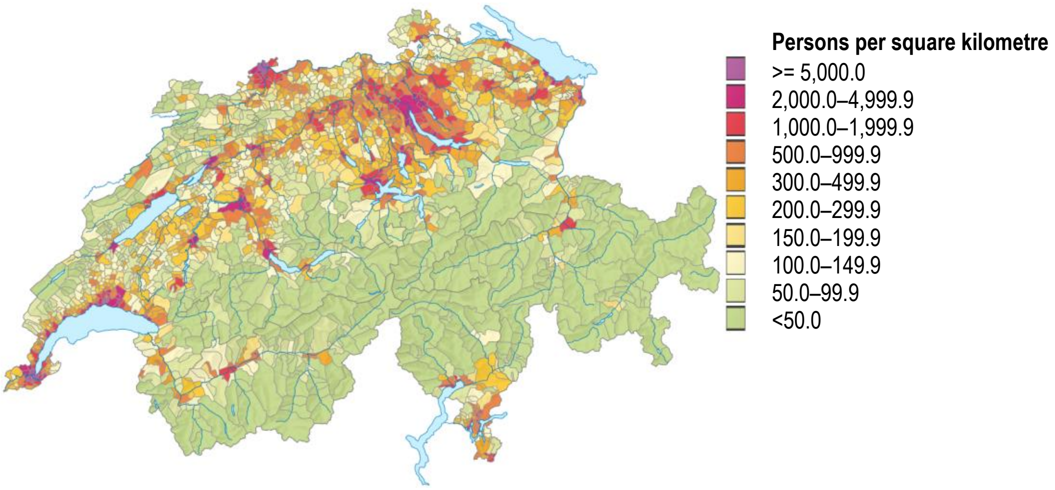
SFSO (2021a)

Switzerland's population density at the end of 2020 was 210 persons per square kilometre. Population is concentrated on the Central Plateau, the major alpine valleys and the Ticino, while the density is substantially lower in the hilly and alpine regions of the country (Fig. 4).

2 https://www.eda.admin.ch/europa/en/home/bilaterale-abkommen/ueberblick.html

3 For more details see https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-83705.html.

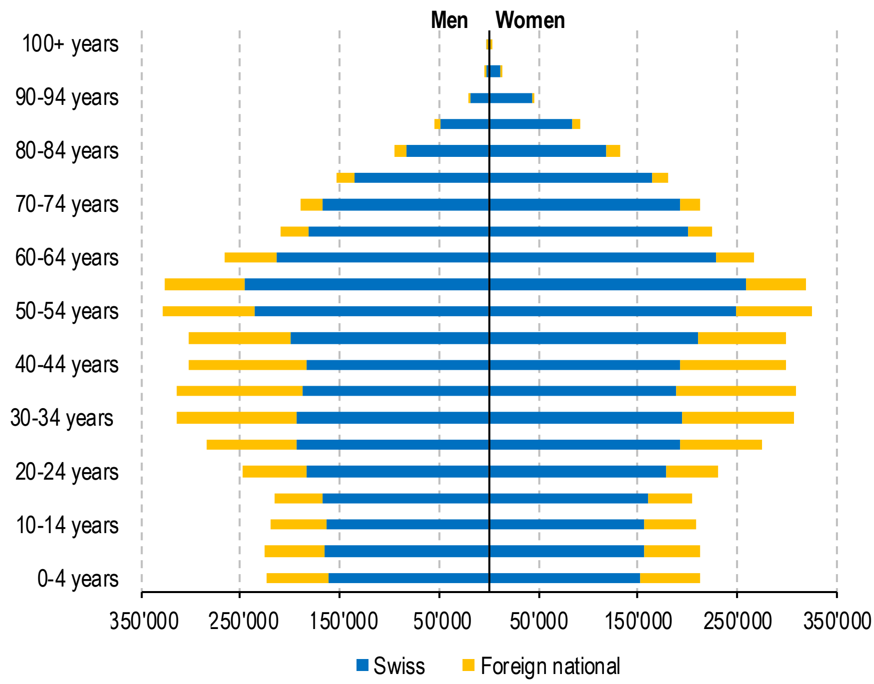
Fig. 4 > Spatial distribution of Switzerland's population at the end of 2020.



SFSO (2021a)

Fig. 5 shows the demographic structure of Switzerland in 2020 by age, sex and nationality. Foreign nationals account for about 25.5 per cent of the permanent Swiss residential population. A growing proportion of the population is of retirement age, while the share of persons below the age of 20 has been declining since the 1970s. Switzerland has four official languages (German, French, Italian, and Romansh). In 2019, 62.1 per cent of Switzerland's permanent population indicated German as the main language, 22.8 per cent French, 8.0 per cent Italian, 0.5 per cent Romansh, and 22.7 per cent other languages (the sum exceeds 100 per cent as some persons indicated more than one language; *SFSO*, 2021b).

Fig. 5 > Age distribution by age, sex and nationality in Switzerland at the end of 2020.



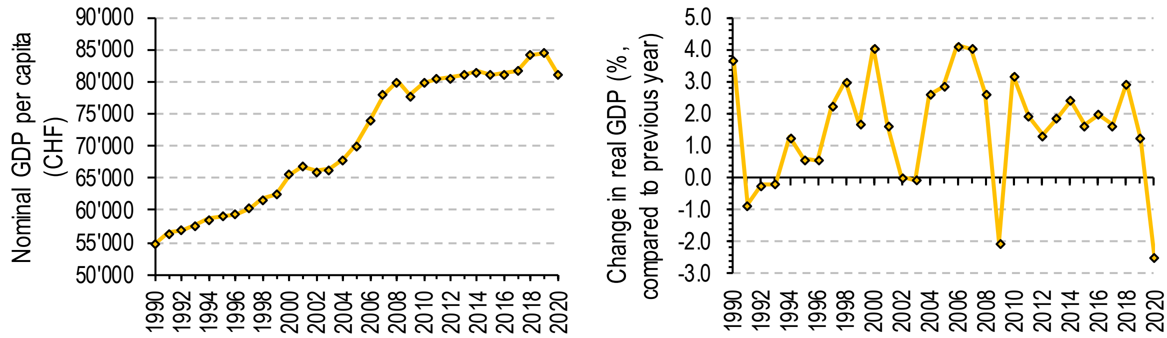
SFSO (2021a)

2.3 Economic profile

Gross domestic product, workforce and gross value added by sectors

Switzerland's nominal gross domestic product was about 706 billion Swiss francs in 2020, corresponding to about 81 thousand Swiss francs per capita (*SECO*, 2021). The nominal gross domestic product per capita increased by 46.3 per cent between 1990 and 2008, and then remained about stable until 2017. After two years (2018 and 2019) with values of about 54 per cent above the 1990 level, the nominal gross domestic product per capita substantially decreased in 2020 due to the measures to contain the corona virus pandemic (Fig. 6, left). Apart from this decrease and a few further exceptions in the early 1990s and in 2009, Switzerland's real gross domestic product increased annually by up to four per cent compared to the previous year over the last three decades (Fig. 6, right).

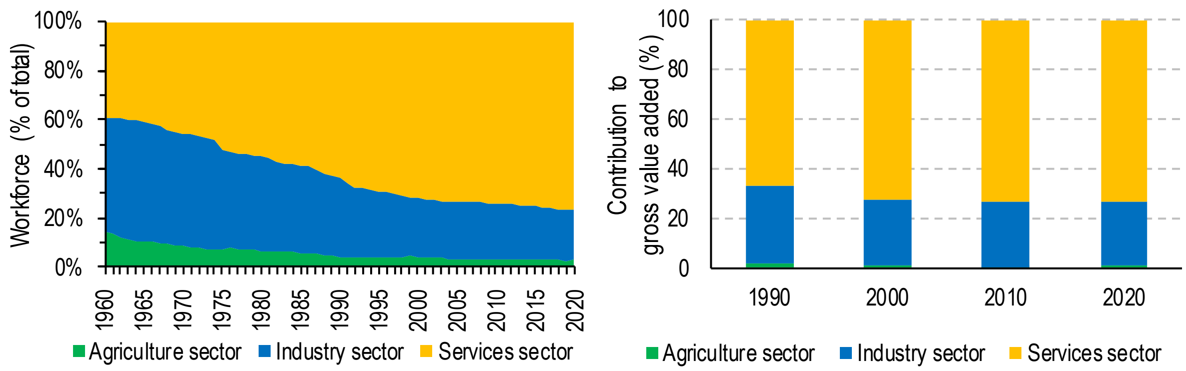
Fig. 6 > Switzerland's nominal gross domestic product (GDP) per capita (left) and percentage change of real gross domestic product (reference year 2015) compared to previous year (right) between 1990 and 2020.



SECO (2021), *SFSO* (2021a)

Between 1960 and 2020 the proportion of the total workforce employed in the different sectors changed substantially (Fig. 7, left); in the agriculture and industry sectors it has fallen from 14.5 and 46.5 per cent to 2.8 and 20.7 per cent, respectively, leading to a substantial increase in the services sector. Accordingly, Switzerland's economy largely depends on the services sector, which in 2020 not only employed 76.4 per cent of the total workforce, but also contributed 73.3 per cent to the gross value added (Fig. 7, right). The structural change to a 'service society' is thus steadily continuing.

Fig. 7 > Contribution of economic sectors to total workforce (left) and gross value added (right) between 1990 and 2020.

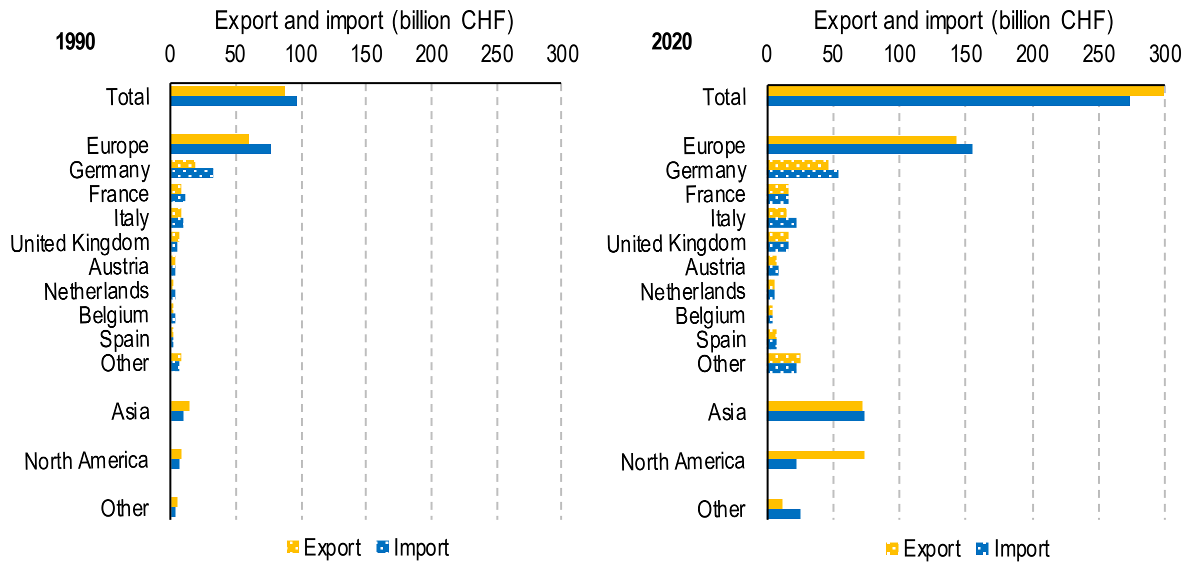


SFSO (2021f), *SECO* (2021)

International trade patterns

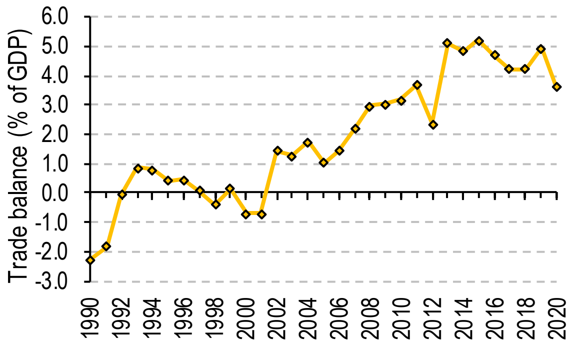
Switzerland has virtually no mineral resources and, historically, no heavy industry. Accordingly, the economy strongly depends on trade with other countries, as Switzerland imports bulk raw materials and exports high-quality goods. In 2020, the value of one tonne of exported goods was about three times higher than the value of one tonne of imported goods (*FOCBS*, 2021). The relatively small size of its domestic market is another factor which has been encouraging Swiss manufacturers to look to foreign markets in order to make investments in research and development worthwhile. As shown in Fig. 8 (left), Switzerland's exports accounted for 88 billion Swiss francs in 1990, while the imports accounted for 97 billion Swiss francs. In 2020, both the exports and imports were substantially higher, accounting for 299 billion and 274 billion Swiss francs, respectively (Fig. 8, right). Switzerland's trade balance (exports minus imports) was about balanced between 1992 and 2001 (within ±1 per cent of the gross domestic product). From 2001 to 2013, exports growth was stronger than imports growth. Between 2013 and 2019, Switzerland's trade balance remained between about four and five per cent of the gross domestic product (Fig. 9), followed by a decrease to 3.6 per cent in 2020 due to the measures to contain the corona virus pandemic. European countries are by far the most important trading partners for Switzerland, accounting for 47.6 per cent of exports and 56.3 per cent of imports in 2020. Largest volumes are traded with Germany, with exports accounting for 46 billion Swiss francs and imports accounting for 53 billion Swiss francs in 2020 (Fig. 8, right). Trade volumes with Italy, France and the United Kingdom are also considerable, with small differences between imports and exports for France and the United Kingdom, but a bias to imports for Italy. Trade with North America is heavily biased towards exports, while it is currently about balanced with Asia. Among the most important traded goods in term of monetary value are chemical and pharmaceutical products, noble metals, jewels and gemstones, machines, instruments and electronics, watches, and precision instruments (Fig. 10).

Fig. 8 > Switzerland's foreign trade (export and import) with important partners in 1990 (left) and 2020 (right).



SFSO (2021g), *SFSO* (2021h)

Fig. 9 > Switzerland's trade balance (export minus import) in per cent of the gross domestic product (GDP) from 1990 to 2020.

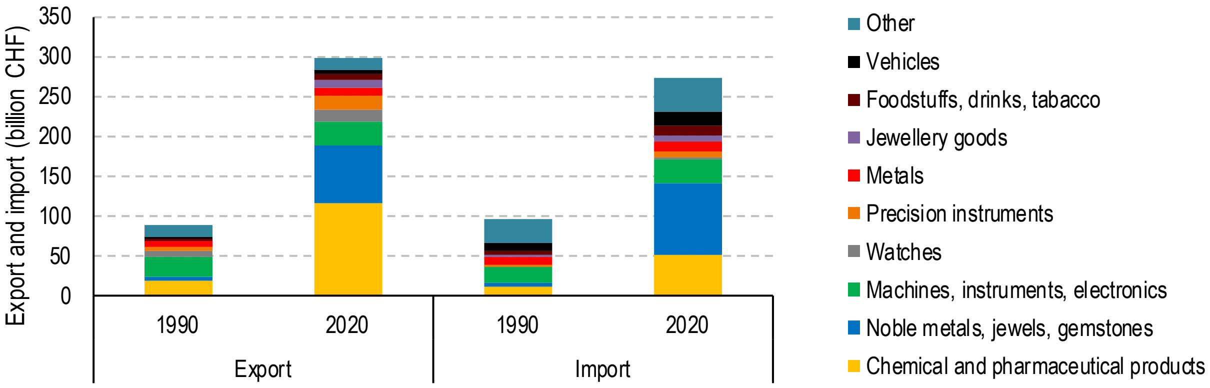


SFSO (2021g), *SFSO* (2021h), *SECO* (2021)

Unemployment, public debt rate and general government spending ratio

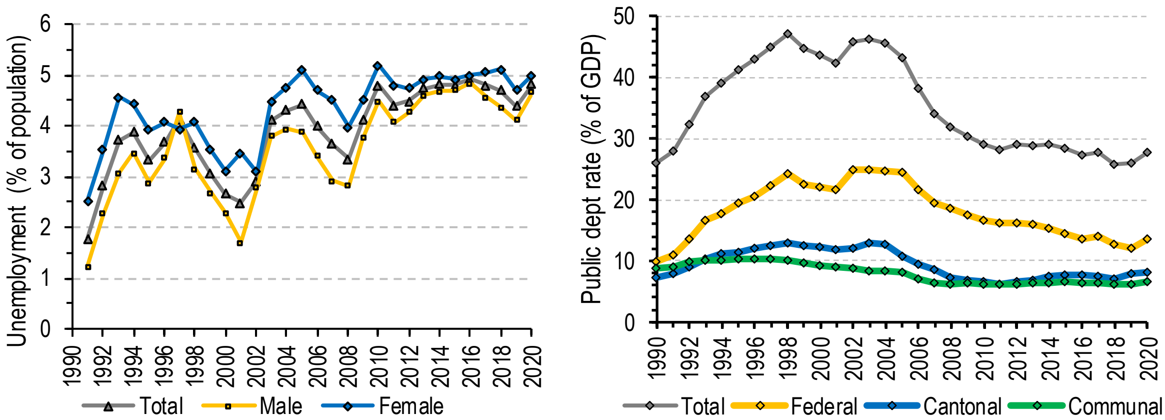
Traditionally a country with low unemployment (less than one per cent), Switzerland experienced a dramatic increase in unemployment from the beginning of the 1990s, as a consequence of the overall economic slow-down. Apart from foreign nationals (both female and male), the category most affected by this development was Swiss women and young people (aged 15 to 25 years). The total rate of unemployment peaked at 4.1 per cent in 1997 and at 4.4 per cent in 2005, and has remained stable at slightly below five per cent since 2010 (Fig. 11, left). In parallel with rising unemployment, aggregate government spending has exceeded revenues at all three administrative levels (federal, cantonal and communal), which has led to increasing public debt in the early to late 1990s (Fig. 11, right). Following a relatively stable period at a high level of between 40 and 50 per cent of gross domestic product, the revenues exceeded the expenditures between 2004 and 2010, and the total public debt rate has remained stable slightly below 30 per cent of the gross domestic product for the last decade. In 2020, Switzerland's general government spending ratio amounted to 37.8 per cent of the gross domestic product, being one of the lowest of OECD countries (*OECD*, 2021; Fig. 12). A substantial increase of the government spending ratio occurred from 2019 to 2020 due to fiscal policy measures taken to mitigate the economic consequences of the corona virus pandemic.

Fig. 10 > Switzerland's foreign trade (export and import) by goods in 1990 and 2020.



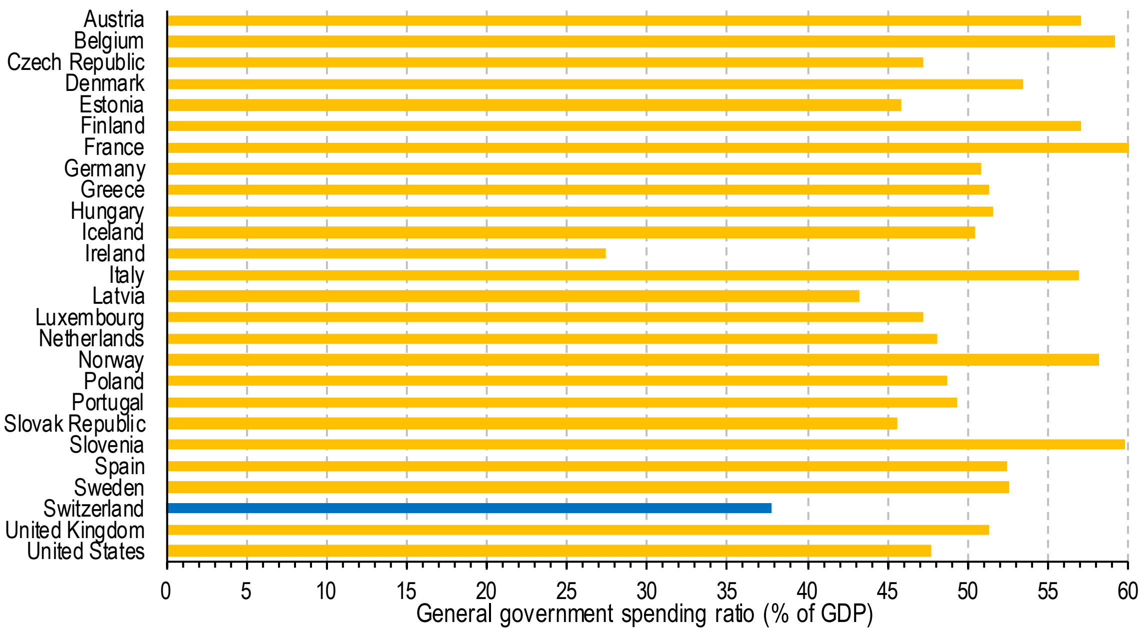
SFSO (2021i)

Fig. 11 > Left: Rates of unemployment (1990–2020). Right: Public debt rate (Maastricht debt ratio) at all administrative levels (federal, cantonal and communal) in percentage of gross domestic product (GDP, 1990–2020, the effect of the fiscal policy measures taken to mitigate the economic consequences of the corona virus pandemic may not yet be fully represented in the data for 2020).



SFSO (2021c), *FFA* (2021)

Fig. 12 > General government spending ratio in 26 OECD countries in 2020.

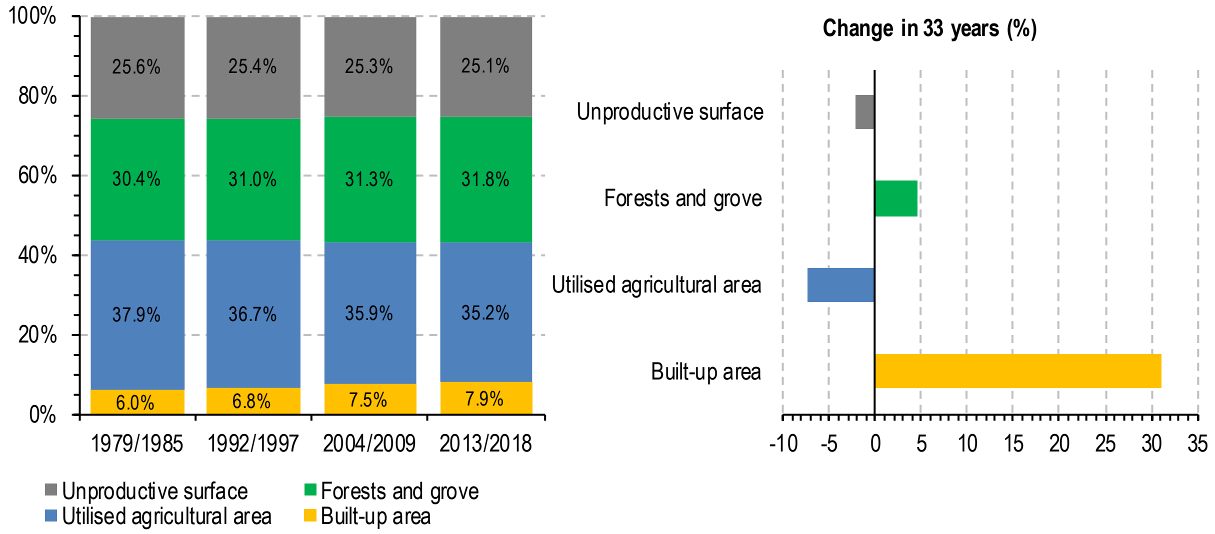


OECD (2021)

2.4 Geographical profile

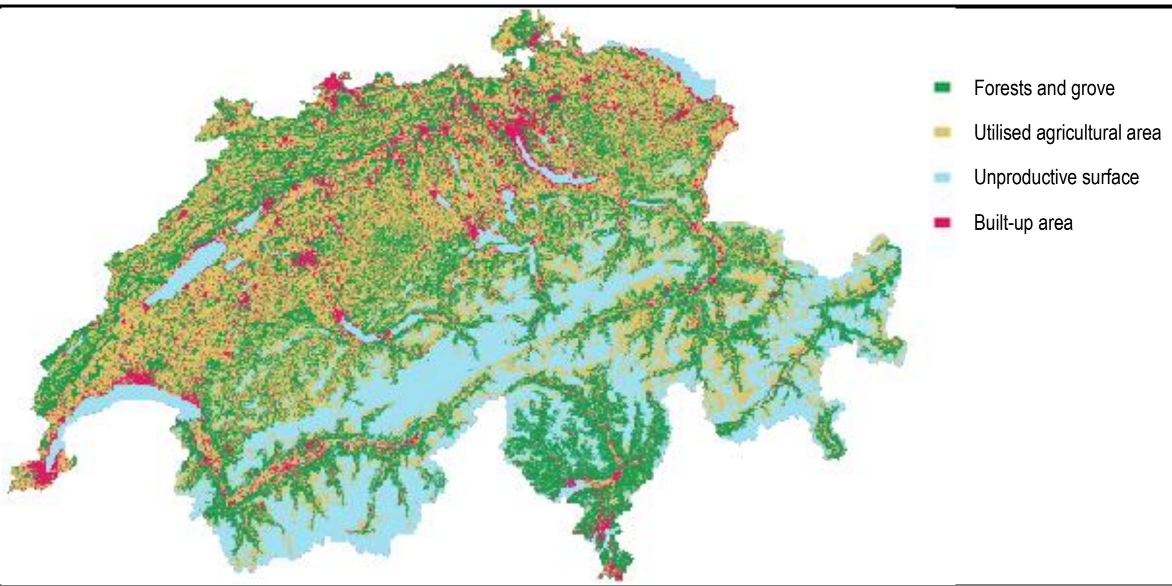
Switzerland, located in the centre of Europe, extends from 45°49’ to 47°48’ north and from 5°57’ to 10°30’ east. It covers an area of 41,285 square kilometres, comprising 25.1 per cent unproductive surface, 31.8 per cent forests and grove, 35.2 per cent utilised agricultural area, and 7.9 per cent built-up area (situation in 2013/2018; *SFSO*, 2021s; Fig. 13, left; Fig. 14). While the built-up area is relatively small, it increased by 31 per cent between 1985 and 2018, and has continued to expand ever since, mainly at the expense of utilised agricultural area (*SFSO*, 2021s; Fig. 13, right).

Fig. 13 > Evolution of different land-use types in Switzerland over the last 33 years (left) and changes in land use between 1979/1985 and 2013/2018 (right). The utilised agricultural area includes alpine pastures.



SFSO (2021s)

Fig. 14 > Switzerland’s land use based on the land-use statistics 2013/2018.



SFSO (2021s)

Switzerland’s topography is defined by the Central Plateau, the Jura mountains and the Alps. About half of Switzerland’s surface area is located above 1,000 metres above sea level and about one quarter of Switzerland’s surface is located above 2,000 metres above sea level (*SFSO*, 2021s). With mean annual precipitation of over 1,400 millimetres, Switzerland is one of the most water-abundant countries in Europe (see also section 2.5). It also has large water storage reservoirs in the form of natural lakes (130 cubic kilometres), artificial reservoirs (3.5 cubic kilometres), glaciers (53 cubic kilometres) and groundwater (150 cubic kilometres) (*FOEN*, 2021a).This storage volume corresponds to 5.6 times the mean annual precipitation. One third of the annual precipitation evaporates, the rest eventually leaves the country as runoff. The great

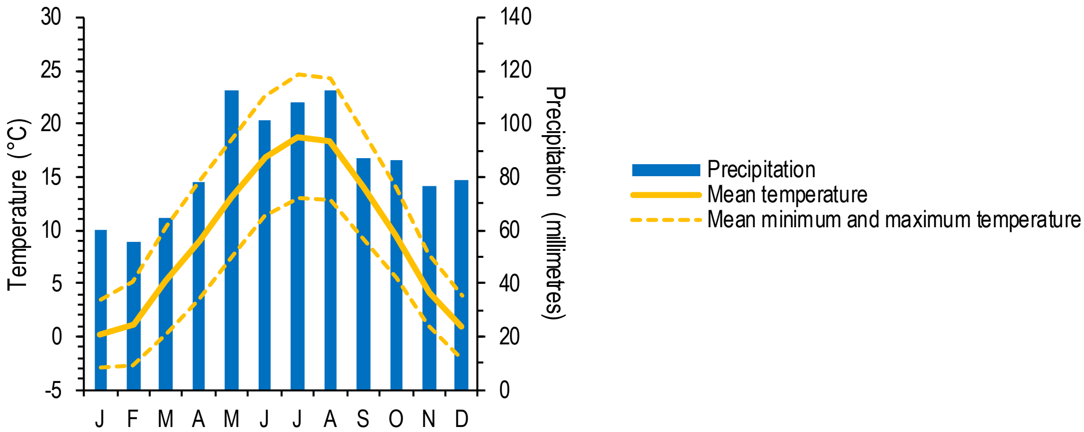
Rhine and Rhone rivers and the main tributaries of the Po and Danube have their sources in the Swiss Alps. The downstream countries depend heavily on runoff from Switzerland for irrigation, cooling, hydro-power production, drinking water, navigation, and other water uses. Changes in the various elements of the Swiss water balance have therefore a direct impact on the downstream riparians.

The location in the heart of Europe and in the centre of the European Union leads to substantial imports and exports of goods and services, and to transit freight flows across Switzerland. The Alps represent a natural barrier for transportation in the north-south direction, i.e. between northern Europe and Italy, but a number of tunnels facilitate large-scale transportation on road and rail across the Alps (section 2.7).

2.5 Climate profile

Climatic conditions vary significantly across Switzerland, depending mainly on altitude and location. As an example for local conditions on the densely populated Central Plateau, the climate graph for Switzerland's capital Bern is provided in Fig. 15. Although the Alps – running from south-west to east – act as a major climatic divide, the observed climate change signals are qualitatively similar north and south of the divide. Long-term measurements since 1864 indicate a marked shift towards a warmer climate (*Begert and Frei*, 2018*; FOEN and MeteoSwiss*, 2020). Changes in mean precipitation are less clear. Trends in annual mean precipitation are predominantly positive but not statistically significant in most regions over the last 100 years (1921–2020). There are indications for a robust increase in winter precipitation when analysing time series starting in 1901 or before (*Scherrer et al.*, 2015), and evidence for an increase in the frequency and intensity of heavy precipitation has been presented (*Scherrer et al.*, 2016). Pronounced trends are also found for cloudiness and sunshine duration (see below). For expected future developments and impacts thereof see section 6.1 (*CH2018*, 2018). In the following, more detailed information is provided with regard to temperature, precipitation, climate indices, and extreme events.

Fig. 15 > Climate graph for Bern, Switzerland's capital, located on the Central Plateau at 553 metres above sea level. Provided are mean values for the period 1991–2020. The mean annual temperature during this period is 9.3 degrees Celsius, the mean minimum and maximum temperatures are 4.7 and 14.0 degrees Celsius. Mean annual precipitation is 1,022 millimetres.

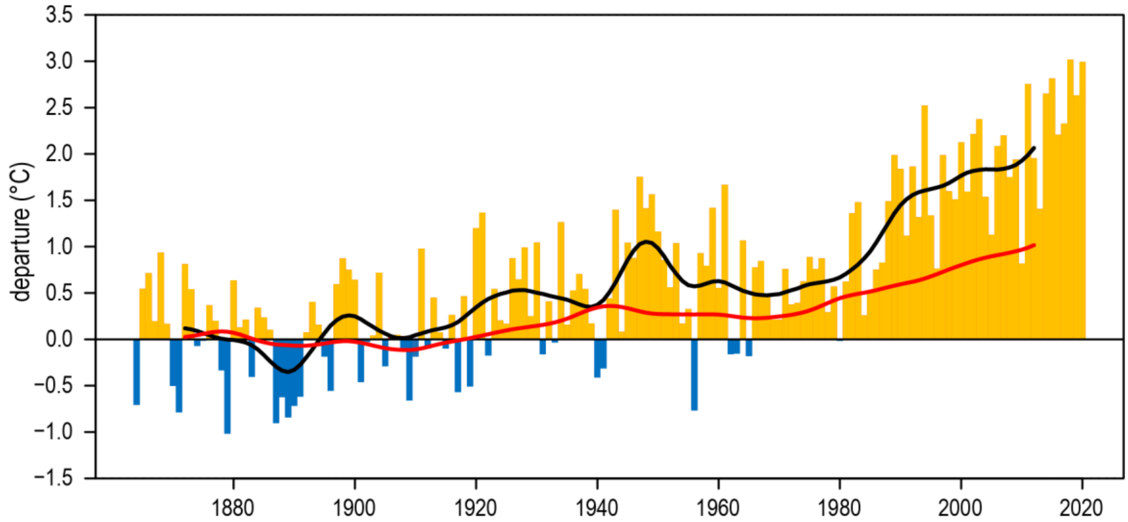


MeteoSwiss (2022)

Temperature

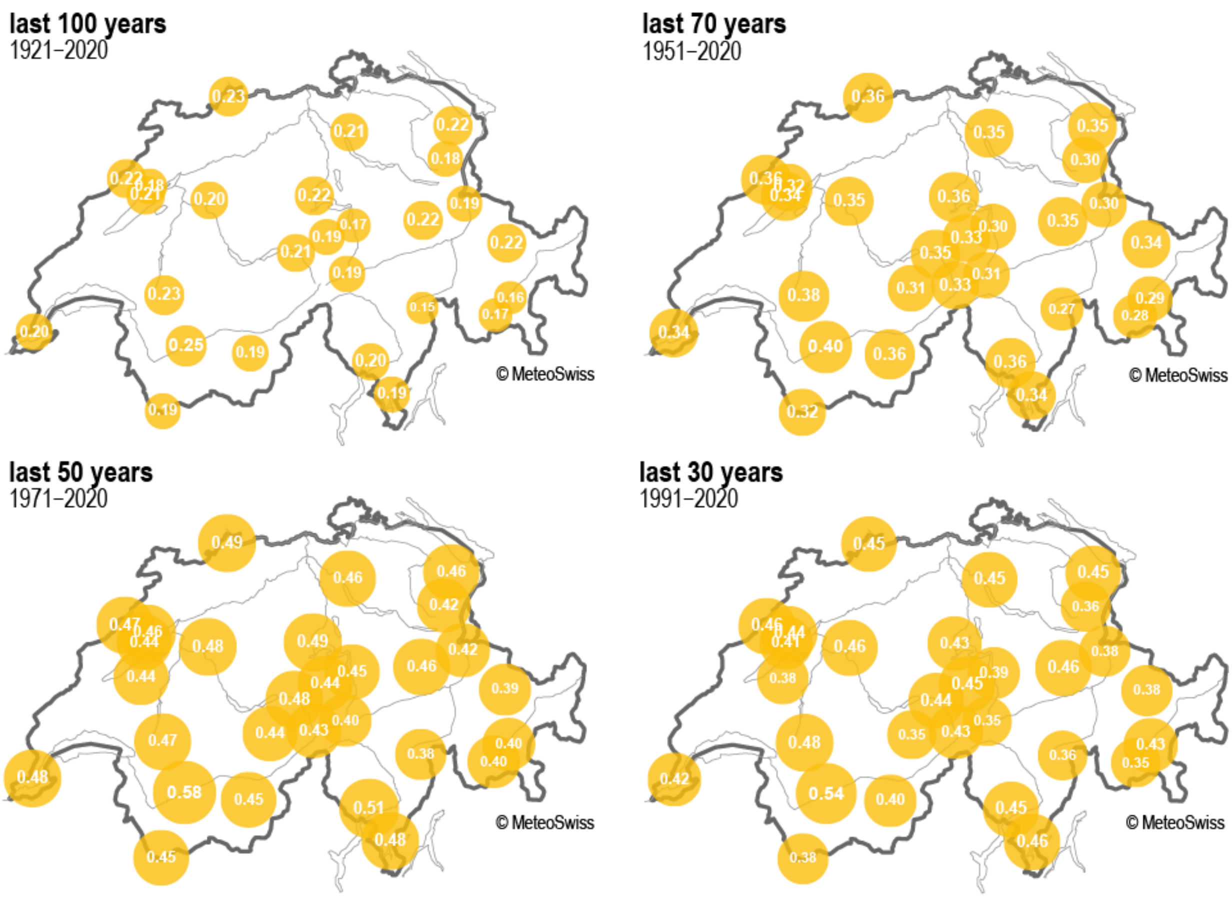
Fig. 16 shows the annual temperature anomaly in Switzerland with respect to 1871–1900 pre-industrial conditions. Annual temperature has increased by more than two degrees Celsius between 1864 and 2020, which corresponds to a linear increasing temperature trend of about 0.14 degrees Celsius per decade. Temperature trends have accelerated substantially for more recent time periods (Fig. 17). Over the last 100 years (1921–2020), annual temperature has increased by about 0.15 to 0.25 degrees Celsius per decade with no pronounced differences between geographical locations (north-south, low-high altitudes). The trend magnitude is similar for all seasons with a slight tendency to somewhat higher values in summer and winter (up to 0.29 degrees Celsius per decade). Annual temperature trends for the last 70 years (1951–2020) are 0.27 to 0.40 degrees Celsius per decade, for the last 50 years (1971–2020) 0.38 to 0.58 degrees Celsius per decade and for the last 30 years (1991–2020) 0.35 to 0.54 degrees Celsius per decade. The trends are roughly in agreement with the trends in other parts of Central Europe. In the last 30 years, the trends were largest and significant in autumn (0.44 to 0.70 degrees Celsius per decade) and summer (0.32 to 0.62 degrees Celsius per decade), insignificant but with a positive sign in spring (0.15 to 0.36 degrees Celsius per decade) and insignificant in winter (–0.12 to 0.39 degrees Celsius per decade). The temperature change in Switzerland since pre-industrial conditions amounts to about twice that of the global mean temperature increase.

Fig. 16 > Global and Swiss mean annual temperature anomalies 1864–2020 (annual temperature shown as deviation from the pre-industrial mean of 1871–1900). The years in Switzerland with positive anomalies (warmer) are shown in orange and those with negative anomalies (cooler) in blue. The black smooth line represents 20-year Gaussian low-pass filtered data. The red smooth line shows the corresponding global temperature anomalies according to the HadCRUT5 dataset (*Morice et al.*, 2021).



MeteoSwiss (2021)

Fig. 17 > Observed trends for annual mean temperature in Switzerland for homogenised station data. Shown are trends in degrees Celsius per decade of the last 100 years (1921–2020, top left), the last 70 years (1951–2020, top right), the last 50 years (1971–2020, bottom left) and the last 30 years (1991–2020, bottom right). All trends are positive and statistically significant on the five per cent significance level.

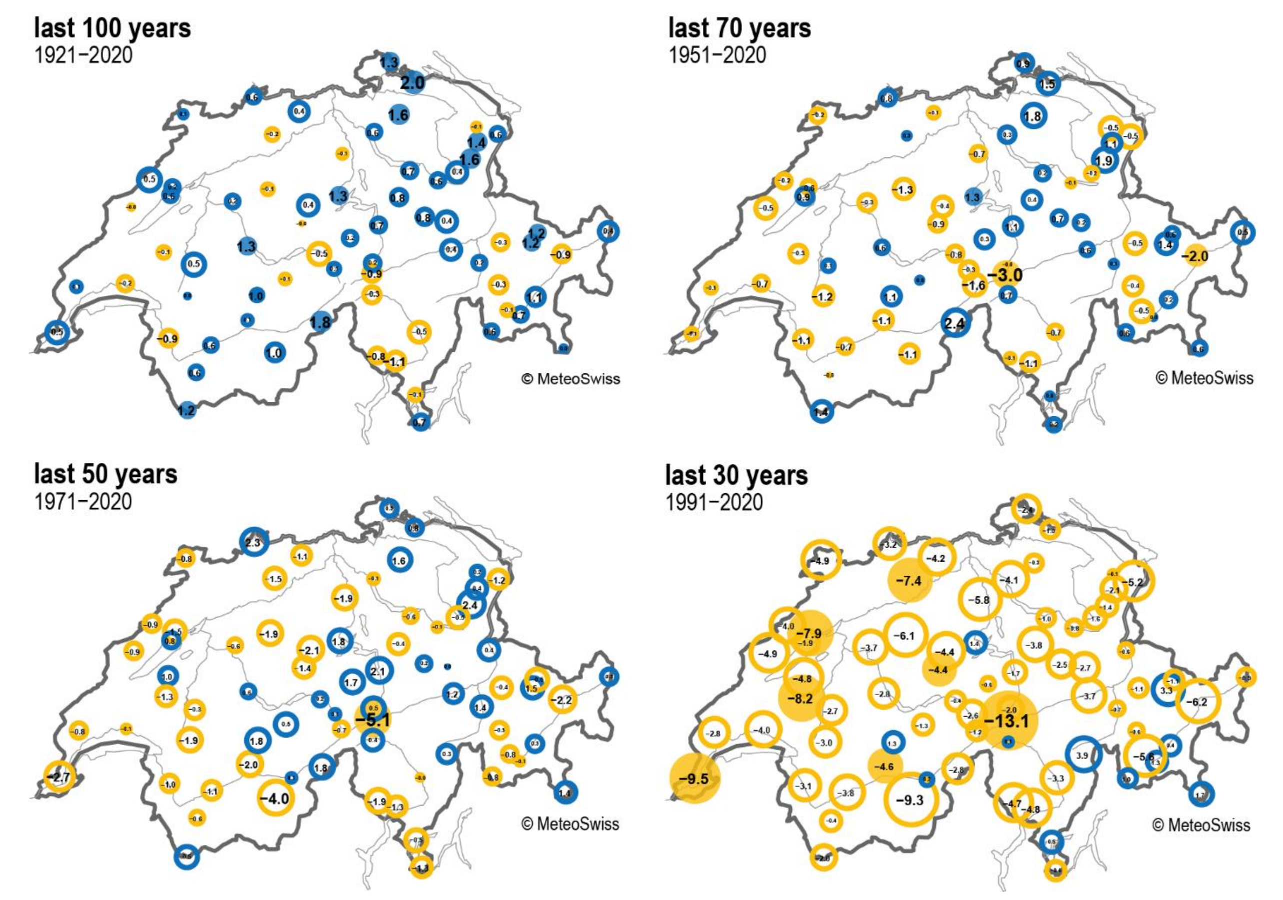


MeteoSwiss (2021)

Precipitation

Fig. 18 shows the annual precipitation trends in Switzerland for the last 100 years (1921–2020), the last 70 years (1951–2020), the last 50 years (1971–2020) and the last 30 years (1991–2020) years. In contrast to temperature, precipitation trends are insignificant for most stations and time periods considered. Some significantly positive trends are found in northern Switzerland and the Alps considering a time period of 100 years. For the majority of the stations however, the trend magnitudes are insignificant. Predominantly negative trends, some of them significant, are found for the last 30 years. This is a good example to show that internal decadal variability can still be larger than any underlying long-term trend. Also on the seasonal scale, most trends in mean precipitation are insignificant or not consistent over time (not shown). There are, however, robust indications for changes in heavy precipitation. Since 1901, the intensity of the annual one-day precipitation maxima has increased by about 12 per cent and the frequency of the all-day 99th percentile events (i.e. precipitation sums of more than 25–105 millimetres per day, depending on the region) by almost 30 per cent on average (*Scherrer et al.*, 2016 and *FOEN and MeteoSwiss, 2020*). The observed changes are consistent with climate model projections, with theoretical understanding of a human-induced change in the energy budget and water cycle and with detection and attribution studies of extremes on larger spatial scales.

Fig. 18 > Observed trends in annual precipitation in Switzerland for homogenised station data. Shown are trends in per cent per decade of the last 100 (1921–2020, top left), the last 70 years (1951–2020, top right), the last 50 years (1971–2020, bottom left) and the last 30 years (1991–2020, bottom right). Positive trends (i.e. more precipitation) are shown in blue, negative trends (i.e. less precipitation) are shown in orange. Filled circles: Trends that are statistically significant (five per cent significance level), open circles: non-significant trends.

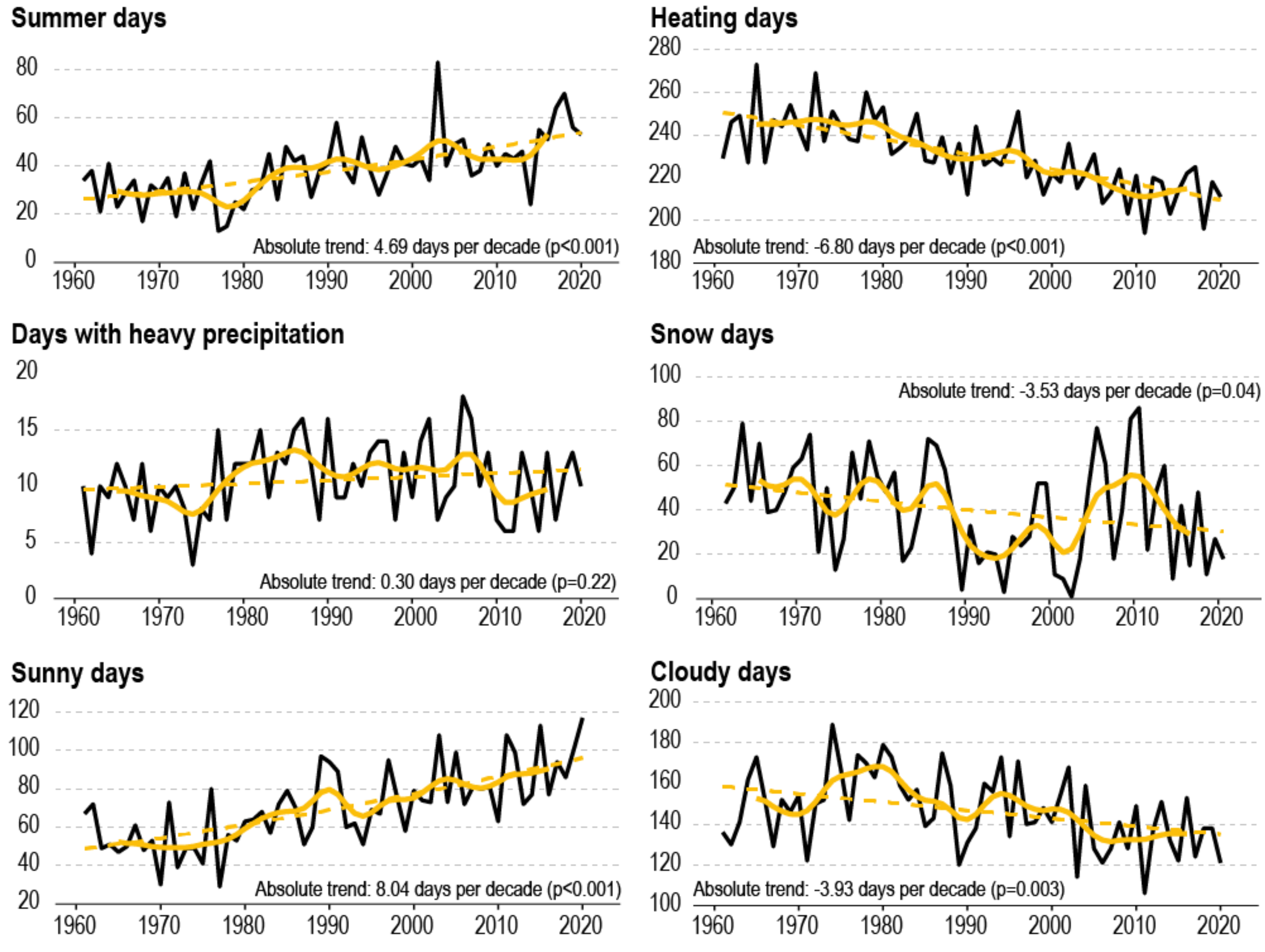


MeteoSwiss (2021)

Climate indices

Fig. 19 shows the evolution of some important climate indices at the station Bern/Zollikofen for the time period from 1961–2020. This station can be considered as representative for the general evolution on the densely populated Central Plateau. The average number of summer days has more than doubled from roughly 25 days per year in the 1960s to more than 50 days per year today (Fig. 19, top left). This increase is highly significant and very similar trends are found for most stations on the Central Plateau. In contrast, the number of heating days has decreased by about 15 to 20 per cent in the same time period (Fig. 19, top right). The number of days with heavy precipitation (Fig. 19, middle left) has increased somewhat, although the trend is not statistically significant. Similar insignificant increases are found for most stations on the Central Plateau. A decrease is found for the number of snow days (Fig. 19, middle right). The number of sunny days (relative sunshine duration larger than 80 per cent, Fig. 19, bottom left) shows a significant increase whereas the number of cloudy days (relative sunshine duration less than 20 per cent) is decreasing (Fig. 19, bottom right). These trends are consistent with most stations on the Central Plateau. Trends in sunshine duration have been negative especially in the period of the late 1940s to about 1980. Today's values are now back to the level seen in the late 19th, early 20th century.

Fig. 19 > Climate indices for the period 1961–2020 at the station Bern/Zollikofen. Observed annual number of summer days (days with maximum temperature ≥25 degrees Celsius, top left), heating days (days with a daily average temperature below 12 degrees Celsius, top right), days with heavy precipitation (daily precipitation >20 mm, middle left), snow days (days with snow depth of at least one centimetre, middle right), sunny days (days with relative sunshine duration larger than 80 per cent, bottom left) and cloudy days (days with relative sunshine duration lower than 20 per cent, bottom right). Homogenised station data are used for the temperature-based and precipitation-based indices. The solid orange line represents 11-year Gaussian low pass filtered data, the dashed orange line the linear fit (logistic regression).

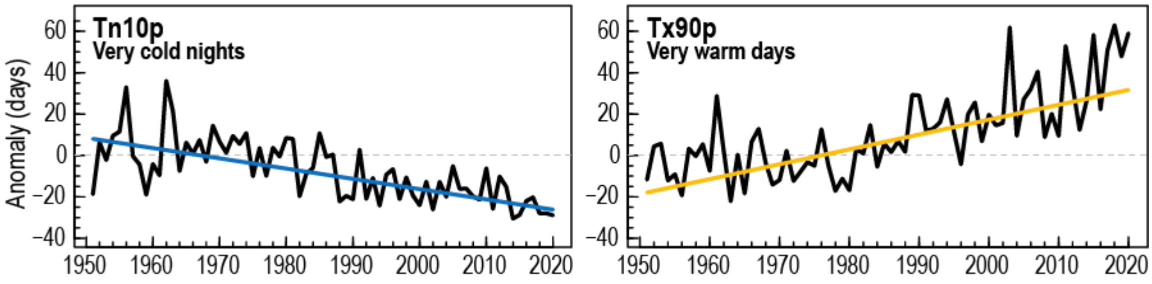


MeteoSwiss (2021)

Extreme events

Numerous extreme climate and weather events struck Switzerland during the last decades (flooding, heat waves, dry periods, storms, etc.). However, due to the strong natural variability, it is challenging to provide evidence for changes in the frequency or intensity of extreme events, in particular in view of Switzerland's relatively small area. Nevertheless, most meteorological stations in Switzerland show a highly significant trend to less very cold nights as well as an increase in very warm days (Fig. 20). Further, the frequency and intensity of heavy precipitation events have increased at most (>90 per cent) of the meteorological stations in Switzerland (*Scherrer et al.*, 2016). For small scale processes such as flash floods, debris flows, landslides, hail events etc. it is very hard to analyse trends because of a relatively short observational record and limited process understanding (*SCNAT*, 2016; *CH2018*, 2018). Extreme events, including related risks, vulnerability and damages, are further discussed in chapter 6.

Fig. 20 > Observations of very cold nights (daily minimum temperature amongst the lowest 10 per cent) and very warm days (daily maximum temperature amongst the highest 10 per cent) in Switzerland, 1951–2020. The mean Mann-Kendall trends for the period 1951 to 2020 are –5.0 days per 10 years for Tn10p and +7.2 days per 10 years for Tx90p. Both trends are highly significant (p<10⁻³).



SCNAT (2016), updated by MeteoSwiss with data from 1951–2020

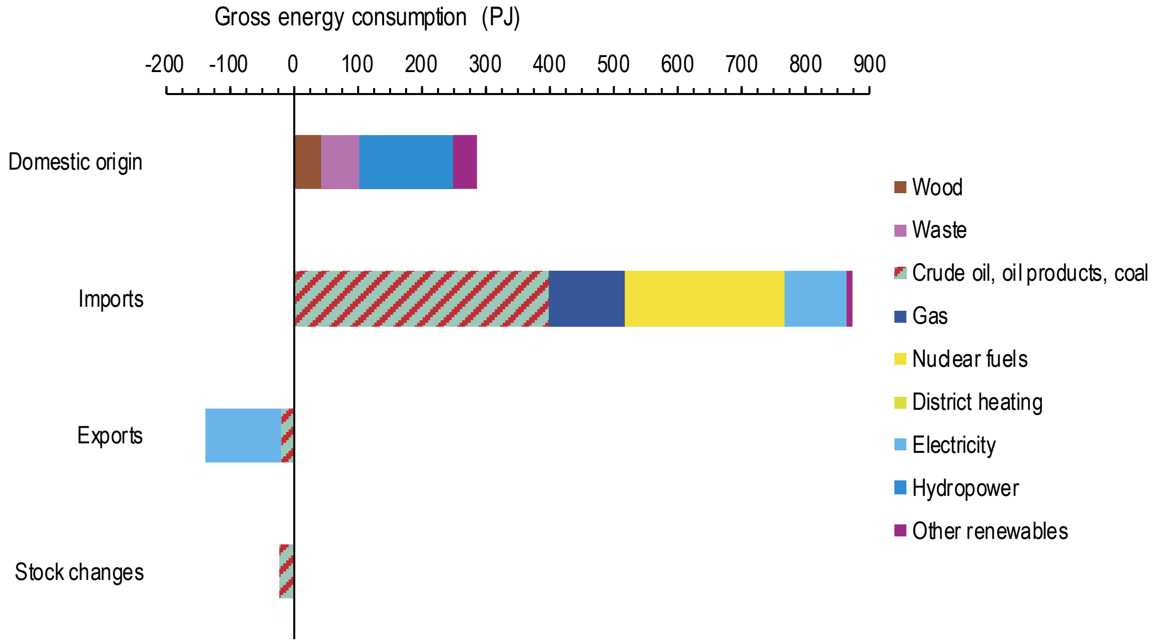
2.6 Energy

Energy supply and final energy consumption

As there are no domestic gas, oil, coal or nuclear fuel resources, Switzerland's primary energy sources are limited to wood, hydropower, waste and other forms of renewable energy sources (wind and solar power, biogas, etc.). Accordingly, Switzerland's energy system largely depends on fossil energy imports, while it is almost self-sufficient regarding carbon-free electricity, as highlighted in the detailed energy flow diagram provided in Fig. 22.

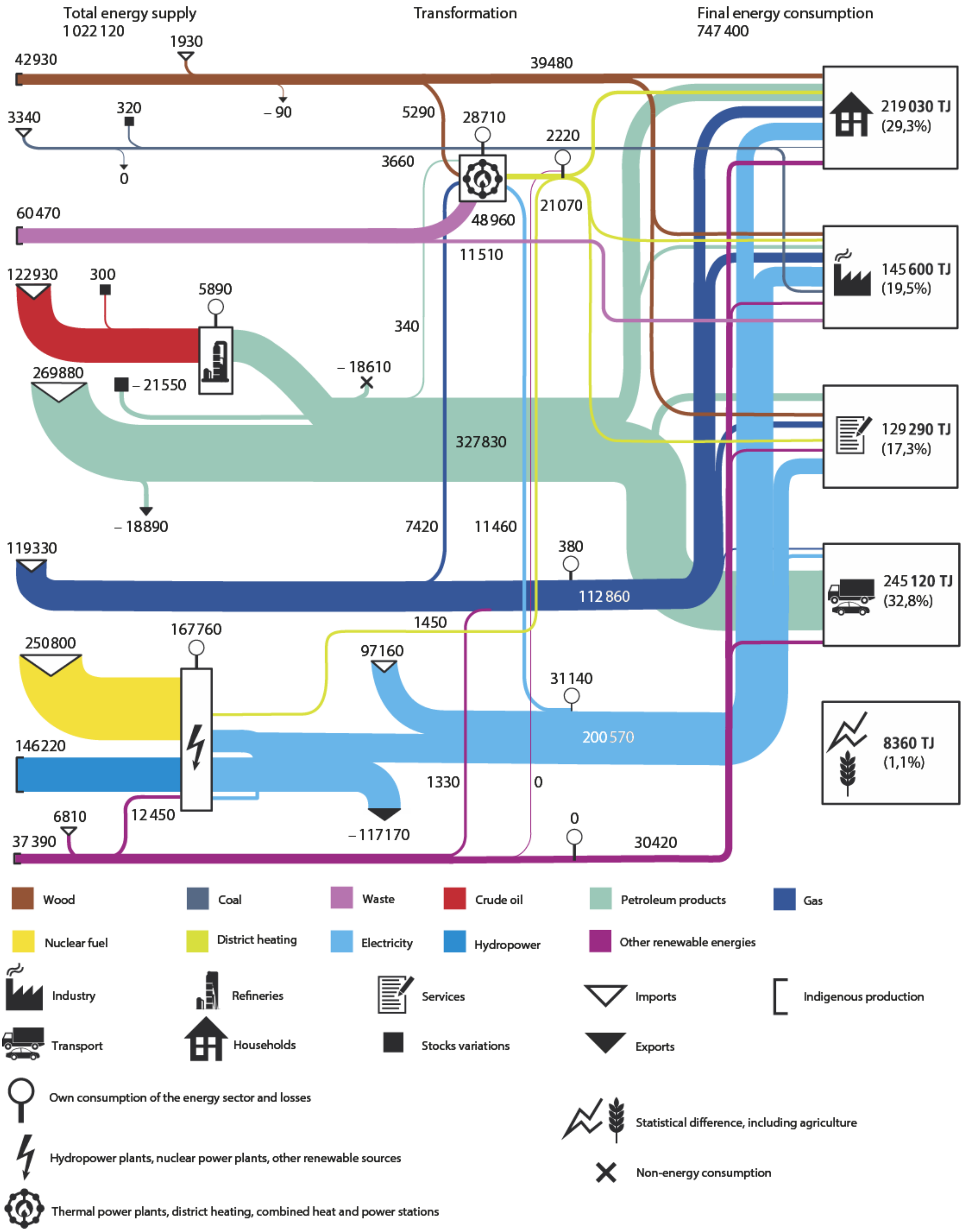
In 2020, gross energy consumption amounted to 1,002,110 terajoules, composed as follows (see Fig. 21): (i) 287,010 terajoules were of domestic origin (50.9 per cent hydropower, 21.1 per cent waste, 15.0 per cent wood, 13.0 per cent other renewable energy sources), (ii) 872,180 terajoules were imported (45.0 per cent crude oil and oil products, 13.7 per cent gas, 28.8 per cent nuclear fuel, 11.1 per cent electricity, 1.0 per cent wood and other renewable energy resources, and 0.4 per cent coal), (iii) exports accounted for a total of 136,150 terajoules (86.1 per cent electricity, 13.9 per cent oil products, 0.1 per cent wood), and (iv) the remaining 20,930 terajoules corresponded to stock changes of mainly crude oil, but also oil products and coal (*SFOE*, 2021a).

Fig. 21 > Switzerland's gross energy consumption in 2020 (1,002,110 terajoules).



SFOE (2021a)

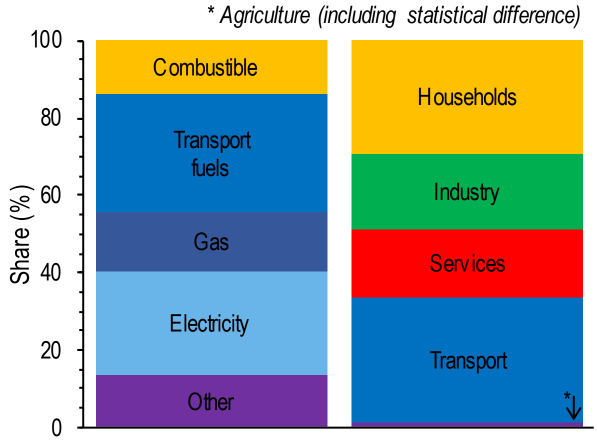
Fig. 22 > Energy flow diagram for Switzerland for 2020 (numbers in terajoules). Gross energy consumption of 1,002,110 terajoules corresponds to total energy supply (1,022,120 terajoules) adjusted by imports (97,160 terajoules) and exports (–117,170 terajoules) of electricity.



SFOE (2021a)

In 2020, the final energy consumption totalled at 747,400 terajoules. The shares of the different energy carriers as well as the consumption in the sectors transport, services, industry, households, and agriculture (including statistical difference) are shown in Fig. 23.

Fig. 23 > Switzerland's final energy consumption in 2020 (747,400 terajoules). The category other includes wood, waste, other renewables, and district heating.

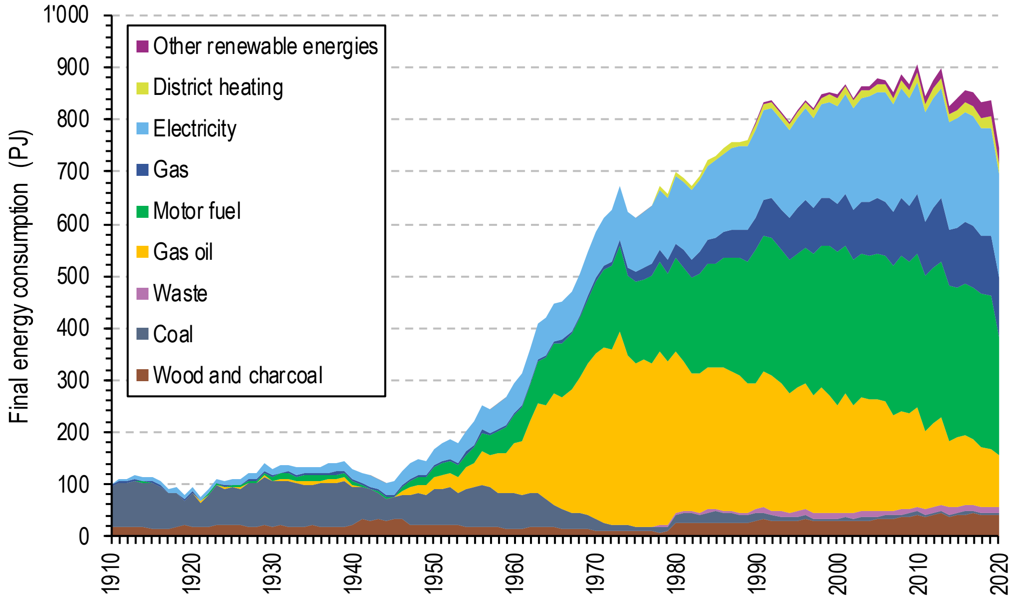


SFOE (2021a)

Final energy consumption started to increase substantially after the first half of the last century, with the largest increases seen in gas oil, motor fuel and electricity (Fig. 24). In order to average the strong impact of meteorological conditions on heating demand, leading to rather large year-to-year variations in the final energy consumption (see also sections 2.5 and 3.2.3), mean values over several years are discussed in the following. Compared to the mean final energy consumption between 1910 and 1915, the mean final energy consumption was more than sevenfold higher between 2015 and 2020. The highest final energy consumption, over a period of five years, occurred between 2009 and 2013, 10.1 per cent higher compared to 1988 to 1992. However, final energy consumption has slightly decreased for about the last decade. In 2020, final energy consumption was remarkably below usual values due to the measures to contain the corona virus pandemic. Renewable energy sources (not including hydropower) still contributed a minor share of 4.1 per cent to the final energy consumption in 2020. Nevertheless, supported by the SwissEnergy programme (section 4.3.2), renewable energy sources gained importance during the last years. Between 1990 and 2020, the annual generation of solar electricity increased from 4 to 9,356 terajoules, while the annual generation of wind electricity increased from 0 to 522 terajoules.

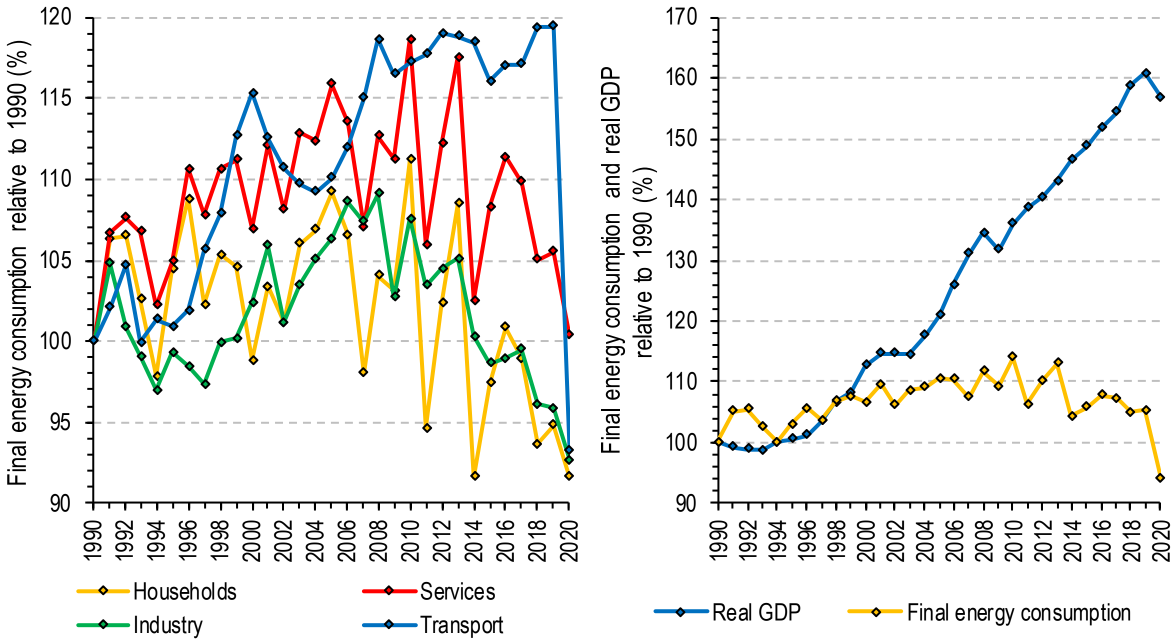
The evolution of final energy consumption by households, services, industry and transport is shown in Fig. 25 (left), relative to 1990. The final energy demand in the transport sector shows an increase of up to about 20 per cent between 1990 and about the last decade, with fluctuations that correlate with the economic development, e.g. periods of stagnation from 1993 to 1996 and from 2001 to 2003, and periods of growth (gross value added) from 1997 to 2000 and 2004 to 2008. The decrease in 2015 mostly results from the collapsing 'fuel tourism' as a consequence of a sudden drop in the exchange rate between the Euro and the Swiss franc once the Swiss National Bank ceased sustaining a minimal exchange rate. In 2020, the measures to contain the corona virus pandemic led to a strong decrease of final energy consumption in the transport sector. As mentioned above, final energy demand of households strongly depends on meteorological conditions. The extraordinary decreases from 2006 to 2007, 2010 to 2011, and 2013 to 2014 reflect the changes from relatively cool to relatively warm winters. From 1990 to 2020, the number of buildings and apartments, as well as the average floor space per person have increased (section 2.10). Both phenomena have resulted in an increase in the total area heated. Over the same period, however, higher standards have been specified for insulation and for combustion equipment efficiency for both new and renovated buildings, compensating for the energy consumption from the additional area heated (section 4.3.4). The final energy consumption of services has also been influenced by the meteorological conditions as well as efficiency improvements. The final energy consumption of the industry sector has shown a decreasing trend since about a decade. Supported by the contributions of households and services, this decreasing trend has been reflected in the total final energy consumption as well, while the real gross domestic product has continued to strongly increase (Fig. 25, right). The reasons for this diverging developments are, on the one hand, an increase in energy efficiency thanks to modern production processes leading to a lower energy input per gross value added. On the other hand, starting in the early 1990s, the production of many energy intensive goods have been sourced out to foreign countries, leading to an even more service-based economy in Switzerland. Although energy-intensive goods have still been consumed in Switzerland, the energy required for their production has no longer been accounted for in the national total.

Fig. 24 > Final energy consumption between 1910 and 2020 according to energy source.



SFOE (2021a)

Fig. 25 > Final energy consumption by households, services, industry and transport between 1990 and 2020, relative to 1990 (left). Final energy consumption and real gross domestic product (GDP, reference year 2015) between 1990 and 2020, relative to 1990 (right).

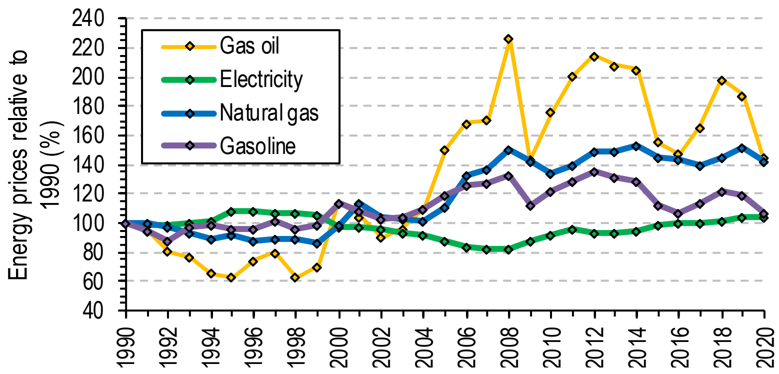


SFOE (2021a)

Energy prices, taxes and subsidies

The evolution of energy prices at the level of consumers is shown in Fig. 26. Prices for gas oil reached historic low values in the mid-1990s, then substantially increased to between 40 to 100 per cent above the prices in 1990. Prices for natural gas and gasoline show similar patterns, although the maximum prices – reached after 2010 – were about 50 and 30 per cent above the prices in 1990, respectively. Until 2008, prices for electricity decreased to about 80 per cent of the prices in 1990, however, then continuously increased to reach again the 1990 level during the most recent years.

Fig. 26 > Relative development of real energy prices (level of consumers, basis 2010) in Switzerland between 1990 and 2020.



SFOE (2021a)

In Switzerland, energy prices at the level of consumers are composed of the basic price, the value-added tax, as well as various energy taxes and climate levies. Regarding the value-added tax, the normal rate of 7.7 per cent applies. Energy taxes and climate levies depend on the fuel type and were as follows (as of 1 January 2022; e.g. *FOCBS*, 2022a):

- Heating and process fuels: (i) mineral oil tax (e.g. 3.00 Swiss francs per 1,000 litres of gas oil or 2.10 Swiss francs per 1,000 kilograms of natural gas) and (ii) CO_2 levy (e.g. 318.00 Swiss francs per 1,000 litres of gas oil or 321.60 Swiss francs per 1,000 kilograms of natural gas);
- Motor fuels: (i) mineral oil tax (e.g. 453.00 Swiss francs per 1,000 litres gasoline, 481.10 Swiss francs per 1,000 litres of diesel oil, or 112.50 Swiss francs per 1,000 kilograms of natural gas), (ii) mineral oil surtax (e.g. 315.20 Swiss francs per 1,000 litres of gasoline, 314.60 Swiss francs per 1,000 litres of diesel oil, or 109.70 Swiss francs per 1,000 kilograms of natural gas), and (iii) for the partial compensation of CO_2 emissions from motor fuels (section 4.4.5), the permitted compensation surcharge on motor fuels amounts to a maximum of 50.00 Swiss francs per 1,000 litres;
- Kerosene: As in other countries, kerosene used for international flights is exempt from taxation, but similar taxes as for other motor fuels apply for kerosene used for domestic flights.

Additionally including transport costs and the trade margin, consumers had to pay the following energy prices as of January 2022 (*FOCBS*, 2022b):

- Gasoline (per litre): 1.780 Swiss francs, including 50.5 per cent of taxes and levies;
- Diesel oil (per litre): 1.830 Swiss francs, including 50.9 per cent of taxes and levies;
- Gas oil (per litre): 0.959 Swiss francs, including 32.6 per cent of taxes and levies.

Tab. 1 shows the relative comparison of energy prices in Switzerland and its neighbouring countries as of January 2022 (*FOCBS*, 2022b), i.e. before the recent developments in the course of 2022. The price for gasoline in Switzerland was about the same as in Germany and Italy, but somewhat higher compared to France and Austria. Diesel oil was generally more expensive in Switzerland compared to its neighbouring countries. With regard to gas oil, energy prices in Switzerland were in the middle of the field, despite the relatively high CO_2 levy (see section 4.2.5).

Tab. 1 > Energy prices in Switzerland and its neighbouring countries as of January 2022, including all taxies and levies (relative prices with prices for Switzerland set to 100.0).

Country	Gasoline	Diesel oil	Gas oil
Switzerland	100.0	100.0	100.0
Germany	100.0	89.1	92.6
France	94.8	87.0	112.0
Italy	100.3	89.9	150.6
Austria	81.2	78.1	93.2

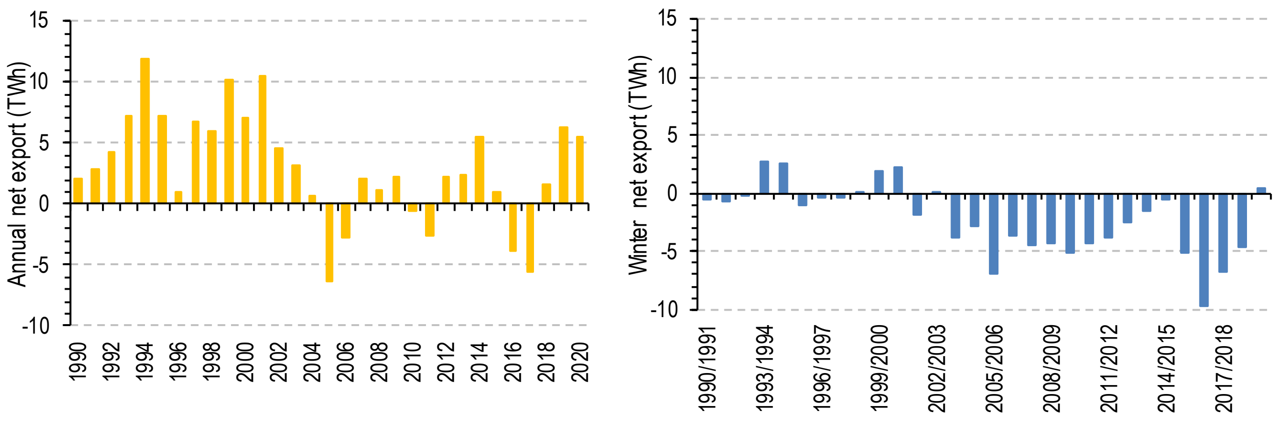
FOCBS (2022b)

Switzerland promotes, on a national and international level, the regulation of fuel consumption and associated greenhouse gas emissions by means of CO_2 pricing, as highlighted in the OECD's report on effective carbon rates (*OECD*, 2021b). According to this report, Switzerland's effective carbon rates[4] for emissions from all sectors (excluding emissions from the combustion of biomass) cover, by 2018, 72 per cent of total emissions with a rate exceeding 120 Euro per tonne of CO_2, 84 per cent of total emissions with a rate exceeding 60 Euro per tonne of CO_2, and 85 per cent of total emissions with a rate exceeding 30 Euro per tonne of CO_2, respectively. In particular, the carbon rates for emissions from road energy cover 100 per cent of total emissions with a rate exceeding 120 Euro per tonne of CO_2. In comparison with other countries, Switzerland's effective carbon rates are exceptionally high. This because of comprehensive fuel taxes in the transport sector (e.g. the mineral oil tax, see section 2.6), the CO_2 levy on heating and process fuels (see section 4.2.5), a highly decarbonised electricity supply as well as low emissions from the industry sector that are largely subject to the Swiss emissions trading scheme (see section 4.2.6).

Electricity trade

According to the Swiss electricity statistics (*SFOE*, 2021b), electricity is traded across Switzerland's borders on a fairly large scale. In 2020, exports accounted for 32.5 terawatt-hours and imports for 27.0 terawatt-hours, corresponding to a substantial amount relative to the total inland electricity production of 69.9 terawatt-hours. Switzerland exchanges electricity with its neighbouring countries Austria, France, Germany, Italy and Liechtenstein. Apart from the years 2005, 2006, 2010, 2011, 2016 and 2017, Switzerland's annual electricity exports exceeded the imports by up to more than 10 terawatt-hours (Fig. 27, left). However, during winter time the situation is different, as Switzerland's imports generally exceed the exports (Fig. 27, right). Among the factors affecting the volume of electricity traded across the borders of Switzerland are hydrological and climatic conditions.

Fig. 27 > Switzerland's net export of electricity from 1990 to 2020. Positive values refer to exports, negative values refer to imports. Left: Total annual net exports. Right: Net exports during winter time.



SFOE (2021b)

2.7 Transport

Overview

Switzerland's transport infrastructure is in a very advanced state. Individual and freight transport is facilitated by the road and rail networks, which overall occupy about two per cent of the total land surface. Public transport is of great importance, meaning that virtually every location can be reached by train or, in particular in more remote regions of the Alps, by scheduled public buses.

[4] According to *OECD* (2021b), effective carbon rates are the total price that applies to CO_2 emissions from energy use as a result of market-based policy instruments. They are the sum of taxes and tradable emission permit prices, and have three components:

- Carbon taxes, which typically set a tax rate on energy based on its carbon content;
- Specific taxes on energy use (primarily excise taxes), which are typically set per physical unit or unit of energy, but which can be translated into effective tax rates on the carbon content of each form of energy;
- The price of tradable emission permits, regardless of the permit allocation method, representing the opportunity cost of emitting an extra unit of CO_2.

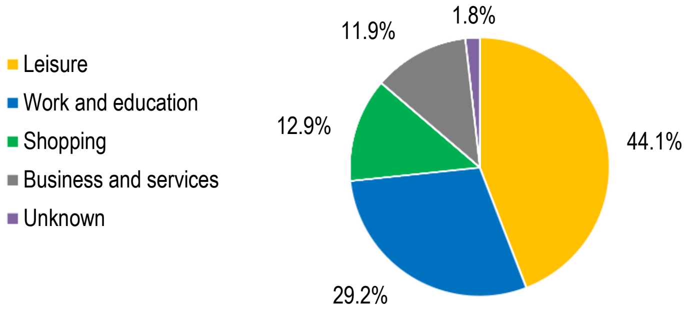
The road network is divided into national roads (2,255 kilometres, thereof 1,544 kilometres highways), cantonal roads (17,219 kilometres) as well as communal and private roads (64,641 kilometres, *SFSO*, 2021d). Most Swiss can reach a highway access within a distance of about 10 kilometres.

The rail network, which is fully electrified, currently has a total length of 5,196 kilometres and includes 1,735 stations. To enhance capacity, reduce travel times, and to allow for synchronised timetables between major connecting stations, several railway projects have been implemented since 1987. Under the first stage of the project RAIL 2000, implemented until 2004, the length of the rail network did not increase significantly, but a schedule with 30-minutes intervals could be widely introduced between all major cities, in particular reducing travel time between Zurich and Bern by 13 minutes. To foster the shift from road to rail, three new railway tunnels, constructed in the framework of the project New Rail Link through the Alps, substantially increased transalpine transport capacity and speed – the Lötschberg base tunnel (34.6 kilometres) opened in December 2007, the Gotthard base tunnel (57.1 kilometres) opened in December 2016, and the Ceneri base tunnel (22.6 kilometres) opened in December 2020. Thanks to the Gotthard base tunnel, the highest elevation for transalpine railway traffic is now as low as 549 metres above sea level. The Federal Act on the Future Development of the Railway Infrastructure (*Swiss Confederation*, 2009) and the Federal Decree on the Financing and Development of Railway Infrastructure (FABI, approved by a popular vote in 2014) regulate the next steps of the modernisation and development of the Swiss rail network, focussing on a further increase of capacity and even better access to the major tunnels crossing the Alps and the high-speed network in neighbouring countries (*FOT*, 2021).

The three national airports Zurich, Geneva and Basel-Mulhouse[5] are the most important aviation infrastructures of Switzerland. A dense network of flight routes connects Switzerland with Europe and with direct flights to important destinations worldwide. More than 100 airlines are serving Switzerland, with five operating as Swiss companies (*LUPO*, 2016).

Last but not least, the Federal Constitution of the Swiss Confederation mandates the federal government to coordinate pedestrian and hiking networks as well as – since a recent popular vote – also cycle paths (see section 4.4.1).

Fig. 28 > Shares of different purposes on total travel distance within Switzerland (i.e. excluding travel distances abroad) in 2015.



SFSO (2017c)

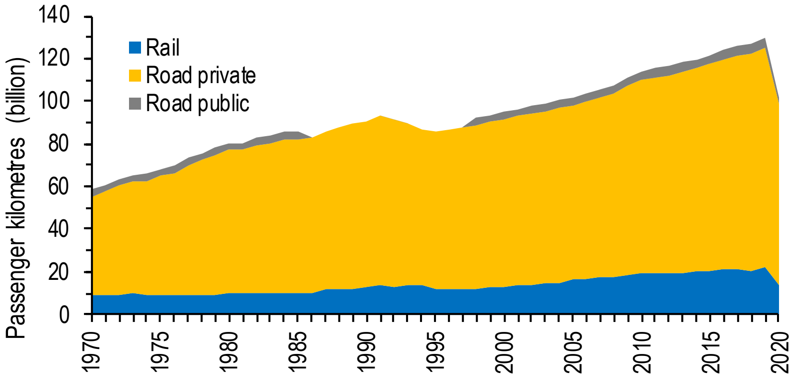
Passenger transport (land-based)

In 2015, each Swiss over the age of six years travelled an average daily distance within Switzerland of 36.8 kilometres, spending 90 minutes (82 minutes without waiting times). In 1994, 2000, 2005, and 2010 the average daily travel distance was 31.3, 35.0, 35.2, and 36.7 kilometres, respectively. The average daily travel distance by car slightly increased between 1994 and 2000 and has remained stable at about 23.8 kilometres thereafter. In contrast, the average daily travel distance using public transport has steadily increased from 5.6 kilometres in 1994 to 9.0 kilometres in 2015, corresponding to an increase of more than 61 per cent. Travel distances for leisure purposes has increased since 1994, accounting for a share of 44 per cent of the total travel distance within Switzerland in 2015. In contrast, travel distances related to work and education accounted for a share of 29 per cent, while travel distances for shopping purposes accounted for a share of 13 per cent (Fig. 28; *SFSO*, 2017c). While the average daily travel distance per person has remained about constant since 2010, passenger kilometres have continued to increase as a result of population growth (Fig. 3 and Fig. 29; *SFSO*, 2021k). Between 1980 and 2015, motorised private transport (total passenger kilometres) has increased by 43.9 per cent and public transport on road and rail (total passenger kilometres) has increased by 83.4 per cent. In 2015, 20.4 per cent of total

5 The airport Basel-Mulhouse is located in France, but operated jointly by France and Switzerland.

motorised passenger kilometres were travelled by public transport means (3.6 per cent public road, 16.8 per cent rail). In Switzerland, non-motorised transport (walking, cycling, hiking, etc.) accounted for almost eight billion passenger kilometres in 2015.

Fig. 29 > Passenger kilometres by motorised traffic on road (private and public) and rail from 1970 to 2020. Road public data from 1986 to 1997 is missing. A strong decrease in passenger kilometres occurred from 2019 to 2020 due to the measures to contain the corona virus pandemic.



SFSO (2021k)

The number of cars in Switzerland has increased from 3.0 million in 1990 to 4.7 million in 2020 (*SFSO*, 2021j), i.e. today less than two persons share a car on average. According to *SFOE* (2021c), the weight of new passenger cars has continuously increased since 1990. Nevertheless, the average specific emissions of new passenger cars decreased from about 200 grams of CO_2 per kilometre in 2002 to about 140 grams of CO_2 per kilometre in 2015, thanks to more efficient motors and a continuous shift from gasoline to diesel oil. Between about 2015 and 2019, the balance of the following evolutions resulted in about constant average specific emissions: (i) the efficiency (fuel consumption per distance) of gasoline and diesel cars did not further improve (because the weight has continued to increase), (ii) the share of new passenger cars fuelled by diesel oil decreased from about 40 per cent to about 25 per cent, and (iii) the share of electric vehicles started to increase slightly. In 2020, the average specific emission of new passenger cars again decreased – by 10.5 per cent compared to 2019 – reaching a value of 123.6 grams of CO_2 per kilometre. This strong decrease resulted from a rapid increase in the share of electric vehicles (from 5.6 per cent in 2019 to 14.4 per cent in 2020).

Freight transport (land-based)

Freight transport in Switzerland is focussed on the Central Plateau and the major transalpine routes (Fig. 30; *SFSO*, 2017b). While freight transport on road and rail has been increasing since the mid-19th century, the shares of freight transported on rail decreased from more than 50 per cent before 1982 to around 40 per in the early 1990s (Fig. 31; *SFSO*, 2021e). It has remained about constant afterwards, mostly due to the restrictions on road freight transport inscribed in the Federal Constitution of the Swiss Confederation in 1994[6], the implementation of the distance-related heavy vehicle charge and corresponding bilateral agreements with the European Union. Moreover, in contrast to France and Austria, the transalpine freight transport in Switzerland is dominated by rail (Fig. 32; *SFSO*, 2021n), inter alia, thanks to newly constructed railway tunnels.

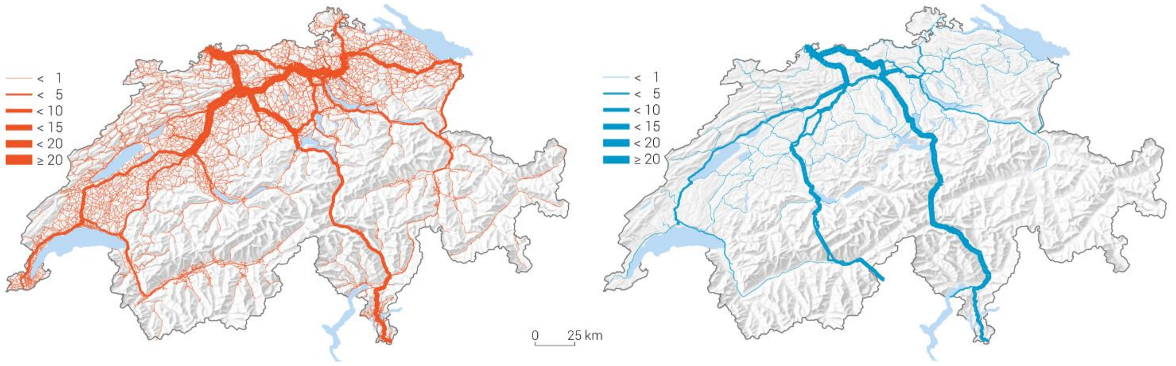
[6] Federal Constitution of the Swiss Confederation, Article 84 'Alpine transit traffic':

The Swiss Confederation shall protect the Alpine region from the negative effects of transit traffic. It shall limit the nuisance caused by transit traffic to a level that is not harmful to people, animals and plants or their habitats.

(i) Transalpine goods traffic shall be transported from border to border by rail. The Swiss Federal Council shall take the measures required. Exceptions are permitted only when there is no alternative. They must be specified in detail in a federal act.

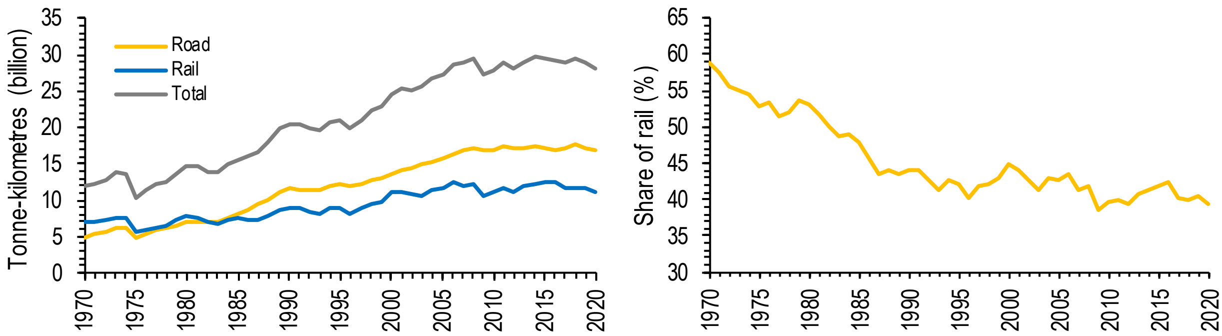
(ii) The capacity of the transit routes in the Alpine region may not be increased. This does not apply to by-pass roads that reduce the level of transit traffic in towns and villages.

Fig. 30 > Freight transport in Switzerland on road (left, red) and rail (right, blue) in 2015 (numbers correspond to million tonnes per year).



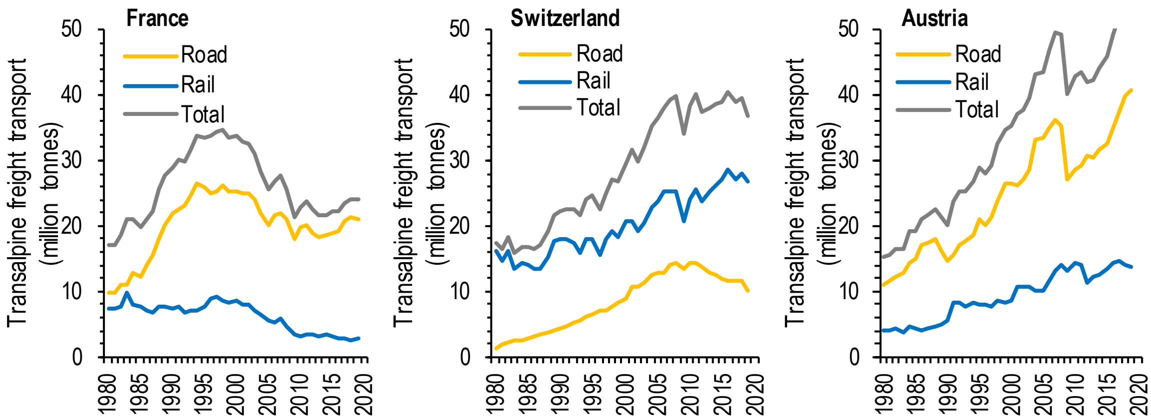
SFSO (2017b)

Fig. 31 > Freight transport on rail and road (tonne-kilometres, right) and share of rail (left) between 1970 and 2020.



SFSO (2021e)

Fig. 32 > Transalpine freight transport including inland, import, export and transit on road (orange) and rail (blue) in France (left, 1980–2019), Switzerland (centre, 1980–2020) and Austria (right, 1980–2019). For Switzerland, transalpine freight transport is dominated by rail, which was responsible for 72 per cent of the total of 34.8 million tonnes transported in 2020.

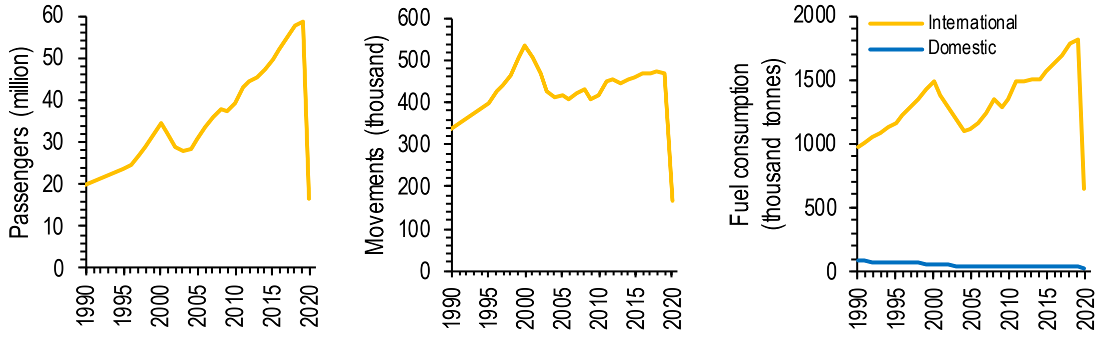


SFSO (2021n)

Aviation

In Switzerland, thanks to the relatively short distances and the dense and efficient road and railway networks, the share of domestic aviation is negligible. However, due to the establishment of a dense network of flight routes to Europe and direct flights to important destinations worldwide, the number of scheduled and charter flights departing from and landing in Switzerland has increased considerably between 1990 and 2000. After 2001, the grounding of the national airline and a general crisis in aviation led to a reduction of flight movements in Switzerland (Fig. 33).

Fig. 33 > Left: Number of passengers between 1990 and 2020 (included are all local and transit passengers of scheduled and charter flights of all national and regional airports of Switzerland). Centre: Number of aircraft movements between 1990 and 2020 (included are all domestic and transit passengers of scheduled and charter flights of all national and regional airports of Switzerland). Right: Amount of fuel sold between 1990 and 2020 within Switzerland for domestic and international aviation.



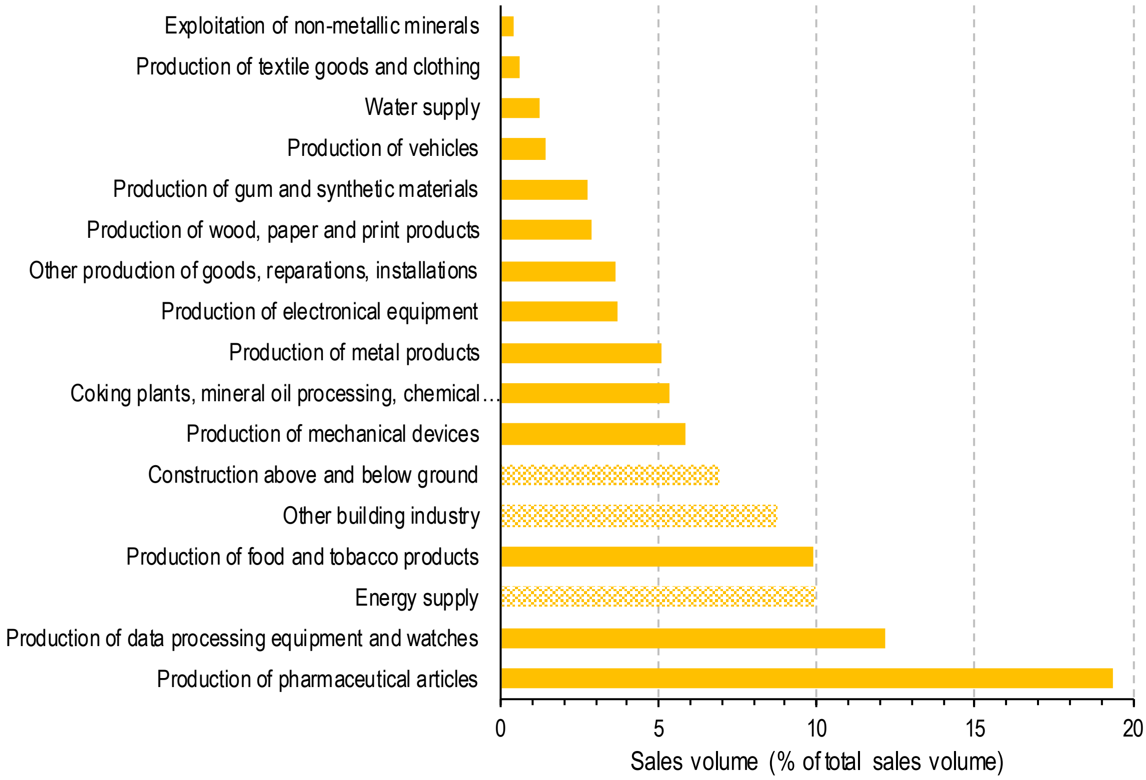
SFSO (2021t); *SFSO* (2021u); *SFSO* (2021v)

Since about 2004, the number of movements (scheduled and charter flights) remained about stable at slightly above 400 thousand movements per year. Nevertheless, the number of passengers (including transfer passengers) steadily increased and almost reached 60 million in 2019, about three times as much as in 1990 and about 1.7 times as much as in the year 2000. In 2019, the fuel consumption was, however, 1.2 times as much as in the year 2000. The strong increase in energy efficiency per passenger kilometre is considered to be the result of operating larger aircraft at even increased load factors, fleet renewal (new aircraft technology) as well as operational optimisations. The measures to contain the corona virus pandemic had a dramatic impact on aviation in 2020. Compared to the previous year, the number of passengers decreased by 72 per cent, the number of flight movements decreased by 64 per cent, and fuel consumption decreased by 64 per cent.

2.8 Industry and services

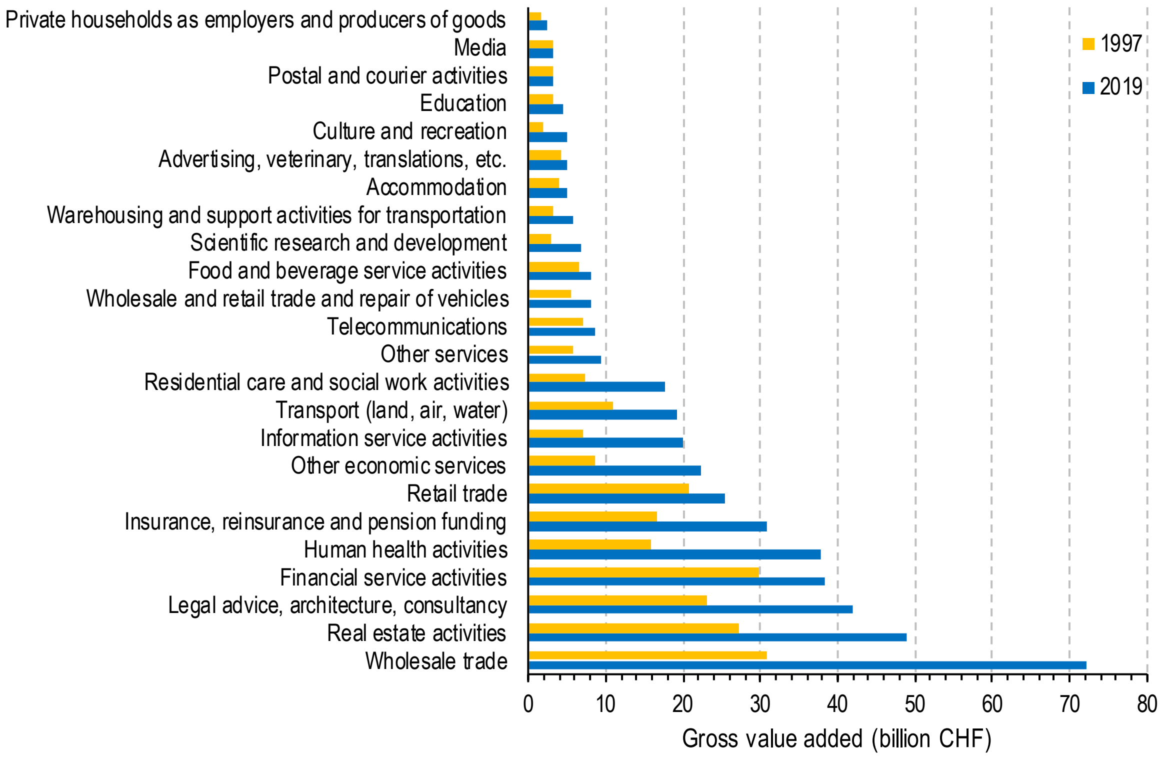
The structure of its industry sector clearly reflects the fact that Switzerland is relatively poor in natural resources. Once evolving from the textile industry – which marked the beginning of industrialisation in Switzerland – mechanical engineering continued to form an important pillar of Switzerland's industry. Currently, in addition to mechanical devices and engines, Switzerland's industry is specialised in the production of data processing equipment and high-precision instruments, particularly watches and goods for medical uses (medical technique). Of importance are further the food processing and chemical industries, in particular the production of pharmaceutical articles. An overview of goods imported to and exported from Switzerland is provided in Fig. 10, while Fig. 34 shows the sales volume within the industry sector in 2019. As highlighted in section 2.3 (in particular in Fig. 7), Switzerland's economy is largely based on the services sector. The services sector is highly diverse, the most important contributions (in descending order) to the total gross value added currently come from (i) wholesale trade, (ii) real estate activities, (iii) legal advice, architecture, consultancy, (iv) financial service activities, (v) human health activities, (vi) insurance, reinsurance and pension funding, and (vii) retail trade (Fig. 35).

Fig. 34 > Sales volume within the industry sector in 2019. Shown are the relative contributions of different branches to the total sales volume of about 506 billion Swiss francs. Included are sales volumes from energy supply and the building industry (lighter colour).



SFSO (2021l)

Fig. 35 > Gross value added by different branches of the services sector in Switzerland in 1997 and 2019.

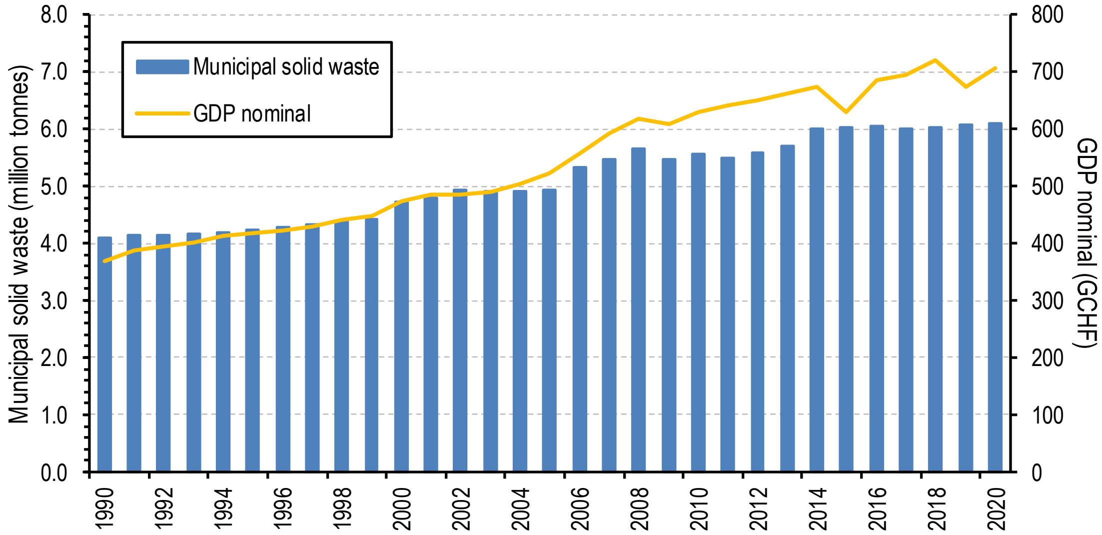


SFSO (2016e), *SFSO* (2021m)

2.9 Waste

With regard to waste treatment, Switzerland has an efficient infrastructure, high standards and clear legislative stipulations in place. The evolution of the amount of municipal solid waste is highly related to increasing prosperity and the steady growth of population. This is shown in Fig. 36, where the evolution of the total amount of municipal solid waste in Switzerland is provided together with the nominal gross domestic product.

Fig. 36 > Evolution of the total amount of municipal solid waste in Switzerland, 1990–2020 (since 2004 without imports of municipal solid waste), together with the nominal gross domestic product.



FOEN (2021d), *SECO* (2021)

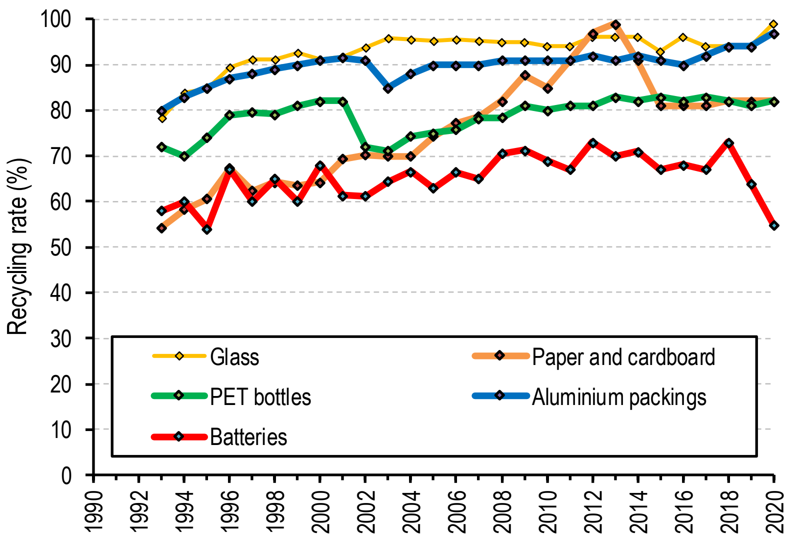
As incineration is mandatory for combustible waste since the year 2000, inputs into solid waste disposal sites have dropped to zero. According to the latest waste statistics (*FOEN*, 2021c; Tab. 2), which covers Switzerland and the principality of Liechtenstein, the total amount of waste (including municipal solid waste, construction waste, industrial and commercial solid waste, sewage sludge, special waste) incinerated amounted to 4.07 million tonnes (corresponding to 468 kilograms per inhabitant) in 2020. Thereof, 0.46 million tonnes originated from abroad, as Switzerland imports waste to operate waste incineration plants at full capacity for power and heat generation. In addition, 3.22 million tonnes (corresponding to 370 kilograms per inhabitant) of municipal solid waste were collected separately (including compost, paper and cardboard, glass, cans, tinfoil, aluminium, PET, textiles, electrical and electronic devices, batteries). The amount of municipal solid waste collected separately for recycling purposes more than doubled since 1990, indicating that today recycling systems are highly developed and supported by the population in Switzerland. In particular, separate collection of PET bottles, which are relevant regarding CO_2 emissions as they comprise petrochemical material, has increased significantly in recent years, with currently more than 82 per cent of the total PET bottles being recycled. Recycling rates of paper and cardboard, glass, aluminium packings, and waste-paper currently all also exceed 80 per cent of the total amounts (Fig. 37). In addition to municipal solid waste, 15.9 million tonnes of construction waste are generated annually in Switzerland. Thereof, 8.4 million tonnes stem from infrastructures such as streets, railways, as well as systems for water, wastewater, gas and electricity systems (*FOEN*, 2016a), and 7.5 million tonnes stem from the building infrastructure (*FOEN*, 2015). Where possible, construction waste is recycled on site. Finally, 1.85 million tonnes of waste were classified as special waste in 2020 (*FOEN*, 2021c; Tab. 2). In Switzerland, the wastewater of virtually the entire population (about 97 per cent) is sewered to a wastewater treatment plant.

Tab. 2 > Amount of waste in Switzerland (CH) and the principality of Liechtenstein (FL) in 2020. The provided number for sewage sludge is an estimate for 2017 covering Switzerland only.

Type of waste	Total (tonnes)	Per capita (kilograms per inhabitant)
Municipal solid waste incinerated (CH, FL)	2 875 000	330
Imports of municipal solid waste for incineration	459 000	53
Waste incinerated in waste incineration plants (municipal solid waste, construction waste, industrial waste, sewage sludge, special waste)	4 072 000	468
Special waste (CH, FL)	1 847 000	212
Sewage sludge (CH, dry matter, 2017)	178 000	20
Municipal solid waste collected separately (CH, FL), thereof:	3 221 000	369.7
Paper and cardboard	*1 174 000*	*134.7*
Compost (digested at central composting sites)	*1 405 000*	*161.3*
Waste glass	*380 000*	*43.8*
Electric and electronic devices	*129 800*	*14.9*
Textiles	*65 100*	*7.5*
PET bottles	*36 100*	*4.1*
Cans	*13 100*	*1.5*
Aluminium packings	*14 600*	*1.5*
Batteries	*3 175*	*0.4*

FOEN (2021c)

Fig. 37 > Evolution of recycling rates in Switzerland, 1993–2020.



SFSO (2021o)

2.10 Building stock and urban structure

Building stock

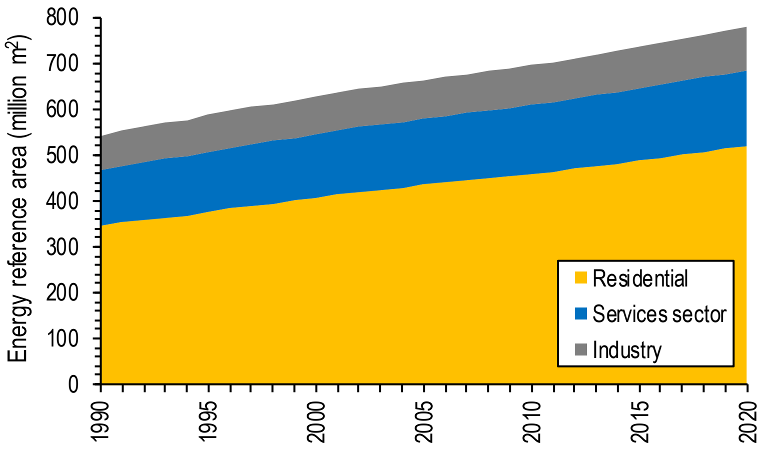
The Swiss Federal Statistical Office keeps track of the building stock in Switzerland. The investigations are based on a complete inventory according to data extracted from the registry of buildings and apartments, with a focus on buildings with (at least partial) residential use. The following points are noteworthy (*SFSO*, 2022b[7]):

- At the end of 2020, the building stock in Switzerland consisted of 1.8 million buildings with at least partial residential use. This corresponds to an increase of 37 per cent compared to 1990, an increase of 21 per cent compared to the year 2000, and an increase of seven per cent compared to 2010. At the end of 2020, 57 per cent of all buildings were one-family homes, 27 per cent multi-family homes, and the rest were buildings with residential and non-residential use. 30 per cent of all buildings were constructed before 1946, 31 per cent between 1946 and 1980, 21 per cent between 1981 and 2000, and 17 per cent between 2001 and 2020;

[7] See also the tables available on https://www.bfs.admin.ch/bfs/en/home/statistics/construction-housing.html.

- At the end of 2020, there was a stock of 4.6 million apartments in Switzerland. This corresponds to an increase of 47 per cent compared to 1990, an increase of 30 per cent compared to the year 2000, and an increase of 14 per cent compared to 2010. The average area was 99 square metres, about the same as in the year 2000. The average area per capita increased from 39 square metres in 1990 to 46 square metres in 2020;
- In accordance with the increase in buildings and apartments, the energy reference area, i.e. the area heated or cooled, has steadily increased for all types of buildings. Between 1990 and 2020, the energy reference area of buildings in the services sector has increased by 35 per cent, of buildings in the industry sector by 27 per cent, and of buildings for residential use by 50 per cent (*SFOE*, 2021d; Fig. 38);
- In 2020, 22 per cent of housings were one-family homes, 58 per cent were multi-family homes and the rest were buildings with mixed residential and non-residential use. About 47 per cent of housings were constructed between 1961 and the year 2000, with about 33 per cent being older and about 20 per cent being younger. The spatial distribution of Switzerland's population is shown in Fig. 4;
- In 2015[8], 63 per cent of all buildings were heated with fossil fuels (i.e. gas oil or gas, while coal became negligible). However, because multi-family homes are more often heated with fossil fuels (72 per cent), an even bigger share of the Swiss population (72 per cent) currently lives in buildings heated with fossil fuels (Fig. 39). While fossil heating systems are, thus, still dominating, heat pumps accounted for about 70 per cent of heating systems installed in newly constructed buildings during 2011–2015 (Fig. 40; *SFSO*, 2017a). *Wüest and Partner* (2016) estimate, that in the context of replacements of heating systems in existing buildings, the non-fossil shares account for about half in the case of one-family homes and for about one third in the case of multi-family homes. Nine out of ten residents lived in a building with a central heating system serving one or more buildings. Two per cent of the complete building stock and four per cent of the population are connected to a public district heating (*SFSO*, 2017a);
- Homeownership rates in Switzerland stay relatively low, as only about 36.4 per cent of households in Switzerland lived in their own homes in 2019. While the percentage of homeowners has continuously increased since 1970 (when it was at 28.5 per cent), it is still low compared to other European countries. The low homeownership rates may, to some extent, represent a hurdle with regard to the modernisation of buildings.

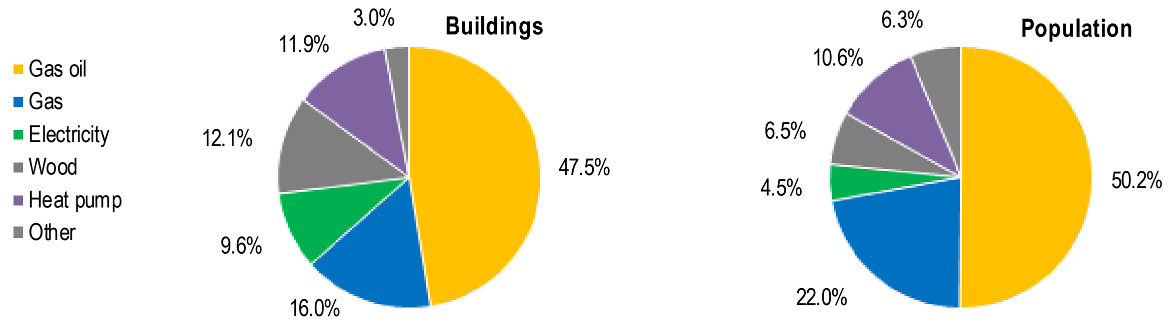
Fig. 38 > Energy reference area in Switzerland between 1990 and 2020.



SFOE (2021d)

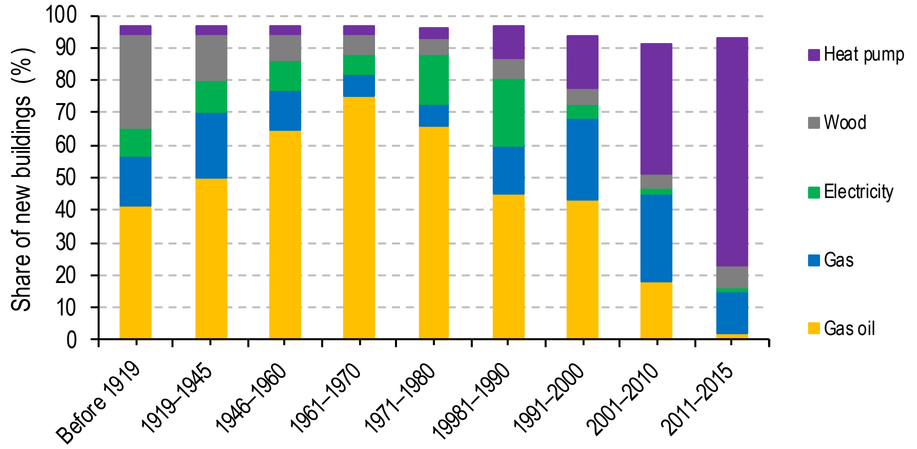
8 Newer data at this level of detail is not available at the moment, because the Swiss Federal Statistical Office currently implements a change in source of data. Moreover, the registry of buildings and apartments may not entirely be up-to-date regarding heating systems, in particular because replacements of heating systems in existing buildings may not be captured by the statistics of all authorities at the communal and cantonal levels. Accordingly, the provided numbers may, to some extent, overestimate the current share of fossil energy carriers.

Fig. 39 > Relative distribution of energy sources for heating systems in buildings in 2015.[8] Left: Buildings. Right: Population.



SFSO (2017a)

Fig. 40 > Share of the five most important energy sources for heating systems in different construction periods (new constructions).[8]



SFSO (2017a)

Urban structure

Constrained by the topography, Switzerland's settlements originally developed along rivers, lakes and valleys – which formed the major trading routes – as well as on the Central Plateau. The formation of settlements has continued incessantly, although not homogeneously in every area due to different factors such as industrialisation and the development of the rail and road networks. Today, Switzerland's urban structure may be best described by the term 'network city', i.e. a large number of interconnected 'nodes' with high densities of population, goods and information which have an extensive and efficient mutual exchange. As showcased in Fig. 41, agricultural areas and forests are an integral part of Switzerland's urban structure. Information regarding Switzerland's population density and the spatial distribution of population is provided in section 2.2 (in particular Fig. 4).

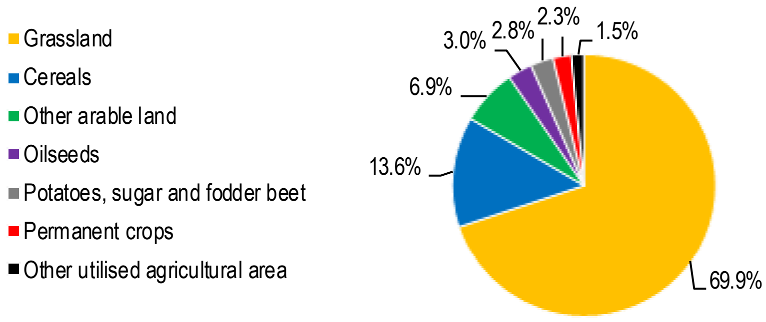
Fig. 41 > Example of Switzerland's urban structure (Kloten, Wallisellen, Opfikon, Hard).

OcCC (2007)

2.11 Agriculture

Switzerland's utilised agricultural area (excluding alpine pastures) accounted for 1.044 million hectares in 2020, corresponding to 25.3 per cent of the total land surface (*SFSO*, 2021q). When alpine pastures are included, the agricultural land surface covers more than a third of the total land surface. The agricultural area (excluding alpine pastures) is cultivated according to the shares shown in Fig. 42, with about 70 per cent being grassland. Due to the spread of built-up and forest areas, the agricultural land surface (including alpine pastures) is steadily decreasing, namely by 7.3 per cent between 1979/1985 and 2013/2018 (Fig. 13).

Fig. 42 > Use of utilised agricultural area (excluding alpine pastures) in Switzerland, 2020.

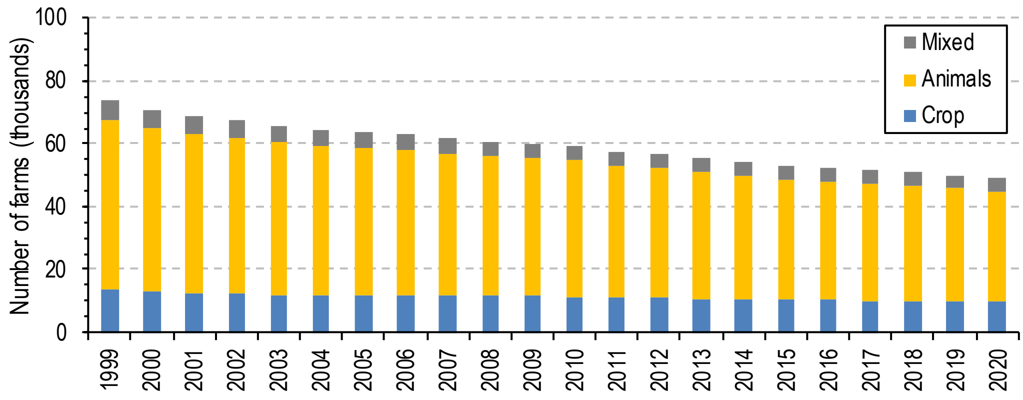


SFSO (2021q)

According to the Swiss Federal Statistical Office (*SFSO*, 2021q), the number of farms has decreased from about 111 thousand in 1975 to about 49 thousand in 2020 (Fig. 43). This decrease corresponds to the closure of more than three farms each day. In concert with the decreasing number of farms, the area per farm has more than doubled since 1975 and a substantial decrease in employees in the agriculture sector has occurred. While in 1960 still 14.5 per cent of the population worked in the agriculture sector, this share decreased to 2.6 per cent in 2020 (*SFSO*, 2022a).

The large share of grassland implicates that the majority of farms keep ruminants (Fig. 43). Nevertheless, as shown in Tab. 3, the number of cattle has decreased by 22 per cent between 1990 and 2020, while the swine population has decreased by 36 per cent. In contrast, an increase has occurred for poultry (+52 per cent). Noteworthy, the milk yield of mature dairy cattle has increased from 15.8 kilograms per head and day in 1990 to 23.3 kilograms per head and day in 2020 (*FOEN*, 2022a). Since the early 1990s, and increasingly since a new agricultural article has been stipulated in the Federal Constitution of the Swiss Confederation in 1996, agricultural policy has become more commercially and environmentally sound, shifting towards more environmentally friendly farming methods. As a consequence, the required ecological standards are met by almost all farms and the share of organic farms reached 15 per cent in 2020 (*SFSO*, 2021r).

Fig. 43 > Number of farms and their economic orientation in Switzerland, 1999–2020.



SFSO (2021p)

Tab. 3 > Livestock population in Switzerland in the years 1990, 2000, 2010, and 2020.

	1990	2000	2010	2020
	1,000 head			
Cattle	1 855	1 588	1 591	1 515
Whereof mature cattle	*783*	*669*	*589*	*546*
Horses, mules and asses	34	62	82	80
Swine	1 965	1 670	1 750	1 448
Sheep	395	421	434	398
Goat	68	62	83	*90*
Poultry	7 310	7 160	10 629	*15 199*
Rabbit	61	28	35	*19*

FOEN (2022a)

2.12 Forest

The results of the fourth national forest inventory (NFI4/2009–2017; *Brändli et al.*, 2020) indicate that 32 per cent of Switzerland's area is covered by forests (see Fig. 44).[9] According to *The World Bank* (2022), this percentage is matched or even exceeded by some of Switzerland's neighbouring countries: Austria (47 per cent), Germany (33 per cent), and Italy (32 per cent). Forest cover is not evenly distributed across Switzerland. More than 50 per cent of forests are located above 1,000 metres above sea level. The Alps have therefore the highest forest cover, with forest areas still expanding, especially through abandonment of subalpine grasslands. Forest exploitation is concentrated in the central lowlands (about 40 per cent of total wood harvest), which are more easily accessible than alpine regions and therefore less cost-intensive in terms of harvest.

31 per cent of Swiss woodland is privately owned, whereas 69 per cent is public property. The majority of the state owned woodland belongs to bourgeois communities and cooperatives (40 per cent) and political communities (28 per cent; comprising municipalities and cantons). Only one per cent of Swiss woodland is owned by the Swiss Confederation.

Since the first national forest inventory (NFI1/1983–1985; *EAFV/BFL*, 1988), the forested area has grown by 11 per cent. The regional differences are striking: the greatest increase was recorded in the Alps (+20.3 per cent) and the Southern Alps (+18.3 per cent) as a consequence of natural regeneration of abandoned land previously used by agriculture, whereas the forested area in the central lowlands (+0.9 per cent) and the Jura mountains (+3.1 per cent) only slightly changed.

According to the results of the fourth national forest inventory (NFI4/2009–2017), Switzerland's forests account for 421 million cubic metres of wood. Of this, 32 per cent are deciduous trees such as beech (18 per cent) and 68 per cent are coniferous trees such as spruce (43 per cent) and fir (15 per cent).[10] Standing volume of living trees has increased since 30 years. Since the third national forest inventory (NFI3/2004–2006), standing volume in Swiss forests have increased by 2.9 per cent on average to 350 cubic metres per hectare. The highest increase was observed in alpine forests which are difficult to access and exploit. This increase is mainly due to a slight decrease in harvest and also a lower share of mortality. Annual harvest and mortality has decreased from 8.6 (periods of NFI2/1993–1995 and NFI3/2004–2006); *Brassel and Brändli*, 1999; *Brändli*, 2010) to 8.0 cubic metres per hectare per year (periods of NFI3/2004–2006 and NFI4/2009–2017; *Brändli et al.*, 2020). This can mainly be attributed to the fact that between the periods of NFI2/1993–1995 and NFI3/2004–2006, the storm 'Lothar' of December 1999 was responsible for high amounts of salvage logging and high mortality rates within Swiss forests.[11] The average annual growth rate has slightly increased from 8.9 (periods of NFI2/1993–1995 and NFI3/2004–2006) to 9.0 cubic metres per hectare (periods of NFI3/2004–2006 to NFI4/2009–2017).

Since 1998, a few scattered forest areas have obtained certification for sustainable forest management under the FSC system (*http://www.fsc.org*) or the Q/PEFC system (*http://www.pefc.org*). Starting in the year 2000, group certifications

9 *https://s.geo.admin.ch/96ecb87b00*

10 *https://s.geo.admin.ch/96ecc516cd*

11 *https://s.geo.admin.ch/96ecd52271*

enabled larger areas joining the scheme, so that the area of certified forest increased by 100 thousand hectares per year. In 2005, this trend began to slab. At the moment, 51 per cent of the Swiss forest area are certified under either one or both of the two certifying systems (*Brändli et al.*, 2020).

Fig. 44 > Switzerland's current forest area. The red areas show areas damaged by the storm 'Lothar' in 1999. For more details see the website indicated below the map.

geo.admin.ch (*https://s.geo.admin.ch/652974182314*)

2.13 Other circumstances

Switzerland reported all national circumstances relevant to greenhouse gas emissions and removals in section 2.1 to 2.12, there are no relevant other circumstances to be reported.

2.14 Relationship between national circumstances and greenhouse gas emissions

Switzerland's greenhouse gas emissions and removals, disaggregated by gas and by sector, are presented and discussed in detail in chapter 3. This section provides information on how the national circumstances presented in section 2.1 to 2.12 affect greenhouse gas emissions and removals, and how the national circumstances and changes therein affect greenhouse gas emissions and removals over time. In this regard, the Swiss Federal Office for the Environment annually publishes a report which discusses the influence of key parameters on greenhouse gas emissions in Switzerland (*FOEN*, 2022b). Based on the latest update of this report, the relationship between key parameters – reflecting Switzerland's national circumstances – and greenhouse gas emissions resulting from different activities[12] are discussed in the following.

[12] For the discussion in section 2.14, the disaggregation follows *FOEN* (2022b) and does not necessarily agree with the definition of sectors in other chapters of Switzerland's eighth national communication:

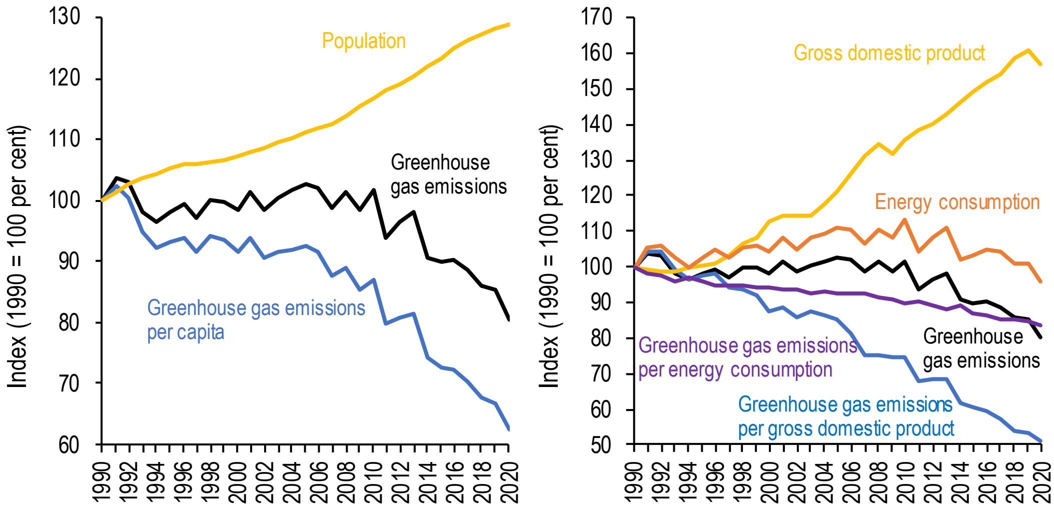
- Emissions related to industry: 1A1 'Energy industries' + 1A2 'Manufacturing industries and construction' + 1B 'Fugitive emissions from fuels' + 2 'Industrial processes and product use' – 1A1 'Energy industries' (other fuels) – 1A2 'Manufacturing industries and construction' (other fuels) – 1A1 'Energy industries' (biomass) – 1A2 'Manufacturing industries and construction' (biomass);
- Emissions related to services: 1A4a 'Commercial/institutional';
- Emissions related to households: 1A4b 'Residential';
- Emissions related to transport: 1A3 'Transport' + 1A5 'Other';
- Emissions related to agriculture: 3 'Agriculture' + 1A4c 'Agriculture/forestry/fishing';
- Emissions related to waste: 5 'Waste' + 1A1 'Energy industries' (other fuels) + 1A2 'Manufacturing industries and construction' (other fuels) + 1A1 'Energy industries' (biomass) + 1A2 'Manufacturing industries and construction' (biomass).

Total greenhouse gas emissions

Fig. 45 shows the relative evolution of Switzerland's total greenhouse gas emissions. When compared to relevant key parameters, the following important observations emerge:

- Over the period from 1990 to 2020, total greenhouse gas emissions were first stable and then started to decrease, despite a substantial population growth (+29.0 per cent). Accordingly, per capita greenhouse gas emissions decreased by 37.6 per cent, from 8.1 tonnes of CO_2 equivalents per capita in 1990 to 5.0 tonnes of CO_2 equivalents per capita in 2020;
- At the same time, Switzerland's gross domestic product substantially increased, but economic growth and greenhouse gas emissions evolved decoupled from each other. Accordingly, greenhouse gas emissions per gross domestic product decreased by 48.7 per cent, from 119 grams of CO_2 equivalents per Swiss franc in 1990 to 61 grams of CO_2 equivalents per Swiss franc in 2020;
- Year-to-year variations in total greenhouse gas emissions were to a large part the consequence of changing meteorological conditions (such as heating degree days and solar insolation), which had a major influence on the demand on heating fuel during winter time. Nevertheless, multi-annual mean greenhouse gas emissions have been decreasing over time, indicating the increasing energy-efficiency, as well as the ongoing substitution of heating and process fuels by renewable energy sources and natural gas;
- For 2020, the measures to contain the corona virus pandemic affected many of the parameters shown in this section (e.g. gross domestic product, gross value added, energy consumption, transport volumes, etc.) and, thus, greenhouse gas emissions linked to this parameters were exceptionally low;
- The reporting under the UNFCCC (i.e. the national greenhouse gas inventory) does not include 'grey emissions', i.e. emissions from the production of imported goods and energy as well as from the disposal of products abroad. Switzerland mainly depends on imported energy and the Swiss economy is strongly based on the services sector. Traditionally, heavy industry is virtually absent in Switzerland due to a lack of local mineral resources. This implies that substantial grey emissions are associated with Switzerland's imports of goods. Currently, greenhouse gas emissions in Switzerland based on a 'consumption perspective' account for 12.6 tonnes of CO_2 equivalents per capita, with about one third of emissions occurring within Switzerland and about two thirds of emissions occurring abroad (see section 6 in *FOEN*, 2022b).

Fig. 45 > Evolution of Switzerland's total greenhouse gas emissions, together with population (left panel) as well as Switzerland's gross domestic product and total energy consumption (right panel), 1990–2020 (relative evolutions with reference year 1990). The respective panels also show the greenhouse gas emissions per capita, per gross domestic product, and per energy consumption.



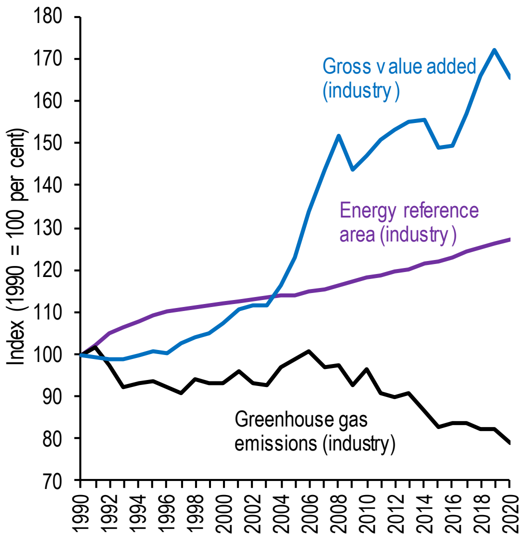
FOEN (2022b)

Greenhouse gas emissions related to industry

Fig. 46 shows the relative evolution of Switzerland's greenhouse gas emissions related to industry.[12] When compared to relevant key parameters, the following important observations emerge:

- Despite a substantial increase in gross value added as well as in the energy reference area related to industry, greenhouse gas emissions related to industry did not increase and were 21 per cent lower in 2020 compared to 1990;
- Accordingly, Switzerland's industry managed to decouple – to a certain degree – economic growth and greenhouse gas emission.

Fig. 46 > Evolution of Switzerland's greenhouse gas emissions related to industry[12], together with the gross value added and the energy reference area related to industry, 1990–2020 (relative evolutions with reference year 1990).



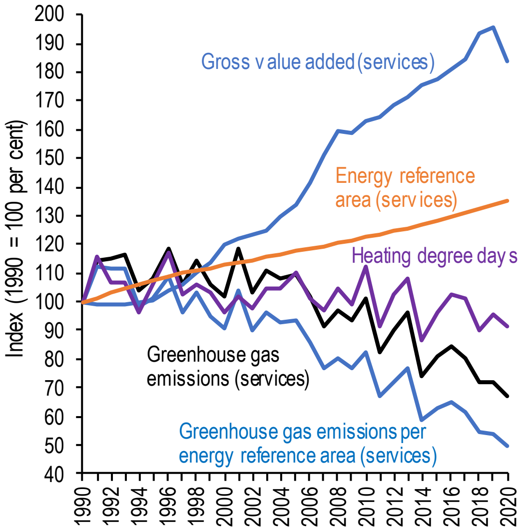
FOEN (2022b)

Greenhouse gas emissions related to services

Fig. 47 shows the relative evolution of Switzerland's greenhouse gas emissions related to services.[12] When compared to relevant key parameters, the following important observations emerge:

- Greenhouse gas emissions related to services were mostly driven by the influence of meteorological conditions (such as heating degree days and solar insolation);
- Despite a substantial increase in the gross value added and the energy reference area related to services, greenhouse gas emissions related to services showed a prolonged decrease (overlain by the year-to-year variability caused by meteorological conditions);
- From 1990 to 2020, the greenhouse gas emissions per energy reference area related to services decreased by 50.4 per cent.

Fig. 47 > Evolution of Switzerland's greenhouse gas emissions related to services[12], together with the gross value added and the energy reference area related to services as well as heating degree days, 1990–2020 (relative evolutions with reference year 1990). Also shown are the greenhouse gas emissions related to services per energy reference area.



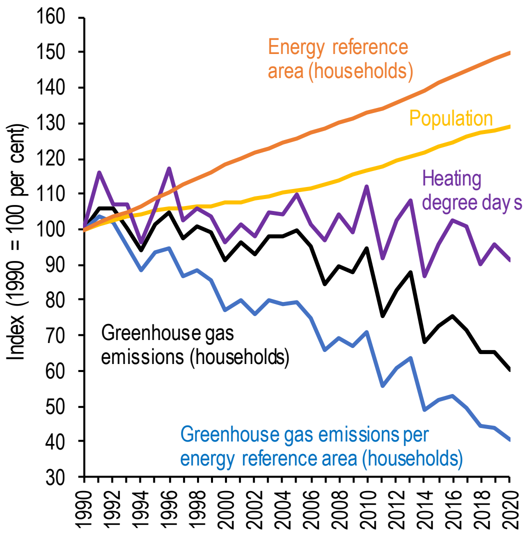
FOEN (2022b)

Greenhouse gas emissions related to households

Fig. 48 shows the relative evolution of Switzerland's greenhouse gas emissions related to households.[12] When compared to relevant key parameters, the following important observations emerge:

- Like the greenhouse gas emissions related to services, greenhouse gas emissions related to households were strongly driven by meteorological conditions (such as heating degree days and solar insolation);
- Apart from the strong influence of meteorological conditions, greenhouse gas emission related to households showed a decreasing trend, despite the fact that the energy reference area related to households, i.e. the heated or cooled living space, as well as population were steadily increasing;
- Accordingly, greenhouse gas emissions related to households per energy reference area steadily decreased, thanks to improving insulation standards, the renovation of older buildings, and the increasing replacement of heating fuel by natural gas and renewables (heating pumps, wood, etc.).

Fig. 48 > Evolution of Switzerland's greenhouse gas emissions related to households[12], together with the energy reference area related to households as well as population and heating degree days, 1990–2020 (relative evolutions with reference year 1990). Also shown are the greenhouse gas emissions related to households per energy reference area.



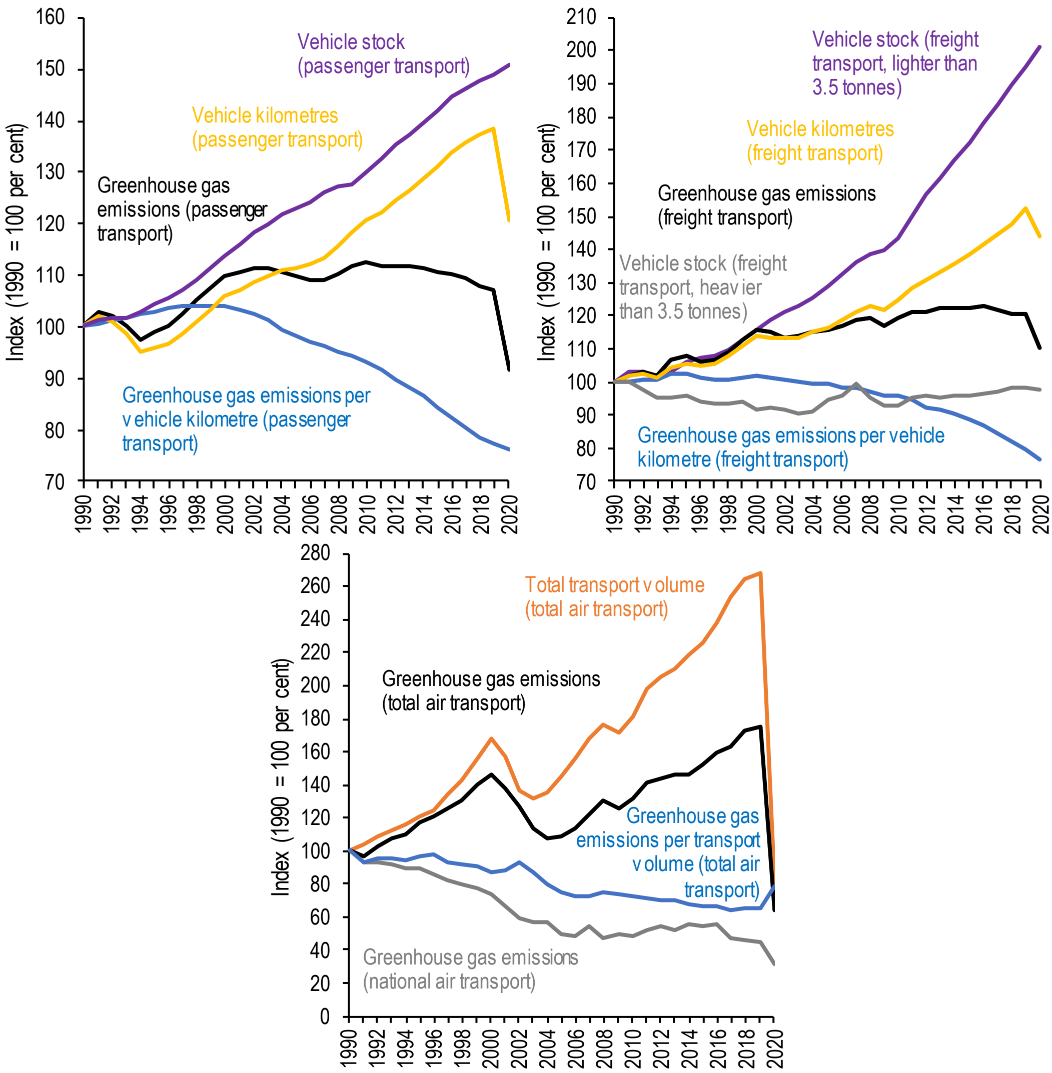
FOEN (2022b)

Greenhouse gas emissions related to transport

Fig. 49 shows the relative evolution of Switzerland's greenhouse gas emissions related to transport.[12] When compared to relevant key parameters, the following important observations emerge:

- The vehicle stock of private transport increased by 51 per cent between 1990 and 2020 and the vehicle kilometres increased by 39 per cent between 1990 and 2019 (falling to 21 per cent above the level of 1990 in 2020 due to the measures to contain the corona virus pandemic);
- Greenhouse gas emissions related to private transport increased by slightly more than 10 per cent between 1990 and around the year 2000, then remained about constant, with a slightly decreasing trend emerging during the last years (and a strong decrease standing out for 2020 due to the measures to contain the corona virus pandemic). The greenhouse gas emissions per vehicle kilometre show a decreasing trend over the last about 20 years, which can be explained by technological progress, i.e. more efficient motors, as well as the increasing use of diesel oil;
- The evolution of the vehicle stock of freight transport needs to be looked at by weight category: The stock of vehicles lighter than 3.5 tonnes increased by 101 per cent between 1990 and 2020, while the stock of vehicles heavier than 3.5 remained about constant;
- While greenhouse gas emission related to freight transport increased by 21 per cent between 1990 and 2019 (falling to 11 per cent above the level of 1990 in 2020 due to the measures to contain the corona virus pandemic), greenhouse gas emissions related to freight transport per vehicle kilometre decreased by 20 per cent and more over the same time period;
- The total transport volume of air transport (including passenger and freight on national and international flights) increased by 170 per cent between 1990 and 2019, with a temporary decrease between 2001 and 2004 as a consequence of the grounding of the national airline and a general crisis in aviation. In 2020, an exceptionally large decrease to 23 per cent below the level of 1990 occurred due to the measures to contain the corona virus pandemic. In contrast to total transport volume, national transport volume is of minor importance and steadily decreased from 1990 to 2005 and then remained at around 50 per cent of the transport volume in 1990;
- Greenhouse gas emissions related to air transport generally followed the same evolution as the transport volume, but thanks to increasing efficiency, the greenhouse gas emissions per transport volume decreased by over a third between 1990 and today. 2019 has been the year with the highest annual greenhouse gas emission from aviation in the country's history. In 2020, the measures to contain the corona virus pandemic led to the grounding of most of the aircraft fleet with a reduction of greenhouse gas emissions of 63 per cent compared to 2019. As for the total transport volume, this corresponds to a reduction below 1990 levels.

Fig. 49 > Evolution of Switzerland's greenhouse gas emissions related to passenger transport (upper left panel), freight transport (upper right panel) and air transport (lower panel, for total air transport and national air transport)[12], together with the vehicle stocks and vehicles kilometres of passenger transport and freight transport, as well as the total transport volume by air, 1990–2020 (relative evolutions with reference year 1990). Also shown are the greenhouse gas emissions related to passenger transport and freight transport per vehicle kilometre as well as the greenhouse gas emissions related to air transport per air transport unit (corresponding to one person or 100 kilograms).



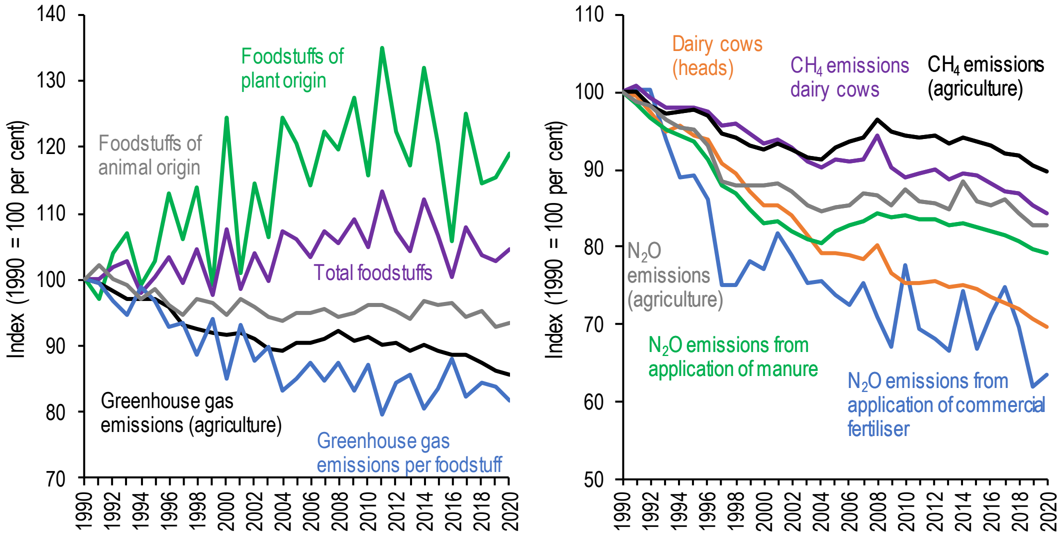
FOEN (2022b)

Greenhouse gas emissions related to agriculture

Fig. 50 shows the relative evolution of Switzerland's greenhouse gas emissions related to agriculture.[12] When compared to relevant key parameters, the following important observations emerge:

- From 1990 to 2020, production of foodstuffs of animal origin decreased and the production of foodstuffs of plant origin increased (showing rather large inter-annual variability), overall resulting in an increase of total foodstuffs by about 5 per cent. As over the same time period, greenhouse gas emissions related to agriculture decreased by 14 per cent, the greenhouse gas intensity (greenhouse gases emitted per unit of foodstuff produced) overall decreased by about 18 per cent. The decrease in greenhouse emissions related to agriculture about followed the decrease in the production of foodstuffs of animal origin;
- From 1990 to 2020, CH_4 emissions related to agriculture decreased by 10 per cent, mainly driven by CH_4 emissions from dairy cows, which decreased along with the number of heads. Over the same time period, N_2O emissions related to agriculture decrease by 17 per cent, induced by decreasing application of manure and commercial fertiliser.

Fig. 50 > Left: Evolution of Switzerland's greenhouse gas emissions related to agriculture[12], together with foodstuffs produced (total, of plant origin, and of animal origin), 1990–2020 (relative evolutions with reference year 1990). Also shown are the greenhouse gas emissions related to agriculture per foodstuff. Right: Evolution of Switzerland's CH_4 and N_2O emissions related to agriculture[12], together with CH_4 emissions from dairy cows and their number (heads) as well as N_2O emissions from the application of manure and of commercial fertiliser, 1990–2020 (relative evolutions with reference year 1990).



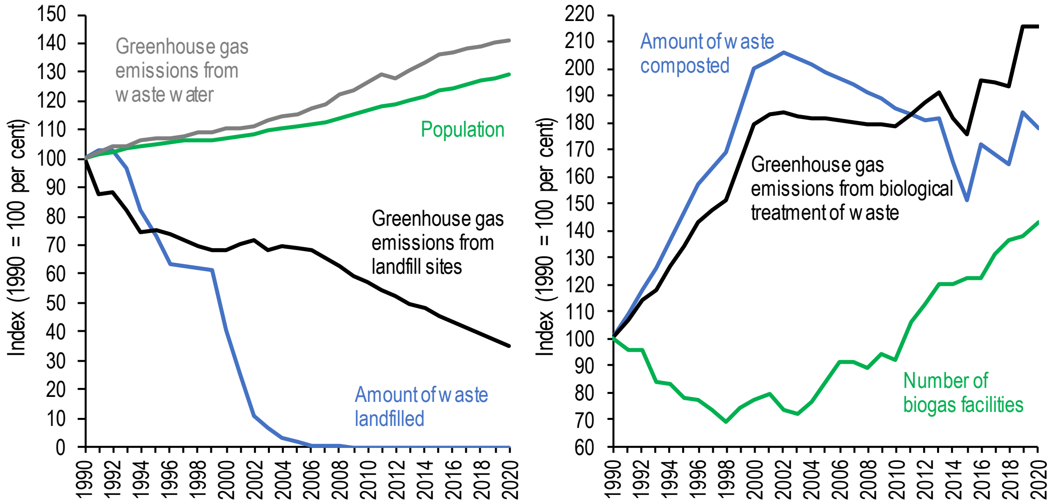
FOEN (2022b)

Greenhouse gas emissions related to waste

Fig. 51 shows the relative evolution of Switzerland's greenhouse gas emissions related to waste.[12] When compared to relevant key parameters, the following important observations emerge:

- In concert with the increase in Switzerland's population, greenhouse gas emissions from waste water treatment increased by 41 per cent from 1990 to 2020;
- Greenhouse gas emissions from landfilled waste decreased by about two thirds from 1990 to 2020. This decrease is caused by the ban on landfilling of combustible waste since the year 2000. However, the greenhouse gas emissions do not closely follow the amount of waste deposited, as the major part of greenhouse gas emissions since the year 2000 has resulted from waste landfilled in the years to decades before;
- Greenhouse gas emissions from biological treatment of waste increased by about 80 per cent from 1990 to about the year 2000, mainly caused by an increase in the amount of waste composted. The increasing number of biogas facilities (+43 per cent from 1990 to 2020) led to a further increase of greenhouse gas emissions during about the last decade.

Fig. 51 > Left: Evolution of Switzerland's greenhouse gas emissions from landfills and waste water treatment, together with Switzerland's population and the amount of waste landfilled, 1990–2020 (relative evolutions with reference year 1990). Right: Evolution of Switzerland's greenhouse gas emissions from biological treatment of waste, together with the amount of waste composted and the number of biogas facilities, 1990–2020 (relative evolutions with reference year 1990).



FOEN (2022b)

2.15 Flexibility in accordance with Article 4, paragraphs 6 and 10, of the Convention

Switzerland does not request any flexibility or consideration in accordance with Article 4, paragraphs 6 and 10, of the Convention.

References

Begert, M., Frei, C., 2018: Long-term area-mean temperature series for Switzerland – Combining homogenized station data and high resolution grid data, International Journal of Climatology, 38, 2792–2807, *https://doi.org/10.1002/joc.5460* [18.07.2022]

Brändli, U.-B. (Red.), 2010: Schweizerisches Landesforstinventar – Ergebnisse der dritten Erhebung 2004–2006. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Swiss Federal Office for the Environment, Bern. *https://lfi.ch/publikationen/publ/ergebnisberichte/LFI3_Ergebnisbericht.pdf* [18.07.2022]

Brändli, U.-B., Abegg, M. and Allgaier Leuch, B. (Red.), 2020: Schweizerisches Landesforstinventar – Ergebnisse der vierten Erhebung 2009–2017. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Swiss Federal Office for the Environment, Bern. *https://lfi.ch/publikationen/publ/ergebnisberichte/LFI4_Ergebnisbericht.pdf* [18.07.2022]

Brassel, P. and Brändli, U.-B., 1999: Schweizerisches Landesforstinventar – Ergebnisse der Zweitaufnahme 1993–1995. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Swiss Agency for the Environment, Forests and Landscape, Bern. *https://lfi.ch/publikationen/publ/ergebnisberichte/LFI2_Ergebnisbericht.pdf* [18.07.2022]

CH2018, 2018: CH2018 – Climate Scenarios for Switzerland, Technical Report, National Centre for Climate Services, Zurich, ISBN: 978-3-9525031-4-0. *https://www.nccs.admin.ch/dam/nccs/de/dokumente/website/klima/CH2018_Technical_Report.pdf* [18.07.2022]

EAFV/BFL, 1988: Schweizerisches Landesforstinventar. Ergebnisse der Erstaufnahme 1982–1986. Eidgenössische Anstalt für das forstliche Versuchswesen, Birmensdorf / Bundesamt für Forstwesen und Landschaftsschutz, Bern. *https://www.lfi.ch/publikationen/publ/ergebnisberichte/lfi1-en.php* [18.07.2022]

FFA, 2021: Hauptaggregate und Prognosen im FS und GFS-Model. Swiss Federal Finance Administration, Bern. 30.08.2021. *https://www.efv.admin.ch/dam/efv/de/dokumente/finanzstatistik/daten/main_extern.xlsx.download.xlsx/main_extern.xlsx* [18.07.2022]

FOCBS, 2021: Swiss-Impex. Swiss Federal Office for Customs and Border Security. *https://www.gate.ezv.admin.ch/swissimpex* [queries from database, 20.09.2021]

FOCBS, 2022a: Steuersätze für die wichtigsten Treib- und Brennstoffe. Swiss Federal Office for Customs and Border Security. T 4.1, 17.01.2022. *https://www.bazg.admin.ch/dam/bazg/de/dokumente/abgaben/minoest-statistik/t4.1.pdf* [18.07.2022]

FOCBS, 2022b: Fiskalbelastungs- und Preisvergleich mit den Ländern der Europäischen Union für Benzin, Dieselöl und Heizöl extraleicht (Status as of 01.01.2022). Swiss Federal Office for Customs and Border Security. 25.03.2022. *https://www.ezv.admin.ch/dam/ezv/de/dokumente/abgaben/minoest-statistik/t4.3.pdf* [18.07.2022]

FOEN and MeteoSwiss, 2020: Climate change in Switzerland (Management Summary), *http://www.bafu.admin.ch/uz-2013-e* [18.07.2022]

FOEN, 2015: Bauabfälle in der Schweiz – Hochbau: Studie 2015. Swiss Federal Office for the Environment, Bern. 28.09.2015. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/abfall/externe-studien-berichte/bauabfaelle_in_derschweiz-hochbaustudie2015.pdf* [18.07.2022]

FOEN, 2016a: Bauabfälle in der Schweiz – Tiefbau: Aktualisierung 2015. Swiss Federal Office for the Environment, Bern. 01.05.2016. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/abfall/externe-studien-berichte/studie_bauabfaelle_tiefbau_2015.pdf* [18.07.2022]

FOEN, 2021a: Effects of climate change on Swiss water bodies. Hydrology, water ecology and water management. Swiss Federal Office for the Environment, Bern. UW-2101-E, 16.03.2021. *www.bafu.admin.ch/uw-2101-e* [18.07.2022]

FOEN, 2021c: Abfallmengen und Recycling 2020 im Überblick. Swiss Federal Office for the Environment, Bern. BAFU-D-963E3401/431, Dezember 2021. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/abfall/statistik/abfallmengen-und-recycling-2020-im-ueberblick.pdf* [18.07.2022]

FOEN, 2021d: Indicators waste – Municipal solid waste. Swiss Federal Office for the Environment, Bern. AB005, 15.12.2021. *https://bit.ly/3mWaDVL* [18.07.2022]

FOEN, 2022a: Switzerland's greenhouse gas inventory 1990–2020: National inventory report, reporting tables (CRF), supplementary information for LULUCF activities under the Kyoto Protocol and SEF tables of the national registry. Submission of April 2022 under the UNFCCC and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [15.04.2022]

FOEN, 2022b: Kenngrössen zur Entwicklung der Treibhausgasemissionen in der Schweiz, 1990–2020. Swiss Federal Office for the Environment, Bern. April 2022. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/kenngroessen_thg_emissionen_schweiz.pdf* [15.04.2022]

FOT, 2021: Eisenbahnausbauprogramme – Bahninfrastrukturfonds (BIF), Standbericht 2020. Swiss Federal Office of Transport, Bern. *https://www.bav.admin.ch/dam/bav/de/dokumente/aktuell-startseite/berichte/sb_eisenbahn_ausbauprogramme/standbericht-2020-eisenbahn-ausbauprogramme.pdf* [18.07.2022]

LUPO, 2016: Bericht 2016 über die Luftfahrtpolitik der Schweiz. Swiss Federal Council, Bern. *http://goo.gl/Dx5mdd* [18.07.2022]

MeteoSwiss, 2021: Klimareport 2020. MeteoSwiss, Zurich. pp. 96, ISSN 2296-1488. *https://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/klimareport_2020_de.pdf* [18.07.2022]

MeteoSwiss, 2022: Climate diagrams and normals per station – Bern / Zollikofen (normal period 1991–2020. MeteoSwiss, Zurich. *https://www.meteoswiss.admin.ch/product/output/climate-data/climate-diagrams-normal-values-station-processing/BER/climsheet_BER_np9120_e.pdf* [18.07.2022]

Morice, C. P., Kennedy, J. J., Rayner, N. A., Winn, J. P., Hogan, E., Killick, R. E. et al., 2021: An updated assessment of near-surface temperature change from 1850: the HadCRUT5 data set. Journal of Geophysical Research: Atmospheres, 126, e2019JD032361. *https://doi.org/10.1029/2019JD032361* [18.07.2022]

OcCC, 2007: Climate Change and Switzerland 2050. OcCC (Advisory Body on Climate Change), Bern. https://naturalsciences.ch/service/publications/76576-climate-change-and-switzerland-2050 [18.07.2022]

OECD, 2021: General government spending (indicator). International Energy Agency, Paris. doi:10.1787/a31cbf4d-en. https://data.oecd.org/gga/general-government-spending.htm [queries from database, 05.04.2022]

OECD, 2021b: Effective Carbon Rates 2021 – Pricing Carbon Emissions through Taxes and Emissions Trading. International Energy Agency, Paris. ISBN-9789264854635. https://doi.org/10.1787/0e8e24f5-en [18.07.2022]

Scherrer, S.C., Begert, M., Croci-Maspoli, M., Appenzeller, C., 2015: Long series of Swiss seasonal precipitation: regionalization, trends and influence of large-scale flow, International Journal of Climatology, 36, https://doi.org/10.1002/joc.4584 [18.07.2022]

Scherrer, S.C., Fischer, E.M., Posselt, R., Liniger,M.A., Croci-Maspoli, M., Knutti,R., 2016: Emerging trends in heavy precipitation and hot temperature extremes in Switzerland. Journal of Geophysical Research: Atmospheres, 121, https://doi.org/10.1002/2015JD024634 [18.07.2022]

SCNAT, 2016: Brennpunkt Klima Schweiz. Grundlagen, Folgen und Perspektiven. Swiss Academies Reports 11 (5). https://proclim.scnat.ch/en/activities/brennpunkt [18.07.2022]

SECO, 2021: BIP gemäss Produktionsansatz, saison- und kalenderbereinigt. Swiss State Secretariat for Economic Affairs, Bern. 02.09.2021. https://www.seco.admin.ch/seco/de/home/wirtschaftslage---wirtschaftspolitik/Wirtschaftslage/bip-quartalsschaetzungen-/daten.html [18.07.2022]

SFOE, 2021a: Gesamtenergiestatistik 2020. Swiss Federal Office of Energy, Bern. 805.006.20 / 08.21 / 1060 / 860490848. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/gesamtenergiestatistik.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTA1Mzc=.html [18.07.2022]

SFOE, 2021b: Schweizerische Elektrizitätsstatistik 2020. Swiss Federal Office of Energy, Bern. 805.005.20 / 07.21 / 1200 / 860490599. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/elektrizitaetsstatistik.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTA1MjA=.html [18.07.2022]

SFOE, 2021c: Energieverbrauch und Energieeffizienz der neuen Personenwagen und leichten Nutzfahrzeuge 2020, 25. Berichterstattung im Rahmen der Energieeffizienzverordnung. Swiss Federal Office of Energy, Bern. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/kennzahlen-fahrzeuge.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTA1MzE=.html [18.07.2022]

SFOE, 2021d: Entwicklung Energiebezugsflächen EBF 1990–2021, jährliches Update. Swiss Federal Office of Energy, Bern. 26.11.2021. https://bit.ly/3sfvPZX [18.07.2022]

SFSO, 2016e: Analyse der Arbeitsproduktivität im Dienstleistungssektor 1997–2014. Swiss Federal Statistical Office, Neuchâtel. 991–1400, 03.11.2016. https://www.bfs.admin.ch/bfs/de/home/statistiken/volkswirtschaft.assetdetail.1220118.html [18.07.2022]

SFSO, 2017a: Bau- und Wohnungswesen 2015. Swiss Federal Statistical Office, Neuchâtel. 908-1400, 11.04.2017. https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen.assetdetail.2341518.html [18.07.2022]

SFSO, 2017b: Verkehrsströme im Güterverkehr. Swiss Federal Statistical Office, Neuchâtel. KM02b-00074-11-c-suis-2017-de, 17.08.2017. https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/gueterverkehr.assetdetail.3222239.html [18.07.2022]

SFSO, 2017c: Verkehrsverhalten der Bevölkerung – Ergebnisse des Mikrozensus Mobilität und Verkehr 2015. Swiss Federal Statistical Office, Neuchâtel. 840-1500, 16.05.2017. https://www.bfs.admin.ch/bfs/en/home/news/whats-new.assetdetail.1840477.html [18.07.2022]

SFSO, 2020a: Szenarien zur Bevölkerungsentwicklung der Schweiz und der Kantone 2020–2050. Swiss Federal Statistical Office, Neuchâtel. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/publikationen.assetdetail.14963221.html [18.07.2022]

SFSO, 2021a: Switzerland's population in 2020. Swiss Federal Statistical Office, Neuchâtel. 1155-2000. https://www.bfs.admin.ch/bfs/en/home/statistics/population/effectif-change/population.assetdetail.19964433.html [18.07.2022]

SFSO, 2021b: Sprachliche Praktiken in der Schweiz – Erste Ergebnisse der Erhebung zur Sprache, Religion und Kultur 2019. Swiss Federal Statistical Office, Neuchâtel. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/sprachen-religionen/sprachen.assetdetail.15324909.html [18.07.2022]

SFSO, 2021c: Erwerbslosenquote gemäss ILO nach Geschlecht, Nationalität und anderen Merkmalen. Swiss Federal Statistical Office, Neuchâtel. je-d-03.03.01.14, 22.03.2022. https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases.assetdetail.je-d-03.03.01.14.html [18.07.2022]

SFSO, 2021d: Streckennetz nach Verkehrsträgern. Swiss Federal Statistical Office, Neuchâtel. je-d-11.03.01.01, 19.09.2021. https://www.bfs.admin.ch/bfs/de/home.assetdetail.18864137.html [18.07.2022]

SFSO, 2021e: Verkehrsleistung im Güterverkehr. Swiss Federal Statistical Office, Neuchâtel. je-d-11.05.01.02, 22.11.2021. https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/gueterverkehr.assetdetail.18864273.html [18.07.2022]

SFSO, 2021f: Wichtige Arbeitsmarktindikatoren, Entwicklung. Swiss Federal Statistical Office, Neuchâtel. je-d-03.01.01.01, 30.04.2021. https://www.bfs.admin.ch/bfs/de/home/statistiken/arbeit-erwerb/erwerbstaetigkeit-arbeitszeit.assetdetail.16904714.html [18.07.2022]

SFSO, 2021g: Ausfuhr nach Handelspartnern (Länder). Swiss Federal Statistical Office, Neuchâtel. je-d-06.05.04, 27.05.2021. https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/aussenhandel.assetdetail.17444482.html [18.07.2022]

SFSO, 2021h: Einfuhr nach Handelspartnern (Länder). Swiss Federal Statistical Office, Neuchâtel. je-d-06.05.03, 27.05.2021. https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/aussenhandel.assetdetail.17444475.html [18.07.2022]

SFSO, 2021i: Aussenhandel nach Waren. Swiss Federal Statistical Office, Neuchâtel. je-d-06.05.02, 27.05.2021. https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/aussenhandel/handelsbilanz-einfuhr-ausfuhr.assetdetail.17444473.html [18.07.2022]

SFSO, 2021j: Strassenfahrzeugbestand nach Fahrzeuggruppe. Swiss Federal Statistical Office, Neuchâtel. cc-d-11.03.02.01.01, 19.10.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/verkehrsinfrastruktur-fahrzeuge/fahrzeuge/strassenfahrzeuge-bestand-motorisierungsgrad.assetdetail.18864205.html* [18.07.2022]

SFSO, 2021k: Verkehrsleistung im Personenverkehr. Swiss Federal Statistical Office, Neuchâtel. je-d-11.04.01.02, 14.12.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/personenverkehr/leistungen.assetdetail.19904693.html* [18.07.2022]

SFSO, 2021l: Umsatz, Waren- und Materialaufwand nach Wirtschaftsabteilungen (hochgerechnet). Swiss Federal Statistical Office, Neuchâtel. je-d-06.04.01, 31.08.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/wertschoepfungsstatistik.assetdetail.18424520.html* [18.07.2022]

SFSO, 2021m: Produktionskonto nach Branchen (59 Branchen). Swiss Federal Statistical Office, Neuchâtel. je-d-04.02.03.01, 28.08.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/volkswirtschaft/volkswirtschaftliche-gesamtrechnung/produktionskonto.assetdetail.18424399.html* [18.07.2022]

SFSO, 2021n: Alpenquerender Güterverkehr (Gesamtverkehr) nach Ländern. Alpensegment: Mt. Cenis/Fréjus bis Brenner. Swiss Federal Statistical Office, Neuchâtel. je-d-11.05.04.03, 22.11.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/gueterverkehr/alpenquerend.assetdetail.18864258.html* [18.07.2022]

SFSO, 2021o: Separat gesammelte Siedlungsabfälle (Recycling) – Sammelquoten, in Prozent. Swiss Federal Statistical Office, Neuchâtel. gr-d-02.03.05.07.01-ind. *https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/umweltindikatoren.assetdetail.20204186.html* [18.07.2022]

SFSO, 2021p: Landwirtschaftsbetriebe nach betriebswirtschaftlicher Ausrichtung – Tausend Betriebe. Swiss Federal Statistical Office, Neuchâtel. gr-d-07.02.02.01.02.01, 11.05.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/land-forstwirtschaft/landwirtschaft/strukturen.assetdetail.17145580.html* [18.07.2022]

SFSO, 2021q: Landwirtschaft und Ernährung – Taschenstatistik 2021. Swiss Federal Statistical Office, Neuchâtel. 871–2100, 22.06.2021. *https://www.bfs.admin.ch/bfs/en/home/statistics/agriculture-forestry.assetdetail.17824819.html* [18.07.2022]

SFSO, 2021r: Landwirtschaftsbetriebe – Tausend Landwirtschaftsbetriebe. Swiss Federal Statistical Office, Neuchâtel. gr-d-07.02.02.01.01.01, 11.05.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/land-forstwirtschaft/landwirtschaft/strukturen.assetdetail.17145591.html* [18.07.2022]

SFSO, 2021s: Die Bodennutzung in der Schweiz – Resultate der Arealstatistik 2018. Swiss Federal Statistical Office, Neuchâtel. 002-1801, 25.11.2021. *https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases/publications.assetdetail.19365051.html* [18.07.2022]

SFSO, 2021t: Schweizerische Zivilluftfahrtstatistik 2020 – 7. Treibstoffverbrauch und Schadstoffemissionen. Swiss Federal Statistical Office, Neuchâtel. su-b-438-11.7.AV-e-7, 16.09.2021. *https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.18564368.html* [18.07.2022]

SFSO, 2021u: Flugpassagiere im Linien- und Charterverkehr. STAT-TAB – interaktive Tabellen (BFS). Swiss Federal Statistical Office, Neuchâtel. *https://www.pxweb.bfs.admin.ch/pxweb/de/px-x-1107020000_102/px-x-1107020000_102/px-x-1107020000_102.px* [queries from database, 03.11.2021]

SFSO, 2021v: Flugbewegungen (Starts und Landungen) im Linien- und Charterverkehr. STAT-TAB – interaktive Tabellen (BFS). Swiss Federal Statistical Office, Neuchâtel. *https://www.pxweb.bfs.admin.ch/pxweb/de/px-x-1107020000_101/px-x-1107020000_101/px-x-1107020000_101.px/table/tableViewLayout2/* [queries from database, 03.11.2021]

SFSO, 2022a: Erwerbstätige (Inlandkonzept) nach Geschlecht, Nationalität und Wirtschaftssektoren. Durchschnittliche Quartals- und Jahreswerte. Swiss Federal Statistical Office, Neuchâtel. je-d-03.02.01.07, 22.03.2022. *https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/tabellen.assetdetail.21825614.html* [18.07.2022]

SFSO, 2022b: Bau- und Wohnungswesen 2020. Swiss Federal Statistical Office, Neuchâtel. 908–2000, 08.06.2022. *https://www.bfs.admin.ch/bfs/de/home/statistiken/bau-wohnungswesen.assetdetail.22304473.html* [18.07.2022]

Swiss Confederation, 1999a: Federal Constitution of the Swiss Confederation of 18.04.1999 (Status as of 13.02.2022). *https://www.admin.ch/opc/en/classified-compilation/19995395/index.html* [18.07.2022]

Swiss Confederation, 2009: Federal Act on the Future Development of the Railway Infrastructure of 20.03.2009 (Status as of 01.01.2016). *https://www.admin.ch/opc/de/classified-compilation/20071907/index.html* [18.07.2022]

The World Bank, 2022: Forest area (% of land area). The World Bank. *https://data.worldbank.org/indicator/AG.LND.FRST.ZS* [queries from database, 19.05.2022]

Wüest and Partner, 2016: Heizsysteme: Entwicklung der Marktanteile 2002–2015 (Aktualisierung 2016). Wüest and Partner AG, Zurich. 103693.0016, 01.05.2016. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/heizsysteme_entwicklungdermarktanteile2002-2015.pdf* [18.07.2022]

Relevant websites

Swiss Confederation: *https://www.admin.ch/gov/en/start.html*

Swiss Federal Office for the Environment: *https://www.bafu.admin.ch/bafu/en/home.html*

MeteoSwiss: *http://www.meteoswiss.ch*

Swiss Federal Office of Energy: *https://www.bfe.admin.ch/bfe/en/home.html*

Swiss Federal Statistical Office (SFSO): *https://www.bfs.admin.ch/bfs/en/home.html*

3 Greenhouse gas inventory information

Comprehensive summary information from the national greenhouse gas inventory on emissions and emission trends prepared according to the UNFCCC Annex I inventory reporting guidelines are presented in BR CTF tables 1(a) to 1(d). The presented data cover the period from 1990 to 2020 and are fully consistent with the reporting tables (CRF) and the national inventory report of the most recent annual inventory submission of April 2022 (*FOEN*, 2022a). To further increase transparency, additional tables which support the descriptive summary in section 3.2 are provided below (section 3.1, Tab. 4 to Tab. 11). Global warming potential values according to the fourth assessment report of the Intergovernmental Panel on Climate Change (*IPCC*, 2007) based on the effect of greenhouse gases over a 100-year time horizon were used.[13] Summary information on Switzerland's national inventory arrangements, including changes since the fourth biennial report, are presented in section 3.3. As required by the 'Guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol', information on the national registry is reported in section 3.4.

3.1 Summary tables

Tab. 4 > Switzerland's greenhouse gas emissions by sector and gas, 2020. The total in the second last column includes indirect CO_2.

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	Indirect CO_2	Total	Share
	kt CO_2eq									
1 Energy	32 150	261.8	239.0	0.0	0.0	0.0	0.0	24.1	**32 675**	*75.3%*
2 Industrial processes and product use	2 026	6.4	605.2	1 387	34.4	137.6	0.4	94.3	**4 292**	*9.9%*
3 Agriculture	44.8	3 822	1 890	0.0	0.0	0.0	0.0	0.0	**5 757**	*13.3%*
5 Waste	8.9	496.3	168.4	0.0	0.0	0.0	0.0	1.2	**674.8**	*1.6%*
6 Other	10.6	0.6	0.5	0.0	0.0	0.0	0.0	1.0	**12.6**	*0.0%*
Total (excluding LULUCF)	**34 241**	**4 588**	**2 903**	**1 387**	**34.4**	**137.6**	**0.4**	**120.6**	**43 412**	***100.0%***
4 LULUCF	–1 768	11.9	50.5	0.0	0.0	0.0	0.0	0.0	**–1 705**	*–3.9%*
Total (including LULUCF)	**32 473**	**4 599**	**2 953**	**1 387**	**34.4**	**137.6**	**0.4**	**120.6**	**41 706**	***96.1%***
International aviation bunkers	2 051	0.2	16.8	0.0	0.0	0.0	0.0	0.0	2 068	*4.8%*
International marine bunkers	13.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	14.0	*0.0%*

FOEN (2022a)

[13] These global warming potential values are consistently used by Switzerland, i.e. in particular also regarding the definition of the quantified economy-wide emission reduction target (Annex B.3.4) and for the calculation of the projections of greenhouse gas emissions (chapter 5).

Tab. 5 > Switzerland's greenhouse gas emissions by gas (excluding LULUCF and international bunkers, including emissions from the sectors 1, 2, 3, 5, and 6), selected years. Also provided are the shares of the different gases in total emissions.

	1990		1995		2000		2005	
	kt CO_2eq	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**
CO_2 (excluding LULUCF)	44 160	*81.8%*	43 419	*82.0%*	43 622	*82.1%*	45 779	*82.5%*
CH_4 (excluding LULUCF)	5 792	*10.7%*	5 517	*10.4%*	5 141	*9.7%*	5 077	*9.2%*
N_2O (excluding LULUCF)	3 361	*6.2%*	3 331	*6.3%*	3 276	*6.2%*	3 132	*5.6%*
HFCs	0.0	*0.0%*	243.7	*0.5%*	636.0	*1.2%*	1 048	*1.9%*
PFCs	116.5	*0.2%*	17.5	*0.0%*	60.9	*0.1%*	50.3	*0.1%*
SF_6	137.0	*0.3%*	93.2	*0.2%*	152.3	*0.3%*	212.7	*0.4%*
NF_3	0.0	*0.0%*	0.0	*0.0%*	0.0	*0.0%*	0.0	*0.0%*
Indirect CO_2	414.0	*0.8%*	306.1	*0.6%*	223.8	*0.4%*	159.8	*0.3%*
Total (excluding LULUCF, including indirect CO_2)	**53 980**	***100.0%***	**52 928**	***100.0%***	**53 113**	***100.0%***	**55 459**	***100.0%***

	2010		2015		2020	
	kt CO_2eq	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**
CO_2 (excluding LULUCF)	45 046	*82.2%*	38 732	*79.9%*	34 241	*78.9%*
CH_4 (excluding LULUCF)	5 019	*9.2%*	4 838	*10.0%*	4 588	*10.6%*
N_2O (excluding LULUCF)	3 085	*5.6%*	2 974	*6.1%*	2 903	*6.7%*
HFCs	1 308	*2.4%*	1 508	*3.1%*	1 387	*3.2%*
PFCs	37.8	*0.1%*	25.5	*0.1%*	34.4	*0.1%*
SF_6	161.2	*0.3%*	278.0	*0.6%*	137.6	*0.3%*
NF_3	12.7	*0.0%*	0.7	*0.0%*	0.4	*0.0%*
Indirect CO_2	147.4	*0.3%*	124.9	*0.3%*	120.6	*0.3%*
Total (excluding LULUCF, including indirect CO_2)	**54 817**	***100.0%***	**48 480**	***100.0%***	**43 412**	***100.0%***

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Tab. 6 > Switzerland's greenhouse gas emissions by gas (excluding international bunkers, including emissions from the sectors 1, 2, 3, 4, 5, and 6), 1990–2020 (steps of two years for years not included in the second commitment period of the Kyoto Protocol). Also indicated are the relative changes in emissions in 2020 relative to 1990 (last column). In 1990, there were virtually no emissions of HFCs and no emissions of NF_3, therefore the relative increases are not indicated for these gases (for absolute changes see Fig. 55).

	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012
	kt CO_2eq											
CO_2 (excluding net CO_2 from LULUCF)	44 160	46 017	42 677	44 107	44 623	43 622	43 464	45 238	45 373	44 711	45 046	42 253
CO_2 (including net CO_2 from LULUCF)	42 032	41 640	39 456	38 482	41 648	48 749	40 712	42 556	43 374	42 450	42 053	39 704
CH_4 (excluding CH_4 from LULUCF)	5 792	5 667	5 505	5 470	5 268	5 141	5 129	5 036	5 091	5 147	5 019	4 946
CH_4 (including CH_4 from LULUCF)	5 820	5 682	5 523	5 486	5 284	5 155	5 147	5 049	5 105	5 159	5 031	4 958
N_2O (excluding N_2O from LULUCF)	3 361	3 321	3 298	3 340	3 213	3 276	3 323	3 106	3 108	3 071	3 085	2 980
N_2O (including N_2O from LULUCF)	3 416	3 367	3 346	3 389	3 261	3 323	3 373	3 152	3 155	3 119	3 134	3 029
HFCs	0.0	15.6	80.2	295.9	456.1	636.0	826.5	1 009.4	1 159.8	1 274.6	1 308.0	1 452.9
PFCs	116.5	80.6	20.9	20.4	23.6	60.9	35.9	68.9	62.3	44.6	37.8	38.8
SF_6	137.0	141.4	106.9	90.1	152.8	152.3	160.7	195.1	196.6	245.1	161.2	229.7
NF_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	12.7	0.5
Indirect CO_2	414.0	373.1	327.9	288.9	251.0	223.8	196.0	166.6	157.2	149.8	147.4	138.6
Total (excluding LULUCF, including indirect CO_2)	**53 980**	**55 615**	**52 016**	**53 613**	**53 987**	**53 113**	**53 134**	**54 821**	**55 148**	**54 643**	**54 817**	**52 040**
Total (including LULUCF, including indirect CO_2)	**51 936**	**51 299**	**48 860**	**48 052**	**51 077**	**58 300**	**50 451**	**52 197**	**53 210**	**52 443**	**51 885**	**49 552**

	2013	2014	2015	2016	2017	2018	2019	2020	Relative change 1990 to 2020
	kt CO_2eq								
CO_2 (excluding net CO_2 from LULUCF)	43 188	39 234	38 732	39 185	38 179	36 874	36 733	34 241	*–22.5%*
CO_2 (including net CO_2 from LULUCF)	41 105	38 868	36 502	36 987	36 220	35 906	34 555	32 473	*–22.7%*
CH_4 (excluding CH_4 from LULUCF)	4 874	4 865	4 838	4 804	4 747	4 712	4 633	4 588	*–20.8%*
CH_4 (including CH_4 from LULUCF)	4 887	4 878	4 851	4 819	4 760	4 724	4 645	4 599	*–21.0%*
N_2O (excluding N_2O from LULUCF)	2 987	2 969	2 974	2 905	3 059	2 926	2 994	2 903	*–13.6%*
N_2O (including N_2O from LULUCF)	3 037	3 019	3 024	2 957	3 110	2 977	3 044	2 953	*–13.6%*
HFCs	1 432	1 469	1 508	1 481	1 504	1 525	1 429	1 387	*See caption*
PFCs	27.7	22.5	25.5	19.5	32.0	36.3	31.8	34.4	*–70.4%*
SF_6	276.0	285.0	278.0	236.1	232.9	182.8	152.0	137.6	*0.4%*
NF_3	0.1	0.6	0.7	0.8	0.8	0.5	0.5	0.4	*See caption*
Indirect CO_2	132.6	129.0	124.9	126.5	125.9	119.8	123.4	120.6	*–70.9%*
Total (excluding LULUCF, including indirect CO_2)	**52 918**	**48 974**	**48 480**	**48 758**	**47 880**	**46 377**	**46 097**	**43 412**	***–19.6%***
Total (including LULUCF, including indirect CO_2)	**50 897**	**48 671**	**46 313**	**46 626**	**45 985**	**45 472**	**43 982**	**41 706**	***–19.7%***

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Tab. 7 > Switzerland's greenhouse gas emissions by sector (excluding LULUCF and international bunkers), selected years. Also indicated are the shares of the different sectors and source categories in total greenhouse gas emissions.

	1990		1995		2000		2005	
	kt CO_2eq	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**
1 Energy	41 842	*77.5%*	41 899	*79.2%*	42 219	*79.5%*	43 981	*79.3%*
1A1 Energy industries	2 519	*4.7%*	2 642	*5.0%*	3 172	*6.0%*	3 816	*6.9%*
1A2 Manufacturing industries and construction	6 570	*12.2%*	6 295	*11.9%*	6 007	*11.3%*	6 041	*10.9%*
1A3 Transport	14 690	*27.2%*	14 314	*27.0%*	15 981	*30.1%*	15 855	*28.6%*
1A4 Other sectors	17 481	*32.4%*	18 056	*34.1%*	16 550	*31.2%*	17 819	*32.1%*
1A5 Other (military)	219.6	*0.4%*	162.8	*0.3%*	151.2	*0.3%*	138.7	*0.3%*
1B Fugitive emissions from oil and natural gas	362.2	*0.7%*	429.3	*0.8%*	358.0	*0.7%*	311.4	*0.6%*
2 Industrial processes and product use	4 012	*7.4%*	3 421	*6.5%*	3 781	*7.1%*	4 432	*8.0%*
3 Agriculture	6 582	*12.2%*	6 371	*12.0%*	5 984	*11.3%*	5 934	*10.7%*
5 Waste	1 118	*2.1%*	918.6	*1.7%*	891.6	*1.7%*	937.9	*1.7%*
6 Other	12.2	*0.0%*	12.1	*0.0%*	13.0	*0.0%*	13.6	*0.0%*
Indirect CO_2	414.0	*0.8%*	306.1	*0.6%*	223.8	*0.4%*	159.8	*0.3%*
from 1 Energy	74.5	*0.1%*	65.0	*0.1%*	49.6	*0.1%*	37.8	*0.1%*
from 2 Industrial processes and product use	336.2	*0.6%*	238.2	*0.5%*	171.2	*0.3%*	119.2	*0.2%*
from 5 Waste	2.2	*0.0%*	1.9	*0.0%*	1.8	*0.0%*	1.6	*0.0%*
from 6 Other	1.1	*0.0%*	1.1	*0.0%*	1.2	*0.0%*	1.2	*0.0%*
Total (excluding LULUCF, including indirect CO_2)	**53 980**	***100.0%***	**52 928**	***100.0%***	**53 113**	***100.0%***	**55 459**	***100.0%***

	2010		2015		2020	
	kt CO_2eq	**Share**	**kt CO_2eq**	**Share**	**kt CO_2eq**	**Share**
1 Energy	43 212	*78.8%*	37 090	*76.5%*	32 651	*75.2%*
1A1 Energy industries	3 846	*7.0%*	3 291	*6.8%*	3 276	*7.5%*
1A2 Manufacturing industries and construction	5 865	*10.7%*	4 979	*10.3%*	4 499	*10.4%*
1A3 Transport	16 336	*29.8%*	15 344	*31.7%*	13 577	*31.3%*
1A4 Other sectors	16 751	*30.6%*	13 124	*27.1%*	10 968	*25.3%*
1A5 Other (military)	137.4	*0.3%*	135.2	*0.3%*	119.5	*0.3%*
1B Fugitive emissions from oil and natural gas	278.2	*0.5%*	217.5	*0.4%*	211.8	*0.5%*
2 Industrial processes and product use	4 530	*8.3%*	4 479	*9.2%*	4 198	*9.7%*
3 Agriculture	6 053	*11.0%*	5 994	*12.4%*	5 757	*13.3%*
5 Waste	862.2	*1.6%*	780.0	*1.6%*	673.6	*1.6%*
6 Other	12.4	*0.0%*	12.5	*0.0%*	11.6	*0.0%*
Indirect CO_2	147.4	*0.3%*	124.9	*0.3%*	120.6	*0.3%*
from 1 Energy	31.6	*0.1%*	26.0	*0.1%*	24.1	*0.1%*
from 2 Industrial processes and product use	113.2	*0.2%*	96.5	*0.2%*	94.3	*0.2%*
from 5 Waste	1.5	*0.0%*	1.3	*0.0%*	1.2	*0.0%*
from 6 Other	1.1	*0.0%*	1.1	*0.0%*	1.0	*0.0%*
Total (excluding LULUCF, including indirect CO_2)	**54 817**	***100.0%***	**48 480**	***100.0%***	**43 412**	***100.0%***

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Tab. 8 > Greenhouse gas emissions and removals in different sectors and source categories (excluding international bunkers), 1990–2020 (steps of two years for years not included in the second commitment period of the Kyoto Protocol). Also indicated are the relative changes in emissions in 2020 relative to 1990 (last column).

	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012
	kt CO_2eq											
1 Energy	41 842	44 279	40 996	42 772	43 431	42 219	42 032	43 546	43 603	42 949	43 212	40 546
1A1 Energy industries	2 519	2 895	2 605	2 861	3 224	3 172	3 390	3 682	4 032	3 837	3 846	3 640
1A2 Manufacturing industries and construction	6 570	6 378	6 151	6 040	6 201	6 007	5 807	6 043	6 206	6 075	5 865	5 433
1A3 Transport	14 690	15 514	14 621	14 378	15 143	15 981	15 601	15 798	15 979	16 649	16 336	16 273
1A4 Other sectors	17 481	18 886	17 007	18 912	18 305	16 550	16 748	17 585	16 954	15 984	16 751	14 808
1A5 Other (military)	219.6	194.0	180.2	151.9	160.9	151.2	154.6	128.9	142.8	130.6	137.4	132.4
1B Fugitive emissions from oil and natural gas	362.2	412.0	432.5	429.0	396.8	358.0	330.6	308.5	289.8	273.5	278.2	258.6
2 Industrial processes and product use	4 012	3 461	3 405	3 332	3 353	3 781	3 994	4 284	4 468	4 508	4 530	4 517
3 Agriculture	6 582	6 466	6 364	6 293	6 046	5 984	5 969	5 861	5 972	6 125	6 053	6 013
5 Waste	1 118	1 024	911	915	895.9	891.6	931.1	948.3	935.3	898.8	862.2	810.2
6 Other	12.2	12.2	12.2	12.1	11.1	13.0	12.9	13.9	12.5	13.0	12.4	14.0
Indirect CO_2	414.0	373.1	327.9	288.9	251.0	223.8	196.0	166.6	157.2	149.8	147.4	138.6
from 1 Energy	74.5	79.6	71.2	63.9	57.4	49.6	44.2	40.0	36.8	33.5	31.6	29.4
from 2 Industrial processes and product use	336.2	290.2	253.7	222.1	190.9	171.2	148.9	123.8	117.7	113.6	113.2	106.6
from 5 Waste	2.2	2.2	1.9	1.8	1.7	1.8	1.7	1.6	1.6	1.6	1.5	1.4
from 6 Other	1.1	1.1	1.1	1.1	1.0	1.2	1.2	1.3	1.1	1.2	1.1	1.2
Total (excluding LULUCF, including indirect CO_2)	**53 980**	**55 615**	**52 016**	**53 613**	**53 987**	**53 113**	**53 134**	**54 821**	**55 148**	**54 643**	**54 817**	**52 040**
4 LULUCF	–2 044	–4 316	–3 156	–5 561	–2 911	5 187	–2 684	–2 623	–1 938	–2 200	–2 932	–2 488
Total (including LULUCF, including indirect CO_2)	**51 936**	**51 299**	**48 860**	**48 052**	**51 077**	**58 300**	**50 451**	**52 197**	**53 210**	**52 443**	**51 885**	**49 552**

	2013	2014	2015	2016	2017	2018	2019	2020	Relative change 1990 to 2020
	kt CO_2eq								
1 Energy	41 472	37 423	37 090	37 489	36 503	35 210	35 087	32 651	*–22.0%*
1A1 Energy industries	3 735	3 605	3 291	3 376	3 294	3 357	3 366	3 276	*30.0%*
1A2 Manufacturing industries and construction	5 499	5 097	4 979	4 986	4 950	4 792	4 705	4 499	*–31.5%*
1A3 Transport	16 188	16 081	15 344	15 182	14 920	14 926	14 883	13 577	*–7.6%*
1A4 Other sectors	15 682	12 275	13 124	13 587	12 992	11 793	11 799	10 968	*–37.3%*
1A5 Other (military)	133.4	138.7	135.2	139.4	127.6	126.6	115.1	119.5	*–45.6%*
1B Fugitive emissions from oil and natural gas	234.7	225.3	217.5	218.7	219.0	216.0	218.6	211.8	*–41.5%*
2 Industrial processes and product use	4 524	4 533	4 479	4 423	4 586	4 454	4 406	4 198	*4.6%*
3 Agriculture	5 954	6 069	5 994	5 957	5 936	5 882	5 783	5 757	*–12.5%*
5 Waste	821.4	808.8	780.0	749.2	715.7	697.4	687.1	673.6	*–39.8%*
6 Other	14.4	11.5	12.5	12.2	12.6	13.5	11.0	11.6	*–4.9%*
Indirect CO_2	132.6	129.0	124.9	126.5	125.9	119.8	123.4	120.6	*–70.9%*
from 1 Energy	27.7	27.0	26.0	25.3	24.8	25.0	24.3	24.1	*–67.6%*
from 2 Industrial processes and product use	102.2	99.7	96.5	98.8	98.7	92.4	96.9	94.3	*–72.0%*
from 5 Waste	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.2	*–46.6%*
from 6 Other	1.3	1.0	1.1	1.1	1.1	1.2	1.0	1.0	*–7.5%*
Total (excluding LULUCF, including indirect CO_2)	52 918	48 974	48 480	48 758	47 880	46 377	46 097	43 412	*–19.6%*
4 LULUCF	–2 021	–303	–2 167	–2 132	–1 895	–905	–2 116	–1 705	*–16.6%*
Total (including LULUCF, including indirect CO_2)	**50 897**	**48 671**	**46 313**	**46 626**	**45 985**	**45 472**	**43 982**	**41 706**	***–19.7%***

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Tab. 9 > Emissions of precursor gases and SO_2 (excluding emissions from LULUCF), 1990–2020.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	kt															
NO_x	144.0	140.9	134.1	122.1	119.4	115.1	109.4	105.1	104.5	104.0	101.8	98.4	93.7	92.6	92.1	92.7
CO	817.1	778.9	718.9	627.3	574.5	531.6	510.5	479.0	458.6	443.8	417.8	389.9	363.3	352.0	335.4	320.0
NMVOC	302.0	287.7	265.0	236.7	221.7	205.4	194.4	182.1	170.9	163.7	154.0	145.2	134.0	125.7	116.4	113.1
SO_2	36.7	36.4	33.9	29.0	26.3	26.1	24.7	21.3	22.1	19.2	16.4	17.2	15.0	15.2	14.9	13.9

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	kt														
NO_x	91.2	89.8	89.5	84.6	83.9	79.7	79.9	79.7	75.7	71.4	69.5	65.9	62.5	59.1	52.8
CO	298.2	283.5	275.8	259.8	254.5	230.7	223.3	215.0	193.7	184.6	185.1	178.3	169.0	168.1	152.0
NMVOC	109.8	107.0	104.8	101.7	99.1	95.1	92.5	90.0	86.4	83.1	80.6	79.7	78.7	77.8	75.9
SO_2	13.2	11.5	11.6	10.3	10.4	8.3	8.5	7.9	7.2	5.5	5.1	4.9	4.7	4.3	3.8

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Tab. 10 > Emissions of precursor gases and SO_2 by sector, 2020.

	NO_x	CO	NMVOC	SO_2
	kt			
1 Energy	48.7	141.5	15.3	3.2
2 Industrial processes and product use	0.2	8.4	39.7	0.5
3 Agriculture	3.7	NO, NA	19.1	NO
5 Waste	0.1	1.5	1.7	0.0
6 Other	0.0	0.6	0.1	0.0
Total (excluding LULUCF)	**52.8**	**152.0**	**75.9**	**3.8**
4 LULUCF	0.0	0.5	69.4	NO
Total (including LULUCF)	**52.8**	**152.5**	**145.3**	**3.8**

NA, not applicable; NO, not occurring
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Tab. 11 > Net emissions (positive) and removals (negative) for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol, 1990–2020.

Greenhouse gas source and sink activities	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	Net emissions/removals (kt CO_2eq)										
A Article 3.3 activities	**83.6**	**83.7**	**83.0**	**85.2**	**96.7**	**106.8**	**109.4**	**114.8**	**125.3**	**128.3**	**129.8**
Afforestation/reforestation	–3.0	–5.9	–8.7	–11.3	–13.3	–14.7	–16.0	–17.0	–17.7	–18.5	–19.3
Deforestation	86.6	89.5	91.7	96.4	110.0	121.5	125.4	131.8	143.0	146.8	149.1
B Article 3.4 activities	**–2 327**	**–5 328**	**–4 686**	**–4 994**	**–3 687**	**–4 588**	**–6 264**	**–4 440**	**–3 463**	**–3 504**	**4 223**
Forest management	–1 159	–4 564	–4 130	–4 518	–3 328	–4 101	–5 962	–4 184	–3 155	–3 118	4 945
Harvested wood products	–1 169	–763.9	–556.4	–476.9	–358.4	–487.0	–301.7	–256.3	–308.3	–385.9	–722.6

Greenhouse gas source and sink activities	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Net emissions/removals (kt CO_2eq)										
A Article 3.3 activities	**132.2**	**134.8**	**137.5**	**140.1**	**142.4**	**145.8**	**154.4**	**152.2**	**155.8**	**160.7**	**163.7**
Afforestation	–20.1	–20.8	–21.6	–22.4	–23.0	–23.6	–24.2	–24.8	–25.4	–23.7	–21.6
Deforestation	152.2	155.6	159.1	162.5	165.4	169.4	178.6	177.0	181.2	184.4	185.3
B Article 3.4 activities	**–2 011**	**–3 315**	**–3 439**	**–3 195**	**–3 436**	**–2 483**	**–1 585**	**–2 763**	**–3 613**	**–3 565**	**–2 083**
Forest management	–1 584	–3 015	–3 080	–2 614	–2 709	–1 942	–1 222	–2 333	–3 193	–3 109	–1 730
Harvested wood products	–426.5	–300.3	–358.4	–580.9	–727.1	–541.3	–363.1	–430.3	–420.3	–455.3	–353.5

Greenhouse gas source and sink activities	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Net emissions/removals (kt CO_2eq)								
A Article 3.3 activities	**165.7**	**168.0**	**169.8**	**167.7**	**168.1**	**175.7**	**179.1**	**177.9**	**180.2**
Afforestation	–20.7	–19.4	–16.8	–18.1	–17.6	–17.2	–15.1	–16.9	–15.9
Deforestation	186.4	187.4	186.6	185.9	185.6	192.9	194.3	194.8	196.1
B Article 3.4 activities	**–3 209**	**–2 965**	**–1 593**	**–3 147**	**–3 018**	**–2 916**	**–1 679**	**–2 659**	**–2 330**
Forest management	–3 077	–3 023	–1 481	–3 052	–2 966	–2 902	–1 583	–2 716	–2 279
Harvested wood products	–132.6	58.3	–112.2	–95.3	–51.9	–14.5	–95.8	57.1	–51.1

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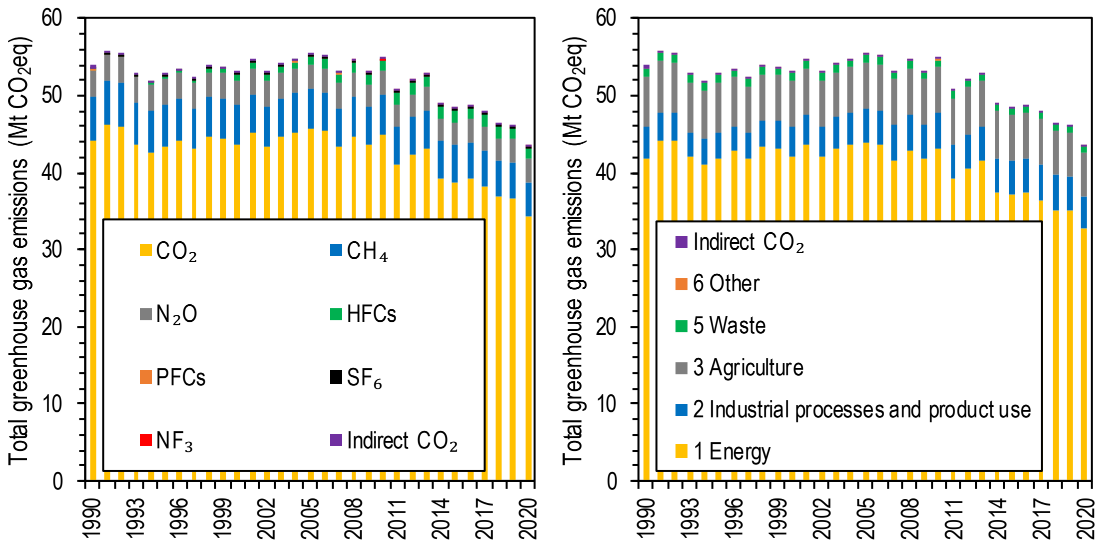
3.2 Descriptive summary

3.2.1 Aggregate greenhouse gas emissions

Switzerland's total greenhouse gas emissions (excluding LULUCF and international bunkers, including indirect CO_2) were 43.412 million tonnes of CO_2 equivalents in 2020 (Tab. 4), corresponding to 5.1 tonnes of CO_2 equivalents per capita. Between 1990 and 2020, total greenhouse gas emissions (excluding LULUCF) were mostly modulated by year-to-year changes in meteorological conditions which drive the amount of fuel needed for heating purposes (Fig. 52). This resulted in minimum emissions of 80.4 per cent in 2020 and maximum emissions of 103.5 per cent in 1991, relative to 1990 (Fig. 54). However, since about ten years, a decreasing trend has superimposed the variations from meteorological conditions. Indeed, average total emissions from 2016 to 2020 (last five years) were 14.0 per cent lower than average total emission from 1990 to 1994 (first five years of the reported period). For 2020, the measures to contain the corona virus pandemic led to a substantial decrease in total greenhouse gas emissions compared to the previous year. Overall, total greenhouse gas emissions evolved largely in parallel with the emissions of CO_2 between 1990 and 2020, since CO_2 persistently constituted the major contributor and since the decrease of CH_4 and N_2O emissions was about offset by the increase of emissions of F-gases in terms of CO_2 equivalents (section 3.2.2, Tab. 5, Fig. 54 and Fig. 55).

Fig. 52 > Switzerland's total greenhouse gas emissions (excluding LULUCF and international bunkers, including emissions from the sectors 1, 2, 3, 5, and 6, including indirect CO_2), 1990–2020. Left: Subdivided by gas. Right: Subdivided by sector.



FOEN (2022a)

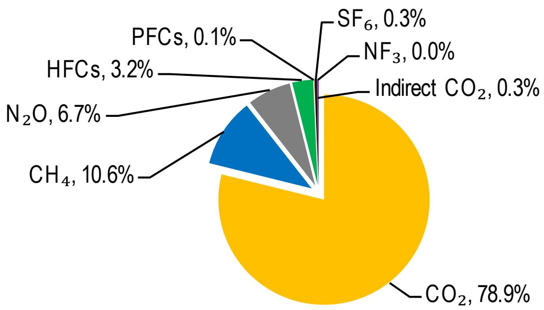
3.2.2 Emission trends by greenhouse gas

The relative contributions of the different gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3, and indirect CO_2) to total greenhouse gas emissions in the year 2020 are shown in Fig. 53. Broken down by gas, the trends in greenhouse gas emissions in Switzerland, from 1990 to 2020, were as follows (Tab. 5, Tab. 6, Fig. 54 and Fig. 55):

- CO_2 was the dominant contributor gas over the full time period (Fig. 52). In 2020, emissions of CO_2 (not including indirect CO_2 and emissions from LULUCF) amounted to 34.241 million tonnes (4.0 tonnes per capita), corresponding to a share of 78.9 per cent in total greenhouse gas emissions (including indirect CO_2, not including emissions from LULUCF, Fig. 53). CO_2 emissions primarily stem from fuel combustion activities, followed by emissions from industrial processes (mainly cement production);
- CH_4 accounted for a share of 10.6 per cent in total greenhouse gas emissions in 2020 (Fig. 53). Between 1990 and 2020, CH_4 emissions decreased by 20.8 per cent. This decrease is mainly attributable to reduced emissions from agriculture, where a reduction of livestock entailed less emissions from enteric fermentation. However, reduced CH_4 emissions from the energy and waste sectors also contribute to the observed decreasing trend in total CH_4 emissions. Particularly noteworthy is a change in waste legislation banning inputs into solid waste disposal sites as of the year 2000 (section 4.8.2), leading to further decreasing CH_4 emissions from waste disposal sites;

- N_2O accounted for a share of 6.7 per cent in total greenhouse gas emissions in 2020 (Fig. 53). Between 1990 and 2020, total N_2O emissions decreased by 13.6 per cent as N_2O emissions from manure management and agricultural soils declined in concert with CH_4 emissions due to decreasing livestock populations and decreasing use of fertiliser;
- Emissions of CH_4 and N_2O originated mainly from sector 3 ‘Agriculture’;
- All emissions of F-gases are attributed by definition to sector 2 ‘Industrial processes and product use’. F-gases increased their share in total greenhouse gas emissions from 0.5 per cent in 1990 to 3.6 per cent in 2020 (Fig. 53, Tab. 5). HFC emissions have substantially increased compared to 1990, because HFCs were introduced as substitutes for CFCs. In contrast, PFC emissions were 70.4 per cent lower in 2020 compared to 1990. In 2020, SF_6 emissions were at the same level as in 1990, with relatively large year-to-year fluctuations. Emissions of NF_3 were of minor importance over the full time period;
- Net CO_2 emissions/removals from LULUCF also showed considerable year-to-year variability, as heavy storms in 1990 and 1999 (‘Lothar’) and other factors had a large influence on the wood harvesting and tree mortality rates in forests. From 1990 to 2020, wood harvesting generally increased but losses due to cut and mortality were still exceeded by the growth of the living biomass pool. Overall, a reduction in net removals within the land use, land-use change and forestry sector is observed between 1990 and 2020 (Fig. 58);
- Indirect CO_2 emissions resulting from the atmospheric oxidation of CH_4, CO and NMVOC emissions show a decreasing trend, which is mainly due to the implementation of post-combustion facilities and reductions of emissions from solvent use. However, indirect CO_2 emissions are of minor importance over the full time period from 1990 to 2020 (see section 3.2.4 for details about the evolution of emissions of precursor gases and the calculation of the related indirect CO_2 emissions).

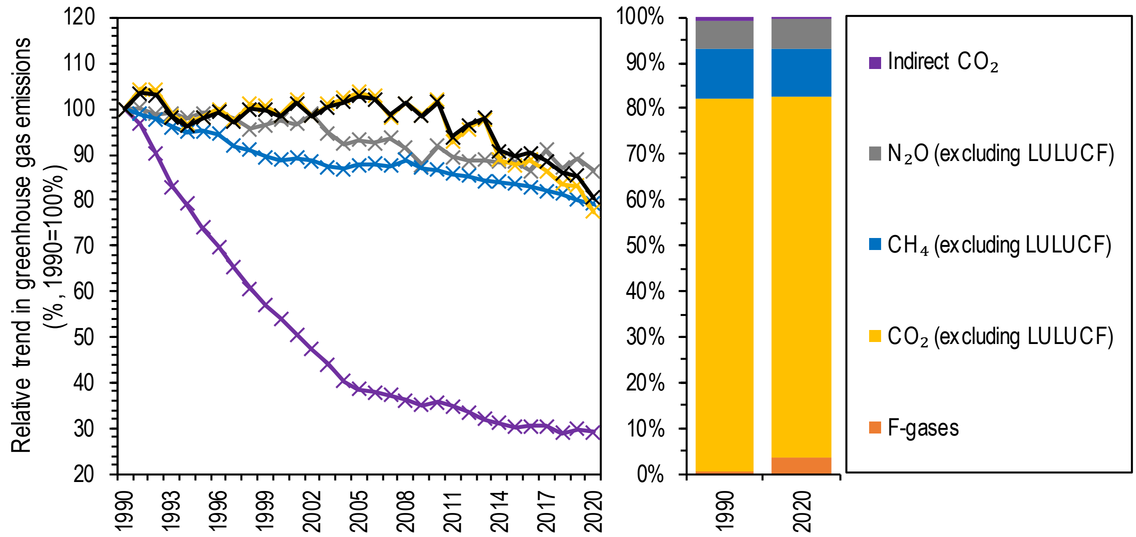
Fig. 53 > Contribution of individual gases to Switzerland’s total greenhouse gas emissions (excluding LULUCF and international bunkers, including emissions from the sectors 1, 2, 3, 5, and 6, including indirect CO_2), 2020.



Total emissions 2020 (including indirect CO_2): 43,412 kt CO_2 eq (=100%)

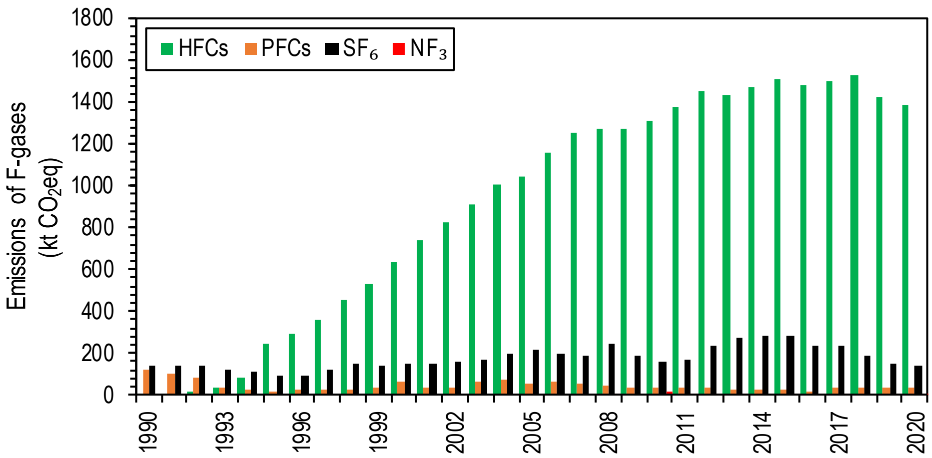
FOEN (2022a)

Fig. 54 > Left: Relative trends in emissions of the greenhouse gases CO_2, CH_4, N_2O, and indirect CO_2 (excluding LULUCF and international bunkers, including emissions from the sectors 1, 2, 3, 5, and 6), 1990–2020. The increase of emissions of F-gases, which amounts to about a factor of seven in 2020 relative to 1990, is shown in Fig. 55. However, F-gases are included in the total (black line). Right: Relative contributions of CO_2, CH_4, N_2O, F-gases, and indirect CO_2 to the total emissions in the years 1990 and 2020 (see also Fig. 53).



FOEN (2022a)

Fig. 55 > Absolute changes in emissions of HFCs, PFCs, SF_6, and NF_3 in Switzerland, 1990–2020. NF_3 emissions are hardly visible (due to values close to zero, see Tab. 6).



FOEN (2022a)

3.2.3 Emission trends by sources and sinks

In the following, details about Switzerland's greenhouse gas emissions (and removals) by the different sectors are provided (Fig. 52 to Fig. 58, Tab. 7 and Tab. 8).

Sector 1 'Energy'

Sector 1 'Energy' represents the major source of greenhouse gases in Switzerland (75.2 per cent of total emissions in 2020); thus, the respective tables and figures also distinguish source categories (1A1 to 1A5 and 1B). The following characteristics are noteworthy:

- Despite differing trends in the source categories, the overall emissions from sector 1 'Energy' remained at a relatively constant level between 1990 and about 2010 (Fig. 57), with some fluctuations mainly caused by year-to-year variations in meteorological conditions. However, a decreasing trend has emerged since about ten years;

- In 2020, more than 90 per cent of Switzerland's electric power was generated by hydroelectric and nuclear power plants (see Table 24 in *SFOE*, 2021a). Therefore, source category 1A1 'Energy industries' plays a minor role (10.0 per cent of total emissions from sector 1 'Energy' in 2020) and represents waste incineration plants rather than classical thermal power stations. While overall emissions from source category 1A1 'Energy industries' increased by 30.0 per cent since 1990, fluctuations were caused by varying combustion activities in the petroleum refinery industry, waste incineration and new installations for district heating;
- Emissions from source category 1A2 'Manufacturing industries and construction' contributed 13.8 per cent to total emissions from sector 1 'Energy' in 2020. Emissions from this source category generally showed a decreasing trend and were 31.5 per cent lower in 2020 compared to 1990. The decreasing emissions mainly resulted from a switch in fuel consumption from other bituminous coal and residual gas oil (i.e. fuels with relatively high emission factors) to other fossil fuels, natural gas, lignite and biomass (i.e. fuels with relatively low emission factors). For instance, the consumption of other bituminous coal in source category 1A2 'Manufacturing industries and construction' decreased by more than 90 per cent since 1990, while the consumption of natural gas about doubled. At the same time, the production in some industry branches substantially decreased (e.g. iron and aluminium production, cellulose and paper production), while it increased or remained about constant in other industry branches (e.g. steel production, food industry, fibreboard production);
- Emissions from source category 1A3 'Transport' (41.6 per cent of total emissions from sector 1 'Energy' in 2020) were highest in 2008 (13.3 per cent above the value in 1990) and slowly decreased during the last about ten years. Between 2016 and 2019, emissions were still 2.0 per cent above the value in 1990, but substantially decreased in 2020 due to the measures to contain the corona virus pandemic (to 7.6 per cent below the value in 1990). Fluctuations indicate a fairly strong correlation between emissions and the economic development, as well as a dependency on the exchange rate between the Euro and the Swiss franc leading to more or less 'fuel tourism' (see also section 2.6 for further discussions);
- Emissions from source category 1A4 'Other sectors' (33.6 per cent of total emission from sector 1 'Energy' in 2020) result from the use of fossil fuels by residential and commercial buildings. Year-to-year variations reflect the impact of meteorological conditions on heating demand. Indeed, emissions showed a strong correlation with the number of heating degree days, an index for cold weather conditions. Throughout the record, emissions generally increased when heating degree days increased and vice versa. From 1990 to 2020, the number of buildings and apartments increased, as well as the average floor space per person and workplace, resulting in a substantial increase of the total area heated. However, over the same period various policies and measures led to higher standards for insulation and to more efficient combustion equipment for both new and renovated buildings, which more than compensated for the emissions from the additional area heated (see section 2.10). Overall, emissions from source category 1A4 'Other sectors' decreased and were 37.3 per cent lower in 2020 compared to 1990;
- Source category 1A5 'Other' covers greenhouse gas emissions from non-road military vehicles including military aviation (0.4 per cent of total emissions from sector 1 'Energy' in 2020). Emissions decreased steadily during the 1990s, due to decreased use of military vehicles and aircrafts. Since 2004 they have stabilised at about 60 per cent of the emissions in 1990;
- Emissions from category 1B 'Fugitive emissions from oil and natural gas' (0.6 per cent of total emissions from sector 1 'Energy' in 2020) are dominated by emissions from transmission and distribution of natural gas. While the length of the natural gas net as well as the amount of gas consumed increased substantially since 1990, emissions from category 1B 'Fugitive emissions from oil and natural gas' decreased thanks to the gradual replacement of cast-iron pipes with polyethylene pipes. In 2020, emissions were 41.5 per cent lower compared to 1990.

Sector 2 'Industrial processes and product use'

Overall, emissions from sector 2 'Industrial processes and product use' showed a decreasing trend in the 1990s and a rebound between 1998 and about 2008, followed by about constant emissions and a slight decrease during the last years (Fig. 56). Mainly driven by economic development in the respective sectors, CO_2 and N_2O emissions decreased from 1990 to about 1998, remaining about constant thereafter. However, increasing emissions of F-gases (mainly HFCs) led to a subsequent increase of total greenhouse gas emissions from sector 2 'Industrial processes and product use' to current emissions of 4.6 per cent above the level in 1990. As F-gases recently reached peak emissions, they are responsible for the reversal of the trend emerging during the last years. The sector's share in total greenhouse gas emissions was 9.7 per cent in 2020 (Tab. 7).

Sector 3 'Agriculture'

Sector 3 'Agriculture' is characterised by CH_4 emissions from enteric fermentation and manure management, as well as by N_2O emissions from agricultural soils and manure management. Overall, CO_2 equivalent emissions decreased by about 11 per cent from 1990 to 2004 and remained about constant thereafter (Fig. 56). The main drivers of this trend are declining livestock (cattle and swine) and reduced fertiliser use. Sector 3 'Agriculture' contributed 13.3 per cent to total greenhouse gas emissions in 2020 (Tab. 7).

Sector 4 'Land use, land-use change and forestry' (LULUCF)

Fig. 58 shows net emissions and removals from sector 4 'Land use, land-use change and forestry' (LULUCF) in Switzerland, which are dominated by biomass dynamics in forests. Throughout the period 1990–2020, except for 2000, the net removals in the land use, land-use change and forestry sector were higher than the net emissions. However, a strong year-to-year variation is evident. The relative changes in the area of forest land are relatively small and fluctuations of the annual net carbon changes in forest management can primarily be explained by changes in the carbon losses from the living biomass pool, dead wood pool and litter pool. The exceptionally high net emissions of forest management in the year 2000 and the small net removals in the following year 2001 originate from the winter storm 'Lothar' at the end of 1999, which caused large-scale damages in forest stands and increased losses of living biomass due to salvage logging. Fluctuations in the harvested wood products pool are mainly caused by changes in the production of sawnwood and panels. The contribution of paper and paperboard to changes in harvested wood products fluctuates over the years, but is rather small compared to the contribution of sawnwood and panels. With regard to its emission reduction commitment, Switzerland accounts for afforestation and reforestation as well as deforestation under Article 3.3 of the Kyoto Protocol and for forest management (including harvested wood products) under Article 3.4 of the Kyoto Protocol (see Annex B.3.5 for details). The respective net emissions and removals are provided in Tab. 11 and displayed in Fig. 59.

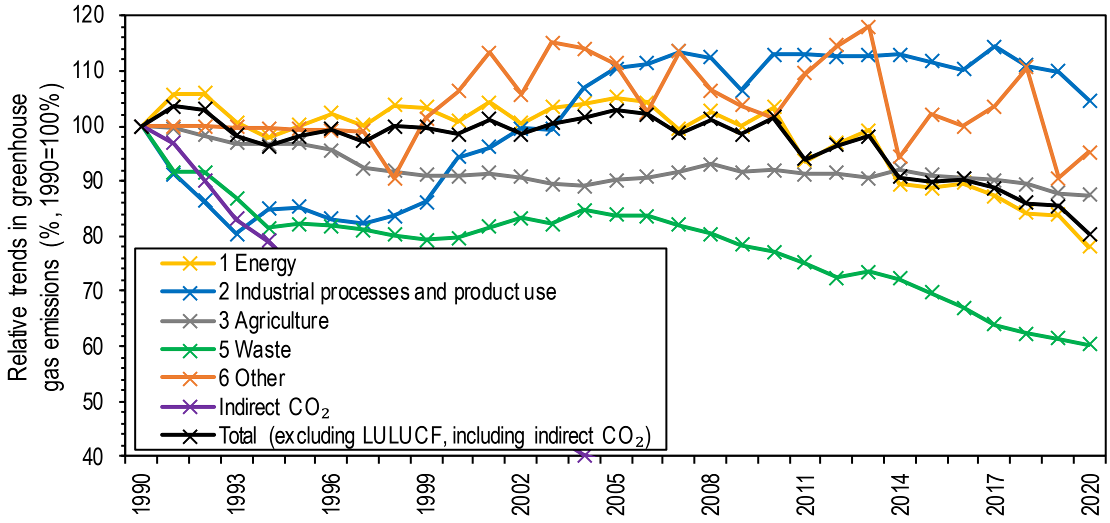
Sector 5 'Waste'

Sector 5 'Waste' contributed 1.6 per cent to total greenhouse gas emissions in 2020 (Tab. 7). Overall, emissions decreased by 39.8 per cent compared to the level in 1990 (Fig. 56), however, the different source categories within the sector showed divergent evolutions. Emissions from solid waste disposal sites decreased by about 65 per cent compared to the value in 1990, as Switzerland continuously increased the share of municipal solid waste incinerated in waste incineration plants. Moreover, since the year 2000, further emission reductions have been induced by a change in legislation completely banning the disposal of combustible municipal solid wastes on solid waste disposal sites. In contrast, emissions from biological treatment of solid waste more than doubled since 1990, as the amount of composted organic waste and the number of biogas facilities increased. Emissions from wastewater treatment and discharge steadily increased since 1990, closely related to population growth. Finally, emissions from incineration and open burning of waste reported in sector 5 'Waste' were, in 2020, about 44 per cent below the value in 1990. However, the vast majority of emissions from incineration of waste are not reported in sector 5 'Waste', but in sector 1 'Energy'. Taken together, waste-related emissions (including emissions from waste management activities reported in sector 5 'Waste', as well as in the source categories 1A 'Energy industries' and 3D 'Agricultural soils') increased by 27.4 per cent compared to the level in 1990 (data not shown in Fig. 56; see Fig. 7-3 and Fig. 7-5 in Switzerland's national inventory report; *FOEN*, 2022a).

Sector 6 'Other'

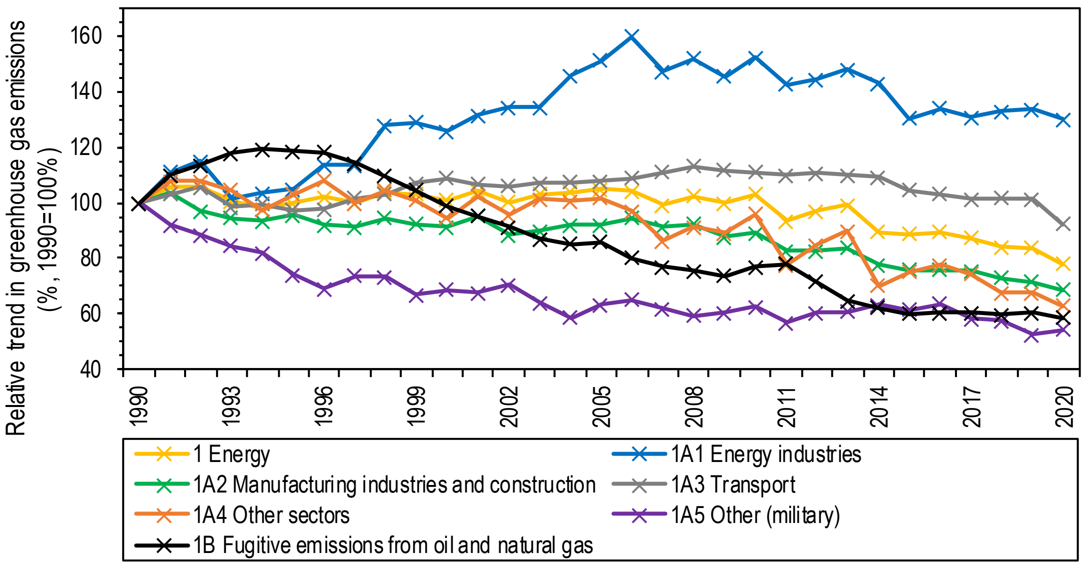
Sector 6 'Other' covers emissions from fire damage in buildings and motor vehicles. The contribution to total greenhouse gas emissions in 2020 was 0.03 per cent (Tab. 7, without indirect CO_2); the sector is, thus, of minor importance. These emissions, as well as the indirect CO_2 emissions from sector 6, are not accounted for in the framework of Switzerland's emission reduction commitment (Annex B.3.3). However, in agreement with the BR CTF tables, total emissions shown in the tables of this chapter include emissions from sector 6.

Fig. 56 > Relative trends in greenhouse gas emissions in the main sectors, 1990–2020. For the relative trend of indirect CO_2 emissions (partly invisible in this figure) see also Fig. 54.



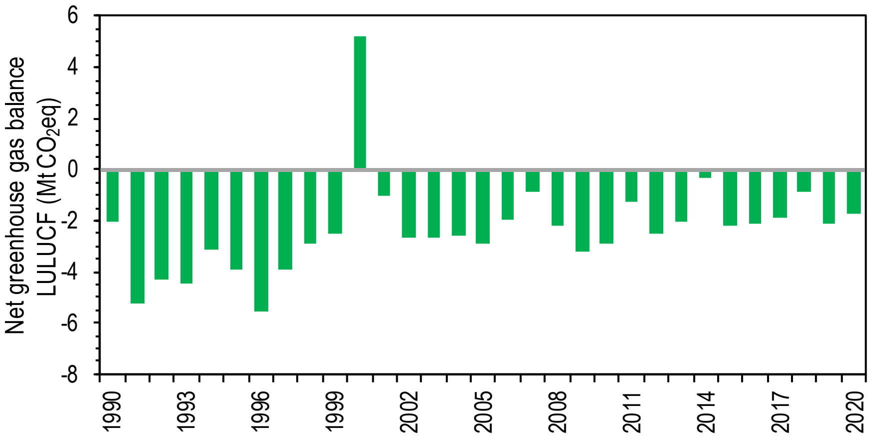
FOEN (2022a)

Fig. 57 > Relative emission trends in sector 1 'Energy' and its source categories (excluding indirect CO_2), 1990–2020.



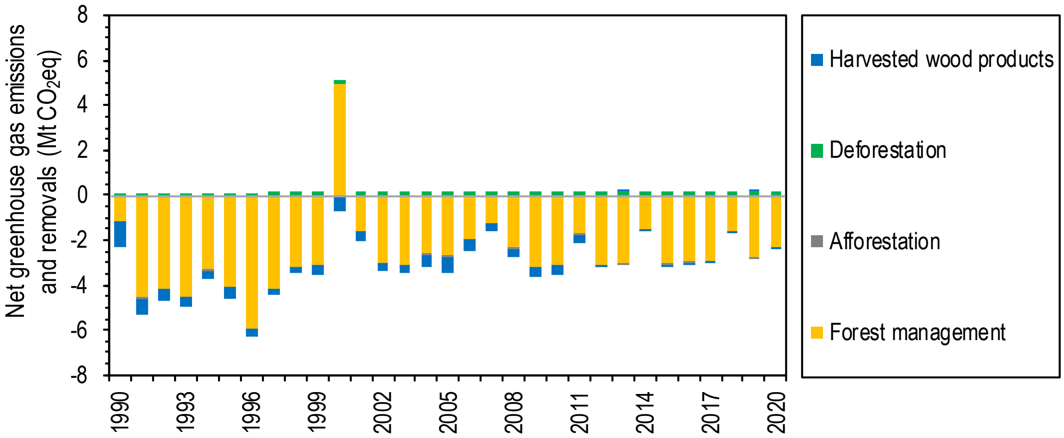
FOEN (2022a)

Fig. 58 > Net greenhouse gas balance of sector 4 ‘Land use, land-use change and forestry’ (LULUCF), 1990–2020. Positive values refer to net emissions, negative values to net removals. The contributions of CH_4 and N_2O are very small compared to the contribution of CO_2.



FOEN (2022a)

Fig. 59 > Net emissions and removals of greenhouse gases for activities under Article 3, paragraph 3 (afforestation and reforestation, deforestation) and paragraph 4 (forest management, harvested wood products) of the Kyoto Protocol, 1990–2020. Positive values refer to net emissions, negative values refer to net removals. As described in detail in Annex B.3.5, these net emissions and removals further need to be offset against Switzerland’s forest management reference level and the technical corrections to Switzerland’s forest management reference level for the accounting. In addition, the forest management cap needs to be respected.



FOEN (2022a)

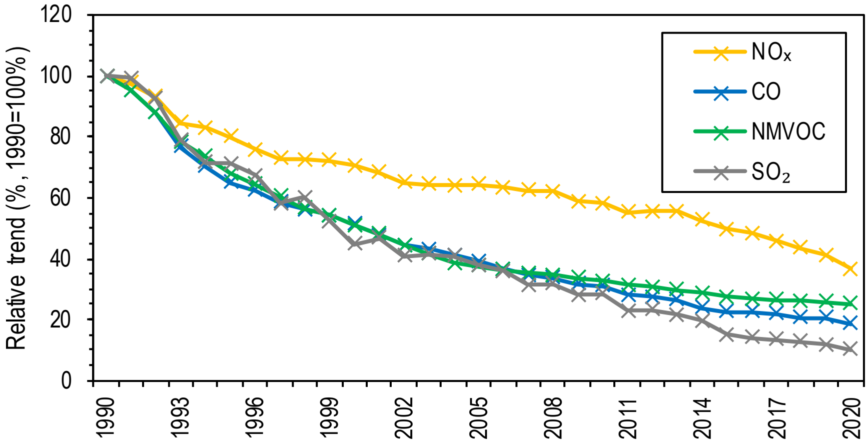
3.2.4 Emission trends of precursor gases and SO_2

Emission trends of precursor gases showed a very pronounced decline since 1990 (Tab. 9 and Fig. 60). By 2020, emissions of the air pollutants NO_x, CO, NMVOC, and SO_2 were between 10.3 and 36.7 per cent of the emissions in 1990, owing to a strict air pollution control policy implementing emission reduction measures. The main reduction measures were international exhaust gas regulations (see section 4.4.8) and the Ordinance on Air Pollution Control (see section 4.5.3) contributing to the abatement of exhaust emissions from road vehicles and stationary combustion equipment, as well as the NMVOC incentive fee leading to reduced emissions from the use of solvents (see section 4.5.4).

In 2020, sector 1 ‘Energy’ was by far the largest source of precursor gases (Tab. 10), with the only exception being NMVOC, where sector 2 ‘Industrial processes and product use’ and sector 4 ‘Land use, land-use change and forestry’ (LULUCF) substantially contributed to total emissions. Fig. 61 shows the relative contributions of the various sectors for each individual gas in 2020 (data from Tab. 10, excluding emissions from LULUCF, which accounted for 47.8 per cent of total NMVOC emissions including LULUCF in 2020).

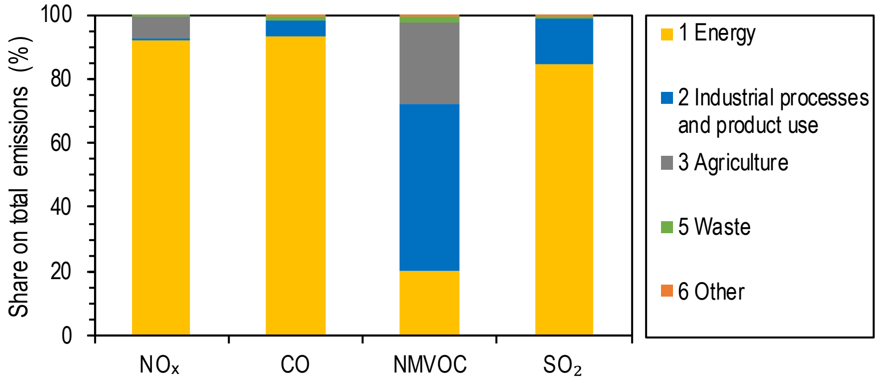
The atmospheric oxidation of CH_4, NO_x, CO, and NMVOC lead to indirect emissions of CO_2 and N_2O, but only indirect CO_2 emissions are included in Switzerland’s national total. Importantly, only fossil emissions and only emissions not already included under the direct CO_2 emissions in other sectors (e.g. when an oxidation factor of 100 per cent is applied) are considered. Details about the calculation of indirect CO_2 emissions, as presented in Tab. 8, are discussed in chapter 9 of Switzerland's national inventory report (*FOEN*, 2022a).

Fig. 60 > Relative trends of emissions of precursor gases and SO_2 (excluding NMVOC from LULUCF), 1990–2020.



FOEN (2022a)

Fig. 61 > Relative contributions of individual sectors to emissions of precursor gases and SO_2 (excluding LULUCF), 2020.



FOEN (2022a)

3.3 National inventory arrangements

In the following, Switzerland's national greenhouse gas inventory system is presented in brief. An in-depth description is provided in Switzerland's national inventory report (*FOEN*, 2022a, chapter 1).

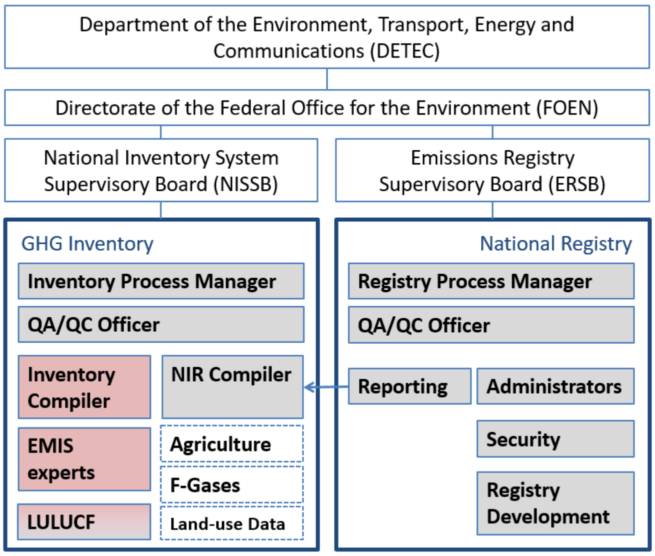
3.3.1 Name and contact information of national entity with overall responsibility

Swiss Federal Office for the Environment
National Greenhouse Gas Inventory System, Dr. Regine Röthlisberger
Climate Division, Section Climate Reporting and Adaptation
CH–3003 Bern, Switzerland
Phone: +41 (0)58 462 92 59
Email: climate@bafu.admin.ch
Web: *www.climatereporting.ch*

3.3.2 Roles and responsibilities: Institutional, legal and procedural arrangements

As shown in Fig. 62, Switzerland's national inventory system is developed and managed under the auspices of the Swiss Federal Department of the Environment, Transport, Energy and Communications. As stipulated in the second CO_2 Act of 23 December 2011 (Article 39), the Swiss Federal Office for the Environment – an office of the Swiss Federal Department of the Environment, Transport, Energy and Communications – is responsible for the assessment of matters relating to climate protection. Accordingly, the Swiss Federal Office for the Environment coordinates the national inventory system.

Fig. 62 > Institutional setting of Switzerland's national inventory system (NIS). The coloured boxes correspond to divisions of the Swiss Federal Office for the Environment (grey: Climate Division; red: Air Pollution Control and Chemicals Division as well as Forest Division). The white boxes correspond to mandated experts outside the Swiss Federal Office for the Environment (dashed frame) or to executive committees (solid frame).



Swiss Federal Office for the Environment

In 2004, as part of the Swiss climate reporting project, the directorate of the Swiss Federal Office for the Environment mandated its Climate, Economics and Environmental Monitoring Division to design and establish the national inventory system in order to ensure full compliance with the reporting requirements of the UNFCCC and the Kyoto Protocol by 2006. With the formal approval of Switzerland's first initial report under Article 7, paragraph 4, of the Kyoto Protocol (*FOEN*, 2006) by the Swiss Federal Council on 8 November 2006, the national inventory system became operative. By providing for structures and in defining tasks and responsibilities of institutions, organisations and consultants involved, the national inventory system itself is a key tool in ensuring and improving the quality as well as the process management of the national greenhouse gas inventory preparation. With the overall responsibility carried by the Climate Division of the Swiss Federal Office for the Environment, the national inventory system covers the following elements:

- Arrangements with partner institutions, relating to roles and responsibilities;
- Participation in the inventory development process;
- Data use, communication and publication;
- Inventory development plan;
- Setting-up and maintaining the QA/QC system;
- Official consideration and approval of data and reports;
- Upgrading and updating of the national air pollution database EMIS;
- Data documentation and storage;
- Management of the national registry.

Two supervisory boards are currently in place with separate mandates and responsibilities. The **national inventory system supervisory board (NISSB)** oversees all aspects related to the national greenhouse gas inventory and the reporting obligations under the UNFCCC (including reporting of the national registry in the national inventory report). It is independent of the inventory preparation process and, by its composition, combines technical expertise and political authority. The **emission registry supervisory board (ERSB)** on the other hand deals with management issues related to the national registry. The main tasks of the two supervisory boards are:

- Official consideration of the annual inventory submission and recommendation of the inventory for official approval by the directorate of the Swiss Federal Office for the Environment;

- Assessment and approval of the recalculation of inventory data;
- Handling of any issues arising from the UNFCCC review process that cannot be resolved at the level of the inventory or registry project managers;
- Facilitation of any non-technical negotiation, consideration or approval processes involving other institutions within the federal administration;
- Support of the registry administration in maintaining a secure and reliable registry environment.

The national greenhouse gas inventory is coordinated by the **inventory process manager**. The process of inventory planning, preparation and management is well-established with responsibilities and decision-making power assigned to specific people or groups. The **inventory QA/QC officer** is responsible for enforcement of the defined quality standards of the national greenhouse gas inventory. The inventory QA/QC officer also advises the national inventory system supervisory board on matters relating to the conformity of the greenhouse gas inventory with reporting requirements.

The **greenhouse gas inventory working group** constitutes a fundamental element of the national greenhouse gas inventory and encompasses all scientific and technical personnel involved in the inventory preparation process or representing institutions that play a significant role as suppliers of data. The group as a whole meets at least once per year to take stock of the state of the inventory, to discuss priorities in the inventory development process, and to address specific issues of general interest that arise, e.g. from domestic or international reviews.

The **greenhouse gas inventory core group** meets four times per year and comprises the inventory experts employed by the Swiss Federal Office for the Environment or mandated on a regular basis, who are entrusted with major responsibilities for inventory planning, preparation and/or management. All inventory data are assembled and prepared for input into the CRF reporter by the greenhouse gas inventory core group, which is also responsible for ensuring the conformity of the inventory with the relevant guidelines. The greenhouse gas inventory core group consists of:

- The inventory project management (with overall responsibility for the integrity of the inventory, communication of data, and information exchange with the UNFCCC secretariat);
- The national inventory compiler (responsible for the national air pollution database EMIS and for the reporting tables (CRF));
- The national inventory report compiler and the lead authors of the national inventory report (responsible for the report and carrying out centralised data assessments such as key category analyses and uncertainty analysis);
- Selected sectoral experts;
- The inventory QA/QC officer.

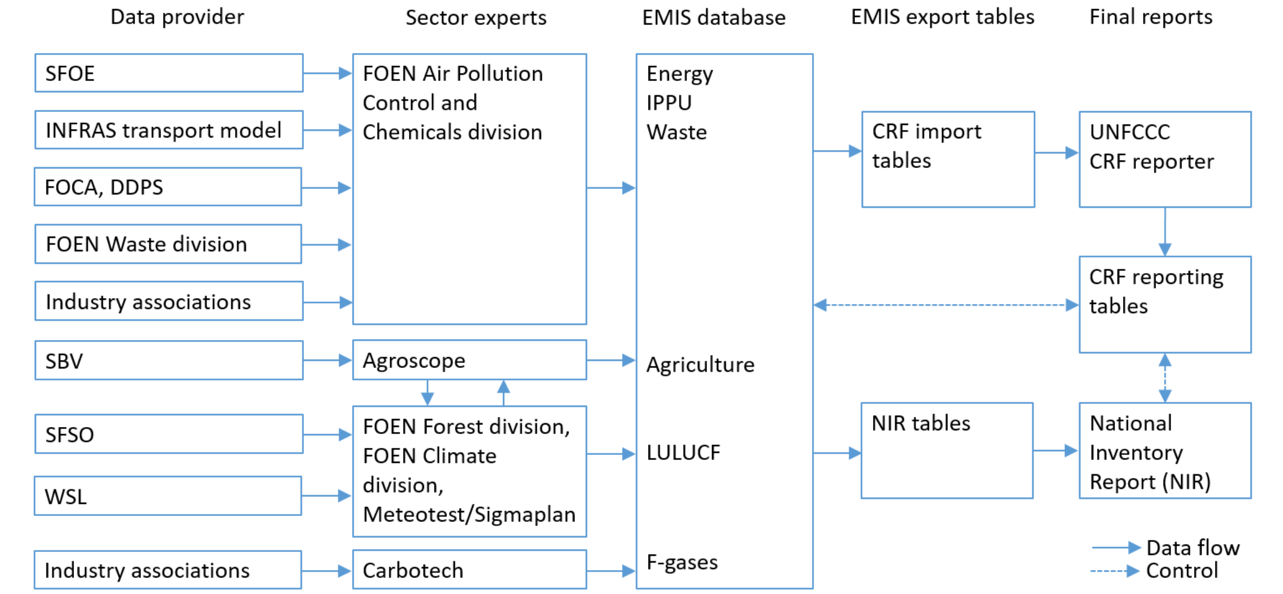
The greenhouse gas inventory core group coordinates and integrates the activities of data suppliers within and outside the Swiss Federal Office for the Environment as well as those of mandated experts. Further data suppliers contributing to the greenhouse gas inventory are institutions of the Swiss federal administration, research institutions, industry associations, and other private entities (see *FOEN*, 2022a for details). Everyone is obliged by Article 46 of the Swiss Federal Act on the Protection of the Environment (*Swiss Confederation*, 1983) to provide the authorities with the information required to enforce the law and, if necessary, to conduct or acquiesce in the conduct of enquiries.

At the operational level, the national registry is largely run independently of the national greenhouse gas inventory. Its operation is coordinated by the **registry process manager** whose work is overseen by the **registry QA/QC officer**.

3.3.3 Process of inventory preparation

The Air Pollution Control and Chemicals Division of the Swiss Federal Office for the Environment maintains the national air pollution database EMIS which contains all data needed to prepare the greenhouse gas inventory. The database was established in the late 1980s. Its initial purpose was to record and monitor emissions of air pollutants, but it has since been extended to cover greenhouse gases as well. Its structure corresponds to the EMEP/CORINAIR system for classifying emission-generating activities. The data needed to prepare the national greenhouse gas inventory in the common reporting format (CRF), as requested by the UNFCCC, is collected by various data suppliers and compiled centrally by the Swiss Federal Office for the Environment. At the same time, background information on data sources, activity data, emission factors and methods used for emission estimation is documented in the database and/or the national inventory report. Since the individual data suppliers bear the main responsibility for the quality of data provided, they are also responsible for the collection of activity data, emission factors, and for the selection of methods compliant with the relevant guidelines.

Fig. 63 > Data collection for the national air pollution database EMIS, from where the data are transferred via the CRF reporter to the reporting tables (CRF). The reporting tables are submitted by means of the UNFCCC submission portal and documented in the national inventory report. The authors of the national inventory report and the reviewers control the correctness of the data transferred from the database into the report (figures and tables shown in the national inventory report are exported directly from the database). The authors further check the correspondence between the exports and the reporting tables. DDPS: Swiss Federal Department of Defence, Civil Protection and Sport, FOCA: Swiss Federal Office of Civil Aviation, FOEN: Swiss Federal Office for the Environment, SBV: Swiss Farmers' Union, SFOE: Swiss Federal Office of Energy, SFSO: Swiss Federal Statistical Office, WSL: Swiss Federal Institute for Forest, Snow and Landscape Research.



Swiss Federal Office for the Environment

Fig. 63 illustrates the data collection and processing steps leading to the reporting tables (CRF) required for reporting under the UNFCCC and the Kyoto Protocol. Most important input data for the national air pollution database EMIS comprise the Swiss overall energy statistics of the Swiss Federal Office of Energy, the Swiss wood energy statistics of the Swiss Federal Office of Energy, various statistics (of the Swiss Federal Office for the Environment) and models for emissions from road transport, statistics and models of non-road activities, modelled emissions based on the import statistics for F-gases (fluorinated greenhouse gases), waste and agricultural statistics, as well as extracts from the national forest inventory and the national forest statistics. Emissions and removals from sector 4 'Land use, land-use change and forestry' (LULUCF) and KP-LULUCF are calculated by the Forest Division of the Swiss Federal Office for the Environment; a detailed description of the calculation of these emissions can be found in chapter 6 of *FOEN* (2022a). Emissions from sector 3 'Agriculture' are compiled by Agroscope, the Swiss Centre of Excellence for Agricultural Research (affiliated with the Swiss Federal Office for Agriculture). Emissions from all other sectors are calculated or compiled by the Air Pollution Control and Chemicals Division of the Swiss Federal Office for the Environment, in parts with the support of external companies shown in Fig. 63 (Carbotech, Meteotest, and Sigmaplan).

Methodologies: General description

Emissions calculations for the various sectors rely on standard methodologies (tier 1, tier 2, or tier 3) according to the 2006 IPCC guidelines for national greenhouse gas inventories (*IPCC*, 2006) and its 2019 Refinements (*IPCC*, 2019), the 2013 KP supplement (*IPCC*, 2014a), and the 2013 wetlands supplement (*IPCC*, 2014b). For the sector 1 'Energy', import and fuel consumption statistics (fuel sales in the transport sector) taken from the Swiss overall energy statistics (e.g. *SFOE*, 2021a) are used as input data, while for the other sectors national statistics and data surveys are consulted.

3.3.4 Key category analysis

A key category analysis is performed annually following the 2006 IPCC guidelines for national greenhouse gas inventories (*IPCC*, 2006). Level and trend assessments are performed for both approach 1 and approach 2, considering the emissions from the base year 1990 and the latest year reported. Emissions from sector 4 'Land use, land-use change and forestry' (LULUCF) as well as indirect CO_2 emissions are included in the key category analysis. Under approach 2, emissions are weighed with their uncertainty estimates. Tab. 12 presents an overview of the resulting key categories for 2020. More details are provided in Switzerland's latest national inventory report (*FOEN*, 2022a).

3.3.5 Recalculation of data

While the inventory has reached a consolidated state, it is continuously improved. Recalculations that further improve the inventory or that implement recommendations and encouragements from the various review procedures are considered (and approved) by the greenhouse gas inventory core group. Substantial recalculations that impact the national total are presented to the national inventory system supervisory board for approval. Recalculations are documented in the national inventory report (see e.g. chapter 10 in *FOEN*, 2022a).

3.3.6 Quality assurance and quality control (QA/QC) and verification plans

The national inventory system has an established quality management system (QMS) that complies with the requirements of ISO 9001:2015. Certification was obtained in 2007 and has been upheld since through annual audits. The quality management system is designed to comply with the revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (FCCC/CP/2013/10/Add.3) to ensure and continuously improve transparency, consistency, comparability, completeness, accuracy, and confidence in national greenhouse gas emission and removal estimates. While a detailed description of the QA/QC procedures, including verification plans, is given in section 1.2.3 of *FOEN* (2022a) and in the quality manual (*FOEN*, 2022b), the most important elements are summarised in the following.

General QC procedures

Routine annual quality control procedures comprise checks related to new data and database operations, spot-checks for transcription errors, correct use of conversion factors and units, and correct calculations:

- There are checklists for the most important sectoral data suppliers, the experts of the national air pollution database EMIS, for the national inventory report compiler, and the QA/QC officer;
- Consistency of data between categories is to a large extent ensured by the design of the database, where specific emission factors and activity data that apply to various categories are used jointly by all categories to calculate emissions;
- Recalculations are compiled in a document and made available to the members of the greenhouse gas inventory core group;
- QC procedures regarding the reporting tables (CRF) comprise a detailed comparison of the tables of the previous submission with those of the current submission for the base year and the latest common year. In addition, the time-series consistency is incrementally checked by comparing the latest inventory year with the preceding year;
- Finally, Switzerland's national inventory report is subject to an internal review prior to submission.

Category-specific QC procedures

Whenever new emission factors are considered, they are compared to the default values of the IPCC guidelines and to the values used in previous years. Similarly, if new activity data have become available for a particular category, a comparison between existing and new activity data is performed. The general procedures regarding category-specific QC are also described in the quality manual (*FOEN*, 2022b), while specific activities are documented in the corresponding sectoral chapters.

Quality assurance procedures

As required by ISO 9001 there are periodic internal audits covering all processes. In addition, an external organisation is mandated to conduct the annual audit of the ISO 9001 quality management system. Results and suggestions for improvements from expert peer reviews commissioned on a case-by-case basis for specific sectors, as well as recommendations and encouragements from the UNFCCC expert review teams are added to the inventory development plan and considered by the greenhouse gas inventory core group for implementation in future submissions.

Verification activities

For sector 1 'Energy', the standard verification activity carried out on an annual basis is the comparison of the sectoral approach with the reference approach (see *FOEN*, 2022a for more details). In addition, the Swiss Federal Office for the Environment supports a long-term monitoring programme from which Switzerland's emissions of some fluorinated greenhouse gases can be estimated based on atmospheric measurements. Similar research projects are currently looking into developing independent estimates of CH_4 and N_2O emissions in Switzerland based on atmospheric measurements and inverse modelling of atmospheric transport.

Treatment of confidentiality issues

Nearly all of the data necessary to compile the Swiss greenhouse gas inventory are publicly available. There are a few exceptions (data referring to a single enterprise, disaggregated emissions of F-gases, some data regarding civil aviation, and unpublished land-use statistics), however, these are made available to the UNFCCC expert review team upon request.

Public access to the greenhouse gas inventory

The Swiss Federal Office for the Environment operates a website (*http://www.climatereporting.ch*) where the Swiss greenhouse gas inventories (national inventory report, reporting tables (CRF), and UNFCCC review reports), the Swiss national communications and other reports submitted under the UNFCCC and the Kyoto Protocol are available. On this website, further background information cited in the national inventory report is provided.

3.3.7 Procedures for official consideration and approval of the inventory

The process for the official consideration of the greenhouse gas inventory is defined in the mandate of the national inventory system supervisory board. At the national inventory system supervisory board meeting taking place after the completion of the inventory (generally in mid-March) the inventory project management hands over the national inventory report and the reporting tables (CRF) to the members of the board for consideration. Subsequently, the chair of the national inventory system supervisory board presents the inventory for official approval to the directorate of the Swiss Federal Office for the Environment.

3.3.8 Changes to the national inventory arrangements since the previous submission

There are no changes to arrangements with other institutions of the Swiss federal administration. Several long-term contracts with private companies and a federal institute are coming to an end in 2022 or 2023 and new contracts are foreseen for the next years (regarding F-gases and LULUCF). Further, two contractors are mandated to support data operation in the national air pollution database EMIS and updating the national inventory report. Uncertainty analysis is performed by the Swiss Federal Office for the Environment.

Tab. 12 > Results of the key category analyses of Switzerland's greenhouse gas inventory (see also Tab. 1-9 in Switzerland's national inventory report; *FOEN*, 2022a). Key categories are ordered by NFR code, whereby categories which are not key categories are not shown. In addition to the emissions of all greenhouse gases from the sectors 1, 2, 3, 5, and 6, emissions from the sector land use, land-use change and forestry (4) as well as indirect CO_2 emissions are also considered. The following abbreviations are used: 'L1' indicates key categories from the level assessment of the most recent inventory year (2020) using approach 1, 'L2' indicates key categories from the level assessment of the most recent inventory year (2020) using approach 2, 'T1' indicates key categories from the trend assessment (1990/2020) using approach 1, and 'T2' indicates key categories from the trend assessment (1990/2020) using approach 2.

NFR code	Source categories and fuels if applicable	CO_2	CH_4	N_2O	HFC	PFC
1A1	Energy industries; gaseous fuels	L1, T1				
1A1	Energy industries; liquid fuels	L1, T1				
1A1	Energy industries; other fuels	L1, T1, L2, T2				
1A2	Manufacturing industries and construction; gaseous fuels	L1, T1, L2				
1A2	Manufacturing industries and construction; liquid fuels	L1, T1				
1A2	Manufacturing industries and construction; other fuels	L1, T1				
1A2	Manufacturing industries and construction; solid fuels	L1, T1				
1A3a	Civil aviation; kerosene	T1				
1A3b	Road transportation; diesel oil	L1, T1		T1		
1A3b	Road transportation; gasoline	L1, T1	T1	T1		
1A4a	Commercial; gaseous fuels	L1, T1				
1A4a	Commercial; liquid fuels	L1, T1				
1A4b	Residential; gaseous fuels	L1, T1, L2				
1A4b	Residential; liquid fuels	L1, T1				
1A4c	Agriculture and forestry; liquid fuels	L1, T1				
1B2	Oil and natural gas energy production; all fuels		L1, T1			
2A1	Cement production	L1, T1, L2				
2B10	Chemical industry, other			L1, T1, L2		
2C3	Aluminium production	T1				T1
2D	Non-energy products from fuels and solvent use; NMVOC (indirect)	T1, L2, T2				
2F1	Refrigeration and air conditioning				L1, T1, L2, T2	
2G	Other product manufacture and use; NMVOC (indirect)	L2				
3A	Enteric fermentation		L1, T1, L2			
3B1–4	Manure management, all livestock, direct		L1, L2	L2		
3B5	Manure management, indirect			L1, L2		
3Da	Direct emissions from managed soils			L1, T1, L2		
3Db	Indirect emissions from managed soils			L1, L2		
4A1	Forest land remaining forest land	L1, T1, L2, T2				
4A2	Land converted to forest land	L1, L2				
4B1	Cropland remaining cropland	T1, L2, T2				
4C1	Grassland remaining grassland	L1, T1, L2, T2				
4C2	Land converted to grassland	L1, T1, L2				
4D1	Wetland remaining wetland	L2				
4E2	Land converted to settlements	L1, L2				
4F2	Land converted to other land	L1, L2				
4G	HWP harvested wood products	T1, T2				
4III	Direct N_2O from disturbance			L2		
5A	Solid waste disposal		L1, T1, L2			
5C	Incineration and open burning of waste			L2		
5D	Wastewater treatment and discharge		L1, T1, L2	L2		

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3.4 National registry

3.4.1 General information

Name and contact information of the registry administrator

Swiss Federal Office for the Environment
Swiss Emissions Trading Registry
Climate Division, Mr. Marcel Kamber
CH–3003 Bern, Switzerland
Phone: +41 (0)58 462 05 66
Email: *emissionsregistry@bafu.admin.ch*
Registry: *https://www.emissionsregistry.admin.ch*
Web: *https://www.bafu.admin.ch/emissions-trading*

Cooperation with other Parties

Switzerland uses a registry software based on the Community Registry software, which was initially developed by the European Union in 2004. Further developments, updates and releases of the software are undertaken in cooperation with Dr. Lippke & Dr. Wagner GmbH. An agreement on linking the emissions trading schemes of Switzerland and the European Union entered into force on 1 January 2020, and the two emissions trading schemes have since been linked (see also 4.2.6).

Description of the database structure and capacity of Switzerland's national registry

Information on the database structure and capacity of Switzerland's national registry is regarded as confidential. The required information has been submitted in the international transaction log (ITL) Registry Initialization Documentation in April 2013, and is available to the UNFCCC expert review team on demand.

Conformity to the technical standards for data exchange

In September 2015, the registry software successfully passed the CP2 Annex H test and therewith conforms to the technical specifications of data exchange standards (DES) for registry systems under the Kyoto Protocol, version 2.0.1.

Procedures employed to minimise and manage discrepancies and to correct problems

In case of discrepancies, the conformity of Switzerland's national registry to DES ensures the correct treatment and reception of information by the ITL. Thus, the common operational procedures of the UNFCCC are followed.

Internal incident and change management procedures were defined in cooperation with Dr. Lippke & Dr. Wagner GmbH, and the Swiss Federal Office of Information Technology, Systems and Telecommunication.

Security measures

Information on security measures is regarded as confidential. The required information has been submitted in the ITL Registry Initialization Documentation in April 2013, and is available to the UNFCCC expert review team on demand.

Information publicly accessible by means of the user interface

Non-confidential information is publicly available on the website of the Swiss emissions trading registry at *https://www.emissionsregistry.admin.ch*. On this website, the national allocation plans within the emissions trading scheme are accessible in the reports 'Allocation' under 'ETS installation operators' and 'ETS aviation operators', respectively. Information made available to the public is conforming to the criteria defined in Annex E to decision 13/CMP.1:

- § 45 13/CMP.1: Report 'Accounts' at *https://www.emissionsregistry.admin.ch*;
- § 46 13/CMP.1: No report available as no ERUs were issued by Switzerland;
- § 47 13/CMP.1: Information on unit holding and transactions for each calendar year is available in the SEF Tables at *http://www.climatereporting.ch* and in the report 'Transaction list at *https://www.emissionsregistry.admin.ch*;

- § 48 13/CMP.1: Report 'Accounts' at *https://www.emissionsregistry.admin.ch*.

Article 65 of the CO_2 Ordinance lists all data held in the Swiss emissions trading registry (*Swiss Confederation*, 2012). The Swiss Federal Office for the Environment may publish the data contained in the Swiss emissions trading registry electronically while preserving manufacturing and trade secrecy. The following information is considered as confidential, and thus not publicly available (Decision 13/CMP.1, paragraphs are indicated in parentheses):

- The representative identifier of the account holder (13/CMP.1, paragraph 45(d));
- The representatives name and contact information (13/CMP.1, paragraph 45(e));
- The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year (the total quantity is only available by account type) (Decision 13/CMP.1, paragraph 47(a));
- The identity of the transferring accounts from which ERUs, CERs, AAUs and RMUs were acquired by Switzerland's national registry of the last three years prior to the reporting year (Decision 13/CMP.1, paragraph 47(d));
- The identity of the acquiring accounts to which ERUs, CERs, AAUs and RMUs were transferred from Switzerland's national registry of the last three years prior to the reporting year (Decision 13/CMP.1, paragraph 47(f));
- Current holdings of ERUs, CERs, AAUs and RMUs in each account (Decision 13/CMP.1, paragraph 47(l)).

Internet address of the interface to Switzerland's national registry

On the website of Switzerland's national registry at *https://www.emissionsregistry.admin.ch*, the user interface is available.

Measures taken to safeguard, maintain and recover data in the event of a disaster

Information on the data backup strategy is regarded as confidential. The required information has been submitted in the ITL Registry Initialization Documentation in April 2013, and is available to the UNFCCC expert review team on demand.

Test procedures

Basic tests are performed by the application support provider Dr. Lippke & Dr. Wagner GmbH, on the ITL DEVELOPER environment. The Annex H test during the registry initialisation process successfully tested the software of Switzerland's national registry against the ITL. New versions, updates or bug fixes of the registry software are tested by the registry administration team in the REGISTRY environment before implementation in the PRODUCTION environment. Major changes are tested including the REGISTRY environment of the ITL. If test end criteria are reached and security testing was successful, the new version or update is installed in the PRODUCTION environment.

3.4.2 Recent changes

Since Switzerland's seventh national communication and fourth biennial report, regular security and usability updates, as well as bug fixing took place. An agreement on linking the emissions trading schemes of Switzerland and the European Union entered into force on 1 January 2020, and the two emissions trading schemes have since been linked (see also 4.2.6).

3.4.3 Status of Switzerland's national registry as of 2021

Switzerland's national registry has been fully operational with the ITL since 4 December 2007. Tab. 13 shows the total quantities of Kyoto Protocol units in Switzerland's national registry related to the first commitment period 2008–2012 (CP1), Tab. 14 the total quantities of Kyoto Protocol units in Switzerland's national registry related to the second commitment period 2013–2020 (CP2), by account type at the end of 2021 (submission of SEF Tables in April 2022).

Tab. 13 > Total quantities of CP1 Kyoto Protocol units in Switzerland's national registry by account type at the end of 2021.

Standard Electronic Format (SEF) Table 4

	Unit type					
Account type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Party holding accounts	–	–	–	–	–	–
Entity holding accounts	–	–	–	–	–	–
Article 3.3/3.4 net source cancellation accounts	172 587	–	1 013 340	–		
Non-compliance cancellation accounts	–	–	–	–		
Other cancellation accounts	4 796 312	3 651 820	–	7 897 328	114 793	–
Retirement account	236 857 347	558 645	8 267 540	16 038 197	–	–
tCER replacement account for expiry	–	–	–	–	–	
lCER replacement account for expiry	–	–	–	–		
lCER replacement account for reversal in storage	–	–	–	–		–
lCER replacement account for non-submission of certification report	–	–	–	–		–
Total	**241 826 246**	**4 210 465**	**9 280 880**	**23 935 525**	**114 793**	**–**

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Tab. 14 > Total quantities of CP2 Kyoto Protocol units in Switzerland's national registry by account type at the end of 2021.

Standard Electronic Format (SEF) Table 4

	Unit type					
Account type	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Party holding accounts	361 768 524	–	–	1 961 642	–	–
Entity holding accounts	–	77 477 573	–	43 482 133	–	–
Retirement account	–	–	–	–	–	–
Previous period surplus reserve account	5 794 523					
Article 3.3/3.4 net source cancellation accounts	–	–	–	–		
Non-compliance cancellation account	–	–	–	–		
Voluntary cancellation account	–	2 388 698	–	30 016 668	–	–
Cancellation account for remaining units after carry-over	–	–	–	–	–	–
Article 3.1 ter and quater ambition increase cancellation account	–					
Article 3.7 ter cancellation account	–					
tCER cancellation account for expiry					–	
lCER cancellation account for expiry						–
lCER cancellation account for reversal of storage						–
lCER cancellation account for non-submission of certification report						–
tCER replacement account for expiry	–	–	–	–	–	
lCER replacement account for expiry	–	–	–	–		
lCER replacement account for reversal of storage	–	–	–	–		–
lCER replacement account for non-submission of certification report	–	–	–	–		–
Total	**367 563 047**	**79 866 271**	**–**	**75 460 443**	**–**	**–**

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References

FOEN, 2006: Switzerland's initial report under Article 7, paragraph 4 of the Kyoto Protocol (including the Update following the UNFCCC review, FCCC/IRR/2007/CHE). Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

FOEN, 2022a: Switzerland's greenhouse gas inventory 1990–2020: National inventory report, as well as reporting tables (CRF) and SEF tables. Submission of April 2022 under the UNFCCC and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

FOEN, 2022b: Qualitätsmanagement Treibhausgasinventar – Handbuch. Bundesamt für Umwelt (BAFU), Bern [German for: Quality management system Greenhouse Gas Inventory – Manual. Federal Office for the Environment (FOEN), Bern [confidential/internal].

IPCC, 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. *https://www.ipcc-nggip.iges.or.jp/public/2006gl* [18.07.2022]

IPCC, 2007: Fourth assessment report. Intergovernmental Panel on Climate Change. *https://www.ipcc.ch/report/ar4/wg1* [18.07.2022]

IPCC, 2014a: 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement). Intergovernmental Panel on Climate Change. Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland. *http://www.ipcc-nggip.iges.or.jp/public/kpsg/index.html* [18.07.2022]

IPCC, 2014b: 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland. *http://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html* [18.07.2022]

IPCC, 2019: 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. *https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html* [18.07.2022]

SFOE, 2021a: Gesamtenergiestatistik 2020. Swiss Federal Office of Energy, Bern. 805.006.20 / 08.21 / 1060 / 860490848. *https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/gesamtenergiestatistik.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTA1Mzc=.html* [18.07.2022]

Swiss Confederation, 1983: Swiss Federal Act on the Protection of the Environment (Environmental Protection Act, EPA) of 07.10.1983 (Status as of 01.01.2022). *https://www.admin.ch/opc/en/classified-compilation/19830267/index.html* [18.07.2022]

Swiss Confederation, 2012: Ordinance on the Reduction of CO_2 Emissions (CO_2 Ordinance) of 30.11.2012 (Status as of 04.03.2022). *https://www.admin.ch/opc/en/classified-compilation/20120090/index.html* [18.07.2022]

4 Policies and measures[14]

This chapter describes policies and measures implemented or planned to be implemented in Switzerland in order to achieve the emission reduction commitments agreed on in the national and international context. Section 4.1 provides information related to the policymaking process in the context of environmental and climate policy, including the general framework of environmental legislation and some further background information on institutional arrangements at the domestic level. Section 4.2 focuses on policies and measures that are effective across sector boundaries. The subsequent sections are organised by sector and present individual mitigation actions (including their mitigation impacts) as listed in BR CTF table 3. Section 4.3 deals with (non-transport) policies and measures related to energy efficiency, reduced energy consumption, and renewable energy. Section 4.4 encompasses aspects of transport infrastructure, sustainable modes of transport, vehicle emission standards, as well as policies and measures in the aviation sector. The remaining mitigation actions cover the following areas: Industrial processes and product use (section 4.5), agriculture (section 4.6), land use, land-use change, and forestry (section 4.7), and waste (section 4.8). Information on the costs, non-greenhouse gas mitigation benefits and interactions of Switzerland's policies and measures is provided in section 4.9. Sections 4.10, 4.11 and 4.12 briefly address the modification of longer-term trends in greenhouse gas emissions, policies and measures no longer in place, and policies and measures leading to an increase in greenhouse gas emissions. Actions related to economic and social consequences of response measures (minimising adverse effects) are addressed in section 4.13. The documentation of the quantified economy-wide emission reduction target as requested by the 'UNFCCC biennial reporting guidelines for developed country Parties' is presented in Annex B.3, including the relation to the national greenhouse gas mitigation targets. Information on the monitoring and evaluation of progress towards the quantified economy-wide emission reduction target as well as the corresponding institutional arrangements is presented in sections 4.1.2 and 4.1.3, respectively.

4.1 Policymaking process

This section provides specific information related to Switzerland's policymaking process in the context of environmental and climate policy. A general overview of the government structure – including background information on the general political organisation in Switzerland – is presented in section 2.1.

4.1.1 Fundamental settings regarding environmental and climate policy

The Federal Constitution of the Swiss Confederation forms the overarching framework for environmental and climate policy in Switzerland. The commitment to sustainable development and long-term preservation of natural resources is listed prominently under the main aims in the general provisions (*Swiss Confederation*, 1999a, Article 2). Following the United Nations Conference on Environment and Development held in Rio in 1992, the Swiss Federal Council established an interdepartmental sustainable development committee consisting of all federal agencies with responsibilities in the field of sustainable development. This committee defined the priorities for action and oversaw implementation and monitoring of progress with the intention to make sustainability assessments an integral part of decision-making and policy evaluation. On 14 December 2018, the Swiss Federal Council established the 2030 Agenda steering committee, replacing the interdepartmental sustainable development committee.[15] The 2030 Agenda steering committee – where federal agencies which bear the main responsibility are represented at senior management level – coordinates the efforts to achieve the 2030 agenda for sustainable development of the United Nations. This includes monitoring the progress regarding achievement of the sustainable development goals in Switzerland, preparing the national reports to the United Nations, setting priorities to reflect the biggest challenges and opportunities for Switzerland, setting national targets, coordinating appropriate measures and cooperating with the cantons, communes and non-state actors.

Further, by decision of the Swiss Federal Council, an interdepartmental committee on climate of the federal authorities ('IDA-Klima') was established as of 14 April 2008. The committee is responsible for the coordination between different policy areas and assures a coherent climate policy of the Swiss Confederation in compliance with the UNFCCC. The

[14] In this chapter, the sections have partly been rephrased and complemented compared to the proposition in paragraph 74 and the annex of the 'Revision of the Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part II: UNFCCC reporting guidelines on national communications' (FCCC/CP/2019/Add.1). The reason for the conservative reorganisation is to structure the description of the different policies and measures (sections 4.2 to 4.8) and to provide additional information (sections 4.9 to 4.13).

[15] https://www.are.admin.ch/are/en/home/sustainable-development/coordination/2030agenda-steering-committee.html

committee, led by the Swiss Federal Office for the Environment, thus coordinates the activities of all federal offices involved in climate policy.

As stipulated in Article 39 of the second CO_2 Act (*Swiss Confederation*, 2011) and more generally also in Article 12 of the Ordinance on the Organisation of the Federal Department of the Environment, Transport, Energy and Communications (*Swiss Confederation*, 1999c), the Swiss Federal Office for the Environment is responsible for matters relating to climate protection. The related Ordinance on the Reduction of CO_2 Emissions (*Swiss Confederation*, 2012), in its chapter 11, details the responsibilities for the implementation of specific measures.

Strategies for sustainable development, long-term mitigation strategies and targets for greenhouse gas mitigation

The Swiss Federal Council set out its main policy focus areas for sustainable development in its 2030 sustainable development strategy (*Swiss Federal Council*, 2021b), adopted as part of the Swiss government's regular legislative planning cycle. This strategy represents an important contribution on the part of Switzerland to achieving the 2030 agenda for sustainable development of the United Nations. An overview of Switzerland's implementation of the 2030 agenda for sustainable development of the United Nations is available in Switzerland's country report published in May 2022 (*Swiss Federal Council*, 2022a).

The 2030 sustainable development strategy, the sixth of its kind since 1997, focuses on three priority topics (including goals and strategic directions), each covering a specific issue which is of central importance to the sustainable development of Switzerland: (i) sustainable consumption and production, (ii) climate, energy and biodiversity, and (iii) equal opportunities and social cohesion. It is accompanied by an action plan featuring 22 measures that contribute to the goals and strategic directions. With a view to achieving the defined goals, the 2030 sustainable development strategy provides a model role for the federal government, outlines horizontal (cross-sectoral) measures such as sustainability monitoring, sustainability assessments, the promotion of local sustainability processes and projects, and closer collaboration with other stakeholder groups. Finally, the 2030 sustainable development strategy sets out the institutional framework for its implementation.

One of the Swiss Federal Council's overarching objectives with regard to the incorporation of the sustainable development principle into the activities of the Swiss government is to combat global warming. By ratifying the UNFCCC in 1993, the Kyoto Protocol in 2003, the Doha Amendment to the Kyoto Protocol in 2015, and the Paris Agreement in 2017, Switzerland internationally committed to contribute to the stabilisation of greenhouse gas emissions at a level that prevents dangerous anthropogenic interference with the climate system. The respective international targets, as well as the translation to Switzerland's national targets, are presented and discussed in Annex B.3. In the long term, Switzerland aims to reduce its greenhouse gas emissions to net zero by 2050. This target lays the foundations for Switzerland's long-term climate strategy to 2050, submitted by Switzerland to the UNFCCC secretariat on 28 January 2021 (*Swiss Federal Council*, 2021a) and currently revisited in fulfilment of a mandate given by the COP in Glasgow.[16] As summarised in a respective factsheet (*FOEN*, 2022), the strategy formulates ten basic strategic principles[17] that will shape Switzerland's climate policy in the coming years. The strategy also presents climate goals and emission pathways for the buildings, industry, transport, agricultural and food sectors, financial markets, synthetic gases, aviation and the waste industry. The long-term climate strategy shows that Switzerland – by consistently applying already known and proven technologies – can reduce its greenhouse gas emissions by 2050 to around 90 per cent of the 1990 level. The remaining emissions must be balanced with negative emission technologies. The Swiss Federal Council aims at strengthening the pioneering role of Switzerland in this field and adopted a roadmap on 18 May 2022. An overview of activities aimed at setting the framework for research and expansion of negative emission technologies is available on the website of the Swiss Federal Office for the Environment.[18]

Efforts in other areas than 'direct' climate policy are key to reach Switzerland's long-term climate targets. Climate, energy, agriculture and tax policies – to name a few – are interrelated and, thus, closely coordinated. The respective policies

16 See decision 1/CMA.3, paragraph 33: 'Invites Parties to update the strategies referred to in paragraph 32 above regularly, as appropriate, in line with the best available science'.

17 The ten basic strategic principles of Switzerland's long-term climate strategy to 2050 are: Seize opportunities, assume responsibility, reduce domestic emissions, reduce emissions across entire value chains, use all energy sources efficiently, the Swiss Confederation and the cantons gear activities to achieving net zero, socially acceptable, economically viable, improve environmental quality, openness to technology.

18 https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/negative-emissions-technologies.html

are themselves guided by strategies, such as the Energy Strategy 2050 (see section 4.3.1) or the climate strategy for agriculture (see section 4.6.4).

The Swiss government is also engaged in elaborating and coordinating adaptation efforts, as reflected in the Swiss adaptation strategy (see section 6.4) and the corresponding adaptation actions (see section 6.6).

Principles and instruments of Switzerland's environmental and climate policy

Deduced from the Federal Constitution of the Swiss Confederation, the principles and instruments of Switzerland's environmental policy are stipulated in the Swiss Federal Act on the Protection of the Environment (Environmental Protection Act, *Swiss Confederation*, 1983), in force since 1985 and revised several times since. The Environmental Protection Act is based on the following three main principles: (i) the principle of precaution, (ii) the control/limitation of ecological damage at the source, and (iii) the polluter pays principle. Consequently, Swiss environmental policy is addressing a wide spectrum of issues, ranging from pollution of air, water and soil, and exposure to noise, to protecting stratospheric ozone or reducing and managing waste. Several policy areas are linked directly or indirectly to the reduction of Switzerland's greenhouse gas emissions. Fiscal incentives are recognised as an essential instrument for promoting the efficient use of resources. The main instruments are the definition of legally binding emission limits, introduction of levies on substances or practices with negative environmental impacts as well as the obligation of environmental impact assessments for particular facilities and installations.

Switzerland's climate policy is based on the Federal Constitution of the Swiss Confederation, in particular Article 74 (environmental protection) and Article 89 (energy policy). The legal centrepiece supplementing the Environmental Protection Act and defining objectives, instruments, measures and general rules of implementation of climate policy on the needed level of detail is the Swiss Federal Act on the Reduction of CO_2 Emissions (CO_2 Act; *Swiss Confederation*, 2011; see sections 4.2.2, 4.2.3, and 4.2.4). The CO_2 Act also contains provisions related to enforcement and evaluation. The implementation of the CO_2 Act is further detailed in the Ordinance on the Reduction of CO_2 Emissions (CO_2 Ordinance; *Swiss Confederation*, 2012), where, inter alia, specific responsibilities for the implementation of measures are assigned. Tab. 15 shows detailed references to enforcement and administrative procedures for some core policies and measures defined in the second CO_2 Act and the corresponding CO_2 Ordinance.

Tab. 15 > Enforcement and implementation responsibilities for core provisions of the second CO_2 Act (*Swiss Confederation*, 2011) and the corresponding CO_2 Ordinance (*Swiss Confederation*, 2012).

Instrument/measure	CO_2 Act	CO_2 Ordinance	Enforcement	Implementation level
Objectives	Article 3	Article 3	If a sector-specific interim target is not achieved, the Swiss Federal Department of Environment, Transport, Energy and Communications, after hearing the cantons and affected parties, shall request the Swiss Federal Council for additional measures.	Federal government
CO_2 levy on heating and process fuels	Articles 29–33	Articles 93–103	The CO_2 Ordinance defines a reduction pathway that needs to be followed (Article 94). If the targets set in the CO_2 Ordinance are not met, the CO_2 levy is increased automatically.	Federal government
Emissions trading scheme	Articles 15–21	Articles 40–65	Companies taking part in the emissions trading scheme have to cover their emissions with emission allowances issued in Switzerland or in the European Union. Emissions not covered entail a sanction of 125 Swiss francs per tonne of CO_2 equivalents.	Federal government
Negotiated reduction commitments (for exemption from the CO_2 levy)	Articles 31–32	Articles 66–79	Companies have to commit to reduce their greenhouse gas emissions. If commitments are not fulfilled, a sanction of 125 Swiss francs is due per tonne of CO_2 equivalents that has been emitted in excess and excess emissions need to be covered with international carbon credits.	Federal government
National buildings refurbishment programme	Article 34	Articles 104–113	Annual reporting on effectiveness of implementation.	Cantons and contractual agreement between the federal government and the cantons
Building codes of the cantons	Article 9	Article 16	Regulated at cantonal level. Cantons have to report annually to the federal government on their activities.	Cantons
CO_2 emission regulations for newly registered vehicles	Articles 10–13	Articles 17–37	If targets are not met, importers of vehicles (passenger cars and light duty trucks) have to pay a sanction.	Federal government
Partial compensation of CO_2 emissions from motor fuel use	Articles 26–28	Articles 86–92	If the obligation to compensate is not fulfilled, a sanction of 160 Swiss francs per tonne of CO_2 must be paid. Additionally, the missing emission reductions must be covered by emission allowances or international carbon credits.	Federal government

Apart from the Environmental Protection Act and the CO_2 Act, there are various other legal provisions that are related to environmental and climate issues. The Energy Act (*Swiss Confederation*, 2016), the Forest Act (*Swiss Confederation*, 1991), the Spatial Planning Act (*Swiss Confederation*, 1979), the Agriculture Act (*Swiss Confederation*, 1998b), the Road Traffic Act (*Swiss Confederation*, 1958), the Heavy Vehicle Charge Act (*Swiss Confederation*, 1997a), the Mineral Oil Tax Act (*Swiss Confederation*, 1996), the Ordinance on Chemical Risk Reduction (*Swiss Confederation*, 2005a), and the Ordinance on the Avoidance and Management of Waste (*Swiss Confederation*, 2015) all have components that contribute to environmental policy goals including emission reductions of greenhouse gases and precursor gases.

To ensure the public availability of information, the website of the Swiss Federal Office for the Environment contains information regarding legislative arrangements, enforcement and administrative procedures.[19] In particular, the Swiss Federal Office for the Environment publishes recommendations on the implementation of the legal provisions in cases where more detailed information is necessary. These recommendations are not legally binding but provide more precise instructions on the application of the legal instruments. For instance, in the context of the second CO_2 Act and the corresponding CO_2 Ordinance, the Swiss Federal Office for the Environment has published recommendations related to the implementation of domestic emission reduction projects in Switzerland[20], the exemption from the CO_2 levy on heating and process fuels for energy intensive companies[21], and the emissions trading scheme.[22]

In view of the world-wide dimension of environmental problems, Switzerland seeks to enhance and support international efforts to tackle issues at the global level. Environmental issues are an integral part of Swiss foreign policy, and Switzerland is contributing at a political as well as at a technological level to solve environmental problems in multilateral contexts.

In Switzerland, the CO_2 Act (Articles 5 and 6) and the corresponding CO_2 Ordinance (Article 4 and Annex 2) provide the legal basis for the implementation and use of flexible mechanisms under the Kyoto Protocol. SwissFlex, the national secretariat for the flexible mechanisms[23], is the designated national authority under the Clean Development Mechanism. It was established in 2004 and announced to the UNFCCC in 2007. SwissFlex publishes and regularly updates the list of letters of approval/authorisation issued under the Clean Development Mechanism.[24] During the second commitment period of the Kyoto Protocol, Switzerland did not engage in or authorise activities under the Joint Implementation mechanism.

Switzerland has played a key role in the international negotiations on Article 6 of the Paris Agreement and continues to engage actively in its implementation. It has advocated clear international rules that (i) ensure environmental integrity of emission reductions, (ii) promote sustainable development in the host country, and (iii) avoid double counting of emission reductions. Switzerland welcomes the adoption of robust rules on Article 6 of the Paris Agreement at COP26 in November 2021 in Glasgow. Switzerland will partly use emission reductions generated in conformity with Article 6 of the Paris Agreement towards the achievement of its nationally determined contribution.[25] Switzerland has already concluded several bilateral agreements with host countries in the context of bilateral cooperation under Article 6.2 of the Paris Agreement.[26] The bilateral agreements set out the framework conditions for the cooperation and define the requirements for the recognition of international transfers of mitigation outcomes. Thereby, the bilateral agreements establish the legal framework for commercial agreements between seller and buyer of mitigation outcomes. The first bilateral agreement of its

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19 https://www.bafu.admin.ch/bafu/en/home/topics/climate.html

20 http://www.bafu.admin.ch/uv-1315-d

21 http://www.bafu.admin.ch/uv-1316-d

22 http://www.bafu.admin.ch/uv-1317-d

23 swissflex@bafu.admin.ch

24 2021: https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/List_of_LoAs_2021.pdf
2006–2020: https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/List_of_LoAs_2006-2020.zip

25 https://www4.unfccc.int/sites/NDCStaging/pages/Party.aspx?party=CHE

26 See https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/compensation/abroad.html, including the subsites 'host countries' and 'pilot projects'.

kind in the world was concluded between Switzerland and Peru on 20 October 2020. Several further bilateral agreements followed, such as with Ghana, Senegal, Georgia, Vanuatu, Dominica, Thailand, Ukraine, Morocco, and Chile.[27]

4.1.2 Monitoring and evaluation of policies and measures

Regarding the monitoring of the overall progress achieved by Switzerland's policies and measures to mitigate greenhouse gas emissions over time (self-assessment), the national greenhouse gas inventory – which is annually submitted to the UNFCCC and also published on the website of the Swiss Federal Office for the Environment[28] – is fundamental. Further, Article 40 of the second CO_2 Act (section 4.2.3) obliges the Swiss Federal Council to periodically evaluate the effectiveness of single policies and measures, and to consider the necessity of additional measures. These evaluations, which need to take into account other climate-relevant parameters such as economic development, population growth and the expansion of traffic, have to be reported to the Swiss Parliament. However, apart from some exceptions (see below), the second CO_2 Act does not define the exact dates or periodicity of the assessments. In the following, the most significant monitoring approaches and ex-post evaluations (either completed or performed repeatedly) are presented.

Sectoral interim targets

Article 3 of the CO_2 Ordinance stipulates sectoral interim targets for the greenhouse gas emissions in 2015:

- Buildings sector: no more than 78 per cent of 1990 emissions;
- Transport sector: no more than 100 per cent of 1990 emissions;
- Industry sector: no more than 93 per cent of 1990 emissions.

The evaluation of the sectoral interim targets took place based on the greenhouse gas inventory published by the Swiss Federal Office for the Environment in April 2017. The buildings sector and the industry sector achieved their interim targets, the transport sector missed it.[29] Under upcoming legislation, the Swiss Federal Council will again be permitted to set reduction targets for individual economic sectors by agreement with the parties concerned.

CO_2 levy on heating and process fuels

In the context of the CO_2 Ordinance (Article 94), the Swiss Federal Council has defined intermediate reduction targets regarding the CO_2 emissions from heating and process fuels for the years 2012, 2014, 2016 and 2020 (see also section 4.2.5). If these targets are not met, the CO_2 levy on heating and process fuels increases automatically to the levels predefined in the CO_2 Ordinance. The increase of the CO_2 levy on heating and process fuels is triggered on the basis of the annual national CO_2 statistics which relies on the official national energy statistics published by the Swiss Federal Office of Energy each year (the CO_2 statistics also forms the basis for the upcoming greenhouse gas inventory). As consumption of heating fuels strongly depends on temperature and solar radiation during the winter season, the corresponding CO_2 emissions are normalised with regard to meteorological conditions before confrontation with the targets.

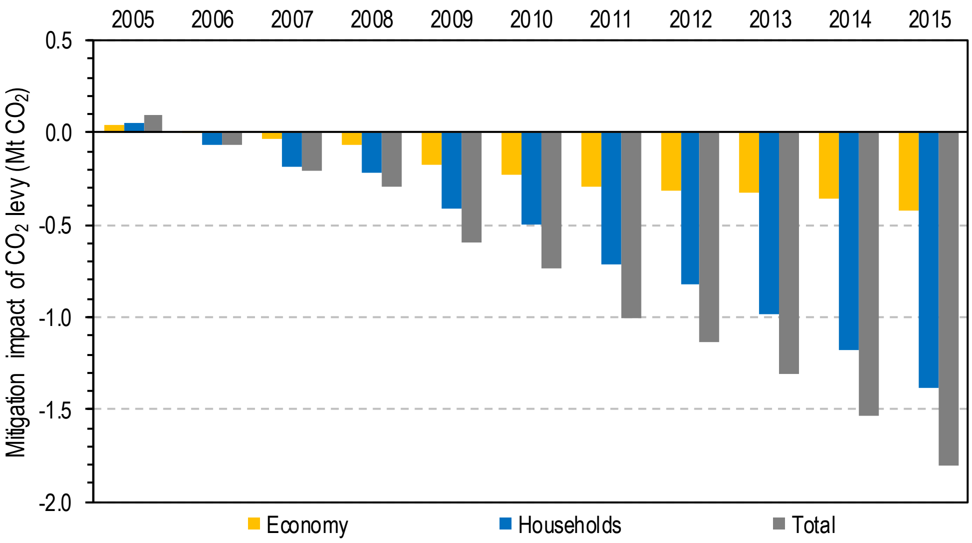
The Swiss Federal Office for the Environment has undertaken an evaluation of the CO_2 levy on heating and process fuels with the goal to estimate the impact of the CO_2 levy on heating and process fuels on emissions since its introduction using both a modelling approach as well as data collected from a firm-level survey (*FOEN*, 2015; *FOEN*, 2016). However, given that the CO_2 Act envisages numerous (and mutually reinforcing) instruments, interdependencies between these instruments are expected. Sorting out the mitigation impact of an individual policy and measure is, thus, very difficult, especially for instruments such as the CO_2 levy on heating and process fuels that have a cross-sectoral impact. In 2017, an update of the model-based estimate was published (*Ecoplan*, 2017), based on a more refined approach that contributed to a more robust assessment of the mitigation impact of the CO_2 levy. Fig. 64 shows the main results, i.e. the mitigation impact that the model attributed to the CO_2 levy for the years 2005 to 2015 (economy, households and total). Since the last update in 2017, the model-based estimate has not been updated again.

[27] https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate--international-affairs/staatsvertraege-umsetzung-klimauebereinkommen-von-paris-artikel6.html

[28] http://www.bafu.admin.ch/greenhouse-gases

[29] https://www.newsd.admin.ch/newsd/message/attachments/48115.pdf

Fig. 64 > Mitigation impact of the CO_2 levy for the years 2005 to 2015, estimated with an econometric model. As explained in *Ecoplan* (2017), up to 0.5 million tonnes of CO_2 of the total mitigation impact indicated for 2015 may be attributed to the national buildings refurbishment programme and the negotiated reduction commitments (for exemption from the CO_2 levy).



Ecoplan (2017)

CO_2 emission regulations for newly registered vehicles

The CO_2 emission regulations for newly registered vehicles (section 4.4.2) are enforced by a sanction mechanism. Accordingly, compliance with the CO_2 emission regulations is monitored and evaluated on a case-by-case basis for small importers (in case the imported vehicle exceeds the CO_2 emission regulations a sanction has to be paid before the vehicle is licensed), or quarterly to annually for large importers. Data on the specific CO_2 emissions of newly registered vehicles are evaluated and published annually by the Swiss Federal Office of Energy.

Further, Article 36 of the CO_2 Ordinance requests that the Swiss Federal Department of Environment, Transport, Energy and Communications reports to the competent commissions of the Council of States and the National Council on the effectiveness of the CO_2 emission regulations for newly registered vehicles every three years. The first report was presented in December 2016 (*DETEC*, 2016), followed by a second report in February 2020 (*DETEC*, 2020).

Partial compensation of CO_2 emissions from motor fuel use

According to chapter 4, section 3 of the CO_2 Act (*Swiss Confederation*, 2011), fossil fuel importers are bound to offset part of the CO_2 emissions from motor fuels sold in Switzerland (section 4.4.5). The compensation obligation arises when fossil motor fuels are released for free circulation in accordance with Article 4 of the Mineral Oil Tax Act (*Swiss Confederation*, 1996). The obligation is thus linked to the same taxable event as the mineral oil tax, which is monitored by the Swiss Federal Office for Customs and Border Security.

The Swiss Federal Audit Office evaluated the activities related to the partial compensation of CO_2 emissions from motor fuel use and published the respective report – including a summary in English – in 2016 (*Swiss Federal Audit Office*, 2016).

National buildings refurbishment programme

Cantons have to report annually on measures implemented within the national buildings refurbishment programme (section 4.3.3) as well as on the development of corresponding CO_2 emissions from buildings on cantonal territory.[30] By providing a standardised format, the Swiss Federal Office for the Environment facilitates this reporting on CO_2 emissions from buildings on cantonal territory, which is due on a biennial basis starting in 2018. So far, reports concerning the effect of climate and energy policies (for buildings at the cantonal level), including CO_2 emissions, are available for the year 2016 (*FOEN and SFOE*, 2018) and the year 2018 (*FOEN and SFOE*, 2020).

[30] See https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/buildings/cantonal-reporting.html for more details.

An ex-post evaluation of the national buildings refurbishment programme is performed annually. Further, a report on the first five years of the programme, including the cumulative effects, was published in March 2016 (*Swiss Federal Council*, 2016a).

The Swiss Federal Audit Office evaluated the activities related to the national buildings refurbishment programme and published the respective report – including a summary in English – in 2013 (*Swiss Federal Audit Office*, 2013).

Emissions trading scheme

The Swiss Federal Audit Office evaluated the activities related to the emissions trading scheme and published the respective report – including a summary in English – in 2017 (*Swiss Federal Audit Office*, 2017a).

Negotiated reduction commitments (for exemption from the CO_2 levy)

The Swiss Federal Office of Energy mandated an evaluation of the activities related to the negotiated reduction commitments (for exemption from the CO_2 levy; see section 4.2.7) and published the respective report in 2016 (*Ecoplan*, 2016).

Energy Act

The Energy Act (*Swiss Confederation*, 2016) sets guidelines for the consumption of energy and electricity as well as for the energy production using renewable sources and hydropower. Monitoring of the respective indicators is part of the Energy Strategy 2050. The fourth monitoring report was published on 26 November 2021.[31] The relevant indicators regarding enhanced energy efficiency and the use of renewable energies evolved satisfactorily, and the intermediate targets prescribed for 2020 (see section 4.3.1) were met comfortably. In the longer term, however, it appears that further efforts are needed to gradually restructure the energy system and, in particular, to promote the development of renewable energies and energy efficiency.

Technology fund

The Swiss Federal Audit Office evaluated the activities related to the technology fund (see section 4.10) and published the respective report – including a summary in English – in 2017 (*Swiss Federal Audit Office*, 2017b). Additionally, the management agency of the technology fund produces an annual report on the activities in the past year (see e.g. *Technology Fund*, 2021).

Other monitoring processes

Several other measures require regular reporting of emissions or of compliance with specific commitments. They are therefore closely monitored on a regular basis. For instance, firms participating in the emissions trading scheme and firms with an individual (negotiated) reduction target that are exempt from the CO_2 levy are obliged to monitor their greenhouse gas emissions and to submit an annual report to the Swiss Federal Office for the Environment.

4.1.3 Institutional arrangements for the monitoring of greenhouse gas mitigation policy

No fundamental changes in domestic institutional arrangements, including legal, administrative and procedural arrangements have occurred since Switzerland’s last submission. The Swiss Federal Office for the Environment, being responsible for matters relating to climate protection (see section 4.1.1), is generally also responsible for the monitoring of progress made with greenhouse gas mitigation policies and measures (see section 4.1.2). In addition, the Swiss Federal Audit Office, within the framework of its activities as an independent inspecting authority, regularly inspects the implementation of greenhouse gas mitigation policies and measures. Institutional arrangements related to Switzerland’s national greenhouse gas inventory system and the national registry are documented in section 3.3 and 3.4, respectively. The Act on Archiving (*Swiss Confederation*, 1998c) regulates the archiving of documents of the federal government, ensuring that documents from all federal institutions that are valuable for legal, political, economic, historical, social or cultural reasons are archived by the Swiss Federal Archives.[32] The compulsory archiving of course also covers all information prepared with regard to e.g. the greenhouse gas inventory, the national and international reporting obligations, the legislative process, and the implementation of policies and measures.

[31] https://www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/monitoring-energy-strategy-2050.html

[32] See https://www.bar.admin.ch/bar/en/home.html for more details.

4.2 Cross-sectoral policies and measures

4.2.1 Overview

While policies and measures addressed in sections 4.3 to 4.8 may have side effects beyond their specific policy domain, the policies and measures presented in section 4.2 are clearly cross-sectoral in nature, i.e. they cannot be assigned to one of the ‘classical’ policy sectors.

Tab. 16 gives an overview of the most relevant cross-sectoral policies and measures. More details and background information on each policy and measure are presented below.

Tab. 16 > Summary of cross-sectoral climate policies and measures. The sector affected is ‘cross-cutting’ for all policies and measures presented in this table. Compared to the previous submission, the policy and measure ‘Third CO_2 Act (2021)’ has been renamed to ‘Third CO_2 Act (2025)’.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq)	
								2020	2025
First CO_2 Act (1999) *	CO_2	Average reduction of CO_2 emissions from fossil fuel use by 10 per cent over the years 2008–2012 (relative to 1990).	Regulatory	Expired (replaced by second CO_2 Act)	First legal basis of Switzerland’s climate policy including the implementation of the first commitment period of the Kyoto Protocol.	2000	FOEN	IE [b]	IE [b]
Second CO_2 Act (2011) *	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	Reduction of all greenhouse gas emissions by 20 per cent by 2020, followed by a further annual reduction of 1.5 per cent in the years 2021–2024 (relative to 1990).	Regulatory	Implemented	Current legal basis of Switzerland’s climate policy including the implementation of the second commitment period of the Kyoto Protocol, as well as the implementation for the first four years (2021–2024) under the Paris Agreement. The provisions cover mitigation as well as adaptation.	2013	FOEN	IE [b]	IE [b]
Third CO_2 Act (2025)	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	Decrease of total greenhouse gas emissions (relative to 1990) by (i) at least 50 per cent by 2030 (including reductions abroad) and (ii) at least 35 per cent in the mean over the years 2021–2030 (including reductions abroad).	Regulatory	Planned	Update of the CO_2 Act providing the legal basis of Switzerland’s climate policy consistent with the Paris Agreement. While mostly covering the same policies and measures as the second CO_2 Act, the third CO_2 Act includes several adjustments of the policies and a few new measures in order to reach the more ambitious national and international targets.	2025	FOEN	IE [b]	IE [b]
CO_2 levy on heating and process fuels *	CO_2	Promote energy efficiency, less CO_2 intensive energy sources and reduced use of fossil heating and process fuels.	Economic, fiscal	Implemented (strengthening planned)	Surcharge on fossil heating and process fuels. Two thirds of the revenues are redistributed to households and businesses, up to one third goes into the national buildings refurbishment programme and – to a small extent – to a technology fund granting loan guarantees for the development of new low-emission technologies.	2008	FOEN	2 000	2 250
Emissions trading scheme *	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	Reducing greenhouse gas emissions of emission-intensive industries and aviation using market-based mechanism.	Economic	Implemented (strengthening planned)	Emissions trading scheme based on the cap and trade principle, enabling the cost-effective achievement of climate-protection targets. Large greenhouse gas-intensive companies are required to participate, medium-sized companies may voluntarily participate. Companies included in the emissions trading scheme are exempt from the CO_2 levy on heating and process fuels. Aviation is included since 2020.	2008	FOEN	600	1 380

Negotiated reduction commitments (for exemption from the CO_2 levy) *	CO_2, N_2O, PFCs	Emission reduction targets agreed with companies exempt from the CO_2 levy on heating and process fuels.	Regulatory	Implemented (strengthening planned)	Binding agreements with eligible small and medium-sized companies. Emission reduction targets take the technological potential and economic viability of measures into account. Targets are calculated from the starting point along a simplified or individual linear reduction trajectory to the endpoint in the year 2020, a linear extrapolation of this reduction trajectory for 2021, followed by a reduction of two per cent per year up to 2024. Alternatively, economically viable measures (measures target) can be determined.	2008	FOEN, SFOE	370	NE [c]

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] The first, second and third CO_2 Acts are the legal framework for various measures. While the expected mitigation impacts of individual policies and measures are presented along with these policies and measures, the total mitigation impacts of the CO_2 Acts correspond to the objectives indicated in the third column.

[c] For 2025, the mitigation impact cannot be estimated for the following reasons: (i) the modalities for the time after 2024 are not yet fully defined, and (ii) with the overachievement of their targets in 2020, companies already fulfilled the requested reductions for the years 2021–2024, i.e. it is unclear whether companies will engage in further measures or not in the upcoming years.

IE, included elsewhere; NE, not estimated
FOEN, Swiss Federal Office for the Environment; SFOE, Swiss Federal Office of Energy

4.2.2 First CO_2 Act (1999)

The first CO_2 Act (*Swiss Confederation*, 1999b) entered into force in May 2000. It formed the legal framework for the implementation of Switzerland's emissions reduction commitment under the Kyoto Protocol by limiting CO_2 emissions from fossil fuel use for heating and transport to 10 per cent below 1990 levels over the period 2008–2012. The overall target was further divided into a reduction target of 15 per cent on heating and process fuels and eight per cent on motor fuels. These targets were set to assure compliance with the target under the Kyoto Protocol, assuming that the aggregate level of other greenhouse gas emissions remained unchanged compared to 1990.

The primary instruments to reach the targets for the period 2008–2012 were:

- Voluntary actions in various areas;
- A subsidiary CO_2 levy on heating and process fuels;
- Measures in other policy areas (waste, agriculture, F-gases) that are relevant to climate change mitigation;
- An emissions trading scheme (cap and trade);
- The complementary use of flexible mechanisms under the Kyoto Protocol.

Estimate of mitigation impact

The expected mitigation impact of the first CO_2 Act corresponds to its objective, i.e. an average reduction by 10 per cent of CO_2 emissions from fossil fuel use over the years 2008–2012 relative to 1990. However, as the first CO_2 Act formed the legal framework for various measures, the mitigation impact is indicated in Tab. 16 and BR CTF table 3 as 'included elsewhere' (i.e. under the policies and measures presented below).

4.2.3 Second CO_2 Act (2011)

The second CO_2 Act (*Swiss Confederation*, 2011) is the current centrepiece of Swiss climate policy. Fully revising the first CO_2 Act, it entered into force on 1 January 2013. It was originally supposed to cover the period from 2013–2020. Due to the lengthy debate in the Swiss Parliament on the (subsequently rejected) third CO_2 Act, it was partially revised and extended by one year until the end of 2021. Following the rejection of the third CO_2 Act in a referendum (see section 4.2.4), the second CO_2 Act was partially revised again and extended until 2024. This second partial revision ensured that the measures that would have expired by the end of 2021 due to the rejection can now be continued at least until 2024.

Apart from defining objectives it forms the foundation for several policies and measures to reach the set targets. Some policies and measures developed or initiated in the context of the first CO_2 Act – such as the CO_2 levy on heating and process fuels, the national buildings refurbishment programme, and the CO_2 emission regulations for newly registered vehicles – are continued.

The national reduction targets of the second CO_2 Act stipulates the reduction of domestic greenhouse gas emissions by 20 per cent by 2020 compared to the 1990 level (see Annex B.3) and the reduction of another 1.5 per cent per year compared to the 1990 level between 2021 and 2024. In contrast to the first CO_2 Act, all gases covered by the Kyoto Protocol are addressed. The second CO_2 Act sets incentives for increasing use of renewable energies, improvement of energy efficiency and development of innovative low-emission technologies. In addition, it gives the Swiss government the responsibility to coordinate measures aimed at adaptation to the impacts of climate change at the national level.

The reduction target of minus 20 per cent by 2020 compared to the 1990 level is shared between the building, industry and transport sectors, but also includes emissions from agriculture and of synthetic greenhouse gases. For 2015, the CO_2 Ordinance sets interim targets which correspond to reductions of 22 per cent for the buildings sector and of seven per cent for the industry sector, as well as zero emissions growth for the transport sector compared to the 1990 level. An evaluation of sectoral achievement of the interim targets was performed in 2017. While the buildings sector and the industry sector both reached their targets, emissions in the transport sector were four per cent higher than in 1990. Only indicative sectoral targets exist regarding reductions by 2020 (by 40 per cent for the buildings sector, by 15 per cent for the industry sector, and by 10 per cent for the transport sector, all compared to the 1990 level). Despite mild weather in the winter months and despite the measures taken to contain the corona virus pandemic (which in particular led to a substantial reduction in emissions from transport), Switzerland narrowly missed its national target for 2020 – even after taking into account the accountable carbon sink (CO_2 storage by Swiss forests and Swiss harvested wood products). The buildings and transport sectors failed to meet their targets; only the industry sector achieved its target. Taking into account international carbon credits generated from the flexible mechanisms under the Kyoto Protocol, Switzerland meets its commitment under the second commitment period of the Kyoto Protocol for the years 2013 to 2020.[33]

The reduction targets for the years 2021–2024 (annual reduction of minus 1.5 per cent compared to the 1990 level) are identical in scope to the reduction target for 2020. However, they are not broken down into sectoral targets, although the CO_2 Act would entitle the Swiss Federal Council to do so. At least 75 per cent of the reduction of emissions must be achieved with domestic measures, the remainder with measures abroad.

Planned strengthening

The second CO_2 Act will have to be revised for the period 2025 onwards. Details of the planned strengthening are presented in section 4.2.4.

Estimate of mitigation impact

The expected mitigation impact of the second CO_2 Act corresponds to its objectives, i.e. to a reduction of greenhouse gas emissions of 20 per cent by 2020 relative to the 1990 level and an additional annual reduction of 1.5 per cent relative to the 1990 level during the years 2021–2024. However, as the second CO_2 Act forms the legal framework for various measures, the mitigation impact is indicated in Tab. 16 and BR CTF table 3 as 'included elsewhere' (i.e. under the policies and measures presented below).

4.2.4 Third CO_2 Act (2025)

A third CO_2 Act that was supposed to replace the second CO_2 Act and to cover the period 2021–2030 was rejected in a popular vote on 13 June 2021 (48.4 per cent voted in favour, 51.6 per cent voted against). Following the rejection, the Swiss Parliament decided to extend the second CO_2 Act until 2024 (see section 4.2.3). For the period 2025–2030, the Swiss Federal Council sent a new version of the third CO_2 Act into public consultation in December 2021. It translates Switzerland's commitments under the Paris Agreement into national law and defines reduction targets for greenhouse gas emissions (see discussion of the estimate of mitigation impact below) as well as the corresponding instruments. It also takes note of the results of the popular vote on 13 June 2021. Instruments that contributed significantly to the rejection were no longer considered. The proposal is instead based on a mix of measures. The steering effect of the CO_2 levy is to

33 See also https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/target-achievement-review/2020-target.html.

be supplemented with effective incentives and targeted promotion and subsidies. In more detail, the following instruments are under discussion:

- The CO_2 levy on heating and process fuels shall continue to be an important pillar of Swiss climate policy. The maximum possible level of the CO_2 levy on heating and process fuels proposed is 120 Swiss francs per tonne of CO_2, which corresponds to its current level. Compared to the second CO_2 Act, the Swiss Federal Council proposes to earmark a larger part (less than half instead of one third) of the revenues for measures in the buildings sector. This allows to continue the existing national buildings refurbishment programme and to provide additional financial support of 40 million Swiss francs per year for the replacement of fossil heating systems. The partial earmarking of the CO_2 levy on heating and process fuels is also to be used to finance projects in the field of geothermal energy, as before, and now also communal and regional energy planning and the risk protection of thermal grids. The latter will be covered by the technology fund (see section 4.10), which will be continued and fed from the CO_2 levy as before;
- The emissions trading scheme, linked with the emissions trading scheme of the European Union since 1 January 2020, shall be continued and will deliver the most of the mitigation effort from industry (see section 4.2.6 for details). The third CO_2 Act creates the prerequisites to be able to take into account planned future tightening in the European Union;
- The negotiated reduction commitments (for exemption from the CO_2 levy) has proven to be a useful instrument to curb emissions at the level of companies. From 2025 on, it shall be available for companies from all sectors. Additionally, the negotiated reduction commitments shall be oriented towards full decarbonisation. In order to provide an incentive for the transition to fossil-free energy consumption, the instrument of negotiated reduction commitments (for exemption from the CO_2 levy) is to expire at the end of 2040. From 2025, operators will thus have 16 years to determine and implement measures to phase out fossil fuels;
- CO_2 emission regulations for newly registered vehicles shall be continued and strengthened in line with the European Union (see section 4.4.2 for details);
- The partial compensation of CO_2 emissions from motor fuel use shall continue. Until 2030, the compensation level will rise up to no more than 90 per cent of total emissions from motor fuels;
- The use of renewable fuels in land transport is to be promoted through a reduction quota and in air transport through a blending quota;
- Public transport companies are to be granted financial aid for the provision of new cross-border long-distance passenger rail services, including night trains, for a limited period until the end of 2030. Because improved international train connections are an alternative to short-distance flights, the subsidies will be financed with the proceeds from the auctioning of emission allowances for aviation and will amount to a maximum of 30 million Swiss francs per year;
- The Swiss Confederation wants to support the conversion of diesel-powered buses and ships to fossil-free electric or hydrogen drives and thus accelerate the efforts already being made by the cantons and municipalities. To incentivise investments the mineral oil tax reliefs for public transport are to be abrogated as of 2025. The Swiss Confederation also plans to financially support charging infrastructures for electric vehicles in multi-party buildings, in companies and in public car parks. Furthermore, it is planned to support the production of sustainable aviation fuels.

These measures are provisional in the sense that they are subject to parliamentary discussion. In general, the described policies and measures correspond to the draft of the Swiss Federal Council (December 2021), but may already include amendments that resulted from the public consultation.

In autumn 2021, the Swiss Parliament has begun its discussion of the so-called ‘Glacier-Initiative’, a popular initiative that aims to anchor the target of reducing Switzerland’s greenhouse gas emissions to net zero by 2050 in the Federal Constitution of the Swiss Confederation. Additionally, the Glacier-Initiative foresees a ban on the use of fossil fuels. Exceptions would be restricted to technically non-substitutable applications, and the resulting emissions would have to be balanced by domestic greenhouse gas sinks. The Swiss Federal Council supports the main goals of the initiative, in particular the enshrinement of the net-zero target in the Federal Constitution of the Swiss Confederation, but proposes several amendments of the legal text. The Swiss Federal Council detailed these amendments in its direct counter proposal to the initiative and submitted the corresponding message in August 2021 to the Swiss Parliament. The parliamentary environment, spatial planning and energy committees decided in autumn 2021 to elaborate an indirect counter proposal to the initiative. This implies that the net-zero target would be anchored in a law instead of the Federal Constitution of the Swiss Confederation. The committees now have time until summer 2022 to draw up a draft legislation, but pursued the constitutional track all the same and adopted, in the spring session 2022, a slightly modified legal text in order to extend the delay statutory for the treatment of the popular initiative by one year up to summer 2023.

For the reporting in the framework of its eighth national communication and fifth biennial report (in particular for the 'with additional measures' scenario in chapter 5), Switzerland takes into account – as a planned policies and measures – the status of the new version of the third CO_2 Act, i.e. the proposal the Swiss Federal Council submitted for public consultation in December 2021, as described above. However, the final outcome is still unknown, as discussions in the Swiss Parliament may lead to changes to this draft. Moreover, an optional referendum – which allows citizens to veto decisions made by the Swiss Parliament – may again represent the last obstacle before the new version of the third CO_2 Act can enter into force.

Estimate of mitigation impact

The expected mitigation impact of the third CO_2 Act corresponds to its objective, i.e. a reduction of total greenhouse gas emissions (relative to 1990) by (i) at least 50 per cent by 2030 and (ii) at least 35 per cent in the mean over the years 2021–2030, both including measures in Switzerland and abroad. As the third CO_2 Act will form the legal framework for the strengthening of various policies and measures currently implemented under the second CO_2 Act, its mitigation impact is indicated in Tab. 16 and BR CTF table 3 as 'included elsewhere' (i.e. under the policies and measures presented below).

4.2.5 CO_2 levy on heating and process fuels

By increasing the price of fossil heating and process fuels, the CO_2 levy sets an incentive to use fossil fuels more efficiently, to invest in low carbon technologies, and to switch to low-carbon or carbon-free energy sources. The CO_2 levy was introduced in January 2008 at an initial rate of 12 Swiss francs per tonne of CO_2. The CO_2 Ordinance foresaw an automatic increase of the rate to a maximum of 120 Swiss francs per tonne of CO_2 in case CO_2 emissions from heating and process fuels exceed the intermediate targets shown in Tab. 17. Because CO_2 emissions from fossil heating and process fuels exceeded the target value in 2020, the rate of the CO_2 levy increased accordingly as of 1 January 2022. The second CO_2 Act does not include any options for increasing the levy rate any further. It will remain at 120 Swiss francs per tonne of CO_2 at least until 2024.

Tab. 17 > Intermediate targets set out in Article 94 of the CO_2 Ordinance to the second CO_2 Act, including corresponding increases of the CO_2 levy in case of non-compliance with the intermediate targets (the intermediate targets set out in Article 3 of the CO_2 Ordinance to the first CO_2 Act are not shown here[34]). The attainment of the targets is evaluated based on the CO_2 statistics which is annually published at the beginning of July and which contains CO_2 emissions from heating and process fuels from the previous year.

As of 1 January 2014: • Increase to 60 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2012 exceed 79 per cent of 1990 emissions. ⇨ The rate of the CO_2 levy has increased to 60 Swiss francs per tonne of CO_2.
As of 1 January 2016: • Increase to 72 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2014 exceed 76 per cent of 1990 emissions; • Increase to 84 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2014 exceed 78 per cent of 1990 emissions. ⇨ The rate of the CO_2 levy has increased to 84 Swiss francs per tonne of CO_2.
As of 1 January 2018: • Increase to 96 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2016 exceed 73 per cent of 1990 emissions; • Increase to 120 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2016 exceed 76 per cent of 1990 emissions. ⇨ The rate of the CO_2 levy has increased to 96 Swiss francs per tonne of CO_2.
As of 1 January 2022: • Increase to 120 Swiss francs per tonne of CO_2 if the CO_2 emissions from heating and process fuels in 2020 exceed 67 per cent of 1990 emissions. ⇨ The rate of the CO_2 levy has increased to 120 Swiss francs per tonne of CO_2.

As a basic principle, proceeds from the CO_2 levy on heating and process fuels are refunded pro-rata to the Swiss population (on a per capita basis) and to the Swiss economy (in proportion to wages paid). However, following a parliamentary decision in June 2009, a third (or a maximum of 300 million Swiss francs per year up to the end of 2017 and a maximum of 450 million Swiss francs as of 2018) of the revenues from the CO_2 levy is earmarked to finance the national buildings

[34] https://www.admin.ch/opc/de/classified-compilation/20070960/201205010000/641.712.pdf

refurbishment programme (see section 4.3.3). This programme is partly co-funded out of cantonal budgets and co-managed by the Swiss government and the cantons. Additionally, 25 million Swiss francs per year are invested in a technology fund to cover bank loans for innovative technologies that reduce greenhouse gas emissions and the consumption of resources, to support the use of renewable energy and to increase energy efficiency (see section 4.10).

Planned strengthening/adjustment

For the years 2025 to 2030, the Swiss Federal Council proposes to leave the maximum levy rate at 120 Swiss francs per tonne of CO_2 as part of the planned new version of the third CO_2 Act. The share earmarked for measures to reduce emissions from buildings and for the technology fund shall be increased to less than half of the revenues, with the following specifications: (i) a maximum of 40 million Swiss francs per year shall be allocated to the cantons for the replacement of fossil heating systems, (ii) a maximum of 45 million Swiss francs per year shall be provided for projects for the use of geothermal energy for heat supply or for spatial energy planning at the communal level, and (iii) a maximum of 35 million Swiss francs per year shall be provided for the technology fund, which is partially used to hedge the risks of thermal grids. The remainder (on average an estimated 430 million Swiss francs per year) shall be directed to the national buildings refurbishment programme.

Estimate of mitigation impact

The CO_2 levy is expected to lead to a reduction of about two million tonnes of CO_2 in 2020. This estimate is consistent with the model-based estimate by *Ecoplan* (2009) when transferred to a rate of the CO_2 levy of 96 Swiss francs per tonne of CO_2 in 2020. The increase of the levy rate to 120 Swiss francs per tonne of CO_2 is projected to lead to an additional reduction of 0.25 million tonnes of CO_2 per year from 2022 onwards (compared to a scenario where the rate is held constant at its previous rate of 96 Swiss francs per tonne of CO_2). Accordingly, the estimated mitigation impact for 2025 is 2.25 million tonnes of CO_2.

While the planned adjustment for the years 2025 to 2030 are not expected to lead to an increase in the mitigation impact, they should ensure that the annual mitigation impact of 2.25 million tonnes of CO_2 can be uphold.

4.2.6 Emissions trading scheme

Switzerland introduced its emissions trading scheme in 2008 in order to give companies – especially those industries with substantial CO_2 emissions resulting from the use of heating and process fuels as well as from cement production – the opportunity to contribute to CO_2 reduction goals under the same rules as their international competitors (at the same time being exempt from the CO_2 levy on heating and process fuels). The emissions trading scheme is based on the cap and trade principle. The cap – i.e. the total quantity of emission allowances newly available each year within the emissions trading scheme – is reduced annually, thereby ensuring a long-term reduction of total emissions of all companies involved. Some of the emission allowances are allocated free of charge, and some are auctioned off. Each year, participants of the emissions trading scheme must cover their actual greenhouse gas emissions with emission allowances (which are to be surrendered to the federal government). In the case of relatively low emissions, participants may sell surplus emission allowances, in the opposite case they may need to buy additional emission allowances.

The emissions trading schemes of Switzerland and the European Union have been linked since 1 January 2020, after several years of negotiations and after further technical developments to ensure compatibility of the two systems. Notable amendments included the mandatory nature of the emissions trading scheme for large, greenhouse gas-intensive companies and partial auctioning of emission allowances. Rules for allocation of free emission allowances were harmonised. The linking has also required an identical sectoral coverage. Therefore, Switzerland has newly included aircraft operators and gas-fired combined-cycle power plants in its emissions trading scheme. For the latter, no free allocation for producing electricity is foreseen. Therefore, potential future gas-fired combined-cycle power plants in Switzerland will have to cover their fossil emissions by buying emission allowances in the emissions trading scheme. Moreover, the CO_2 price must cover external cost which are currently set at 121.50 Swiss francs per tonne of CO_2 charged against the refund of the CO_2 tax. With the linking, the obligation to offset emissions from gas-fired combined-cycle power plants has expired (see section 4.11).

For industrial installations the cap was reduced annually by 1.74 per cent of the 2010 baseline between 2010 and 2020 (in 2020, the cap corresponded to around 4.9 million tonnes of CO_2 equivalents). Between 2021 and 2025, the annual reduction is 2.2 per cent of the 2010 baseline. For aircraft operators, the cap was determined in 2018 based on transport performance (measured in tonne-kilometres) and a benchmark approach as in the European Union; it will be reduced by 2.2 per cent of the baseline each year starting in 2021. Between 2013 and 2020, participants of the emissions trading scheme were allowed to surrender to the Swiss government a limited amount of international carbon credits.[35]

Planned strengthening

Planned strengthening of Switzerland's emissions trading scheme will be guided by the relevant provisions in the European Union. Possible strengthening may include a higher annual rate to lower the cap by 4.2 per cent of the baseline, further reinforced benchmarks, enlarged sectoral coverage (e.g. navigation), as well as a carbon border adjustment mechanism. For aircraft operators possible strengthening may also include a phasing out of the free allocation of emission allowances.

Estimate of mitigation impact

Industrial installations covered by the emissions trading scheme reduced their emissions by approximately 600 thousand tonnes of CO_2 equivalents in the period 2013–2020. By 2025, the additional mitigation impact resulting from the increased annual reduction rate of the cap from 1.74 to 2.2 per cent of the baseline from 2021 onwards is estimated at 650 thousand tonnes of CO_2 equivalents. In addition, the inclusion of aircraft operators is estimated to contribute approximately 130 thousand tonnes of CO_2 equivalents by 2025 as a result of increasing the annual rate to lower the aviation cap from 0 to 2.2 per cent of the baseline as of 2021 (no mitigation impact yet for 2020). By 2025, the overall mitigation impact of the emissions trading scheme is thus estimated at 1,380 thousand tonnes of CO_2 equivalents.

The mitigation impact of the planned strengthening for the years up to 2030 cannot yet be estimated.

4.2.7 Negotiated reduction commitments (for exemption from the CO_2 levy)

Companies pursuing CO_2 intensive activities listed in Annex 7 of the CO_2 Ordinance may apply for an exemption from the CO_2 levy without participation in the emissions trading scheme, provided they commit to lower their onsite greenhouse gas emissions (negotiated reduction commitment). Thereby all technically feasible and economically viable measures with a pay back of less than four years have to be implemented.

Up to 2020, the companies' targets were calculated along a linear reduction trajectory from 2013 to 2020. For 2021, these reduction targets were linearly extrapolated. Between 2022 and 2024, greenhouse gas emissions must be reduced by two per cent per year compared to 2021 levels.

Small companies emitting less than 1,500 tonnes of CO_2 equivalents per year do not have to follow a certain emissions path, but can apply for an exemption from the CO_2 levy by taking predefined economically viable measures (measures target). Their extension beyond 2020 bases on a simple multiplication of the hitherto measures targets (factor 1.125 for 2021, factor of two up to 2024).

Up to 2021, companies outperforming their reduction targets could be issued domestic carbon credits (attestations), which can be sold (e.g. to fossil fuel importers bound to offset part of the CO_2 emissions from motor fuels, see section 4.4.5). At no time, however, can attestations be counted towards the own or another companies' negotiated reduction commitment.

[35] According to Article 55b of the CO_2 Ordinance (up to the version from 1 November 2020) the maximum quantity of international carbon credits participants of the emissions trading scheme were allowed to surrender to the Swiss government to cover their actual greenhouse gas emissions over the period 2013 to 2020 is calculated as follows: (i) for installations that were previously taken into account in the emissions trading scheme in the years 2008–2012: 11 per cent of five times the emission allowances allocated annually on average in this period minus the international carbon credits that were taken into account during this period, and (ii) for the other installations and greenhouse gas emissions: 4.5 per cent of the greenhouse gas emissions during the years 2013–2020.

Companies that have not reached their negotiated reduction commitment and have not been issued domestic carbon credits (attestations) may have, to a limited amount, international carbon credits taken into account towards meeting their reduction commitment.[36]

The elaboration of negotiated reduction commitments and their implementation is assisted by two organisations mandated by the federal government (Swiss Energy Agency of the Economy and Cleantech Agency Switzerland, see section 9.2.2).

Planned strengthening

Negotiated reduction commitments (for exemption from the CO_2 levy) have proven to be a valuable instrument. As part of the new version of the third CO_2 Act (see section 4.2.4), the Swiss Federal Council thus proposes its continuation beyond 2024, making it available for companies from all sectors. However, the hitherto implemented incremental improvements will not be sufficient with regard to the net-zero target by 2050. In order to incentivise the transition to fossil-free energy consumption, the negotiated reduction commitments (for exemption from the CO_2 levy) is planned to expire in 2040, giving operators 16 years to phase out the use of fossil fuels. This period is considered to allow for replacing existing fossil plants by CO_2-free technologies at the end of their technical lifetime. As of 2025, it is planned that each company with a negotiated reduction commitment (for exemption from the CO_2 levy) must depict a decarbonisation roadmap. This proposition of the Swiss Federal Council is subject to a formal consultation and may thus change in the light of stakeholder comments or parliamentary discussion at a later stage.

Estimate of mitigation impact

For 2020, the mitigation impact of the negotiated reduction commitments (for exemption from the CO_2 levy) is estimated at 370 thousand tonnes of CO_2 equivalents (Tab. 16 and BR CTF table 3). This estimate is derived from the detailed monitoring reports of all exempt companies (reduction trajectory and measures target). The mitigation impact achieved by 2020 substantially exceeded the overall reduction commitments of exempt companies by 70 thousand tonnes of CO_2 equivalents. For 2025, the mitigation impact cannot be estimated and is indicated as 'NE' in Tab. 16 and BR CTF table 3 for the following reasons: (i) the modalities for the time beyond 2024 are not yet fully defined, and (ii) with the overachievement of their targets in 2020, companies already fulfilled the requested reductions for the years 2021–2024, i.e. it is unclear whether companies will engage in further measures or not in the upcoming years.

The planned continuation of the instrument beyond 2024 aims at completely avoiding emissions of fossil CO_2 in the longer term.

4.3 Energy

4.3.1 Overview

Energy policy was anchored in the Federal Constitution of the Swiss Confederation in 1990, when an energy article was added. This article stipulates that the Swiss government and the cantons are obliged to use their competences to ensure an adequate, broad-based, secure, economic and ecological energy supply, and the economical and efficient use of energy. This comprehensive list of requirements places high demands on energy policy at the federal and cantonal levels, including the ability to find compromise solutions that meet all criteria.

The energy article in the Federal Constitution of the Swiss Confederation is elaborated further in the Energy Act (*Swiss Confederation*, 2016), the Nuclear Energy Act (*Swiss Confederation*, 2003) and the Electricity Supply Act (*Swiss Confederation*, 2007). In addition to legal instruments and related measures, the energy policies of the Swiss government and the cantons are also based on energy perspectives (i.e. models and scenarios of future energy production and consumption), strategies (i.e. goal-oriented policy packages), implementation programmes focussing on information and promotion, and the periodic evaluation of energy-related measures at the municipal, cantonal and federal level.

[36] According to Article 75 of the CO_2 Ordinance the maximum quantity of international carbon credits companies may have taken into account is calculated as follows: (i) for companies that were already subject to a reduction obligation in the years 2008–2012: eighth per cent of five times the average allowed emissions annually in this period, minus the international carbon credits that were taken into account during 2008–2012 but that were not required for meeting the 2008–2012 reduction commitment, and (ii) for the remaining companies and greenhouse gas emissions: 4.5 per cent of the greenhouse gas emissions of the years 2013–2020.

Following the nuclear reactor disaster of Fukushima in 2011 the Swiss Federal Council and the Swiss Parliament decided on Switzerland's progressive withdrawal from nuclear energy sources. This decision, together with further far-reaching changes in the international energy environment, has required an upgrading of the Swiss energy system. For this purpose the Swiss Federal Council developed the Energy Strategy 2050, which has been in force since January 2018.

The strategy addresses the impacts of the country's decision for a progressive withdrawal from nuclear energy. The existing nuclear power plants will shut down at the end of their technically safe operating life and will not be replaced with new ones. The first nuclear power plant closed down for commercial reasons on 20 December 2019 and the last one will likely be running beyond the mid-2030s. As nuclear energy currently contributes a large share to Switzerland's electricity generation (see section 2.6), the generation gap resulting from the decommissioning of nuclear power plants will need to be largely filled by renewable electricity generation, maintaining the high standards of supply security.

On 18 June 2021, the Swiss Federal Council adopted a draft of the Swiss Federal Act on Secure Power Supply Using Renewable Energy, therewith starting the legislative process in the Swiss Parliament. With the newly proposed legislation the expansion of domestic renewable energies and the security of supply in Switzerland – especially during the winter – should be strengthened. In order to achieve the goals of the Energy Strategy 2050 and of Switzerland's long-term climate strategy to 2050 (*Swiss Federal Council*, 2021a), comprehensive electrification is required in the transport and heating sector. To achieve this, domestic electricity generation from renewable energies must be expanded quickly and consistently. The security of the grid and electricity supply must also be strengthened with further specific measures. With the Swiss Federal Act on Secure Power Supply Using Renewable Energy, the Swiss Federal Council is proposing the necessary changes to the Energy Act (*Swiss Confederation*, 2016) and the Electricity Supply Act (*Swiss Confederation*, 2007). It thus creates a legal framework that provides planning security and investment incentives to expand renewable electricity production and integrate it into the market. The most important measures contained in the planned Swiss Federal Act on Secure Power Supply Using Renewable Energy are:[37]

- **Target values:** The Energy Act is planned to be amended by new binding target values for the years 2035 and 2050. The target values set the desired expansion of hydropower and other renewable energies as well as the reduction in energy and electricity consumption per capita. In this way, the Energy Act will become more bindingly aligned with the goals of supply security and of climate policy, creating planning security for investments;
- **Measures to promote renewable electricity generation:** The previous instruments for renewable electricity production are limited to the end of 2022 (feed-in tariff system, see section 4.3.5) and 2030 (investment aids, see section 4.3.6). They are planned to be extended to 2035 – timed to match the statutory target value of 2035 – and designed more closely to the market. For example, large photovoltaic installations are to be funded by means of competitive tenders. The feed-in tariff system – running out as foreseen in current legislation – is planned to be replaced by investment contributions. This eases the administrative burden and enables more additional construction per subsidy franc. More financial resources should become available for large hydropower plants. According to the plans, the support instruments will continue to be financed through the network surcharge of 2.3 cents per kilowatt-hour and the network surcharge will not be increased, but will be charged for a longer period of time;
- **Electricity market opening:** The complete opening of the electricity market should strengthen decentralised renewable electricity production. It is planned to enable innovative business models (e.g. energy communities) that are not permitted in a monopoly today, and thus a better integration of renewable electricity into the market. End consumers and end consumers who produce electricity themselves (prosumers), producers and electricity suppliers should thus receive economically important freedom. In order to protect small end consumers such as households from price abuse, there should still be a basic supply. It should offer an electricity product that consists exclusively of local renewable energy.

Tab. 18 gives an overview of the most climate-relevant policies and measures in the energy sector. The following sections provide more details and background information on each policy and measure.

[37] See also https://www.newsd.admin.ch/newsd/message/attachments/67174.pdf.

Tab. 18 > Summary of policies and measures in the energy sector. The sector affected is 'energy' for all policies and measures presented in this table.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq)	
								2020	2025
SwissEnergy programme *	CO_2	Promotion of energy efficiency and the increased use of renewables.	Information, education	Implemented	Major policy instrument engaging cantons, municipalities, industry, as well as environmental and consumer associations for awareness raising and the promotion of increased energy efficiency and the enhanced use of renewable energy.	2001	SFOE	NE [b]	NE [b]
National buildings refurbishment programme *	CO_2	Refurbishment of existing buildings envelope and incentives for renewable energy, energy recuperation and optimisation of building technology.	Economic	Implemented (strengthening planned)	The programme increases the energy efficiency of buildings and promotes the use of renewable energies in the buildings sector. Financed by one third of the revenue from the CO_2 levy on heating and process fuels, with additional funds provided by the cantons.	2010	SFOE, FOEN, cantons	1 120	1 490
Building codes of the cantons *	CO_2	Stringent energy consumption standards for new and existing buildings.	Regulatory	Implemented (strengthening planned)	A set of common energy, 'CO_2' and insulation standards (model provisions) of buildings agreed on by the cantonal energy directors. They aim at reducing energy consumption and CO_2 emissions as well as at increasing production of renewable energy (electricity and heat). Implementation of the latest set of measures was endorsed in 2015, and transposed into cantonal legislation by eighteen cantons so far.	1992	Cantons, in coordination with SFOE	1 760	1 760 [c]
Feed-in tariff system *	CO_2	Promotion of renewable electricity production to reach targets of the Energy Act.	Regulatory	Implemented	The promotion system applies to photovoltaics, wind, biomass, small hydropower and geothermal plants. The administrative tariffs cover the generation costs based on reference plants over 15 to 25 years. The promotion system will face out by the end of 2022. New plants can apply for investment aids.	2009	SFOE	432	505
Investment aids *	CO_2	Promotion of renewable electricity production to reach targets of the Energy Act.	Regulatory	Implemented (strengthening planned)	Investment aids apply to photovoltaics, wind, biomass, hydropower and geothermal plants. The contributions depend on the technology and are between 20 and 60 per cent of the investment costs. Starting 2023 the investment contribution for large photovoltaic installations are going to be awarded by tenders.	2014	SFOE	157	NE [d]
Negotiated reduction commitment of municipal solid waste incineration plant operators	CO_2	Contribution to emission reduction by municipal solid waste incineration plant operators through energy efficiency measures and metal recuperation.	Regulatory	Implemented	Agreement committing the association of municipal solid waste incineration plant operators to establish a monitoring system and to reduce net CO_2 emissions. Implementation of the agreement exempts municipal solid waste incineration plant operators from participation in the emissions trading scheme.	2014	FOEN	200 [e]	NE [f]

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] See section 4.3.2 for more information regarding the mitigation impact.

[c] In the absence of updated studies, the same mitigation impact as for 2020 is also reported for 2025, however, the impact might become larger as more cantons put into force updated energy acts.

[d] By 2025, the power generation from plants with an investment aid is expected to increase substantially. The exact increase – and thus the mitigation impact – depends on a number of variables (legislation in force, electricity prices, authorisation processes, etc.) and cannot be estimated yet.

[e] By 2020, the Swiss Association of Municipal Solid Waste Incineration Plants reached its agreed (net) emission reduction commitment of 200 thousand tonnes of CO_2 equivalents below 2010 emissions. The recuperation of metals may lead to (indirect) reductions of greenhouse gas emissions outside Switzerland.

[f] As there is no intermediate target for 2025, the mitigation impact is indicated as 'not estimated'. The target for 2030 is 100 thousand tonnes of CO_2 equivalents (carbon capture and storage). In addition, the commitment in place up to 2020 will be continued.

NA, not applicable; NE, not estimated
FOEN, Swiss Federal Office for the Environment; SFOE, Swiss Federal Office of Energy

4.3.2 SwissEnergy programme

In 2001, the Swiss Federal Council has launched the SwissEnergy programme, in line with the Energy Act and the CO_2 Act that have come into force in 1999 and 2000, respectively. It aims at reducing fossil fuel use and CO_2 emissions as required by the CO_2 Act and contains targets for electricity generation and heat production from renewable sources. The SwissEnergy programme represents a major policy instrument for awareness raising and promoting an increase in energy efficiency and the enhanced use of renewable energy (see section 9.2.2). Measures are mostly voluntary in nature, supporting the effect of regulatory measures. In 2018, the Swiss Federal Council mandated the continuation of the programme for a third decade until 2030.

The SwissEnergy programme is managed by the Swiss Federal Office of Energy. Projects are usually run in close cooperation with cantons, municipalities, and industry, as well as environmental and consumer associations. Programme results are subject to detailed monitoring and verification. To support the Energy Strategy 2050, the SwissEnergy programme's annual budget has been increased from about 30 million Swiss francs in 2012 to around 44 million Swiss francs up to 2030.

The previous focal points of the SwissEnergy programme have been replaced by priority fields of action. This corresponds to the current needs regarding flexibility and prioritisation of the SwissEnergy programme. The three priority fields of action are:

- Building efficiency and renewable energies for private households;
- Mobility of private households and companies;
- Facilities and processes in industry and services.

These three fields of action cover a total of 74 per cent of Switzerland's final energy consumption. Accordingly, at least three quarters of the total budget of the SwissEnergy programme should be used for measures in these three fields of action.

The priority fields of action are supplemented by further fields of action, including large-scale renewable energy facilities and grids and storage. The fields of action are supported by cross-cutting themes. These include education and training, cities, municipalities, neighbourhoods and regions, communication, cooperation with the climate programme of the Swiss Federal Office for the Environment, digitalisation and innovation. The cross-cutting themes are central to addressing the priority fields of action.

Many minimum efficiency performance standards, previously introduced in the form of voluntary agreements (cars, some appliances) or codes of conduct (some energy-using products), are now legally mandated and aligned with the standards of the European Union. Hence, the role of the SwissEnergy programme is shifting towards one as a facilitator for the above mentioned regulations and laws.

Estimate of mitigation impact

The SwissEnergy programme covers a number of fields each requiring the use of very different – and very specific – instruments and means of communication. The focus of the programme is on soft measures (information, consulting, training and continuing education, quality assurance), therefore the mitigation impact cannot be quantified for lack of methodology. In addition, the SwissEnergy programme provides advice about implementation of regulations and promotional programmes and is primarily responsible for ensuring that enough trained people are available and that measures are publicised. These are necessary activities, but their mitigation impact cannot be looked at in isolation from the measures being applied. For all these reasons, the mitigation impact of the SwissEnergy programme is reported as 'not estimated' in Tab. 18 and BR CTF table 3.

4.3.3 National buildings refurbishment programme

In order to increase the refurbishment rate of buildings and to promote the use of renewable energies in the buildings sector, a third of the revenues from the CO_2 levy on heating and process fuels, but no more than 300 million francs per year, were earmarked for this purpose in the first CO_2 Act. Based on the revised Energy Act (*Swiss Confederation*, 2016), more funding has been available since 1 January 2018 as the maximum amount earmarked was increased from 300 million to 450 million Swiss francs per year. With the CO_2 levy rising to 120 Swiss francs per tonne of CO_2 as of 2022, revenues allow for the first time to tap the full legally possible amount.

In 2009, the Swiss Parliament adopted the national buildings refurbishment programme (operational since 1 January 2010). The programme was collectively developed by the cantons, represented by the Conference of Cantonal Energy Directors, and the Swiss federal administration (Swiss Federal Office of Energy, Swiss Federal Office for the Environment). The cantons are responsible for its implementation. The duration of the programme is unlimited. A mid-term evaluation was submitted to the Swiss Parliament in 2016. Some numbers on the programme taken from the most recent annual reporting (*SFOE*, 2020) are given below.

2.3 billion Swiss francs have been paid out as part of the national building refurbishment programme since 2010. In 2020, disbursements amounted to 299 million Swiss francs. Unlike in previous years, most of this was paid out for replacements of fossil heating systems. The thermal insulation of individual components comes second. The contributions to system renovations and indirect measures such as training and education have increased as well in 2020.

From 2010 to 2020, the average abatement cost per tonne of CO_2 amounted to 141 Swiss francs (combined funds from the federal and the cantonal level). Beyond the national buildings refurbishment programme, the Swiss federal administration and several cantons fund measures such as promotion of photovoltaics and consulting of building owners. However, there is no systematic overarching evaluation of the quantitative effect of these measures on CO_2 emissions.

Planned strengthening/adjustment

With the new version of the third CO_2 Act submitted to formal consultation, the Swiss Federal Council intends to earmark up to 50 per cent of the revenues from the CO_2 levy to reinforce the national buildings refurbishment programme to boost replacements of fossil heating systems. 40 million Swiss francs per year shall be allocated to the replacement of fossil heating systems.

Estimate of mitigation impact

A model assigning a CO_2 effect to each measure implemented (e.g., per square metre of insulation) was used to calculate the mitigation impact of the national buildings refurbishment programme. For the calculation, free rider effects (measures that would have been realised also in the absence of subsidies) were also taken into consideration and assumptions were made concerning the funds to be allotted. The model, taking into account the investments available up to 2025, estimates a mitigation impact of 1.12 million tonnes of CO_2 equivalents by 2020 and of 1.49 million tonnes of CO_2 equivalents by 2025 (Tab. 18 and BR CTF table 3).

Estimates of the planned strengthening for the years up to 2030 are currently not available, but the mitigation impact achieved every year will most likely further increase.

4.3.4 Building codes of the cantons

The cantons are responsible to decree any regulations in the buildings sector. Under the second CO_2 Acts they are required to define standards for the continuous reduction of CO_2 emissions in new and existing buildings (Article 9). In order to harmonise the building codes throughout Switzerland, the cantons, under the guidance of the Conference of Cantonal Energy Directors, agreed on model provisions. A first set was established in 1992 and thereafter updated periodically (i.e. in 2000, 2008, and 2014, see *EnDK*, 2014). These standard regulations need to be implemented by means of cantonal energy acts, which – in each canton – are subject to an optional referendum (allowing citizens to veto the decisions made). At the end of 2021, the model provisions have been introduced in 18 cantons so far. Thereby, some cantons stand somewhat behind the requirements of the model provisions, while others are frontrunners and completely ban the installation and replacement of fossil heating systems. After the rejection of the third CO_2 Act – which would have contained the introduction of federal CO_2 standards per square metre of heated surface – the cantons have taken the reins again and are introducing stricter energy acts themselves. More detailed information is available in the annually published report summarising the state of energy and climate policy in the cantons (*EnDK/SFOE/FOEN*, 2021).

Planned strengthening

The implementation of the model provisions in cantonal legislation is an ongoing process, leading to a continuous strengthening. The cantons are currently working on a revision of the model provisions, planned to be introduced by 2025. Under the title ‘energy hub buildings’, the further development should take into account that buildings are increasingly becoming the central control point for the consumption, production and storage of energy (see also *EnDK*, 2021).

Estimate of mitigation impact

The mitigation impact of the building codes of the cantons on greenhouse gas emissions mainly results from insulation requirements for building refurbishment and for new constructions, as well as prescriptions with regard to heating systems. For 2020, the mitigation impact is estimated at 1.76 million tonnes of CO_2 equivalents, based on assumptions about the energy reference area, rate of refurbishment, heat consumption before and after renovation, and heat consumption of new buildings (*EPFL and Infras*, 2016; *EPFL*, 2017). In the absence of updated studies, the same mitigation impact as for 2020 is also reported for 2025 in Tab. 18 as well as in CRF Table 3, however, the impact might become larger as more cantons put into force updated energy acts.

In the long term, the building codes of the cantons are going to contribute to making the buildings sector fossil-free.

4.3.5 Feed-in tariff system

The feed-in tariff system, which entered into force in 2009 with a revision of the Energy Act, aims at increasing the renewable power production according to the targets of the Energy Act (Article 2). The promotion system applies to photovoltaics, wind, biomass, small hydropower and geothermal plants. The administrative tariffs cover the generation costs based on reference plants over 15 to 25 years. In 2018, with the first package of measures of the Energy Strategy 2050, the feed-in tariff system was replaced by feed-in premiums to entice producers to sell their electricity when demand is high, giving them an incentive to sell electricity when it is in short supply and thus to fetch higher prices. The promotion system is financed by a network surcharge, which is paid by all consumers of electricity. Only energy intensive firms can apply for a refund under certain conditions (e.g. a commitment to increase energy efficiency).

Planned strengthening

The promotion system will face out at the end of 2022. New plant investors can apply for investment aids (see section 4.3.6).

Estimate of mitigation impact

In 2020, power plants supported by the feed-in tariff system generated 3,844 gigawatt-hours. As this energy amount substitutes imported power or power generated by other sources, the mitigation impact achieved through the feed-in tariff system is calculated based on greenhouse gas emissions resulting from the average consumer mix (128 grams of CO_2 equivalents per kilowatt-hour of electricity), corrected by greenhouse gas emissions resulting from the average renewable energy mix (15.7 grams of CO_2 equivalents per kilowatt-hour of electricity). For 2020, the mitigation impact is estimated at 432 thousand tonnes of CO_2 equivalents. By 2025, the expected power generation from the feed-in tariff system is estimated at about 4,500 gigawatt-hours. Accordingly, a mitigation impact of 505 thousand tonnes of CO_2 equivalents results, about 70 thousand tonnes of CO_2 equivalents more than in 2020.

4.3.6 Investment aids

Investment aids were first introduced in 2014 for small photovoltaic installations through a parliamentary initiative. In 2018, another amendment to the Energy Act (first package of measures of the Energy Strategy 2050) extended the so-called ‘one-off investment grants’ for small photovoltaic installations to new beneficiaries, i.e. large photovoltaic installations, hydropower plants, biomass plants as well contributions for ‘seek and find’ for geothermal plants. The possible contribution depends on the technology and ranges between 20 and 60 per cent of the total investment costs. Thanks to the investment aids the renewable power production targets for 2020 and 2035 according to Article 2 of the Energy Act can be achieved. These targets follow the path needed to achieve the goals of the Energy Strategy 2050, i.e. 100 per cent renewable energy production by 2050. Similar to the feed-in tariff system (section 4.3.5) the investment aids are financed by a network surcharge, which is paid by all consumers of electricity. Only energy intensive firms can apply for a refund under certain conditions (e.g. a commitment to increase energy efficiency). According to current legislation renewable plants are eligible for investment grants until the end of 2030.

In 2021, based on a parliamentary initiative (19.433), the Swiss Parliament approved an amendment to the Energy Act which is scheduled to enter into force in January 2023. The law extends the eligibility for investment grants to all renewable technologies. Moreover, the investment contribution for large photovoltaic installations are going to be awarded by tenders. In addition, new contributions for the running costs for biomass plants are going to be guaranteed to prevent these plants to stop operation, since their production costs are very high. The investment contributions will phase out by the end of 2030. The funding is guaranteed through the present network surcharge.

Planned strengthening

According to the new draft of the Energy Act, which is currently being debated by the Swiss Parliament, the investment grants are planned to be prolonged until 2035. This should ensure to meeting the 2035 renewable power production targets which are in line with the goal of net-zero emissions by 2050.

Estimate of mitigation impact

Between 2014 and 2020, power plants supported with an investment aid generated about 1,400 gigawatt-hours. As this energy amount substitutes imported power or power generated by other sources, the mitigation impact achieved through the investment aids is calculated based on greenhouse gas emissions resulting from the average consumer mix (128 grams of CO_2 equivalents per kilowatt-hour of electricity), corrected by greenhouse gas emissions resulting from the average renewable energy mix (15.7 grams of CO_2 equivalents per kilowatt-hour of electricity). For 2020, the mitigation impact is estimated at 157 thousand tonnes of CO_2 equivalents. By 2025, the power generation from plants with an investment aid is expected to increase substantially. The exact increase – and thus the mitigation impact – depends on a number of variables (legislation in force, electricity prices, authorisation processes, etc.) and cannot be estimated yet.

4.3.7 Negotiated reduction commitment of municipal solid waste incineration plant operators

Greenhouse gas emissions from waste incineration plants have increased to about two million tonnes of CO_2 equivalents (roughly four per cent of the national total) by 2015, mainly due to growth of the economy and the population. In the context of national climate mitigation commitments, municipal solid waste incineration plant operators are expected to contribute their share. In 2014, the Swiss Federal Department of Environment, Transport, Energy and Communications concluded an agreement with the Swiss Association of Municipal Solid Waste Incineration Plants. This agreement commits the association to reduce net CO_2 emissions by 200 thousand tonnes by 2020, compared to 2010 levels, and to reduce cumulative net emissions over the period 2010–2020 by one million tonnes. Additionally, the association was obliged to establish a monitoring system to track progress towards these targets, and it must annually report progress to the Swiss Federal Office for the Environment. Since the potential for direct emission reductions at the incineration plants is limited, improvements in the efficiency of the use of the heat generated and avoided emissions (mostly occurring outside Switzerland) through the recuperation of metals are taken into account (bottom ash of the municipal solid waste incineration plants containing on average about 10 per cent scrap iron and significant amounts of non-iron metals such as aluminium, copper, brass etc.). Implementation of the agreement exempts municipal solid waste incineration plant operators from participation in the emissions trading scheme.

As documented in the monitoring report for the year 2020, the Swiss Association of Municipal Solid Waste Incineration Plants met the targets of its commitment if the impacts of the variability of winter temperatures on heat demand is considered. Because the agreement has expired at the end of 2021, the Swiss Federal Department of Environment, Transport, Energy and Communications and the Swiss Association of Municipal Solid Waste Incineration Plants have concluded a follow-up agreement covering the period until 2030. The two parties signed this agreement in March 2022. The new agreement calls the Swiss Association of Municipal Solid Waste Incineration Plants for equipping at least one plant with a unit for carbon capture and storage with a capacity of 100 thousand tonnes of CO_2 by 2030. Additionally, the Swiss Association of municipal solid waste incineration plants also commits to further reduce its net CO_2 emissions as defined in the previous agreement. Notably, the agreement does not include a reduction target for the (direct) emissions from waste incineration plants, implying that these emissions might still increase.

Estimate of mitigation impact

By 2020, the Swiss Association of Municipal Solid Waste Incineration Plants reached its agreed (net) emission reduction commitment of 200 thousand tonnes of CO_2 equivalents below 2010 emissions. For 2030, the expected mitigation impact of the agreement corresponds to its objectives, i.e. 100 thousand tonnes of CO_2 equivalents (carbon capture and storage). In addition, the commitment in place up to 2020 will be continued. As there is no intermediate target for 2025, the mitigation impact of the negotiated reduction commitment of municipal solid waste incineration plant operators is indicated as 'not estimated' in Tab. 18 and BR CTF table 3 for the respective year.

4.4 Transport

4.4.1 Overview

Over the years, Switzerland has developed an integral transport policy, seeking better coordination between transport modes, spatial planning, and taking into account environmental and sustainability concerns. While several strategies aim at reducing specific energy consumption or CO_2 emissions from the transport sector – like the road map 2025 for e-mobility in Switzerland (goal: 50 per cent of newly registered cars shall be electric cars by 2025, 20,000 public charging stations country-wide)[38] – many are part of the general transport policy approach that involves reducing unnecessary motorised mobility through tight coordinated transport infrastructure and land-use planning, shifting traffic from road to more environmentally friendly modes, and improving intermodal transport chains and interconnectivity. The guidelines for this more comprehensive national transport concept have been laid down in the 1980s by the Swiss Coordinated Transport Policy Bill.[39] Recently, they have been broadened and amended by the Programme Part of the Strategic Plan for Transport (*DETEC*, 2021).

The latest projections for passenger and freight transport (*ARE*, 2021a) still show substantial growth rates for the coming decades. Sustainable management of this growth represents a major challenge. Spatial development and infrastructure planning are key factors influencing future emissions from the transport sector. The coordination of spatial planning and transport infrastructure development by concentrating population and transport growth in areas where non-motorised and public transport offer comparative advantages is a viable option to curb transport growth and urban sprawl. Switzerland has therefore adjusted its spatial planning tools on the federal and cantonal level by developing the Agglomeration Programme (see below). For over 20 years, the coordination of pedestrian and hiking networks has been laid down in the Federal Constitution of the Swiss Confederation. As a reaction to a federal popular initiative and to strengthen non-motorised transport, the Swiss Federal Council formulated a counter-proposal to lay down cycle networks in a similar manner. The Swiss population voted in favour of this counter-proposal on 23 September 2018. A respective law (Bicycle Routes Act) has been put forward for parliamentary discussion in 2021 and has been adopted in March 2022.

Switzerland has an excellent and very dense rail infrastructure that is permanently maintained, modernised, and improved. The first phase of a major expansion of rail transport capacity, RAIL 2000, was opened on 12 December 2004. It has marked a milestone for Swiss public passenger transport, as rail service levels have increased by 12 per cent from one day to the next (more trains and faster connections between Swiss cities). As a follow-up of RAIL 2000, the Swiss Federal Act on the Future Development of Rail Infrastructure (*Swiss Confederation*, 2009) was enacted in 2009 to further modernise and expand the Swiss rail network. With the opening of the last of the three base tunnels in September of 2020, the Monte Ceneri, the project New Rail Links through the Alps was completed and is now fully enhancing capacity and reducing travel time for freight and passenger transport (the Lötschberg base tunnel opened in 2007 and the Gotthard base tunnel in 2016). Furthermore, there are other projects under way for expanding rail capacity by 2025 for passenger and freight transport in the country. By also improving connections to the European high-speed rail network, Swiss transport policy encourages the modal shift of short-distance international passenger traffic from air to rail.

In the past, financing of the major rail infrastructure projects was secured on the basis of the temporary 'FinÖV', a public transport fund, which drew revenues from the heavy vehicle charge. As of 1 January 2016 – subsequent to a federal

[38] Roadmap Elektromobilität 2022: *https://roadmap-elektromobilitaet.ch*.

[39] Gesamtverkehrskonzeption (1977). Stab GVF. Online: *https://www.alptransit-portal.ch/de/ereignisse/ereignis/die-gesamtverkehrskonzeption/?no_cache=1&cHash=ea54b930f67a615ddf8bf179ba7ae582*.

popular vote in 2014 – operation, maintenance, and extension of rail infrastructure have been financed through a single, open-ended ‘Rail Infrastructure Fund’.

From 2007 to 2017, funding for development and maintenance of road infrastructure was provided through the ‘Infrastructure Fund for Agglomeration Transport, the National Highway Network and Major Roads in Mountain Areas and Peripheral Regions’. In 2018, this fund was replaced by the time-unlimited ‘Fund for the National Road Motorway Network and the Agglomeration Traffic’. Out of this fund, Switzerland runs an agglomeration programme aimed at providing financial resources for infrastructure projects promoting public and non-motorised transport in sub-urban regions and agglomerations.

The two-lane Gotthard road tunnel connecting northern Switzerland to the Ticino and Italy opened in 1980. After more than forty years of operation, it needs major refurbishment. The Swiss Federal Council and the Swiss Parliament proposed to construct a second tunnel. This would allow for closing of the first tunnel during refurbishment works without lengthy interruption of this important traffic link. In addition, two tunnels would lead to safer operating conditions in the future. A referendum on this proposal was held in 2016 and approved. The referendum was motivated by concerns that the two tunnels will be opened to four-lane traffic once refurbishment of the first tunnel is completed – leading to a conflict with the intention of Article 84 of the Federal Constitution of the Swiss Confederation stating that the capacity of the transit routes in the alpine region may not be increased (section 4.4.6). The construction of the second road tunnel started in 2021 and the opening is scheduled for 2029.

Switzerland has excellent international flight connections, with many direct flights to and from economically important destinations. As the share of emissions from Switzerland’s domestic aviation is very small, Switzerland’s aviation policy is focused on international aviation, and, thus, mainly targets bunker fuels. Switzerland joined the International Civil Aviation Organisation in 1947 and the European Civil Aviation Conference in 1955. Under the air transport agreement between Switzerland and the European Union, which came into effect on 1 June 2002, Switzerland adopted European civil aviation legislation that has been in force when the agreement was concluded and regularly adapts the agreement to new legislation entering into force in the European Union. In 2006, Switzerland joined the European Aviation Safety Agency. Switzerland’s aviation legislation and policy is therefore shaped by the regulations of the International Civil Aviation Organisation and the European Civil Aviation Conference, as well as by developments within the European Union. Switzerland’s foreign relations are further governed by bilateral and multilateral agreements; bilateral aviation agreements have been concluded with more than 130 countries. Switzerland is engaged in the environmental expert groups of the International Civil Aviation Organisation and the European Civil Aviation Conference in order to support harmonisation and further development of international environmental aviation standards and measures. Switzerland directly applies environmental standards of the International Civil Aviation Organisation and their revisions in their national aviation legislation. This includes environmental technical standards for aircraft registered in Switzerland (like the CO_2 emissions standard for aircraft and non-volatile particle matter emission regulations for aircraft engines) and market based policies and measures like the carbon offsetting and reduction scheme for international civil aviation (CORSIA), where Swiss air operators have to comply with. The international orientation of Switzerland’s aviation policy is reflected in the policies and measures presented in the sections 4.4.9 to 4.4.12. Since the linking of the emissions trading schemes of Switzerland and the European Union as of 1 January 2020, Switzerland has newly included aircraft operators in its emissions trading scheme. The respective information with regard to aviation is thus included under the cross-sectoral policies and measures (see section 4.2.6). The policy and measure named ‘inclusion of aviation in the emissions trading scheme’ as reported in previous reports is no longer listed separately in Tab. 19 and BR CTF table 3 (see section 4.11).

Tab. 19 gives an overview of the climate-relevant policies and measures of the transport sector, while the following sections provide more details and background information on each policy and measure.

Tab. 19 > Summary of policies and measures in the transport sector. The sector affected is 'transport' for all policies and measures presented in this table.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq) 2020	2025
CO_2 emission regulations for newly registered vehicles *	CO_2	Reduction of average fuel consumption and CO_2 emissions from new passenger cars and light commercial vehicles.	Regulatory	Implemented (strengthening planned)	CO_2 emission targets for newly registered vehicles in line with regulations of the European Union. The target by 2020 for passenger cars (fleet average) has been set at 95 grams of CO_2 per kilometre, for light commercial vehicles at 147 grams of CO_2 per kilometre. Vehicle importers have to pay a penalty if the individually specified target is not met.	2012	SFOE, FEDRO	210	550
Energy label for new motor vehicles *	CO_2	Promote visibility of cars with low average fuel consumption, low CO_2 emissions and high energy efficiency. Raise awareness of car and light commercial vehicle buyers and ensure transparent customer information.	Information, regulatory	Implemented (strengthening planned)	Mandatory label for cars displayed at the point of sale, in online configurators and in advertisements providing information on the fuel consumption (litres per 100 kilometre), CO_2 emissions (in grams of CO_2 per kilometre) and energy efficiency class of every passenger car. Requirements on the declaration of fuel consumption and CO_2 emissions for cars and light commercial vehicles in advertising, sales documents and online applications.	2003	SFOE	IE [b]	IE [b]
Climate Cent *	CO_2, CH_4, N_2O	Offset of transport emissions (i) through funding of mitigation projects within Switzerland and (ii) by use of international carbon credits.	Voluntary agreement	Expired (implemented from 2005 to 2012)	Voluntary initiative by mineral oil industry instead of a CO_2 levy on fossil motor fuels. Obligation (i) to offset two million tonnes of CO_2 during the first commitment period of the Kyoto Protocol (2008–2012) through investments in domestic emission reduction projects and (ii) to purchase a total of 16 million international carbon credits. Financed by a surcharge of 0.015 Swiss francs per litre on motor fuels.	2005	Climate Cent Foundation	NA [c]	NA [c]
Partial compensation of CO_2 emissions from motor fuel use *	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	Domestic mitigation projects as compensatory measure (instead of a CO_2 levy on motor fuels).	Regulatory	Implemented (strengthening planned)	Obligation for importers to offset part of the CO_2 emissions from motor fuel use through investments in domestic emission reduction projects. Financed by a surcharge on imported fuels not exceeding 0.05 Swiss francs per litre of fuel. The share of CO_2 emissions to be offset gradually increases (from 2 per cent in 2014 to 20 per cent in 2024).	2013	Foundation for Climate Protection and Carbon Offset, FOEN	1 300	NE [d]
Heavy vehicle charge *	CO_2	Reduction of transalpine road traffic, increase of transport rates on rail, limit increase in heavy vehicles on the road.	Fiscal	Implemented	Charges applied to passenger and freight transport vehicles of more than 3.5 tonnes gross weight, aiming at a shift of transalpine transport from road to rail. The level of the charge depends on the distance driven, the maximum weight, and emissions standards of the individual vehicle.	2001	FOCBS, FOT	100	120
Mineral oil tax reduction on biofuels and natural gas *	CO_2	Promotion of low carbon motor fuels.	Fiscal	Implemented	Tax reduction of 0.4 Swiss francs per litre of gasoline equivalent for natural gas and liquefied petroleum gas (LPG). Complete tax exemption for biogas and other renewable if certain (ecological and social) criteria are met. Tax revenue losses are	2008	FOCBS, in collaboration with FOEN and SECO	IE [e]	IE [e]

					compensated by increasing tax rates on liquid fossil motor fuels.				
International exhaust gas regulations (NMVOC) *	Indirect CO_2	Improvement of air quality through O_3 abatement.	Regulatory	Implemented	Limits for NMVOC emissions of motor vehicles, also leading to a reduction of indirect CO_2 emissions.	1974	FEDRO	200	200
CO_2 emissions standard for aircraft *	CO_2	Reduction of average fuel consumption and CO_2 emissions from new and in-production aircraft.	Regulatory	Implemented	CO_2 emission targets for new aircraft designs from 2020, for in-production aircraft from 2023 and production cut-off from 2028.	2020	FOCA	NA [f]	250
Carbon offsetting and reduction scheme for international civil aviation (CORSIA)	CO_2	Carbon neutral growth of international civil aviation as of 2020.	Regulatory	Implemented	Emissions from international civil aviation above 2020 levels will have to be offset by operators. Applicable standards and recommended practices are currently being developed by the International Civil Aviation Organisation.	2020	FOCA, FOEN	NA [f]	NE [g]
Non-volatile particle matter emission regulation for aircraft engines	Non-CO_2	Reduction of the number of emitted soot particles for new engine designs.	Regulatory	Adopted	Coated soot particle emissions are directly connected to ice particle generation, cloud formation and the optical properties of clouds. Emission reductions positively affect the non-CO_2 impact of aviation.	2023	FOCA	NA [f]	–20 % in particle emissions [h]
Sustainable aviation fuel policy	CO_2, non-CO_2	Production and use of low fossil carbon aviation fuels.	Regulatory	Planned	Introduction of sustainable aviation fuel with blending mandate for fuel suppliers, support for production upscaling and research to improve technologies, especially for renewable synthetic fuels.	2025	FOCA, FOEN	NA [f]	100

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] The mitigation impact of the energy label for new motor vehicles is included in the mitigation impact of the CO_2 emission regulations for newly registered vehicles.

[c] Total domestic reductions achieved by the Climate Cent Foundation during the first commitment period (2008–2012) was 2.7 million tonnes of CO_2 equivalents. The ongoing mitigation impact of Climate Cent Foundation projects after 2012 is contained in the subsequent measure 'Partial compensation of CO_2 emissions from motor fuel use'. Total contribution of international carbon credits acquired by the Climate Cent Foundation during the first commitment period (2008–2012) was 16.0 million tonnes of CO_2 equivalents.

[d] For 2025, the mitigation impact cannot yet be estimated, because the share of CO_2 emissions from motor fuels to be offset by fuel importers of motor fuels remains to be defined for the years beyond 2024.

[e] The mitigation impact of the mineral oil tax reduction on biofuels and natural gas is included under the partial compensation of CO_2 emissions from motor fuel use. For 2020, domestic emission reduction projects that bring biofuels on the market achieved an estimated mitigation impact of about 500 thousand tonnes of CO_2.

[f] The mitigation impact of these policies and measures will develop after 2020.

[g] The mitigation impact of the CO_2 emissions standard for aircraft has been overruled by a much stronger impact resulting from the corona virus pandemic. In 2020, CO_2 emissions from international aviation departing Switzerland fell by 64 per cent. Due to the difficulties in estimating the future short to medium-term course of international civil aviation, no mitigation impact is currently available for 2025.

[h] There is no methodology yet to translate the reduction of soot number and mass emissions into CO_2 equivalents.

IE, included elsewhere; NA, not applicable
FOCBS, Swiss Federal Office for Customs and Border Security; FEDRO, Swiss Federal Roads Office; FOCA, Swiss Federal Office of Civil Aviation; FOEN, Swiss Federal Office for the Environment; FOT: Swiss Federal Office of Transport; SECO, Swiss State Secretariat for Economic Affairs; SFOE, Swiss Federal Office of Energy

4.4.2 CO_2 emission regulations for newly registered vehicles

Because a voluntary agreement signed in 2002 by the Association of Swiss Automobile Importers to reduce the specific fuel consumption of first-time registration cars was insufficient, the Swiss Parliament amended the CO_2 Act in 2011 to include CO_2 emission regulations for newly registered vehicles. The prescriptions have entered into force in July 2012, based on the regulations in the European Union. In the first phase from 2012 through 2019, a fleet average target of 130 grams of CO_2 per kilometre was applied. In consequence, the fleet average emission of new cars decreased from 155 grams of CO_2 per kilometre in 2011 to 138 grams of CO_2 per kilometre in 2019. As of 1 January 2020, targets of 95 grams of CO_2 per kilometre for new passenger cars and of 147 grams of CO_2 per kilometre for light commercial vehicles have entered into effect as part of the Energy Strategy 2050 (section 4.3.1). For new cars, average fleet emissions stood at 124 grams per kilometre in 2020. For new light commercial vehicles, emissions have decreased from 214 grams of CO_2 per kilometre in 2011 to 176 grams in 2020. Most vehicle importers reached their individual targets. The CO_2 emission regulations for newly registered vehicles are enforced by a sanction mechanism (see also section 4.1.2). Sanctions payed by those importers with excess emissions amounted to 148 million Swiss francs for both vehicle categories in 2020. From

2021 onward, the targets are translated to account for the change to the new Worldwide Harmonised Light Vehicle Test Procedure (118 grams of CO_2 per kilometre for cars, 186 grams of CO_2 per kilometre for light commercial vehicles).

Planned strengthening

The third CO_2 Act – as rejected on 13 June 2021 – would have included strengthened emission reduction targets for new cars, vans and heavy duty vehicles in line with the regulation of the European Union. For 2025 onward, the Swiss Federal Council still plans to further strengthen the CO_2 targets for new cars and vans along the lines of the Regulation (EU) 2019/631 of the European Union. The new version of the third CO_2 Act thus comprises targets defined as a percentage reduction from the 2021 starting points (industry-wide average target levels according to the Worldwide Harmonised Light Vehicle Test Procedure): (i) 15 per cent reduction for new cars and vans from 2025 onward, (ii) 37.5 per cent reduction for new cars as well as 31 per cent reduction for new vans from 2030 onward.

Estimate of mitigation impact

The mitigation impact is estimated at 210 thousand tonnes of CO_2 equivalents per year in 2020 and 550 thousand tonnes of CO_2 equivalents per year in 2025 (Tab. 19 and BR CTF table 3, see also *SFOE*, 2017). This mitigation impact is calculated by comparing a scenario where the new vehicle fleets attain the implemented targets from 2020 onward with only little delay to a scenario where only autonomous technological progress leads to a slower decrease of specific CO_2 emissions. Due to ongoing fleet turnover, the average mitigation impact in the period from 2020 to 2030 amounts to 460 thousand tonnes of CO_2 per year. No estimate is available for the mitigation impact of the planned strengthening for the years 2025 and 2030.

4.4.3 Energy label for new motor vehicles

Since 2003, the compulsory energy label for newly sold cars has informed customers at the point of sale about fuel consumption, specific CO_2 emissions and energy efficiency. The energy label ensures transparency when buying a car and serves to make the different drive technologies comparable. It also serves as the basis for calculating motor vehicle tax in certain cantons. It classifies cars into one of seven energy efficiency classes from A to G using well-to-wheel energy consumption. Evaluation criteria are adapted at yearly intervals to follow technological development in the automotive sector. The label as well as the customer information regulations have been strengthened from January 2020 onward. Curb mass of new vehicles is not considered any more for energy efficiency classification, while new car advertisements and online configurators have to display the colour band efficiency rating. The customer information regulations have been extended to light commercial vehicles. Further strengthening is planned as of 1 January 2023 in that the classification criteria are anchored to the CO_2 target values and the classification process will consider the uneven distribution of the vehicle range across the different drivetrain technologies. The energy label supports the efforts with regard to the CO_2 emission regulations for newly registered vehicles (section 4.4.2).

Estimate of mitigation impact

The energy label for new motor vehicles is a purely informative measure for car buyers. An estimate from 2005 found a positive impact on energy efficiency. However, there is no recent quantitative estimate. Surveys demonstrate that energy efficiency and low fuel consumption are important criteria for the purchase of new cars and the energy label is known among a majority of car buyers. A positive overall impact on energy efficiency is expected. In any case, the mitigation impact of the energy label for new motor vehicles is included in the mitigation impact of the CO_2 emission regulations for newly registered vehicles (section 4.4.2), and, thus, reported as ‘included elsewhere’ in Tab. 19 and BR CTF table 3.

4.4.4 Climate Cent

The first CO_2 Act in 1999 (section 4.2.2) did not contain a CO_2 levy on motor fuels. Instead, the federal government entered into a voluntary agreement with the Climate Cent Foundation, a private sector initiative, in 2005. The agreement contained the obligation to account for annual emission reductions of 3.2 million tonnes of CO_2 equivalents through international carbon credits (CERs, ERUs) and 0.4 million tonnes of CO_2 equivalents through domestic emission reduction projects, respectively, during the period 2008–2012. The so-called ‘Climate Cent’, setting a surcharge of 0.015 Swiss francs per litre on motor fuels, was levied from October 2005 to August 2012.

As of 2013, the Climate Cent was replaced by the legally binding obligation for importers of fossil motor fuels to compensate part of the emissions linked to fossil motor fuel use (section 4.4.5). Excess revenues amounting to 150 million Swiss francs – collected by the Climate Cent Foundation until 2012 – are to be used by the foundation for the acquisition of international carbon credits. These will be handed over to the Swiss government to meet obligations under the international climate regime, as detailed in an agreement between the Climate Cent Foundation and the federal government (*Climate Cent Foundation and Swiss Confederation*, 2013).

Estimate of mitigation impact

The Climate Cent was implemented from 2005 to 2012. The ongoing mitigation impact of projects of the Climate Cent Foundation after 2012 is contained in the subsequent measure partial compensation of CO_2 emissions from motor fuel use (section 4.4.5). During the first commitment period of the Kyoto Protocol (2008–2012), the international carbon credits acquired by the Climate Cent Foundation accounted for 16.0 million tonnes of CO_2 equivalents, while domestic reductions achieved by the Climate Cent Foundation during the same time period accounted for 2.7 million tonnes of CO_2 equivalents (*Climate Cent Foundation*, 2013). As the Climate Cent has expired, the mitigation impact for 2020 is indicated as 'not applicable' in Tab. 19 and BR CTF table 3.

4.4.5 Partial compensation of CO_2 emissions from motor fuel use

Since 2014, fossil fuel importers have been bound to offset part (at most 40 per cent) of the CO_2 emissions from motor fuels sold in Switzerland through investments in domestic emission reduction projects based. The offset is financed by a surcharge on imported fuels which shall not exceed 0.05 Swiss francs per litre of fuel. The Swiss Federal Council determined the share of CO_2 emissions from motor fuels to be offset by fuel importers within Switzerland as follows:

- Two per cent in 2014–2015;
- Five per cent in 2016–2017;
- Eight per cent in 2018–2019;
- Ten per cent in 2020;
- 12 per cent in 2021.

As of 2022, the share of CO_2 emissions from motor fuels to be offset by fuel importers within Switzerland shall be at least 15 per cent. The total share, to be reach by means of emission reduction projects within Switzerland and abroad, shall be:

- 17 per cent in 2022;
- 20 per cent in 2023;
- 23 per cent as of 2024.

The revenues and climate change abatement measures are managed by the Foundation for Climate Protection and Carbon Offset (KliK), the follow-up organisation to the Climate Cent Foundation (see section 4.4.4). By the end of 2015, KliK has been budgeting for the compensation of a cumulative total of 6.5 million tonnes of CO_2 equivalents for the years 2013 to 2020, achieved by national projects and programmes, as well as the purchase of eligible domestic carbon credits (*KliK*, 2016). The budget estimate corresponds to a surcharge of 0.01 to 0.02 Swiss francs per litre of fossil motor fuel.

For domestic emission reduction projects in order to fulfil the mandatory compensation of CO_2 emissions from motor fuel use, the Swiss Federal Office for the Environment may issue tradable attestations. Domestic emission reduction projects must be registered in advance and the emission reductions achieved must be accounted for annually in a monitoring report. Attestations can only be issued for voluntary measures that go beyond legal requirements and that are not already supported otherwise. Those with compensation obligations can initiate domestic emission reduction projects themselves – in a slightly different form – but cannot receive attestations for them. Domestic emission reduction projects cover a variety of different technological areas such as energy efficiency on the supply and demand side, renewable energy, fuel switch, transport, avoidance of emissions of CH_4, N_2O and F-gases, biological sequestration, and others. A detailed list of domestic emission reduction projects in these various technological areas is available on the website of the

Swiss Federal Office for the Environment[40], where the expected and actual emission reductions from currently registered domestic emission reduction projects are presented as well.[41]

Planned strengthening

It is planned to continue and strengthen the partial compensation of CO_2 emissions from motor fuel use in the framework of the third CO_2 Act (4.2.4). The proposal by the Swiss Federal Council contains the following cornerstones: (i) the Swiss Federal Council determines the share of CO_2 emissions from motor fuels to be offset by fuel importers at a maximum of 90 per cent, and (ii) the Swiss Federal Council can determine a share of emissions to be compensated domestically. The maximum permissible price surcharge that fuel importers are allowed to pass on to consumers shall not exceed five centimes per litre. Additionally, a single measure is now to ensure the admixture of renewable fuels. Instead of indirectly via CO_2 compensation in combination with tax relief (as under the current legislation), fuel importers are to be directly obliged to reduce a certain percentage of CO_2 emissions from transport by placing renewable fuels on the market. The Swiss Federal Council is to determine this proportion within a range of five to ten per cent.

Estimate of mitigation impact

For 2020, the Swiss Federal Office for the Environment has issued attestations corresponding to about 1,300 thousand tonnes of CO_2 equivalents. Three quarters of this mitigation impact comes from three projects that either increase carbon fixation in long-living harvested wood products or promote the use of biogenic fuels. For 2025, the mitigation impact cannot yet be estimated, because the share of CO_2 emissions from motor fuels to be offset by fuel importers of motor fuels remains to be defined for the years beyond 2024. Nevertheless, the mitigation impact is considered to increase substantially in future years (with likely a substantial share achieved abroad), depending on the pending final decision on the share of CO_2 emissions from motor fuels to be offset by importers of motor fuels. Accordingly, in Tab. 19 and in BR CTF table 3, the mitigation impact of the partial compensation of CO_2 emissions from motor fuel use indicated as 1,300 thousand tonnes of CO_2 equivalents for 2020 and as 'not estimated' for 2025.

4.4.6 Heavy vehicle charge

Switzerland's freight transport policy is based on Article 84 of the Federal Constitution of the Swiss Confederation (as amended in 1994) which requires transalpine freight transport to be shifted from road to rail. This goal is to be reached by the so-called heavy vehicle charge, in combination with measures to improve competitiveness of international rail transport. Since 2001, passenger and freight transport vehicles of more than 3.5 tonnes of gross weight have been charged a fee, calculated according to three criteria: (i) kilometres travelled on Swiss roads, (ii) vehicle specific maximum authorised gross weight, and (iii) pollutants according to EURO classes. The heavy vehicle charge was implemented in three stages between 2001 and 2008, accompanied by increasing permissible maximum weight for trucks (40 tonnes instead of 28 tonnes). As of July 2021, the charge has been increased, depending on the vehicle class (EURO 1 – EURO 5 currently at 3.10 Swiss francs per hundred tonne kilometres, and EURO 6/VI currently at 2.28 Swiss francs per hundred tonne kilometres[42]). Heavy vehicles with electric or hydrogen drive are currently exempt from the fee. One third of net revenue goes to the cantons which use their allocation mainly to meet their share of the uncovered road transport costs. Two-thirds of net revenue goes to the federal government which uses its share primarily to finance major public transport projects such as the new transalpine rail links, the links to the European high-speed network as well as for the rail noise control programme.

Estimate of mitigation impact

The fee has prompted a significant renewal of the truck fleet in the year before its introduction. This was due to the fact that the charge depends on the maximum weight and on emissions standards of the individual vehicle. The heavy vehicle charge results in a positive overall environmental balance, in particular thanks to reduced emissions of air pollutants and greenhouse gases from road freight transport. According to model calculations for the year 2005 (*ARE*, 2007), air quality has improved by 10 per cent (particle emissions) and 14 per cent (nitrogen oxides), respectively. CO_2 emissions have decreased by six per cent compared to a scenario without the introduction of the heavy vehicle charge (and with a weight

[40] https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/verminderungsmassnahmen/kompensation/inland/registrierte-projekte.html

[41] https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/verminderungsmassnahmen/kompensation/inland/wirkung.html

[42] https://www.ezv.admin.ch/ezv/de/home/information-firmen/transport--reisedokument--strassenabgaben/schwerverkehrsabgaben--lsva-und-psva-/lsva---allgemeines---tarife.html

limit of 28 tonnes). In the absence of more recent estimates, it is assumed that the heavy vehicle charge has persistently led – and will continue to lead – to a reduction of CO_2 emissions from road freight transport by six per cent compared to a scenario without its introduction. Application of these assumptions to the (reported or projected) emissions of road freight transport suggests a mitigation impact of the heavy vehicle charge of about 100 thousand tonnes of CO_2 in 2020 and of about 120 thousand tonnes of CO_2 in 2025 (Tab. 19 and BR CTF table 3).

4.4.7 Mineral oil tax reduction on biofuels and natural gas

A mineral oil tax is usually levied on sales of mineral oils (see section 2.6). On 1 July 2008, an amendment to the Mineral Oil Tax Act entered into force, providing tax incentives for low carbon fuels. A tax reduction of 0.4 Swiss francs per litre of gasoline equivalent has been granted for natural gas and liquefied petroleum gas. Complete tax exemptions for biogas and other renewable fuels have been granted, if certain criteria are met. In March 2014, the Swiss Parliament decided to tighten these criteria by amending the Mineral Oil Tax Act as well as the Environment Protection Act. Since then, the ecological criteria have been: (i) a minimum of 40 per cent greenhouse gas reduction based on life cycle analysis (LCA), (ii) a net environmental burden not significantly exceeding the one of fossil fuels, and (iii) the cultivation of biofuels must not endanger biodiversity, in particular rainforests. Minimum requirements for socially acceptable production conditions have been: (i) social legislation applicable at the production location of raw materials and fuels is respected, (ii) at least the fundamental conventions of the International Labour Organisation (ILO) are complied with, and (iii) cultivation of biofuels has to be realised on legally acquired soils. Tax revenue losses have been counterbalanced by increasing tax rates on liquid fossil motor fuels. In contrast to other countries, Switzerland has no quotas for biofuels. The mineral oil tax reduction on biofuels and natural gas was extended until 2024 following a decision by the Swiss Parliament.

Planned strengthening

The Swiss Federal Council proposed in the new version of the third CO_2 Act that the CO_2 reduction potential of biofuels shall be exploited with a mandatory quota. Importers of motor fuels shall be bound to reduce at least five per cent and a maximum of ten per cent of their emissions by bringing biofuels on the market. At the same time, the mineral oil tax reduction on biofuels and natural gas shall be extended until the end of 2030.

Estimate of mitigation impact

Current activities that bring biofuels on the market are all registered as domestic emission reduction projects (see also sections 4.4.4 and 4.4.5). Based on the corresponding monitoring reports[43], the mitigation impact of the mineral oil tax reduction on biofuels is estimated at about 500 thousand tonnes of CO_2, corresponding to about four per cent of the emissions of the transport sector (values for 2020). However, because this mitigation impact is already included under the partial compensation of CO_2 emissions from motor fuel use (section 4.4.5), the mitigation impact of the mineral oil tax reduction on biofuels and natural gas is reported as 'included elsewhere' in Tab. 19 and BR CTF table 3 for both, 2020 and 2025 (Tab. 19 and BR CTF table 3).

4.4.8 International exhaust gas regulations (NMVOC)

At the beginning of the 1970s, the first exhaust gas regulations have been introduced in Switzerland. With the goal of limiting emissions of air pollutants (such as CO, NMVOC, NOx, etc.) from vehicles and machineries, numerous subsequent regulations have followed. Since 1995, Switzerland has harmonised its standards with those of the European Union, replacing national regulations with the corresponding directives of the European Union and adopting the dates for their entry into force.[44] The regulations have led to strongly decreasing emissions of air pollutants, e.g. thanks to the implementation of the three-way catalytic converter. Indirect CO_2 emissions have decreased in concert.

Estimate of mitigation impact

In 1990, the emissions of NMVOC of road traffic amounted to about 100 thousand tonnes. In 2020, emissions of NMVOC of road traffic have dropped to below 10 thousand tonnes of NMVOC, and are projected to continue to decrease up to 2025 and beyond. Without measures since 1990, it is assumed that the emission factors would have remained constant,

[43] See projects listed under *https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/verminderungsmassnahmen/kompensation/inland/registrierte-projekte/5-2.html*.

[44] See the following website for more details about the regulations in place: *https://www.bafu.admin.ch/bafu/de/home/themen/luft/fachinformationen/massnahmen-zur-luftreinhaltung/massnahmen-zur-luftreinhaltung-beim-strassenverkehr.html*.

resulting in emissions of around 70 thousand tonnes of NMVOC in 2020 and 2025. Lowering emissions of NMVOC by 60 thousand tonnes results in corresponding lower emissions of indirect CO_2. By 2020 and 2025, the estimated greenhouse gas mitigation impact is about 200 thousand tonnes of CO_2 (Tab. 19 and BR CTF table 3), based on a carbon content of NMVOC of 90 per cent for emissions from combustion engines (diesel oil and gasoline mostly contain hydrocarbons and have a very low content of oxygen, sulphur, nitrogen etc.).[45]

4.4.9 CO_2 emissions standard for aircraft

Switzerland helped in the process for the adoption of the first CO_2 emissions standard for civil aircraft by the International Civil Aviation Organisation, which is the world's first global design certification standard governing CO_2 emissions. In Switzerland, the standard is applicable to Swiss registered new relevant aircraft type designs from 2020. It will also apply to relevant aircraft type designs already in production as of 2023. Those in-production aircraft which by 2028 do not meet the standard will no longer be able to be produced unless their designs are sufficiently modified.

Estimate of mitigation impact

Because the CO_2 emissions standard for aircraft will develop its mitigation impact after 2020, the mitigation impact for 2020 is reported as 'not applicable' in Tab. 19 and BR CTF table 3. The 2025 impact is estimated as 250 thousand tonnes of CO_2 equivalents. The amount will strongly depend on accelerated phase-out of older aircraft, restructuring and the rate of recovery from the corona virus pandemic.

4.4.10 Carbon offsetting and reduction scheme for international civil aviation (CORSIA)

In 2017, the International Civil Aviation Organisation assembly decided to introduce the so-called carbon offsetting and reduction scheme for international civil aviation (CORSIA). Under this scheme the CO_2 emissions of international air transport which exceed the levels of the year 2019 will have to be offset by the air traffic operators. Already in 2017, Switzerland has announced its willingness to participate in the scheme together with the 43 other member states of the European Civil Aviation Conference. Applicable standards and recommended practices for the scheme are in force, which includes the standards for eligible CO_2 compensation projects and eligible renewable fuels (sustainable aviation fuels with fossil carbon reduction based on life-cycle emissions standards). The pilot phase with more than 100 participating countries including Switzerland has started.

Estimate of mitigation impact

Emissions of international civil aviation activities exceeding 2019 levels covered by the scheme will be offset (carbon neutral growth on the basis of 2019). As the pilot phase started in 2020, the mitigation impact of this measure will develop after 2020 and is reported, for 2020, as 'not applicable' in Tab. 19 and BR CTF table 3. In 2020, the CO_2 emissions for international flights departing Switzerland fell by 64 per cent due the corona virus pandemic. In consequence, none of the remaining CO_2 emissions in 2020 was compensated. The corona virus pandemic had an emission reduction effect which surpassed any planned market-based reduction measure. Due to the difficulties in estimating the future short to medium-term course of international civil aviation, no mitigation impact is currently available for 2025 (Tab. 19 and BR CTF table 3 thus indicate 'not estimated').

4.4.11 Non-volatile particle matter emission regulation for aircraft engines

Switzerland has been a main contributor to the development of the first global regulation for ultrafine particle emissions from aircraft engines, which is applicable worldwide since 2020. The regulation was introduced not only with a view to address health impacts but also to reduce ultrafine soot emissions during cruise substantially. These emissions are an important trigger for aviation non-CO_2 climate impacts. From 2023, new engine types will have to meet regulatory limits, which are approximately 30 per cent more stringent than for current in-production engines.

[45] In the greenhouse gas inventory, the oxidation factors used to calculate CO_2 emissions from road traffic are assumed to be 100 per cent. Accordingly, indirect CO_2 emissions resulting from the atmospheric oxidation of NMVOCs are already included under direct CO_2 emissions in this case (see section 3.2.4 for more details). The values related to indirect CO_2 emissions provided in chapter 3 and chapter 5 (section 5.3.6) strictly avoid double counting.

Estimate of mitigation impact

There is currently no method available for converting climate impacting particle cruise emissions into CO_2 equivalents. Emissions reduction potentials depend on fleet renewal but roughly, a 20 per cent reduction in the number of emitted particles in 2025 seems to be possible (relative to fuel consumption).

4.4.12 Sustainable aviation fuel policy

In the framework of the new version of the third CO_2 Act, it is planned to introduce a sustainable aviation fuel blending mandate for aviation fuel suppliers, in coordination with the ReFuel programme in the European Union. Starting in 2025, the aviation fuel made available should contain two per cent of sustainable aviation fuel, with this share increasing over time. Furthermore, it is planned to support research for technology improvements and upscale of plants which produce the most environmentally sustainable aviation fuels in the longer term.

Estimate of mitigation impact

The amount of sustainable aviation fuel blending will be limited by the amount of acceptable market distortion (due to higher fuel price) and the availability of fuels meeting the sustainability criteria. If the measure is successfully implemented, around two per cent of fossil CO_2 emissions from bunker fuels – corresponding to about 100 thousand tonnes of CO_2 – could be avoided at the beginning of the measure (by 2025). Technically, up to 50 per cent of sustainable aviation fuel blend is possible to be used with the current aircraft fleet.

4.4.13 Further relevant measures

This section provides a brief overview of further measures with limited direct impact on greenhouse gas emission levels, e.g. measures that may indirectly contribute to climate policy goals (e.g. by reducing precursor gas emissions) and measures focussing on non-greenhouse gas emissions that may have favourable side effects on climate change mitigation.

Further measures to promote rail transport

With the opening of the Ceneri Base Tunnel and the commissioning of the four-metre corridor, the project New Rail Links through the Alps has been completed in 2020. However, a ramp-up phase is still needed before the new infrastructure is fully operational and the new productivity and modal shift potential can fully be exploited. The modernisation of the access routes in neighbouring countries is behind schedule, so that favourable production conditions for rail freight transport are not yet available along the entire north-south rail corridor. By building the three new base tunnels and by upgrading the access routes, Switzerland has managed to bring the north and south of the country – as well as Europe – closer together. Journey times between north and south are reduced by up to one hour for passengers, whilst the flat link increases rail’s environmentally-friendly credentials for freight traffic.

Various accompanying measures on the road and rail side are applied at different points in the value chain of freight transport. Without the central instruments (the heavy vehicle charge and the project New Rail Links through the Alps) and the accompanying measures, an additional 800,000 heavy goods vehicles would cross the Alps in Switzerland every year.

The land transport agreement between Switzerland and the European Union secures the Swiss policy and the modal shift efforts in the European context. The European Union respects the Swiss policy objectives and the necessary measures taken (in particular the heavy vehicle charge).

Switzerland is strongly committed to further simplify and strengthen cross-border rail transport. This goal is pursued by reducing obstacles and dismantling existing national requirements. The work to implement the technical pillar of the 4th European Union railway package has been launched. Switzerland is involved in the Netherlands’ initiative to promote international passenger rail transport within the framework of a European platform created for this purpose. The Swiss focus lies on improving customer-friendly international ticketing and contributing its experience in the planning of supply-oriented interval timetables and instruments of train path protection to strengthen the ‘Trans-Europe-Express 2.0’ initiative, which was launched in 2020 as part of Germany’s Presidency of the Council of the European Union.

Greenhouse gas emissions from marine bunker fuels

As a landlocked country, Switzerland operates only a small fleet of ships at the international level. Consequently, greenhouse gas emissions from marine bunker fuels are negligible (see Tab. 4) and only include emissions from fuel sold within the borders of Switzerland for international transport on the Lake Geneva, Lake Constance, and the Rhine. Nevertheless, in the framework of its membership to the International Maritime Organisation (IMO), Switzerland supports the introduction and further strengthening of obligations to reduce greenhouse gas emissions from international navigation. Switzerland ratifies, as a basic principle, all environmentally relevant international agreements related to international navigation and implements them, as required, in domestic legislation. On the basis of Article 9 of the Maritime Navigation Act, the compliance with international agreements and domestic legislation is enforced by inspections by the Swiss Maritime Navigation Office or by its recognised organisations.

Air pollution control measures at cantonal and communal level

The cantons are in charge of the implementation of the Ordinance on Air Pollution Control. Within the transport sector, the most important measures include speed reduction in city areas, parking space management and programmes for renewing bus fleets (installation of CRT particle filters). The annual cantonal motor vehicle tax depends on different parameters such as vehicle weight and engine capacity, which provides an incentive to buy and use cars that are more fuel efficient. Moreover, many cantons have adopted rebate and feebate regimes for cars, based on criteria such as the energy label category, fuel or drivetrain type, and specific CO_2 emissions.

Euro emission standards

Switzerland is following the European path of reducing air pollutants (NO_x, non-methane hydrocarbons, total hydrocarbons, CO, and particulate matter) by introducing stricter Euro emissions standards for new vehicles. Since 2015, the Euro 6/VI standard has been mandatory for new vehicles. With regard to reducing particulate matter and diesel soot emissions, particle filter trap systems have been introduced for various types of vehicles.

Gothenburg Protocol

In 2005, Switzerland ratified the Gothenburg Protocol to abate acidification, eutrophication and ground-level ozone (under the Geneva Convention on Long-range Transboundary Air Pollution within the framework of the United Nations Economic Commission for Europe). The implementation of this protocol and compliance with the prescribed national emission ceilings contributes to the reduction of ozone and secondary particulate precursors. It also contributes to avoiding emissions of indirect greenhouse gases. Up to the present, Switzerland fulfilled the different commitments which are included. The Gothenburg Protocol was revised in 2012 and the amended protocol has been in force since 2019. The revised version also addresses particulate matter (PM2.5) and black carbon. It contains national emission reduction commitments for sulphur dioxide, nitrogen oxides, ammonia, volatile organic compounds and particulate matter for 2020 and to be maintained beyond. The obligations of the Gothenburg Protocol include the application of best available techniques and emission limit values for various industrial and mobile sources, as well as for combustion installation and agriculture. The implementation of the Gothenburg Protocol creates benefits for human health, ecosystems (air, water, soils, vegetation) and materials, i.e. the impacts are thus not limited to the transport sector. According to the submission 2022 of the emission data for 2020, it appears that Switzerland achieved the targeted national emission reduction commitments.

4.5 Industrial processes and product use

4.5.1 Overview

Most greenhouse gas reduction policies and measures in the industry sector are implemented under the CO_2 Act and target CO_2 emissions from fossil fuel use. These policies and measures are presented together with the cross-sectoral policies and measures (section 4.2). The main instruments affecting greenhouse gas emissions from industry are (i) the CO_2 levy on heating and process fuels (section 4.2.5), (ii) the emissions trading scheme (section 4.2.6), and (iii) the negotiated reduction commitments (for exemption from the CO_2 levy) (section 4.2.7).

However, emissions of F-gases and precursor gases – such as NMVOCs – are not tackled by the CO_2 Act. Instead, specific policies and measures have been developed on the basis of the Environmental Protection Act and specified in the Ordinance on Chemical Risk Reduction (*Swiss Confederation*, 2005a), the Ordinance on Air Pollution Control (*Swiss Confederation*, 1985), as well as in the Ordinance on the Incentive Tax on Volatile Organic Compounds (*Swiss Confederation*, 1997). NMVOCs are used as solvents in numerous industries, are contained in many products such as paints, varnishes and various cleaning solutions, and are emitted by industrial processes, product use and by incomplete fuel combustion. If these compounds become airborne, they contribute (together with nitrogen dioxide) to the excessive formation of ground-level ozone (summer smog). In addition, NMVOCs oxidise in the atmosphere within days and are, thus, a source of indirect CO_2 emissions. In order to reduce NMVOC emissions, Switzerland has three policies and measures in place: (i) the international exhaust gas regulations for motor vehicles, which are fully implemented in Swiss regulations and where Switzerland is highly involved in the development (reported under the transport sector, see section 4.4.8), (ii) the Ordinance on Air Pollution Control for stationary sources (section 4.5.3), and (iii) the NMVOC incentive fee to reduce diffuse emissions of NMVOCs (section 4.5.4). Regarding the reduction of F-gas emissions, provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, and NF_3) are in place (section 4.5.2).

The policies and measures of the industrial processes and product use sector are summarised in Tab. 20 and detailed in the following sections.

Tab. 20 > Summary of policies and measures in the industry sector. The sector affected is 'industry/industrial processes' for all policies and measures presented in this table.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq)	
								2020	2025
Provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3) *	All F-gases	Reduction in consumption and emissions of F-gases. The reduction in consumption aims to meet the phase-down schedule for Switzerland under the Kigali-Amendment of the Montreal Protocol.	Regulatory	Implemented (strengthening planned)	Regulations relating to, inter alia, refrigerants, aerosol dispensers, plastic foams, solvents containing PFCs, HFCs or HFEs, extinguishing agents, and SF_6 in electrical distribution equipment.	2003	FOEN, cantons	1 113 [b]	1 566 [b]
Ordinance on Air Pollution Control *	Indirect CO_2	Improvement of air quality through O_3 abatement.	Regulatory	Implemented	Limits for NMVOC emissions of stationary installations, also leading to a reduction of indirect CO_2 emissions.	1986	FOEN, cantons	IE [c]	IE [c]
NMVOC incentive fee *	Indirect CO_2	Improvement of air quality through O_3 abatement.	Economic	Implemented	Market-based instrument to reduce NMVOC emissions, also leading to a reduction of indirect CO_2 emissions.	2000	FOCBS	380	380
Obligations in relation to chemical conversion processes (N_2O) *	N_2O	Reduction of N_2O emissions as by-product in the manufacture of chemical substances.	Regulatory	Implemented	N_2O generated as a by-product must be converted in accordance with the state of the art provided this is technically and operationally feasible and economically viable.	2022	FOEN	NA	550

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] Values by gas:
2020: HFCs ➔ 1,062 kt CO_2eq, PFCs ➔ 2 kt CO_2eq, SF_6 and NF_3 ➔ 69 kt CO_2eq
2025: HFCs ➔ 1,469 kt CO_2eq, PFCs ➔ 9 kt CO_2eq, SF_6 and NF_3 ➔ 88 kt CO_2eq

[c] The estimate of mitigation impact is included under the 'NMVOC incentive fee'.

IE, included elsewhere
FOCBS, Swiss Federal Office for Customs and Border Security; FOEN, Swiss Federal Office for the Environment

4.5.2 Provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3)

The three main lines of action in the area of F-gases are: (i) to limit the use of these substances to those applications where there is no alternative at the current state of technology, (ii) when such substances are used, to reduce emissions as far as possible, and (iii) where feasible, to engage in voluntary binding agreements with industry.

F-gases are regulated in the Ordinance on Chemical Risk Reduction under the name of 'substances stable in the atmosphere', including fluorinated substances, such as HFCs, PFCs, SF_6, NF_3 and HFEs (*Swiss Confederation*, 2005a). In particular, Annex 1.5 of the Ordinance on Chemical Risk Reduction contains general provisions to control their use and emissions, labelling requirements for containers and switchgear, and a licensing scheme for the import and export of HFCs (to fulfil Switzerland's obligations under the Kigali Amendment to the Montreal Protocol). Further provisions on specific uses of F-gases are covered in other annexes of the Ordinance on Chemical Risk Reduction (see below).

Refrigerants

Emissions of refrigerants from stationary equipment dominate total F-gas emissions. Therefore, the regulations in Annex 2.10 of the Ordinance on Chemical Risk Reduction most importantly aim at reducing emissions from such stationary equipment. Further provisions are in place to regulate appliances working with F-gases as refrigerants.

Refrigerants containing F-gases have been regulated since 2003. In 2004, the placing on the market of stationary equipment containing more than three kilograms of F-gases has been subjected to a permit, being contingent on the conditions that no alternative at the current state of technology was available and emissions were reduced as far as possible. In 2012, provisions were added that limit refrigerant charges in certain types of equipment. In 2013, a partial ban has replaced the permit mentioned above. This ban applies to the placing on the market of certain types of stationary equipment containing F-gases, depending on the cooling capacity, the global warming potential of the refrigerant, and the sector of use. The ban has been tightened twice, in 2015 and 2019, respectively. In 2019, additionally a restriction to the servicing of stationary equipment with refrigerants with a high global warming potential has been introduced, along with additional bans on certain types of appliances operating with F-gases where state of technology alternatives are available. The state of technology is published and updated regularly after consulting with the sectors concerned. To ensure the transparency and proportionality of the relatively complex system, several technical guidelines relating to the relevant technology and to the implementation of the various measures to improve confinement have been developed in collaboration with cantonal authorities and the sectors concerned.

Aerosol dispensers

In the area of aerosol dispensers, emissions of F-gases (mainly HFCs) are limited by restrictions on use in Annex 2.12 of the Ordinance on Chemical Risk Reduction. Applications for which exemptions are inevitable are medical and pharmaceutical applications, in particular metered dose inhalers. For other applications where these substances may be required, e.g. for safety reasons, the state of technology is changing rapidly, and it seems more appropriate to use the option of granting temporary exemptions based on individual technically justified requests.

Plastic foams

The measures currently implemented in Switzerland with regard to plastic foams (such as restrictions on their use in Annex 2.9 of the Ordinance on Chemical Risk Reduction and further provisions for their disposal by incineration and recycling) limit emissions of F-gases from those foams. F-gases (mainly HFCs) may only be used in plastic insulating foams and under severe restraints: (i) if they offer significant advantages in thermal insulating efficiency in case of spatial constraints and (ii) where non-flammability is required, in agreement with the current state of technology. Rapidly advancing technology requires that the state of technology and application criteria need to be clarified in guidelines developed and updated in collaboration with the producers and professional users, as well as with the cantonal enforcement authorities.

Solvents containing HFCs, PFCs or HFEs

The use of solvents containing HFCs, PFCs or HFEs is currently restricted in Annex 2.3 of the Ordinance on Chemical Risk Reduction to surface treatment installations with specific technical characteristics to reduce emissions. Exemptions can be given to further uses (in practice almost exclusively within the electronic and precision industry), in cases where sound alternative technology is not available. To reduce emissions, consumer goods containing such solvents have been banned.

Extinguishing agents

Since 1996, the supply and import of extinguishing agents made of F-gases and of appliances or stationary equipment containing such agents are banned (Annex 2.11 of the Ordinance on Chemical Risk Reduction). However, temporary exemptions are granted in cases where no viable alternatives are available.

SF_6 in electrical distribution equipment

The use of SF_6 is only authorised in particle accelerators and electrical equipment that operates at more than one kilovolt, whose gas compartment is hermetically sealed or constantly monitored. The emissions of SF_6 from this sector are governed by a voluntary agreement established in 2002 by the high-voltage industry, which was updated in 2014 and 2020.[46] The maximum amount of annual emissions agreed was 4.5 tonnes until 2012, decreasing to 3.65 tonnes in 2020 and to 1.35 tonnes thereafter. Further, recovery of SF_6 from decommissioned equipment must be guaranteed.

Other application sectors

The use of PFCs and SF_6 in tyres, insulating windows and sport shoes is banned since 2003. SF_6 as protecting gas in magnesium and aluminium smelting was banned after 31 December 2016. Other uses can be authorised temporarily upon request if it is shown that there is no environmentally superior alternative and that emission levels are kept to a minimum according to the best available techniques.

Furthermore, under Annex I of the Ordinance concerning Lists Regarding the Movement of Waste, waste containing HFCs counts as special waste. Thus, the movement of such waste is controlled, and it must be treated by licensed enterprises in an environmentally sound manner.

Planned strengthening

In order to fulfil Switzerland’s obligations under the Montreal Protocol and its Kigali Amendment (in particular the phase down of HFC consumption to 15 per cent of its baseline until the year 2036), the Ordinance on Chemical Risk Reduction is expected to be revised regularly with a view to further restricting the uses of HFC, where the evolving state of technology provides new alternatives.

Estimate of mitigation impact

For estimating the mitigation impact, emission scenarios were calculated with and without existing policies and measures (see section 5.3.2; *Carbotech*, 2020). The emission scenarios cover metal production, electrical equipment, refrigerants, solvents, aerosols, foam blowing, electrical equipment, and others. The dominating sector is refrigeration, contributing roughly 80 per cent in total CO_2 equivalent emissions of substances stable in the atmosphere. Input data for projecting the development of this key sector are the statistics available on currently installed stationary equipment, as well as assumptions on future market growth and leakage rates during operation and disposal. As shown in Tab. 20 and BR CTF table 3, the emission modelling suggests a total mitigation impact of 1,113 thousand tonnes of CO_2 equivalents by 2020 and 1,566 thousand tonnes of CO_2 equivalents by 2025 (see also Tab. 28 and Fig. 67).

4.5.3 Ordinance on Air Pollution Control

The Ordinance on Air Pollution Control is based on the Environmental Protection Act and has been in force since 1986. It contains – beside other prescriptions – emission limits for NMVOCs for stationary installations. It also prescribes that emissions shall be captured as fully and as close to the source as possible and shall be removed in such a way as to prevent excessive ambient air pollution levels. Furthermore, it gives the possibility to the authorities to limit emissions preventively as far as technically and operationally feasible and economically acceptable.

Estimate of mitigation impact

The estimate of mitigation impact is included under the NMVOC incentive fee (section 4.5.4), and, thus, reported as ‘included elsewhere’ in Tab. 20 and BR CTF table 3.

4.5.4 NMVOC incentive fee

The NMVOC incentive fee is defined in the Ordinance on the Incentive Tax of Volatile Organic Compounds, which is based on the Environmental Protection Act, and which has been in force since 1997. The incentive fee has been levied since 1 January 2000, amounting to two Swiss francs per kilogram of NMVOC emitted into the air. Since 2003, the fee has been three Swiss francs per kilogram of NMVOC. As a market-based instrument in the field of environmental protection, it creates a financial incentive to further reduce NMVOC emissions.

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46 https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/sector-agreements/agreement-sf6.html

Estimate of mitigation impact

As in Switzerland's last submission, the mitigation impact is estimated based on a hypothetical scenario using real activity data and keeping the emission factors constant from 1990 onwards. The determined reduction of about 173 thousand tonnes of (anthropogenic) NMVOC emissions results from the combined impact of the Ordinance on Air Pollution Control (4.5.3) and the NMVOC incentive fee. Using a carbon content of NMVOC of 60 per cent, the greenhouse gas mitigation impact – due to the reduction of indirect CO_2 emissions[47] – is about 380 thousand tonnes of CO_2 equivalents in 2020 and 2025.

4.5.5 Obligations in relation to chemical conversion processes (N_2O)

Since 1 January 2022, N_2O has newly been regulated under the Ordinance on Chemical Risk Reduction (*Swiss Confederation,* 2005a). This means that companies in the chemical industry have to avoid their N_2O emissions by technical means. According to Annex 1.5 (Number 9, paragraph 2) of the Ordinance on Chemical Risk Reduction, any facility that produces chemical substances such as nitric acid, caprolactam, nicotinic acid (niacin) etc. with N_2O as by-product must convert it in accordance with the state of the art provided this is technically and operationally feasible and economically viable. This amendment to the Ordinance on Chemical Risk Reduction is the political and legislative response to the discovery of a previously unknown source of N_2O from the niacin production process at a specific chemical plant.

Estimate of mitigation impact

First experiences with the catalyst installed at the respective chemical plant in the course of 2021 indicate that about 98 per cent of N_2O emissions can be avoided, corresponding to about 550 thousand tonnes of CO_2 equivalents per year. Accordingly, in Tab. 20 and in BR CTF table 3, the mitigation impact of the obligation in relation to chemical conversion processes (N_2O) is indicated as 550 thousand tonnes of CO_2 equivalents for 2025 and as 'not applicable' for 2020 (as the policy and measure was implemented after 2020).

4.6 Agriculture

4.6.1 Overview

Articles 104 and 104a of the Federal Constitution of the Swiss Confederation form the basis for agricultural policy in Switzerland. They mention sustainability as one of the guiding principles. The Agriculture Act, which came into force in 1999, provides a framework for sustainable development in the agriculture sector. In its Article 2, as amended in 2014, it stipulates that the federal government shall, inter alia, take measures to promote the sustainable use of natural resources as well as animal-friendly and climate-friendly production.

Greenhouse gas emissions in agriculture strongly depend on the portfolio of activities chosen by farmers. An important parameter influencing this decision is the relative economic profit achievable by the different activities. Their attractiveness depends on the price level of agricultural goods and services as well as on the mode and level of agricultural subsidies. Agricultural policy, as it is designed in Switzerland, influences both, prices of agricultural products and subsidies and is therefore an important factor determining the amount of greenhouse gas emissions.

Tab. 21 gives an overview of the climate-relevant policies and measures in the agriculture sector, while the following sections provide more details and background information on each policy and measure.

[47] This estimate includes fossil and biogenic NMVOC emissions. In contrast to the estimates presented here, the values related to indirect CO_2 emissions provided in chapter 3 and chapter 5 (section 5.3.6) only consider fossil carbon and strictly avoid double counting. However, in 1990 almost 80 per cent of NMVOC emissions resulted from the use of solvents anyway.

Tab. 21 > Summary of policies and measures in the agriculture sector. The sector affected is 'agriculture' for all policies and measures presented in this table.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq) 2020	2025
Proof of ecological performance to receive direct payments *	CH_4, N_2O, CO_2	Incentives related to ecological goals.	Economic	Implemented (strengthening planned)	Direct payments are contingent on appropriate soil nutrient balance, suitable proportion of ecological compensation areas, crop rotation system, soil protection, selective application of crop protection agents, and animal husbandry in line with legal provisions.	Early 1990s	FOAG	700	700
Resource programme (subsidies for a more efficient use of natural resources) *	CH_4, N_2O, CO_2	Promotion of efficient use of natural resources.	Economic	Implemented	Subsidising measures for more efficient use of natural resources such as nitrogen, phosphorous and energy, protection and sustainable use of soils, and biodiversity. To qualify for subsidies, measures must go beyond legal requirements or the criteria for other funding programmes.	2008	FOAG	NE [b]	NE [b]
Climate strategy for agriculture *	CH_4, N_2O, CO_2	Long-term mitigation and adaptation in the sector.	Information, planning	Implemented (strengthening planned)	Declaration of intent to reduce greenhouse gas emissions by one third by 2050 compared to 1990 with technical, operational and organisational measures and by another third with measures influencing food consumption and production. Framework for the development, testing and implementation of specific future measures in mitigation and adaptation.	2011	FOAG	NE [c]	NE [c]
Agricultural policy 2014–2017 and 2018–2021 *	CH_4, N_2O, CO_2	More targeted use of the direct payments system.	Economic	Implemented (strengthening planned)	Abolition of unspecific direct payments (livestock subsidies, general acreage payments). Additional funds for environmentally-friendly production systems and for the efficient use of resources, e.g., increase in nutrient efficiency and ecological set-aside areas, reduction of ammonia emissions.	2014	FOAG	300	300
Enhancement of label standards	CH_4, N_2O, CO_2	Reduction of greenhouse gas emissions from agricultural production of label producers by 10 per cent compared to 2016.	Voluntary/negotiated agreement	Planned	Admission of technical measures into the label standards with the goal of reducing greenhouse gas emissions.	2022	IP-SUISSE	0	130

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] The direct impact of the resource programme (subsidies for a more efficient use of natural resources) is considered negligible as most of the projects work with a small pilot group only. The indirect mitigation impact of the programme achieved through spill-over effects cannot be estimated due to the lack of specific information. However, a rather large climate-related project started in 2022 and will have its main effect after 2025.

[c] The climate strategy for agriculture aims at setting out long-term targets to be reached with deduced policies and measures and has, thus, a positive mitigation impact. However, because the measures so far introduced in the framework of the climate strategy for agriculture aim at the exchange and transfer of knowledge, no methodological approaches are available to quantify the mitigation impact.

NE, not estimated
FOAG, Swiss Federal Office for Agriculture; IP-SUISSE, Swiss Association of Integrated Producing Farmers

4.6.2 Proof of ecological performance to receive direct payments

Direct payments are tied to ecological standards, i.e. farmers are eligible for payments only if they fulfil the so-called proof of ecological performance. This is the case when the nutrient balance is maintained, a suitable proportion of farmland is managed as ecological compensation area, a crop rotation system is in place, soil protection is given due consideration, crop protection agents are chosen and applied selectively, and livestock is kept in accordance with legal regulations and animal welfare requirements. Since direct payments are an essential part of the income for most famers, the proof of ecological performance is widespread. Around 90 per cent of all farms receive direct payments and thus are managed according to the guidelines of the proof of ecological performance.[48]

Planned strengthening

One of the measures as proposed by the Swiss Federal Council within the parliamentary initiative 19.475 (*Swiss Confederation*, 2019) will affect the proof of ecological performance. As it is part of the development of the agricultural policy, it is included in section 4.6.5 to prevent double counting.

Estimate of mitigation impact

It is assumed that the introduction of the proof of ecological performance was the main driver for the reductions in agricultural greenhouse gas emissions in the 1990s and early 2000s (about 700 thousand tonnes of CO_2 equivalents). The impact of the introduction of the proof of ecological performance to receive direct payments is clearly reflected in substantial decreases of the main drivers of agricultural greenhouse gas emissions during this time period. Indeed, total cattle decreased by 14 per cent from 1990 to 2000, while total commercial fertiliser decreased by 23 per cent over the same time period (see also Fig. 73). However, other factors like price signals certainly also have contributed to this trends. Therefore, the estimate may represent an upper limit. It is assumed that further reductions in agricultural greenhouse gas emissions due to the proof of ecological performance since the early 2000s have been very limited. Therefore, the mitigation impact is estimated at 700 thousand tonnes of CO_2 equivalents for both, 2020 and 2025. The mitigation impact of the planned strengthening is included in section 4.6.5.

4.6.3 Resource programme (subsidies for a more efficient use of natural resources)

On the basis of an amendment to the Agriculture Act in 2008, a new instrument called resource programme was introduced. Through this programme, the federal government is subsidising measures for the more efficient use of natural resources in the agriculture sector. Target areas are resources such as nitrogen, phosphorous and energy, protection and sustainable use of soils, and biodiversity. To qualify for subsidies, measures must go beyond legal requirements or the criteria for other funding programmes. Support is given to measures that need financial support in an introductory phase, but that will run without further payments afterwards. Therefore, payments are restricted to six years. The specified targets and measures, as well as the spatial dimension and the participation of farms can vary considerably between different projects. In 2021, 51 bottom-up projects have been initiated and half of them are already completed. Approximately one third of the projects deal with ammonia emission reduction, the others contain measures with the aim to improve soil fertility, biodiversity or energy efficiency. From 2016 to 2021, two initiatives with the focus on the reduction of agricultural greenhouse gas emissions were carried out. Other projects in relation to greenhouse gas emissions are focusing on humus (start in 2017), nitrogen use efficiency (start in 2018), use of organic soils (start in 2019) and agroforestry (start in 2020). Two projects with a focus on reduction of greenhouse gas emissions from milk production and soil carbon sequestration will presumably start in 2022. The requirements for projects eligible under the resource programme have been revised in 2014. More emphasis has been given to innovation and accompanying research. With that, the variety of projects has been enhanced and the transfer of know-how beyond the project has been improved.

Estimate of mitigation impact

The mitigation impact of the projects which focus on other aspects than the reduction of greenhouse gas emissions cannot be estimated due to the lack of specific information. The current projects on the mitigation of greenhouse gas emissions target a low number of pilot farms. Their impact is thus negligible. Also, the spill-over effects of the programme remain mostly unclear. Consequently, the mitigation impact for the resource programme (subsidies for a more efficient use of natural resources) is reported as ‘not estimated’ in Tab. 21 and BR CTF table 3.

4.6.4 Climate strategy for agriculture

The climate strategy for agriculture was published in 2011 by the Swiss Federal Office for Agriculture (*FOAG*, 2011). This strategy is a declaration of intent, guiding agriculture and food production in Switzerland in their efforts to reduce greenhouse gas emissions and adapt to a changing climate. It sets out common guidelines and long-term targets and identifies priorities and possible areas where action can be taken. Greenhouse gas emissions by the agriculture sector are to be reduced by at least one-third by 2050 (compared to 1990 levels) through technical and organisational measures.

48 *https://www.agrarbericht.ch/de/politik/direktzahlungen/finanzielle-mittel-fuer-direktzahlungen*

Further reductions are aspired by influencing production structures as well as consumption patterns. At the same time, agricultural production (nutritional energy) as well as other public and ecological services are to be maintained. Implementing activities in the context of the climate strategy for agriculture include: (i) intensification of agricultural research, (ii) development of appropriate legal framework, and (iii) empowerment of the stakeholders concerned.

Since the publication of the climate strategy for agriculture a platform in the fields of renewable energy, energy efficiency and climate change mitigation has been supported with financial aid from the federal government.[49] The aim of the platform is to facilitate the exchange and transfer of knowledge between research, advisory services, industry and farmers. Congresses and workshops are organised, mitigation options identified and tools developed.

Planned strengthening

Currently, the climate strategy for agriculture is being revised. The topic is approached from a holistic food system perspective, allowing to address aspects that go beyond, but influence, agricultural production itself. The revised strategy bases on and concretises existing strategies such as the Switzerland's long-term climate strategy to 2050 (*Swiss Federal Council*, 2021a), the strategy for adaptation to climate change in Switzerland (*Swiss Federal Council*, 2012a) or the 2030 sustainable development strategy (*Swiss Federal Council*, 2021b). New long-term goals for 2050 are set targeting the areas of production as well as nutrition. The agricultural greenhouse gas emissions from Swiss production shall be reduced by 40 per cent by 2050 compared to 1990 and the greenhouse gas footprint of the food consumed by the population living in Switzerland shall be reduced by two thirds by 2050 compared to 2020. The revised strategy will include a set of policies and measures to reach the set goals.

It was previously planned that the reduction target for the agriculture sector set out by the climate strategy for agriculture is made mandatory by including it in the third CO_2 Act (section 4.2.4). With the rejection of the third CO_2 Act by the Swiss electorate this option is no longer under discussion.

Estimate of mitigation impact

The climate strategy for agriculture aims at setting out long-term targets to be reached with deduced policies and measures and has, thus, a positive mitigation impact. However, because the measures so far introduced in the framework of the climate strategy for agriculture aim at the exchange and transfer of knowledge, no methodological approaches are available to quantify the mitigation impact. Accordingly, the mitigation impact is reported as 'not estimated' in Tab. 21 and BR CTF table 3.

4.6.5 Agricultural policy 2014–2017 and 2018–2021

In 2013, the Swiss Parliament adopted the agricultural policy 2014–2017. The key element of this quadrennial programme for agriculture was the further development of the direct payments system. Measures with unspecified aims have been replaced by specific tools. Subsidies for livestock have been converted to subsidies for ensuring food security, dependent on land use. The funds freed by the abolishment of the general acreage subsidy have been used, inter alia, for new direct payment types for environmentally-friendly production systems and for the efficient use of resources. Concretely, payments have been effected for e.g. organic farming, grassland-based ruminant production, conservative soil cultivation, as well as for precise application of fertiliser and plant protection agents. The legal framework of agricultural policy 2014–2017 has been designed in a way that has enabled the inclusion of further elements under the new direct payment types by adjusting the corresponding ordinance. In 2017, the Swiss Parliament has adopted the continuation of the agricultural policy, setting the financial framework for the period 2018–2021. Further, another two elements have been introduced: (i) payments for differentiated feeding of pigs according to age, and (ii) nutritional needs and payments for reduced use of plant protection agents in vine and sugar beet.

Planned strengthening

As of 2022, the new agricultural policy (AP22+) should have become effective. However, it has been suspended by the Swiss Parliament in 2021, requesting the federal government to write a report on the further development of the agricultural policy. On the basis of the report, which was published in summer 2022 (*Swiss Federal Council*, 2022b), the Swiss Parliament will decide to either completely reject the new agricultural policy (AP22+) or to resume the debate on it.

[49] See https://www.agrocleantech.ch.

Central elements of the new agricultural policy (AP22+), however, have been taken up by the parliamentary initiative 19.475 submitted in 2021 (*Swiss Confederation*, 2019), with the aim of making Switzerland's agriculture more sustainable. Accordingly, nitrogen and phosphorus losses from agriculture are to be reduced appropriately and concentrated feed and fertiliser deliveries are to be reported to the federal government so that it can balance the nutrient surpluses nationally and regionally. To implement the parliamentary initiative 19.475, changes in the affected decrees are required. Respective proposals have been sent to public consultation and it is planned that first measures will become effective as of 1 January 2023.

Estimate of mitigation impact

In a simplified way it can be assumed that the mitigation impact of the further development of the direct payments system corresponds to the difference between the WEM and the WOM scenarios (see section 5.3.3 and Tab. 29), i.e. about 300 thousand tonnes of CO_2 equivalents for both, 2020 and 2025. The planned strengthening is expected to lead to an additional reduction of emissions by 200 thousand tonnes of CO_2 equivalents by 2025.

4.6.6 Enhancement of label standards

Various private labels are improving their label products in terms of sustainability. A tangible step in the area of climate has been taken by IP-SUISSE (Swiss Association of Integrated Producing Farmers).[50] This association aims at improving the production standards regarding biodiversity, social equality, pesticide use, animal welfare and climate. In order to further improve the respective label in the area of climate, IP-SUISSE carried out a pilot project within the scope of the resource programme. The goal of the project, which ended in 2021, was to develop a climate score system. In order to produce under the label a certain amount of technical measures must be implemented by the producers, expressed as a score (*Alig et al.*, 2015; *Furrer et al.*, 2021). The climate measures are collected in a catalogue indicating, in case of the climate score system, the reduction potential for greenhouse gas emissions of each measure. One point equals a reduction of one tonne of CO_2 equivalent. The climate score system has been broadly implemented for all label producers in late 2020 as beta system. Until 2022, the implementation of the score system will be further concretised, the minimum score that needs to be achieved will be defined, and the score system will become mandatory for all label producers.

Estimate of mitigation impact

IP-SUISSE counts about 9,000 label producers, accounting for about one fifth of all farms in Switzerland. Their aim is to achieve a reduction of greenhouse gas emissions on the totality of the label farms by 10 per cent by 2025 compared to the level in 2016, equalling about 130 thousand tonnes of CO_2 equivalents. As the programme will only become mandatory in 2022, the enhancement of label standards did not yet lead to a mitigation impact in 2020.

4.7 Land use, land-use change and forestry

4.7.1 Overview

There is a long tradition of forest protection in Switzerland. The first Forest Act came into force in 1876. It covered the alpine region and its aim was to put a halt to deforestation, to secure the remaining forest area, to manage it in a sustainable way, and to promote afforestation. The Forest Act of 1902 covered the whole country. The forest acts have resulted in an increase of the forested area in Switzerland from 0.7 million hectares in the mid-19th century to over 1.3 million hectares today (*Brändli et al.*, 2020). Switzerland's total forest area continues to increase, although the changes in forest area vary significantly from region to region. The strongest increase in forest area can be observed in the Alps and in the Southern Alps. The forest area in the Central Plateau is relatively stable.

Due to the age structure, large fractions of the Swiss forest are mature for harvesting. Consequently, the levels of harvesting should rise in the near future. On one hand, this contributes to avoiding episodic large quantities of greenhouse gas emissions originating from decay, should an excessive accumulation of carbon stocks be disturbed by drought, fires, storms, or insect attacks. On the other hand, as the forest, its products and services could be broadly affected by climate change there is need to support forests to adapt to climate change. Adaptation processes in forests are best induced through regeneration.

[50] https://www.ipsuisse.ch

In Switzerland, the climate-related goals of forest policy are to adapt forests by increasing resilience to climate change and – taking into account the high growing stock – to reduce CO_2 emissions by substituting other materials or fossil fuels rather than enhancing the forest sink capacity. The highest possible substitution effect can be achieved through the principle of cascaded use of wood. With the planned step-by-step phase-out of nuclear energy, renewable energy sources will play a crucial role for the nationwide energy supply (see Energy Strategy 2050 as addressed in section 4.3.1). This development is likely to lead to a more intensive use of energy wood and an increase in timber harvesting.

The most recent changes in the Federal Act on Forest (in force since 1 January 2017) pursue the above-mentioned goals and strengthen the measures concerning adaptation to and mitigation of climate change. Furthermore, new instruments for the prevention and abatement of harmful organisms have been defined in the latest revision.

Among others, mitigation of climate change is a major objective of the Forest Act and the Forest Policy, which form both part of the legislative arrangements and administrative procedures. At the same time, by applying sustainable forest management practices in Swiss forests, complete use of the wood harvesting potential and conservation of biodiversity are envisaged. The objective of mitigating climate change includes the optimisation of the climate protection services of Swiss forest (*FOEN*, 2007). These climate protection services comprise (i) the sequestration of carbon in the forest, (ii) the carbon fixation in long-living harvested wood products, and (iii) the substitution of fossil fuels by using fuel wood (energetic substitution) or by replacing energy-intensive construction materials like steel by wood (material substitution). The climate protection services ensure sustainable use of the natural resource 'wood'.

Tab. 22 gives an overview of the most climate-relevant policies and measures in the land use, land-use change and forestry sector, while the following sections provide more details and background information on each policy and measure.

Tab. 22 > Summary of policies and measures regarding land use, land-use change and forestry sector. The sector affected is 'forestry/LULUCF' for all policies and measures presented in this table. Compared to the previous submission, the policies and measures 'Wood Action Plan' and 'Measures within Forest Policy 2020' have been renamed to 'Wood Action Plan (implementation of Swiss Wood Resource Policy)' and 'Measures within Forest Policy (objectives and implementation)', respectively.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq) 2020	2025
Forest Act (sustainable forest management and forest area conservation) *	CO_2	Limiting harvest to size of growth increment in forests, obligation to compensate for any deforestation.	Regulatory	Implemented	Ban on clearcutting, no deforestation unless it is replaced by an equal area of afforested land or an equivalent measure to improve biodiversity.	First implemented in 1876, main revisions/ extensions in 1902 and 1993	FOEN, cantons	NE [b]	NE [b]
Wood Action Plan (implementation of Swiss Wood Resource Policy) *	CO_2	Ecologically and economically effective use of wood.	Information, education, research	Implemented	Policy package implementing Forest Policy in the area of better use of the wood harvest potential. Primary fields of action are 'Swiss wood value added' and 'climate-appropriate buildings', and the cross-cutting themes communication and innovation.	2009	FOEN	IE [c]	IE [c]
Measures within Forest Policy (objectives and implementation) *	CO_2	Promote the use of wood and the substitution of carbon-intensive resources.	Information	Implemented	Improvement of conditions for an efficient and innovative forestry and wood industry. Targets for the consumption of sawn timber and timber products and for CO_2 emission reductions through enhanced use of wood. Long-term target of a CO_2 balance between forest sink, wood use and wood substitution effects. Given the current age structure of Swiss forests, this implies aiming at increased harvesting rates over the coming years.	2011	FOEN, cantons	1 200	1 200

Forest Act (changes due to revision 2017) *	CO_2	Promote the use of wood and the substitution of carbon-intensive resources. Precautionary measures against climate change.	Regulatory, Information	Implemented	New legal base for Wood Action Plan (see above) and new legal instrument to promote the use of sustainably produced timber for the construction of federal buildings. Adaptation measures with the aim to increase the adaptive capacity of Switzerland's forests and combating invasive species.	2017	FOEN, cantons	NE [b]	NE [b]

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] See the respective sections (4.7.3 and 4.7.5) for a qualitative discussion of the mitigation impact.

[c] The respective effects are included under the measures within Forest Policy (objectives and implementation). Reductions result from substitution of other materials or fossil fuels (and thus impact emissions outside the land use, land-use change and forestry sector). While these indirect reductions are not included in the modelling of emissions (see section 5.3.4), the value of 1,200 thousand tonnes of CO_2 equivalents only includes the substitution effect and does not reflect the corresponding reduction of carbon storage by the forest.

IE, included elsewhere; NE, not estimated
FOEN, Swiss Federal Office for the Environment

4.7.2 Forest Act (sustainable forest management and forest area conservation)

The Forest Act, as revised in 1993, reaffirms the long-standing Swiss tradition of preserving both forest area and forests as natural ecosystems. It prescribes sustainable forest management, prohibits clearcutting, and bans deforestation unless it is replaced by an equal area of afforested land or an equivalent measure to improve biodiversity. At an average increment of 10.8 million cubic metres per year and an average of cut and mortality of 9.2 cubic metres per year, 1.6 million cubic metres remain unlogged annually (values for survey periods of NFI3/2004–2006 and NFI4/2009–2017; *Brändli et al.*, 2020) – mainly in forests that are difficult to access and in forest reserves. The federal authorities would like to increase Switzerland's annual wood harvest since the forests' sustainable potential for supplying domestic construction and energy wood is not being exploited completely. Specific measures aiming, inter alia, at the better exploitation of the existing potential of wood as a renewable resource are described below (sections 4.7.3 to 4.7.5).

Estimate of mitigation impact

There are no quantitative estimates available, but the impact is assumed to be positive (see qualitative evaluation in sections 4.7.3 and 4.7.5). It is difficult or nearly impossible to define scenarios including elements like 'avoiding natural disturbances' or 'adaptation of forests' because such scenarios would include a lot of speculative assumptions. Moreover, while the mitigation impacts of these elements are quite important for forest ecosystem functioning, they are only of minor importance for Switzerland's current national CO_2 budget. Therefore, no quantitative information is provided. The active promotion of wood will have a positive impact on the pool of harvested wood products (more carbon stored), but will have a reverse impact on the carbon stored in the forest. In a current study, the CO_2-effects of different forest management and wood use scenarios is being quantified (results are expected in 2023).

4.7.3 Wood Action Plan (implementation of Swiss Wood Resource Policy)

The Wood Resource Policy (first initiated in 2008, updated in 2014, 2017 and 2021; see e.g. *FOEN/SFOE/SECO*, 2021) supports Switzerland's sustainable development strategy. It makes significant contributions to forest, climate, energy and regional policy and other sectoral policies, and also to the sustainable development goals of the United Nations. The Swiss Federal Office for the Environment is the lead agency for this policy. It is implemented with relevant partners mainly through the Wood Action Plan with its two priority areas: (i) 'Swiss wood value added' (i.e. to revitalise and develop Swiss forestry and timber value added networks as well as the market for wood from Switzerland's forests) and 'climate-appropriate buildings', and (ii) the cross-cutting themes 'communication and innovation'. In 2021, a new programme phase of the Wood Action Plan has started (2021–2026).

Estimate of mitigation impact

There are no quantitative estimates available, but the overall mitigation impact of the Wood Action Plan is assumed to be positive. The promotion of 'climate-appropriate buildings' increases the carbon stored in the pool of harvested wood products. It is a challenge to define and model a scenario including the goal 'climate-appropriate buildings' because this would include a lot of speculative assumptions. Therefore, only a descriptive and not a quantitative estimate is provided. By aiming to use wood for material purposes and afterwards for energetic purposes, the carbon stored in long-lived harvested wood products will increase and therefore the overall mitigation impact is estimated to be positive. Only mitigation impacts of harvested wood products can be accounted for in the LULUCF sector. The mitigation impact of substitution effects are reflected indirectly in the energy sector.

4.7.4 Measures within Forest Policy (objectives and implementation)

The Forest Policy 2020, which was approved by the Swiss Federal Council in 2011, is a strategic document built on the Forest Act of 1993 and the Forest Ordinance of 1992 and designed to trigger improvements to it. Consequently, the Forest Act and Forest Ordinance have been updated in 2017 (see section 4.7.5) based on an intermediate evaluation of the Forest Policy 2020. For the period after 2020, the Forest Policy (the former addition '2020' is no longer specified) is continued with updated and complemented measures for the period 2021–2024 and defined as 'Forest Policy: objectives and measures 2021–2024' (*FOEN*, 2021).

The Forest Policy ensures sustainable forest management while creating favourable conditions for an efficient and innovative forestry and wood industry. The policy sets out eleven strategic objectives. It identifies five objectives that pose the greatest challenges: (i) exploiting the potential sustainable wood supply, (ii) contributing to mitigation of, and enhancing resilience to, climate change, (iii) maintaining the protective forest services, (iv) increasing biodiversity by conserving forests as near-natural ecosystems, and (v) conservation of the forest area in its spatial distribution.

The Forest Policy contains a comprehensive set of strategic and specific measures, indicators and target values that go with every objective. Some examples related to mitigation are (i) under the Forest Policy, the consumption of sawn timber and timber products should be increased by 20 per cent by 2030 compared to 2008 levels, (ii) at the same time, the substitution effect through enhanced use of wood should be increased by 1.2 million tonnes of CO_2 equivalents per year compared to 1990 (*FOEN*, 2007), and (iii) in the long term, a sustainable equilibrium between forest sink, wood use and wood substitution effects is sought.

Estimate of mitigation impact

According to the Forest Policy, the mitigation impact by substitution is estimated at 1.2 million tonnes of CO_2 equivalents (see page 48 in *FOEN*, 2021; value based on *FOEN*, 2007). For a qualitative evaluation see sections 4.7.3 and 4.7.5. The estimated mitigation impact of 1.2 million tonnes of CO_2 equivalents results from the use of wood for materials and energy and includes the mitigation impacts achieved in other sectors, e.g. when wood replaces fossil fuels or CO_2-intense materials (such as cement and steel) in energy industry, building and housing, industrial processes, etc. This may thus lead to some overlap with the individual estimates of the mitigation impacts for policies and measures affecting these other sectors, however, double counting is carefully avoided for the projections and the estimate of the aggregate effect of policies and measures (as the mitigation impact resulting from substitution of materials and fossil fuels is not accounted for in the WEM and WAM scenarios of the LULUCF sector). The envisaged increase of the consumption of sawn timber and timber products will result in a decrease of carbon stored in the forest, but will in exchange increase the amount of carbon stored in long-lived harvested wood products. Due to the lack of further information, the mitigation impact of 1.2 million tonnes of CO_2 equivalents according to *FOEN* (2007) is reported for 2020 and 2025. Currently, a follow-up study analysing in more detail the substitution effect of wood for materials and energy is underway.

4.7.5 Forest Act (changes due to revision 2017)

In 2017, a revised version of the Forest Act entered into force. The revised Forest Act foresees measures to promote timber which was produced sustainably and in close-to-nature silvicultural systems. A goal of these measures to promote timber is reducing CO_2 emissions through the use of harvested wood products. Since 2017, the Swiss government has been required, if suitable, to use domestic wood in its own building projects that complies with the above mentioned criteria. Further, Article 28a of the revised Forest Act – entitled 'precautionary measures against climate change' – is the first legal provision in a federal sector law that explicitly addresses the issue of adaptation to climate change. With the revised Forest Act the Swiss government financially supports adaptation measures with the aim to increase the adaptive capacity of Switzerland's forests (see also section 6.3.8). Further, the revised Forest Act allows for taking measures to combat invasive species outside of protective forests. Non-native pests – such as the Asian longhorn beetle, whose numbers have recently increased – will be controlled.

Estimate of mitigation impact

There are no quantitative estimates available, but overall the mitigation impact of the Forest Act (changes due to revision 2017) is assumed to be positive:

- In the medium to long term, climate change mitigation efforts cannot be sustained without adaptation. Adaptive forest management in Switzerland aims to avoid major emissions from collapsing forest stands that are not adapted to climate change. The Forest Act prescribes to prepare Swiss forests for future climate conditions by adaptation measures. In pursuing this objective, increased short-term emissions from forest management are to be expected, but in the long term, removals should compensate for them. Swiss forests are often characterised by high carbon stocks. To convert these old forests into more stable younger forests, a decrease in biomass is necessary and net emissions will occur if the harvested biomass is not entirely transformed into harvested wood products. Further, specific forest stand types might need a change in species composition because of changing climate and corresponding changing stand characteristics. This exchange in tree species composition is typically spread over decennia. CO_2 emissions from these measures are expected to be moderate or small;
- By combating invasive species, CO_2 emissions from tree mortality caused by insect diseases can be avoided;
- The more active promotion of wood use (e.g., the commitment for the construction of federal buildings) has a positive mitigation impact because the pool of harvested wood products will be increasing.

4.8 Waste

4.8.1 Overview

The aim of Swiss waste policy is to close the material cycle and to treat the waste that cannot be recycled in such a way that it becomes a material suitable for final disposal. In principle, all waste should be recycled or incinerated. If this is not technically possible or economically acceptable, the waste and incineration residues are landfilled after suitable treatment. Since 2000, untreated combustible waste may no longer be landfilled; the capacity of municipal solid waste incineration plants has been increased accordingly.

The most important strategy to reduce emissions from waste incineration is to increase recycling. Well-developed recycling systems exist for many types of waste. In 2020, 53 per cent of the total amount of municipal waste was collected separately and recycled (see section 2.9 and Tab. 2). The corresponding figure for the year 2000 was 45 per cent. The recycling rates are particularly high (more than 90 per cent) for glass, aluminium packaging and waste paper (see section 2.9, Fig. 37).

In general, waste disposal in Switzerland is financed according to the polluter-pays principle, i.e. those who produce more waste must also pay more for its disposal. In 2020, about 95 per cent of the Swiss population financed their waste disposal entirely or partially through volume-based charges, and the remaining five per cent through taxes or a flat-rate fee. Tab. 23 provides an overview of climate-relevant policies and measures regarding waste management, which are explained in more detail in the following sections. The negotiated reduction commitment of municipal solid waste incineration plant operators – an agreement between the Swiss Federal Department of Environment, Transport, Energy and Communications and the Swiss Association of Municipal Solid Waste Incineration Plants – aims at effectively reducing fossil CO_2 emissions from waste incineration and to accelerate the deployment of carbon capture and storage (CCS). It is presented in detail in section 4.3.7, as the emissions from municipal solid waste incineration plants are attributed to the energy sector.

Tab. 23 > Summary of policies and measures regarding waste management. The negotiated reduction commitment of municipal solid waste incineration plant operators is presented together with the policies and measures of the energy sector (section 4.3.7). The sector affected is 'waste management/waste' for all policies and measures presented in this table.

Name of policy or measure [a]	Greenhouse gas(es) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative, in kt CO_2eq) 2020	2025
Ban on landfilling of combustible waste *	CH_4	Avoid emissions from solid waste disposal sites, use waste as an energy source.	Regulatory	Implemented	Prohibition on landfilling of combustible waste.	2000 [b]	FOEN	173	145
Ordinance on the Avoidance and Management of Waste *	CO_2	Optimisation of energy recovery by municipal solid waste incineration plants.	Regulatory	Implemented	Mandatory minimal energy recovery rate.	2016	FOEN	28	28

[a] Policies and measures marked with an asterisk (*) are included in the 'with measures' projection.

[b] Regulations regarding the installation of technical equipment for the collection and removal of landfill gas were already established in the 1990s.

FOEN, Swiss Federal Office for the Environment

4.8.2 Ban on landfilling of combustible waste

Since 2000, disposal of combustible solid wastes on landfills has been banned. All Swiss waste incineration plants use the combustion heat they produce to generate electricity or to supply district heating networks and industrial facilities. Today, Swiss waste incineration plants supply around two per cent of Switzerland's total energy consumption. As a consequence of the ban on landfilling, CH_4 emissions from solid waste disposal sites have declined substantially. In addition, regulations regarding landfilling established in the 1990s led to the installation of technical equipment for the collection and removal of landfill gas (*Consaba*, 2016).

Estimate of mitigation impact

The mitigation impact of the ban on landfilling of combustible waste is estimated by comparing the 'with existing measures' (WEM) and 'without measures' (WOM) scenarios as used for Switzerland's projections of greenhouse gas emissions (for methodological details see section 5.3.5). Accordingly, it is assumed that the mitigation impact of the ban on landfilling of combustible waste corresponds to 173 thousand tonnes of CO_2 equivalents in the year 2020 and to 145 thousand tonnes of CO_2 equivalents in the year 2025 (these estimates do not include the different evolutions of biogas production which lead to further differences between the two scenarios for the waste sector).

4.8.3 Ordinance on the Avoidance and Management of Waste

In Switzerland, the disposal of waste is regulated by the Ordinance on the Avoidance and Management of Waste (*Swiss Confederation*, 2015). This ordinance has replaced the former Technical Ordinance on Waste since 1 January 2016. The new ordinance aims in particular at the sustainable use of renewable and non-renewable raw materials, among other things by promoting closed material cycles. At the same time, the reduction of environmental pollution is to be further improved through the separation and proper treatment of hazardous substances and the proper disposal of waste of all kinds. The reliability of the entire waste disposal system is to be strengthened by ensuring adequate structures for the collection, transport and treatment of the various types of waste.

The most important objective of the Ordinance on the Avoidance and Management of Waste with a direct impact on greenhouse gas emissions is to optimise the energy recovery of municipal waste in incineration plants. This is done by specifying a minimum energy recovery rate of 55 per cent of the energy content of the incinerated waste (binding as of 1 January 2026). All 29 Swiss municipal waste incineration plants supply energy either in the form of electricity or heat for district heating. While many waste incineration plants have recovery rates that are well above the minimum legal requirements, there are a few plants that need further technical investment to achieve the minimum recovery rate. The revision of the Ordinance on the Avoidance and Management of Waste of April 2022 has introduced an article according to which the construction of new plants or the expansion of the capacity of existing ones must be planned in such a way that at least 80 per cent of the energy content is used outside the installation. This high energy efficiency requirement can be achieved, for example, through increased use of district heating or CO_2 capture (which is also explicitly considered as use outside the installation).

Estimate of mitigation impact

Municipal solid waste incineration plants with an insufficient recovery rate have to raise their energy efficiency in order to meet the mandatory requirements. Applied to the actual situation in 2016, an additional minimal recovery of 107 gigawatt-hours is needed that all municipal solid waste incineration plants fulfil the legal requirements. Assumed that this additional energy is supplied as heat for district heating and, therefore, replaces fossil heating fuels, a reduction of 28 thousand tonnes of CO_2 can be obtained. This may be a conservative assumption, because an energetic optimisation of a municipal solid waste incineration plant will usually aim at higher energy recovery rate than required by the Ordinance on the Avoidance and Management of Waste. However, there is a transition period until 2026, i.e. the full mitigation impact may develop after 2020. To account for these effects, the value of 28 thousand tonnes of CO_2 is provided as the best estimate for the mitigation impact for both year, 2020 and 2025, in Tab. 23. The short-term mitigation impact of the additional increase of the minimum energy efficiency to 80 per cent is difficult to estimate quantitatively, but it will certainly lead to a further positive mitigation impact in the long-term.

4.9 Costs, non-greenhouse gas mitigation benefits and interactions of policies and measures

The UNFCCC reporting guidelines on national communications encourage Parties to report on costs, non-greenhouse gas mitigation benefits and interactions of policies and measures. It turned out that gaining this information is very challenging and Switzerland is therefore not in a position to comprehensively report this information for every single policy and measure. However, information for selected policies and measures as well as a discussion of the challenges regarding the reporting of this information is provided in the following.

Costs of policies and measures

Evaluation of the costs of policies and measures is particularly challenging, e.g. because the definition of costs is ambiguous and because many policies and measures are closely interlinked. Accordingly, Switzerland does not evaluate its policies and measures regarding costs on a regular basis, and no consistent methodology to estimate costs of all individual policies and measures exists. However, the social costs and benefits of the policies and measures are expected to be moderate. In 2017, the Swiss Federal Office for the Environment published a synthesis report focussing on the economic assessment of climate policy measures after 2020 (*FOEN*, 2017). As described in section 4.2.4, the third CO_2 Act as planned at this point in time could not enter into force. Nevertheless, the following information allows for a good understanding of the potential costs and economic impacts of policies and measures enforced to mitigate climate change in Switzerland:

- The economy-wide cost of the CO_2 levy, the most relevant policy and measure in this context, has been analysed in detail. Since 2018, the federal government has set the rate of the CO_2 levy to 96 Swiss francs per tonne of CO_2, and has increased it to 120 Swiss francs per tonne of CO_2 as of 1 January 2022. This currently results in annual revenues of about 1.4 billion Swiss francs. A third of the revenues (at most 450 million Swiss francs) flows into the national buildings refurbishment programme, allowing the federal government and the cantons to support energy-efficient renovations. Another 25 million Swiss francs is transferred to the technology fund. Around two thirds of the revenues are available annually for redistribution. The federal government distributes the funds between the population and the Swiss economy in proportion to the CO_2 levy payed. Currently, the redistribution to the population is 88.20 Swiss francs per capita (including the redistribution of revenues from the NMVOC incentive fee) and the redistribution to the Swiss economy is 29.70 Swiss francs per 100,000 Swiss francs settled old-age and survivor's insurance payroll of employees. Households living in poorly isolated buildings that still rely on fossil heating systems are affected relatively strongly. However, the redistribution of the CO_2 levy on a per capita basis significantly moderates these negative effects and counteracts the regressive nature that carbon taxes generally have;
- Before the implementation of the linking of the emissions trading schemes of Switzerland and the European Union, it was estimated that Switzerland's gross domestic product would increase by approximately 0.04 per cent in 2030, compared to a scenario where the two emissions trading schemes are operated separately. It was further estimated that the inclusion of aircraft operators in the emissions trading scheme would slightly reduce the growth rate of value added of the aviation sector, but this effect would most probably not fully counteract the overall positive impact of the linking;
- The remaining policies and measures are expected to have only a minor or even negligible impact on the overall economy. Additionally, possible secondary benefits of the reduction of emissions (such as lower health costs, lower dependency on fossil fuels, impacts on innovation etc.) are difficult to quantify and are generally not taken into account. It is likely that the overall economic impact of the proposed measures would be positive if their benefits were also considered;
- The costs for the emission reductions outside Switzerland will strongly depend on the corresponding prices. Currently, reductions abroad are a relatively cheap mitigation option when compared to reductions in Switzerland. However, costs for reductions abroad are likely to increase in the future when developing countries will have to fulfil their commitments under the Paris Agreement.

Administrative costs of policies and measures

Because market-based policies and measures such as the CO_2 levy and the emissions trading scheme play a dominant role in Switzerland's climate policy, the administrative costs are generally moderate. For the CO_2 levy, the compensation for implementation expenses is defined in the CO_2 Ordinance (Article 132) and amounts to 1.45 per cent of the receipts (this percentage may be reduced as receipts increase). Non-market-based polices and measures such as the CO_2 emission regulations for newly registered vehicles or the negotiated reduction commitments (for exemption from the CO_2 levy) require more personal and financial resources.

Non-greenhouse gas mitigation benefits of policies and measures

Non-greenhouse gas mitigation benefits of policies and measures are generally difficult to estimate. The main benefits come from the reduction of other air pollutants and the corresponding decrease of health and damage costs. Until 2020, these benefits (mainly due to the CO_2 levy on heating and process fuels) are estimated to be 100 million to 200 million Swiss francs per year (*Econcept*, 2008). Policies and measures that increase energy efficiency contribute to energy security and reduce the potential costs of shortages in energy supply. The same holds for policies and measures that lower the demand for fossil fuels. These policies and measures reduce the dependency on fossil energy imports. For instance, a reduction of greenhouse gas emission by 20 per cent relative to 1990 would correspond to a reduction of the dependency on fossil fuels from abroad by around 2.7 per cent. For any other secondary benefits, no robust quantifications are available.

Interactions of policies and measures

Around three quarters of Switzerland's greenhouse gas emissions result from fossil fuel use. Energy and climate policy are therefore closely linked. The main objective of the Energy Strategy 2050 (increasing energy efficiency and the use of renewable energy) also contributes to the mitigation of CO_2 emissions. However, the implementation of the Energy Strategy 2050 will also lead to an increasing demand for electricity (e-mobility, heat pumps, etc.). In the short to medium term, it will probably not be possible to cover this demand entirely with renewable energies. Accordingly, the Swiss Federal Council has instructed the Swiss Federal Department of the Environment, Transport, Energy and Communications to draw up the necessary provisions for the construction and operation of peak-load power plants.[51] This may pose a challenge to Switzerland's efforts to reduce CO_2 emissions, but the legal provisions are intended to ensure the climate-neutral operation of the peak-load power plants, for example through the use of CO_2-free fuels or through compensation (e.g. gas-fired combined-cycle power plants would be included in the emissions trading scheme). Peak-load power plant may only be used in exceptional situations when the electricity market can temporarily no longer meet demand, and they should not distort the electricity market. Implementing the Energy Strategy 2050 not only requires adjustments to the Energy Act, but also to the CO_2 Act.

Applying a computable general equilibrium model, *EPFL and Infras* (2016) and *EPFL* (2017) suggested that the combined mitigation impact of policies and measures in the energy sector may be larger than the sum of the mitigation impacts estimated for individual policies and measures. In their model, the combined effects of policies and measures result to be responsible for about 12 per cent of the aggregate effect individual policies and measures.

4.10 Modification of longer-term trends in greenhouse gas emissions

Switzerland's policies and measures described in section 4.2 to 4.8 are generally set out to modify the short-term and longer-term trends in anthropogenic greenhouse gas emissions and removals (obviously aiming at reducing net emissions of greenhouse gases). In line with the general objectives of the Convention, they aim at promoting efficiency improvements in the energy, transport and waste sectors, give preference to the sustainable use of renewable resources in agriculture and forestry, and set incentives for the use of climate-friendly substances in the industry sector. The modification of the longer-term trend in greenhouse gas emissions achieved by Switzerland's policies and measures becomes obvious when comparing the 'with existing measures' (WEM) and 'without measures' (WOM) scenarios as presented in chapter 5 (and in particular in Fig. 65). Further, emission trends will be modified by measures where the immediate effect on greenhouse gas emission levels is not a priority, but where longer-term contributions to a low-emission economy and society are targeted. Some examples of particular interest are:

- **Masterplan Cleantech:** In 2011, the Swiss government published the Masterplan Cleantech for Switzerland (*OPET*, 2011). This strategy aimed at improving resource efficiency and promoting renewable energies. It encouraged cooperation among companies, research centres, cantons and the federal government. Under its heading, promotional programmes for research and innovation, knowledge and technology transfer, education and

[51] https://www.uvek.admin.ch/uvek/de/home/uvek/medien/medienmitteilungen.msg-id-87202.html

advanced training, and export promotion were topics receiving particular attention. The evaluation of the first years of the Masterplan Cleantech – i.e. 2011 to 2014 – showed a highly positive picture, as it was estimated that the clean technology sector contributed an estimated gross value added of 49 billion Swiss francs and employed 530 thousand persons in 2013 (*SFOE, FOEN, SERI and SECO*, 2015). Based on these results, the Swiss Federal Council decided in 2016 to continue the Masterplan Cleantech as a coordination instrument for the years 2017–2019. From then on, new cleantech measures have been defined within the framework of current strategies, and review mandates have been given to ensure their integration into existing dossiers and strategies. Accordingly, the implementation of cleantech measures in existing and new strategies has proven successful. In particular, measures could be assigned to other existing dossiers and strategies (Energy Strategy 2050, Sustainable Development Strategy, etc.) within the framework of the review mandates and then processed there. A strategy specifically geared to cleantech is no longer necessary due to the integration that has taken place. On 27 September 2019, the Swiss Federal Council has therefore decided to no longer pursue the cleantech priority with an independent strategy. However, measures to strengthen cleantech should continue to be implemented emphatically in other, existing strategies;[52]

- **Technology fund:** In the context of the second CO_2 Act, a technology fund, financed with 25 million Swiss francs per year from the revenue of the CO_2 levy, was established in 2013. This fund provides for loan guarantees for innovative companies in order to ease access to capital for investments in developing new low-emission technologies. The website of the technology fund contains detailed information on the conditions and procedures to receive loan guarantees, and on the portfolio with innovative companies that already received a loan guarantee due to their contribution to climate protection.[53] Moreover, the website of the Swiss Federal Office for the Environment includes annual review reports.[54] As of 2020, the portfolio consists of 112 loan guarantees to 102 companies with a total amount of 168 million Swiss francs. Mobility, components/sensors, agriculture/forestry and ‘other sectors’ together account for more than half of the total loan guarantees. Mobility (17 per cent) includes companies that build electric commercial vehicles and energy-efficient refrigerated containers or develop software for fleet management and tracking of containers and freight railcars. The components/sensors segment (17 per cent) includes companies that offer Internet of Things (IoT) solutions, line monitoring, measurement devices for coating thickness, resource-saving surface treatment, inspection drones or compressors. The companies in the agriculture/forestry category (13 per cent) sell solar-powered water pumps, locally produced shrimps, fish and other food products, drones for optimised fertiliser use, products to promote bee health, and farm management software. For many companies, it is difficult to assign them to a specific sector. They are thus summarised as ‘other sectors’ (12 per cent). They sell, for example, software for measuring CO_2 emissions, sustainable clothing or CO_2 ratings for securities, stocks and bonds, improved weather forecasts, data and apps on consumer goods (palm oil), online translation services for major events or methods for reducing shipping in online trading. Keywords describing further branches include: power sector (solar, wind, water, biomass), energy storage, energy supply, smart buildings (heating, ventilation, air conditioning), recycling, chemistry, construction and materials, air pollution control, and smart grid;
- **Information, training and advisory services:** Since 2013, the second CO_2 Act, in its Article 41, has requested the federal government and the cantons to support measures for the integration of elements relevant regarding climate change in communication, education and professional training programmes at all levels. This includes improving knowledge about mitigation of greenhouse gas emissions as well as adaptation to climate change. More details are available in chapter 9.

4.11 Policies and measures no longer in place

The climate policies and measures developed over the past years are well-established. As described under the respective sections, some of the policies and measures implemented have been adapted and strengthened over time. Apart from few exceptions (see below), all policies and measures listed in Switzerland’s latest submission are still part of the national

[52] For details see *https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-76558.html*.

[53] See *https://www.technologyfund.ch* and *https://www.technologyfund.ch/portfolio*.

[54] *https://www.bafu.admin.ch/tech-fund*

portfolio.[55] Accordingly, BR CTF table 3 has been updated to a minor degree only to reflect the most recent status of policies and measures in Switzerland. The following policies and measures have been removed from the reporting, either because they are not in force anymore, included elsewhere or considered less important with regard to the achievement of mitigation commitments:

- **Obligation to offset emissions from gas-fired combined-cycle power plants:** Between 2008 and 2019, the first and second CO_2 Acts stipulated that gas-fired combined-cycle power plants with a capacity larger than 100 megawatts would have obtained planning permission only if their CO_2 emissions would have been fully compensated. Compared to the first CO_2 Act, the possibility to use flexible mechanisms under the Kyoto Protocol to compensate for CO_2 emissions had been raised from 30 to 50 per cent under the second CO_2 Act. With the linking of the emissions trading schemes of Switzerland and the European Union, Switzerland has included gas-fired combined-cycle power plants in its emissions trading scheme as of 1 January 2020 (see section 4.2.6). Therewith, the obligation to offset emissions from gas-fired combined-cycle power plants, as lastly stipulated in the Articles 22–25 of the second CO_2 Act, has expired. Notably, to this day no gas-fired combined-cycle power plants have been in operation in Switzerland, and it is unclear whether there will be a need for such power plants to cover future electricity demand;
- **Inclusion of aviation in the emissions trading scheme:** Since the linking of the emissions trading schemes of Switzerland and the European Union as of 1 January 2020, Switzerland has newly included aircraft operators in its emissions trading scheme. The respective information with regard to aviation is thus included under the cross-sectoral policies and measures (see section 4.2.6). The policy and measure named 'inclusion of aviation in the emissions trading scheme' as reported in previous reports is no longer listed separately in Tab. 19 and BR CTF table 3;
- **Exemption from electricity network surcharge:** The Energy Act foresees full or partial refund of the electricity network surcharge (raised for the promotion of renewable energies) to energy-intensive companies if they commit to enhance energy efficiency in a target agreement. This policy and measure was described in detail in previous reports and is still in place. However, the policy and measure is primarily a relief for electricity-intensive companies so that the network surcharge is better accepted rather than a typical climate measure. Therefore, it is no longer reported in Tab. 18 and BR CTF table 3. In contrast, the two policies and measures named 'feed-in tariff system' (4.3.5) and 'investment aids' (4.3.6) were included, which have a more direct climate relevance.

4.12 Policies and measures leading to an increase in greenhouse gas emissions

No significant changes have occurred since Switzerland's last submission with regard to Switzerland's commitment under Article 4, paragraph 2(e)(ii), of the UNFCCC to identify and periodically update the policies and practices that encourage activities that lead to greater levels of anthropogenic greenhouse gas emissions than would otherwise occur. In brief, the decision to not replace nuclear power plants at the end of their service life will require other options for power generation. While it is unclear whether there will be a need for gas-fired combined-cycle power plants, such plants would potentially lead to additional greenhouse gas emissions. Nevertheless, operators of gas-fired combined-cycle power plants are included in the emissions trading scheme, ensuring the mitigation of the respective emissions. Further, as detailed in section 4.13, there are a few tax exemptions and reductions at the federal level providing limited support to users of fossil fuels: Farmers, foresters, fishermen and the fuel use of snow cats are exempt from the mineral oil tax that is normally levied on sales of mineral oils[56], while public transport companies benefit from a reduced rate. The reasoning for these tax exemptions are to avoid putting a strain on the production within the agriculture sector, to avoid levying taxes which are earmarked for expenditures related to road traffic from users of non-road vehicles (such as snow cats), or to avoid levying taxes from companies which are subsidised because they render services for the public benefit. Certain exemptions must also be considered with a view to integrating and supporting mountain and peripheral regions.

55 The following polices and measures have been renamed in preparation of this report as noted in the captions of the overview tables to the policies and measures of each sector: (i) the previous 'Third CO_2 Act (2021)' is now named 'Third CO_2 Act (2025)' (see Tab. 16), (ii) the previous 'Wood Action Plan' is now named 'Wood Action Plan (implementation of Swiss Wood Resource Policy)' (see Tab. 22), and (iii) the previous 'Measures within Forest Policy 2020' is now named 'Measures within Forest Policy (objectives and implementation)' (see Tab. 22).

56 See also section 4.13, footnotes 57 and 58.

4.13 Economic and social consequences of response measures (minimising adverse effects)

Detailed information on the assessment of the economic and social consequences of response measures are requested by paragraph 13 of the revised UNFCCC reporting guidelines on national communications (see the annex to decision 6/CP.25). Further, paragraph 36 of the guidelines for the preparation of information under Article 7 of the Kyoto Protocol (FCCC/CP/2001/12/Add.3, Annex) requests information on how Parties strive to implement policies and measures under Article 2 of the Kyoto Protocol in such a way as to minimise adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9, of the Convention, taking into account Article 3 of the Convention.

In the following, Switzerland reports the requested information, thereby addressing the actions mentioned in Decision 31/CMP.1, paragraph 8 (FCCC/KP/CMP/2005/8/Add.4). Further information regarding financial support for any economic and social consequences of response measures is provided in section 7.1.5.

Context

Switzerland strives to design climate change policies and measures in a way as to ensure a balanced distribution of mitigation efforts by implementing climate change response measures in all sectors and for different gases. Indirectly, this approach is deemed to minimise also potential adverse impacts on concerned actors (including developing countries). Given Switzerland's size and share in international trade (mainly with the European Union), it is assumed that Swiss climate change policies do not have any significant adverse economic, social or environmental impacts in developing countries. Additionally, the policies and measures are very much compatible and consistent with those of the European Union in order to avoid trade distortion, non-tariff barriers to trade and to set similar incentives. All major legal reform projects in Switzerland are to be accompanied by impact assessments, inter alia including evaluation of trade-related issues. This approach strives for climate change response measures which are least trade distortive and do not create unnecessary barriers to trade. Consistently, Switzerland notifies all proposed non-tariff measures having a potential impact on trade to the World Trade Organisation.

Impact assessments of legal reform projects are accompanied by a broad internal and external consultation process, inter alia inviting competent and potentially affected actors to provide advice on economic, social and environmental aspects of proposed policies and measures. The open public consultation process, together with regular policy dialogues with other countries, guarantee that domestic and foreign stakeholders can raise concerns and issues related to new policy initiatives, including their coherence with other policies and measures and those concerns about possible adverse impacts on other countries.

In the framework of the Comprehensive Economic Partnership Agreement (CEPA) between member states of the European Free Trade Association and Indonesia, Switzerland is piloting a new regulatory mechanism to link the granting of certain trade preferences with sustainable production and processing methods.

Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Environmental policy in Switzerland, including climate change policies, is guided by the polluter pays principle, as enshrined in the Swiss Federal Act on the Protection of the Environment (*Swiss Confederation*, 1983). Accordingly, the internalisation of external costs and adequate price signals are key aspects of Switzerland's climate change policy. Regarding greenhouse gas emissions, market-based instruments – such as the Swiss emissions trading scheme (section 4.2.6), the supplemental use of international carbon credits from the Clean Development Mechanism (Annex B.3.6) or the CO_2 levy on heating and process fuels (section 4.2.5) – are important measures to put a price on emissions of greenhouse gases that are then reflected in market prices and thus internalizing externalities.

Regarding fiscal incentives, tax and duty exemptions and subsidies, price-based measures are recognised as essential instruments for promoting the efficient use of resources and to reduce market imperfections. In 2001, Switzerland introduced a heavy vehicle charge (section 4.4.6). It is applied to passenger and freight transport vehicles of more than 3.5 tonnes gross weight. The impact of the heavy vehicle charge was most clearly demonstrated by changes in traffic volume (truck-kilometres), but also by reduced air pollution, a renewal of the heavy vehicle fleet and an increase of load per vehicle, i.e. fewer trucks transported more goods. Two thirds of the revenues are used to finance major railway infrastructure projects (such as the base tunnels through the Alps, see section 2.7), and one third is transferred to the cantons. The Swiss Federal Office for Spatial Development annually publishes a report analysing all external effects of transport (including costs and benefits). The most recent estimates for 2018 correspond to total external costs of transport of about 13.7 billion Swiss francs with external costs related to climate contributing about 2.8 billion Swiss francs (*ARE*, 2021b).

In 2008, Switzerland introduced the CO_2 levy on heating and process fuels to set an incentive for a more efficient use of fossil fuels, promote investment in energy-efficient technologies and the use of low-carbon or carbon-free energy sources (section 4.2.5). Companies, especially those with substantial CO_2 emissions from use of heating and process fuels, may apply for exemption from the CO_2 levy on heating and process fuels, provided the company commits to emission reductions (section 4.2.7). The company has to elaborate an emission reduction target based on the technological potential and economic viability of various measures within the company. While the proceeds from the CO_2 levy on heating and process fuels were initially to be fully refunded to the Swiss population (on a per capita basis) and to the Swiss economy (in proportion to wages paid), a parliamentary decision of June 2009 earmarked a third of the revenues from the CO_2 levy on heating and process fuels for CO_2 relevant measures in the buildings sector (section 4.3.3). As of 1 January 2018, the funds for the national buildings refurbishment programme are limited to a maximum of 450 million Swiss francs per year (previously 300 million Swiss francs per year).

In general, Switzerland does not subsidise fossil fuels. However, depending on the definition, there are some policies in place that may be regarded as fossil fuel subsidies, but these policies are only applicable to small amounts of fossil fuels consumed in Switzerland. At the federal level, a few tax exemptions and reductions provide limited support to users of fossil fuels. Farmers, foresters, fishermen and the fuel use of snow cats are exempt from the mineral oil tax that is normally levied on sales of mineral oils, while public transport companies benefit from a reduced rate. These mineral oil tax exemptions in the specific sectors are listed in appendix 3 of the Swiss Federal Council's subsidy report (*Swiss Federal Council*, 2008). Moreover, the mineral oil tax refunds in the agriculture sector was subject to an examination by the Swiss Federal Audit Office. In the respective report published in August 2018, the Swiss Federal Audit Office recommends the preparation of a legislative revision to abolish the mineral oil tax refunds in the agriculture sector (economic support for agriculture should be provided entirely in the form of direct payments).[57] The implementation of this recommendation is still pending, as the Swiss Federal Council does not see any urgency for a system change[58] for the following reason: The mineral oil tax refunds are currently based on standard consumption, which means that the amount of the refunds does not depend on effective fuel consumption. Accordingly, farms can benefit if they have below-average fuel consumption thanks to energy-efficient management of their land and crops (e.g. by using electric tractors). The refunds according to standard consumption thus already create a certain incentive to use fuel efficiently. Some vehicles are also exempt from the performance-related heavy vehicle charge, e.g. agricultural vehicles, vehicles used for the concessionary transport of persons or vehicles for police, fire brigades, oil and chemical emergency units, civil protection and ambulances.

Worldwide subsidies for fossil fuels are estimated at 300 billion to 500 billion US dollars per year, depending on what is measured (consumption/production subsidies) and the level of energy prices. This huge market distortion does not only produce severe fiscal problems and opportunity costs for the countries concerned, it also poses a major obstacle for enhanced investments in energy efficiency measures and renewable energies. Switzerland as a founding member of the Friends of Fossil Fuels Subsidy Reform supports the gradual and sustained phasing out of fossil fuel subsidies and the reduction of unnecessary market distortions. Furthermore, Switzerland contributes to the Energy Sector Management Assistance Programme administered by the World Bank. This programme manages the Energy Subsidy Reform Facility that offers technical assistance for states that want to reform their fossil fuel subsidies, and provides the analytical basis for the implementation of such reforms.[59]

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57 *https://www.efk.admin.ch/en/publications/economy-and-administration/economy-and-agriculture/3374-mineral-oil-tax-refunds-in-agriculture-federal-department-of-finance-federal-department-of-economic-affairs-education-and-research-federal-customs-administration-federal-office-for-agriculture.html*

58 See *https://www.parlament.ch/en/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20184261*.

59 For more details see *www.esmap.org*.

Removing subsidies associated with the use of environmentally unsound and unsafe technologies

Switzerland does not subsidise the use of environmentally unsound and unsafe technologies with a direct negative climate impact.

Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

Switzerland does not support any activities linked to the technological development of non-energy uses of fossil fuels in developing countries.

Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

Switzerland is an active participant in the negotiations for a plurilateral initiative with five other members of the World Trade Organisation (Costa Rica, Fiji, Iceland, New Zealand, Norway) on the Agreement on Climate Change, Trade and Sustainability (ACCTS) that seeks to liberalise trade in environmental goods and services, eliminate harmful fossil fuel subsidies, and promote voluntary eco-labelling programmes.

Furthermore, Switzerland advocates the use of the most efficient technologies available for gas mid-stream and down-stream projects in developing countries. The Swiss policy on fossil fuel investments by multilateral development banks (MDBs) rejects investments in coal financing and up-stream fossil fuel activities but allows support to gas power plants as well as gas mid-stream and down-stream projects in limited circumstances when four cumulative criteria (need, efficiency, additionality and transition) are met. This ensures that the project is in line with the goals of the Paris Agreement.

Several Swiss universities conduct research in the field of carbon capture and storage and cooperate with other research institutions, companies and universities primarily in Europe and northern America to further develop the technology. Currently, Switzerland is not supporting any least developed countries and other developing countries in the development of fossil fuel-fired power plants with carbon capture and storage technology, because Switzerland is of the view that the technology is not sufficiently mature and cost effective yet.

Strengthening the capacity of developing country Parties for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

Switzerland supports through different projects the enhancement of efficiency in industrial production, i.e. ‘cleaner production’. These cleaner production projects promote eco-efficient means of production and better working conditions attained through technological improvements and behavioural changes in both management and staff in industrial companies and services. The resulting rise of economic and environmental efficiency and improved competitiveness is gained through the systematic optimisation of energy use, processing of raw material, more efficient use of resources and thus better protection of the environment. Switzerland also supports efforts aiming at the adoption of cleaner fuel standards (i.e. with lower sulphur content) as well as higher vehicle emission standards, which can reduce air pollution.

Switzerland also supports through different projects the energy efficiency and decarbonisation of end-use sectors such as construction and transportation. These projects support the use of low greenhouse gas construction materials and processes, the efficiency of heating of building and facilities, meeting the growing need for cooling while avoiding soaring energy demand and greenhouse gas emissions, and improve efficiency of energy use for transport.

Furthermore, there is a rising awareness and demand by consumers for environmentally sound products. In order to alleviate potential adverse economic impacts of corresponding national measures, Switzerland promotes and supports the development of international standards, especially with regard to the sustainable use of natural resources (including agricultural commodities), e.g. through the creation of sustainability standards, financial incentives and favourable framework conditions in developing countries.

Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Most developing and transition countries have, in recent years, taken important steps towards trade liberalisation, in order to align their trade policies with international trade agreements. The Swiss State Secretariat for Economic Affairs supports these efforts, because a multilaterally acknowledged and respected set of regulations for international transactions not only strengthens trade as such, but also creates more potent and legally secure markets to the benefit of all players.

The measures taken by the Swiss State Secretariat for Economic Affairs aim at creating the necessary conditions for earning additional income in the beneficiary countries and thereby contribute directly to the alleviation of poverty. The Swiss State Secretariat for Economic Affairs is focusing on three areas of intervention along the value chain: (i) enabling framework conditions for trade, (ii) international competitiveness, and (iii) improving market access.

Conversely, measures taken to help countries highly dependent on fossil fuel consumption to reduce this consumption through energy efficiency measures and the transition to renewable energies allows them to free up resources that were dedicated to this consumption, to accordingly invest in the diversifying of their economies – notably their energy sector, and to limit their exposure to the risk of a concomitant increase in fossil fuel prices.

Regarding market access, trade between developing and industrial countries is often insufficiently developed respectively not diversified enough. On the one hand, in some developing countries there is still a lack of necessary production capacities, quality standards, transport infrastructure and know-how; on the other hand, tariff and non-tariff barriers to trade make economic diversification and direct access to markets more difficult.

Switzerland promotes access to Swiss markets by granting preferential tariffs on products from developing and emerging countries. In addition, the Swiss State Secretariat for Economic Affairs runs programmes for promoting imports to Switzerland and the rest of Europe. Easing market entry for products from disadvantaged countries is an important contribution to the promotion and diversification of trade, the increase of export revenues and thus to the economic development of the partner countries. Switzerland supports developing and transition countries in the following areas:

- Generalised system of preferences;
- Swiss Import Promotion Program;[60]
- Promotion and strengthening of private voluntary social and environmental standards based on international multi-stakeholder approaches, such as Better Cotton, 4C (Common Code for the Coffee Community), Roundtable for Sustainable Biofuels, etc.

Finally, Switzerland is a strong supporter of the Extractive Industries Transparency Initiative. Switzerland acts based on the conviction that an efficient, inclusive and sustainable use of natural resources is an important driving force for sustainable economic growth, contributing to sustainable development and poverty reduction. The sustainable management of natural resources – as supported by the Extractive Industries Transparency Initiative principle and criteria including regular publication and audit of revenues – is key to mobilise the funds for diversification strategies.

Changes compared to the previous submission

There are no fundamental changes compared to the previous submission.

[60] www.sippo.ch

References

Alig, M., Prechsl, U., Schwitter, K., Waldvogel, T., Wolff, V., Wunderlich, A., Zorn, A., Gaillard, G., 2015: Ökologische und ökonomische Bewertung von Klimaschutzmassnahmen zur Umsetzung auf landwirtschaftlichen Betrieben in der Schweiz. Agroscope Science, 29. Agroscope, Ettenhausen. *https://ira.agroscope.ch/de-CH/Page/Einzelpublikation/Download?einzelpublikationId=35396* [18.07.2022]

ARE, 2007: Volkswirtschaftliche Auswirkungen der LSVA mit höherer Gewichtslimite. Swiss Federal Office for Spatial Development, Bern. *https://bit.ly/2OUGWTs* [18.07.2022]

ARE, 2021a: Schweizerische Verkehrsperspektiven 2050. Swiss Federal Office for Spatial Development, Bern. 16.11.2021 *https://www.are.admin.ch/dam/are/de/dokumente/verkehr/publikationen/verkehrsperspektiven-schlussbericht.pdf* [18.07.2022]

ARE, 2021b: Externe Kosten und Nutzen des Verkehrs in der Schweiz – Strassen-, Schienen-, Luft- und Schiffsverkehr 2018. Swiss Federal Office for Spatial Development, Bern. 06.07.2021. *https://www.are.admin.ch/dam/are/de/dokumente/verkehr/publikationen/externe_kosten_undnutzendesverkehrsinderschweiz.pdf* [18.07.2022]

Brändli, U.-B., Abegg, M. and Allgaier Leuch, B. (Red.), 2020: Schweizerisches Landesforstinventar – Ergebnisse der vierten Erhebung 2009–2017. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Swiss Federal Office for the Environment, Bern. *https://lfi.ch/publikationen/publ/ergebnisberichte/LFI4_Ergebnisbericht.pdf* [18.07.2022]

Carbotech, 2020: Emissionsperspektiven F-Gase: HFKW, PFKW, NF_3 und SF_6 (Update 2020). Carbotech AG, Basel. [confidential/internal]

Climate Cent Foundation and Swiss Confederation, 2013: Agreement between the Climate Cent Foundation and the Swiss Confederation regarding the modalities governing the termination of contractual relations between the Swiss Confederation and the Foundation, and the use of the Foundation's surplus assets. *https://bit.ly/2Ovbc8q* [18.07.2022]

Climate Cent Foundation, 2013: Abschlussbericht 2005–2013. Climate Cent Foundation, Zurich. *https://bit.ly/2ryXEQi* [18.07.2022]

Consaba, 2016: Erhebung Verwertung Deponiegas über Fackelanlagen in der Schweiz, 1990 bis 2014. Consaba GmbH (A. Bauen), Bern. 23.09.2016. *https://bit.ly/37QIHcY* [18.07.2022]

DETEC, 2016: Auswirkungen der CO_2-Emissionsvorschriften für neue Personenwagen 2012–2015. Swiss Federal Department of the Environment, Transport, Energy and Communications, Bern. 20.12.2016. *https://bit.ly/2OS4uIu* [18.07.2022]

DETEC, 2020: Auswirkungen der CO_2-Emissionsvorschriften für neue Personenwagen 2012–2018. Swiss Federal Department of the Environment, Transport, Energy and Communications, Bern. 18.02.2020. *https://bit.ly/3xfODsX* [18.07.2022]

DETEC, 2021: Mobilität und Raum 2050 – Sachplan Verkehr, Teil Programm. Swiss Federal Department of the Environment, Transport, Energy and Communications, Bern. 20.10.2021. *https://www.are.admin.ch/dam/are/de/dokumente/raumplanung/dokumente/bericht/sachplan-verkehr-programm-m-u-r-2050.pdf* [18.07.2022]

Econcept, 2008: Reduktion Treibhausgasemissionen: Gutachten Sekundärnutzen. Econcept, Zurich (mandated by the Swiss Federal Office for the Environment, Bern). *https://bit.ly/2Oy1u5d* [18.07.2022]

Ecoplan, 2009: Volkswirtschaftliche Auswirkungen der Schweizer Post-Kyoto-Politik. Ecoplan, Bern (mandated by the Swiss Federal Office for the Environment, Bern). *https://bit.ly/2L2ydgz* [18.07.2022]

Ecoplan, 2016: Externe Evaluation der Zielvereinbarungen – Umsetzung, Wirkung, Effizienz und Weiterentwicklung. Ecoplan, Bern (mandated by the Swiss Federal Office of Energy, Bern). November, 2016. *https://www.bfe.admin.ch/bfe/de/home/news-und-medien/evaluationen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvODU4Ng==.html* [18.07.2022]

Ecoplan, 2017: Wirkungsabschätzung der CO_2-Abgabe – Aktualisierung bis 2015. Ecoplan, Bern (mandated by the Swiss Federal Office for the Environment). 16.06.2017. *https://bit.ly/2q2grmt* [18.07.2022]

EnDK, 2014: Mustervorschriften der Kantone im Energiebereich, Ausgabe 2014. Conference of Cantonal Energy Directors, Chur. *https://bit.ly/37KPSmN* [18.07.2022]

EnDK, 2021: Gebäude wird zum Energiehub – Winterstromproduktion im Inland muss zulegen. Press relase by the Conference of Cantonal Energy Directors, 20.08.2021, Chur. *https://www.endk.ch/de/ablage/dokumentation-archiv-muken/20210820_Medienmitteilung_EnDK_d.pdf* [18.07.2022]

EnDK/SFOE/FOEN, 2021: Stand der Energie- und Klimapolitik in den Kantonen, 2021. Conference of Cantonal Energy Directors, Chur / Swiss Federal Office of Energy, Bern / Swiss Federal Office for the Environment, Bern. 11.08.2021. *https://www.bfe.admin.ch/bfe/de/home/politik/kantone-und-gemeinden.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvYWQvMTA1NTY=.html* [18.07.2022]

EPFL and Infras, 2016: Emissions scenarios without measures, 1990–2030. Swiss Federal Institute of Technology in Lausanne, ENAC IA LEURE, Lausanne / Infras, Zurich (mandated by the Swiss Federal Office for the Environment, Bern). 04.05.2016. *https://bit.ly/2rzNsH8* [18.07.2022]

EPFL, 2017: Updated emissions scenarios without measures, 1990–2035. Swiss Federal Institute of Technology in Lausanne, ENAC IA LEURE, Lausanne (mandated by the Swiss Federal Office for the Environment, Bern). 12.10.2017. *https://bit.ly/33An5hn* [18.07.2022]

FOAG, 2011: Klimastrategie Landwirtschaft: Klimaschutz und Anpassung an den Klimawandel für eine nachhaltige Schweizer Land- und Ernährungswirtschaft. Swiss Federal Office for Agriculture, Bern. *https://bit.ly/2OwmJEt* [18.07.2022]

FOEN and SFOE, 2018: Wirkung der Klima- und Energiepolitik in den Kantonen 2016, Sektor Gebäude. Swiss Federal Office for the Environment, Bern / Swiss Federal Office of Energy, Bern. *https://bit.ly/2qNMyH8* [18.07.2022]

FOEN and SFOE, 2020: Wirkung der Klima- und Energiepolitik in den Kantonen 2018, Sektor Gebäude. Swiss Federal Office for the Environment, Bern / Swiss Federal Office of Energy, Bern. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/wirkung-der-klima-und-energiepolitik-in-den-kantonen-2016-sektor-gebaeude.pdf* [18.07.2022]

FOEN, 2007: The CO_2 Effects of the Swiss Forestry and Timber Industry – Scenarios of future potential for climate change mitigation. Swiss Federal Office for the Environment, Bern. UW-0739-E. *www.bafu.admin.ch/uw-0739-e* [18.07.2022]

FOEN, 2015: Wirkungsabschätzung CO_2-Abgabe – Synthese (Modellrechnungen). Swiss Federal Office for the Environment. Bern. *https://bit.ly/2R3Wx5C* [18.07.2022]

FOEN, 2016: Wirkungsabschätzung CO_2-Abgabe auf Brennstoffe – Direktbefragungen zur Abschätzung der Wirkung der CO_2-Abgabe auf Unternehmensstufe. Swiss Federal Office for the Environment, Bern. *https://bit.ly/37Qg2oc* [18.07.2022]

FOEN, 2017: Synthesebericht: Volkswirtschaftliche Beurteilung der klimapolitischen Massnahmen nach 2020. Swiss Federal Office for the Environment, Bern. *https://bit.ly/2QVxXDZ* [18.07.2022]

FOEN, 2021: Forest Policy: objectives and measures 2021–2024. For the sustainable management of forests in Switzerland. Swiss Federal Office for the Environment, Bern. UI-2119-E, 20.12.2021. *www.bafu.admin.ch/ui-2119-e* [18.07.2022]

FOEN, 2022: Factsheet – Long-term climate strategy. Swiss Federal Office for the Environment, Bern. 26.01.2022. *https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/fachinfo-daten/faktenblatt_langfristige_klimastrategie.pdf* [18.07.2022]

FOEN/SFOE/SECO, 2021: Wood Resource Policy. Strategy, Objectives and Wood Action Plan 2021–2026. Swiss Federal Office for the Environment, Bern / Swiss Federal Office of Energy, Bern / Swiss State Secretariat for Economic Affairs, Bern. UI-2103-E, 20.06.2021. *www.bafu.admin.ch/ui-2103-e* [18.07.2022]

Furrer, C., Stüssi, M., Bystricky, M. 2021: Umweltbewertung ausgewählter Klimaschutzmassnahmen auf Landwirtschaftsbetrieben. Agroscope Science, 121. Zürich, Switzerland. *https://ira.agroscope.ch/de-CH/Page/Einzelpublikation/Download?einzelpublikationId=49432* [18.07.2022]

KliK, 2016: Jahresbericht 2015 der Stiftung Klimaschutz und CO_2-Kompensation KliK, Zurich. *https://bit.ly/2XYERtw* [18.07.2022]

OPET, 2011: Masterplan Cleantech – A federal government's strategy to improve resource efficiency and promote renewable energies. Swiss Federal Office for Professional Education and Technology, Bern. *https://bit.ly/34uUuM0* [18.07.2022]

SFOE, 2017: CO_2-Emissionsvorschriften für Personenwagen und leichte Nutzfahrzeuge – Grundlagenbericht. Swiss Federal Office of Energy, Bern. *https://www.bfe.admin.ch/bfe/de/home/effizienz/mobilitaet/co2-emissionsvorschriften-fuer-neue-personen-und-lieferwagen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRtaW4uY2gvZGUvcHVibGljYX/Rpb24vZG93bmxvY-WQvODU4OQ==.html* [18.07.2022]

SFOE, 2020: Das Gebäudeprogramm. Jahresbericht 2020. Swiss Federal Office of Energy, Bern. *https://bit.ly/3DtatvA* [18.07.2022]

SFOE, FOEN, SERI and SECO, 2015: Masterplan Cleantech – Eine Strategie des Bundes für Ressourceneffizienz und erneuerbare Energien – Bericht über die Umsetzung der Massnahmen. Swiss Federal Office of Energy, Bern / Swiss Federal Office for the Environment, Bern / State Secretariat for Education, Research and Innovation, Bern / State Secretariat for Economic Affairs, Bern. 08.05.2015. *https://www.newsd.admin.ch/newsd/message/attachments/39299.pdf* [18.07.2022]

Swiss Confederation, 1958: Strassenverkehrsgesetz (SVG) vom 19.12.1958 (Stand am 01.01.2020). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/19580266/index.html* [18.07.2022]

Swiss Confederation, 1979: Swiss Federal Act on Spatial Planning (Spatial Planning Act, SPA) of 22.06.1979 (Status as of 01.01.2019). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/19790171/index.html* [18.07.2022]

Swiss Confederation, 1983: Swiss Federal Act on the Protection of the Environment (Environmental Protection Act, EPA) of 07.10.1983 (Status as of 01.01.2022). *https://www.admin.ch/opc/en/classified-compilation/19830267/index.html* [18.07.2022]

Swiss Confederation, 1985: Swiss Federal Ordinance on Air Pollution Control (OAPC) of 16.12.1985 (Status as of 01.01.2022). *https://www.admin.ch/opc/en/classified-compilation/19850321/index.html* [18.07.2022]

Swiss Confederation, 1991: Swiss Federal Act on Forest (Forest Act, ForA) of 04.10.1991 (Status as of 01.01.2022). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/1992/2521_2521_2521/en* [18.07.2022]

Swiss Confederation, 1996: Mineralölsteuergesetz (MinöStG) vom 21.06.1996 (Stand am 01.01.2022). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/19960320/index.html* [18.07.2022]

Swiss Confederation, 1997: Verordnung über die Lenkungsabgabe auf flüchtigen organischen Verbindungen (VOCV) vom 12.11.1997 (Stand am 01.06.2022). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/1997/2972_2972_2972/de* [18.07.2022]

Swiss Confederation, 1997a: Bundesgesetz über eine leistungsabhängige Schwerverkehrsabgabe (Schwerverkehrsabgabegesetz, SVAG) vom 19.12.1997 (Stand am 01.01.2022). Swiss Confederation. *https://bit.ly/2L5fYHw* [18.07.2022]

Swiss Confederation, 1998b: Swiss Federal Act on Agriculture (Agriculture Act, AgricA) of 29.04.1998 (Status as of 01.03.2022). Swiss Confederation. *https://www.admin.ch/opc/en/classified-compilation/19983407/index.html* [18.07.2022]

Swiss Confederation, 1998c: Swiss Federal Act on Archiving (Archiving Act, ArchA) of 26.06.1998 (Status as of 01.05.2013). Swiss Confederation. *https://www.admin.ch/opc/en/classified-compilation/19994756/index.html* [18.07.2022]

Swiss Confederation, 1999a: Federal Constitution of the Swiss Confederation of 18.04.1999 (Status as of 13.02.2022). *https://www.admin.ch/opc/en/classified-compilation/19995395/index.html* [18.07.2022]

Swiss Confederation, 1999b: Swiss Federal Act on the Reduction of CO_2 Emissions (First CO_2 Act) of 08.10.1999 (Status as of 01.05.2012). Swiss Confederation. *http://www.admin.ch/opc/de/classified-compilation/19995362/index.html* [18.07.2022]

Swiss Confederation, 1999c: Ordinance on the Organisation of the Federal Department of the Environment, Transport, Energy and Communications of 06.12.1999 (Status as of 01.01.2019). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/2000/44/de* [18.07.2022]

Swiss Confederation, 2003: Nuclear Energy Act (NEA) of 21.03.2003 (Status as of 01.01.2022). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/2004/723/en* [18.07.2022]

Swiss Confederation, 2005a: Ordinance on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (Chemical Risk Reduction Ordinance, ORRChem) of 18.05.2005 (Status as of 01.05.2022). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/2005/478/en* [18.07.2022]

Swiss Confederation, 2007: Bundesgesetzüber die Stromversorgung (Stromversorgungsgesetz, StromVG) vom 23.03.2007 (Stand am 01.06.2021). Swiss Confederation. *https://www.fedlex.admin.ch/eli/cc/2007/418/de* [18.07.2022]

Swiss Confederation, 2009: Swiss Federal Act on the Future Development of the Railway Infrastructure of 20.03.2009 (Status as of 01.01.2016). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/20071907/index.html* [18.07.2022]

Swiss Confederation, 2011: Swiss Federal Act on the Reduction of CO_2 Emissions (Second CO_2 Act) of 23.12.2011 (Status as of 01.01.2022). Swiss Confederation. *http://www.admin.ch/opc/en/classified-compilation/20091310/index.html* [18.07.2022]

Swiss Confederation, 2012: Ordinance on the Reduction of CO_2 Emissions (CO_2 Ordinance) of 30.11.2012 (Status as of 01.06.2022). Swiss Confederation. *https://www.admin.ch/opc/en/classified-compilation/20120090/index.html* [18.07.2022]

Swiss Confederation, 2012a: Adaptation to climate change in Switzerland. Goals, challenges and fields of action. First part of the Swiss Federal Council's strategy adopted on 2 March 2012. *www.bafu.admin.ch/ud-1055-e* [18.07.2022]

Swiss Confederation, 2015: Ordinance on the Avoidance and the Disposal of Waste (Waste Ordinance, ADWO) of 04.12.2015 (Status as of 01.04.2022). Swiss Confederation. *https://www.admin.ch/opc/en/classified-compilation/20141858/index.html* [18.07.2022]

Swiss Confederation, 2016: Swiss Federal Act on Energy of 30.09.2016 (Status as of 01.01.2021). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/20121295/index.html* [18.07.2022]

Swiss Confederation, 2019: Parlamentarische Initiative 19.475: Das Risiko beim Einsatz von Pestiziden reduzieren. Swiss Confederation. *https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20190475* [18.07.2022]

Swiss Federal Audit Office, 2013: Gebäudeprogramm von Bund und Kantonen – Evaluation der Programmorganisation. Swiss Federal Audit Office, Bern. *https://bit.ly/37R36OO* [18.07.2022]

Swiss Federal Audit Office, 2016: Prüfung der CO_2-Kompensation in der Schweiz. Swiss Federal Audit Office, Bern. 25.05.2016. *https://bit.ly/2OtVni6* [18.07.2022]

Swiss Federal Audit Office, 2017a: Evaluation der Lenkungswirkung des Emissionshandelssystems. Swiss Federal Audit Office, Bern. 11.01.2017. *https://bit.ly/2OwNV5V* [18.07.2022]

Swiss Federal Audit Office, 2017b: Prüfung der Aufsicht über den Technologiefonds. Swiss Federal Audit Office, Bern. 11.01.2017. *https://bit.ly/2rBQBq1* [18.07.2022]

Swiss Federal Council, 2008: Subventionsbericht des Bundesrates vom 30.05.2008. Swiss Federal Council, Bern. *https://bit.ly/2XZHSdp* [18.07.2022]

Swiss Federal Council, 2016a: Wirksamkeit der Finanzhilfen zur Verminderung der CO_2-Emissionen bei Gebäuden gemäss Artikel 34 CO_2-Gesetz. Swiss Federal Council, Bern. 31.03.2016. *https://bit.ly/2DpxAto* [18.07.2022]

Swiss Federal Council, 2021a: Switzerland's Long-Term Climate Strategy. Swiss Federal Council. Bern, Switzerland. *https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/reduction-targets/2050-target/climate-strategy-2050.html* [18.07.2022]

Swiss Federal Council, 2021b: 2030 Sustainable Development Strategy. Swiss Federal Council, Bern. 23.06.2021. *https://www.are.admin.ch/dam/are/en/dokumente/nachhaltige_entwicklung/publikationen/sne2030.pdf.download.pdf/sne2030.pdf* [18.07.2022]

Swiss Federal Council, 2022a: Implementing the 2030 Agenda for Sustainable Development: Voluntary National Review of Switzerland 2022. Swiss Federal Council, Bern. 04.05.2022. *https://www.eda.admin.ch/content/dam/agenda2030/en/documents/laenderbericht2022_EN.pdf* [18.07.2022]

Swiss Federal Council, 2022b: Zukünftige Ausrichtung der Agrarpolitik – Bericht des Bundesrates in Erfüllung der Postulate 20.3931 der WAK-S vom 20. August 2020 und 21.3015 der WAK-N vom 2. Februar 2021. Swiss Federal Council, Bern. 22.06.2022. *https://www.parlament.ch/centers/eparl/curia/2020/20203931/Bericht%20BR%20D.pdf* [18.07.2022]

Technology Fund, 2021: Jahresrückblick 2020 Technologiefonds. Technology Fund, mandated by the Swiss Federal Office for the Environment, Bern. 15.06.2021. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/@zur_Ver%C3%B6ffentlichung_Jahresbericht_2020_final.pdf* [18.07.2022]

5 Projections and total effect of policies and measures

In this chapter, Switzerland's greenhouse gas emission projections under the following three scenarios are reported:

- The 'with existing measures' (WEM) scenario, encompassing currently implemented and adopted policies and measures. The WEM scenario thus reflects the current state of legislation (as of summer 2022), also taking into account the stipulated strengthening of existing policies and measures (i.e. any strengthening foreseen under current legislation);
- The 'without measures' (WOM) scenario, excluding all implemented, adopted and planned policies and measures to the extent possible. However, autonomous diffusion of technological progress takes place also under the WOM scenario, leading to a gradual improvement of energy efficiency (which is obviously slower than under the WEM scenario);
- The 'with additional measures' (WAM) scenario, encompassing implemented, adopted and planned policies and measures. The WAM scenario thus takes into account – in addition to all policies and measures considered under the WEM scenario – the planned strengthening of existing policies and measures as well as new policies and measures that have not yet been put in concrete terms but are planned in order to further advance Switzerland's contribution to climate mitigation.

Section 5.1 presents Switzerland's total greenhouse gas emissions projected under the WEM, WOM and WAM scenarios from 1990 to 2035, disaggregated by sector and by gas. The projections are presented relative to actual and unadjusted inventory data for the preceding years (*FOEN*, 2022a). An overview of measures considered under the different scenarios and details about the historical and projected key underlying assumptions driving the emission scenarios are provided in this section as well. In section 5.2, the assessment of the aggregate effect of policies and measures is discussed. Information on the methodology applied as well as the underlying assumptions specific to each sector are presented in section 5.3.1 for the energy sector (including transport), in section 5.3.2 for the industrial processes and product use sector, in section 5.3.3 for the agriculture sector, in section 5.3.4 for the land use, land-use change and forestry sector, in section 5.3.5 for the waste sector, in section 5.3.6 for indirect CO_2 emissions, and in section 5.3.7 for international transport. Section 5.3.8 and section 5.3.9 present major changes since Switzerland's last submission and information on the sensitivity analysis, respectively. BR CTF tables 5 and 6(a) to 6(c) provide a summary of Switzerland's updated projections, however, due to technical constraints of the BR CTF platform, the projections could only be reported for the years up to 2030 in the BR CTF tables 6(a) to 6(c).

5.1 Projections

5.1.1 Policies and measures considered under the WEM, WOM and WAM scenarios

Tab. 24 gives an overview of the policies and measures considered under the different scenarios; details regarding each policy and measure are discussed in chapter 4.

Tab. 24 > Policies and measures considered under the WEM, WOM and WAM scenarios (policies and measures marked with a dot are considered under the respective scenario). The bifurcation points for the WEM and WOM scenarios are shown in Tab. 30. Under the WAM scenario, some measures are strengthened/adjusted compared to the WEM scenario.

Measure	Section in chapter 4	Sector	WEM	WOM	WAM	Remark
First CO_2 Act (1999)	4.2.2	Cross-sectoral	•		•	
Second CO_2 Act (2011)	4.2.3	Cross-sectoral	•		•	
Third CO_2 Act (2025)	4.2.4	Cross-sectoral			•	Planned policy and measure.
CO_2 levy on heating and process fuels	4.2.5	Cross-sectoral	•		•	The planned strengthening/adjustment does not lead to an additional mitigation impact under the WAM scenario compared to the WEM scenario (see section 4.2.5).
Emissions trading scheme	4.2.6	Cross-sectoral	•		•	The strengthening of the WAM compared to WEM will be guided by the relevant provisions in the European Union. So far, the strengthening could not yet be translated to a concrete mitigation impact and is therefore not taken into account.
Negotiated reduction commitments (for exemption from the CO_2 levy)	4.2.7	Cross-sectoral	•		•	WAM strengthened compared to WEM.

SwissEnergy programme	4.3.2	Energy	●		●	The Swiss Federal Office of Energy refrains from estimating the mitigation impact of the SwissEnergy programme (for explanations see section 4.3.2). In contrast, *Prognos et al.* (2020) implicitly include this policy and measure when estimating overall technical progress.
National buildings refurbishment programme	4.3.3	Energy	●		●	WAM strengthened/adjusted compared to WEM.
Building codes of the cantons	4.3.4	Energy	●		●	The strengthening of the WAM compared to WEM is not yet well enough defined to be translated to a concrete mitigation impact and could therefore not be taken into account.
Feed-in tariff system	4.3.5	Energy	●		●	See investment aids for the planned strengthening.
Investment aids	4.3.6	Energy	●		●	The Swiss Federal Office of Energy refrains from estimating the mitigation impact of the Investment aids beyond 2020 (for explanations see section 4.3.6). In contrast, *Prognos et al.* (2020) implicitly include this policy and measure when estimating overall technical progress. For the WAM scenario, the planned prolongation beyond 2030 could not be taken into account, as the respective bottom-up estimates are not available.
Negotiated reduction commitment of municipal solid waste incineration plant operators	4.3.7	Energy				This policy and measure points at the net emissions of municipal solid waste incineration plants, i.e. it is expected that emission reductions are achieved mainly by indirect savings thanks to the additional production of electricity and heat as well as the recovery of metals from the bottom ash. In particular the latter may indirectly reduce greenhouse gas emissions outside Switzerland. For these reasons, the policy and measure is not considered for the projections (all scenarios). The new agreement which aims at equipping at least one plant with a unit for carbon capture and storage is also not considered, given its limited impact and pilot character.
CO_2 emission regulations for newly registered vehicles	4.4.2	Transport	●		●	WAM strengthened compared to WEM.
Energy label for new motor vehicles	4.4.3	Transport	●		●	
Climate Cent	4.4.4	Transport	●		●	
Partial compensation of CO_2 emissions from motor fuel use	4.4.5	Transport	●		●	WAM strengthened compared to WEM.
Heavy vehicle charge	4.4.6	Transport	●		●	
Mineral oil tax reduction on biofuels and natural gas	4.4.7	Transport	●		●	WAM strengthened compared to WEM.
International exhaust gas regulations (NMVOC)	4.4.8	Transport	●		●	Relevant for indirect CO_2 emissions.
CO_2 emissions standard for aircraft	4.4.9	Transport	●	●	●	As this policy and measure is of global significance, it is assumed that it does not lead to differences between the WEM, WOM and WAM scenarios.
Carbon offsetting and reduction scheme for international civil aviation (CORSIA)	4.4.10	Transport				Not explicitly included in the emission perspectives.
Non-volatile particle matter emission regulation for aircraft engines	4.4.11	Transport				Relevant for aviation non-CO_2 climate impacts from clouds.
Sustainable aviation fuel policy	4.4.12	Transport			●	Planned policy and measure.
Provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3)	4.5.2	IPPU	●		●	WAM strengthened compared to WEM.
Ordinance on Air Pollution Control	4.5.3	IPPU	●		●	Relevant for indirect CO_2 emissions.
NMVOC incentive fee	4.5.4	IPPU	●		●	Relevant for indirect CO_2 emissions.
Obligations in relation to chemical conversion processes (N_2O)	4.5.5	IPPU	●		●	Catalyst installed at the respective chemical plant in the course of 2021.

Proof of ecological performance to receive direct payments	4.6.2	Agriculture	●	●	●	Because the bifurcation point of the WEM and WOM scenarios of this measure is 2011 (Tab. 30), most of the mitigation impact provided in section 4.6.2 and Tab. 21 is reflected in all scenarios (as the mitigation impact reported in Tab. 21 is mostly achieved in the early 1990s).
Resource programme (subsidies for a more efficient use of natural resources)	4.6.3	Agriculture	●		●	
Climate strategy for agriculture	4.6.4	Agriculture	●		●	WAM strengthened compared to WEM.
Agricultural policy 2014–2017 and 2018–2021	4.6.5	Agriculture	●		●	WAM strengthened compared to WEM.
Enhancement of label standards	4.6.6	Agriculture				Planned policy and measure not explicitly included in the emission perspectives.
Forest Act (sustainable forest management and forest area conservation)	4.7.2	LULUCF	●		●	
Wood Action Plan (implementation of Swiss Wood Resource Policy)	4.7.3	LULUCF	●		●	
Measures within Forest Policy (objectives and implementation)	4.7.4	LULUCF	●		●	
Forest Act (changes due to revision 2017)	4.7.5	LULUCF	●		●	
Ban on landfilling of combustible waste	4.8.2	Waste	●		●	
Ordinance on the Avoidance and Management of Waste	4.8.3	Waste	●		●	

IPPU, industrial processes and product use; LULUCF, land use, land-use change and forestry

5.1.2 Key underlying assumptions

To provide a general overview of the drivers of Switzerland's greenhouse gas emission scenarios, Tab. 25 shows key underlying assumptions used for the modelling of projections. The information provided corresponds to the information reported in BR CTF table 5 and provides the basis for all scenarios (see section 5.3 for assumptions which vary from scenario to scenario). Population is assumed to increase considerably over the coming decades.[61] Other key underlying assumptions are also projected to increase in the future. Indeed, Switzerland's gross domestic product, which also strongly influences energy consumption and greenhouse gas emissions, is assumed to increase considerably over the coming decades. The projection of the energy reference area – i.e. the sum of heated gross floor areas, above and below ground – is closely related to the projection of population, but additionally reflects the increasing demand for living area per capita and fewer persons per household (Tab. 25 shows the total energy references area, including household, services and industries). The projection of heating degree days follows the climate scenarios established for Switzerland (RCP4.5, see section 6.3.9 for more details). While for historical years the heating degree days reflect the observed natural variability of meteorological conditions (mainly during winter), a smooth trend is assumed for projected years reflecting the expected average meteorological conditions. Accordingly, for future years the greenhouse gas emissions scenarios are based on average meteorological conditions, which are also reflected in the average day temperatures. However, as in the past, actual emissions may vary substantially from year to year in the future as well. The projections of energy prices reflect the values used by the International Energy Agency in its World Energy Outlook 2018.[62] The key underlying assumptions 1–8 stem from *Prognos et al.* (2020), no values are provided in the respective data table[63] for the years 1990 and 1995 (relevant for the projections are in particular the values reaching beyond the latest inventory year). In the data table, *Prognos et al.* (2020) provide plenty of further and very detailed assumptions used to establish the projections, such as energy uses in different sectors, split of energy carriers, etc. The key underlying assumptions 9–10 with regard to transport stem from *FOEN* (2022a) and are directly implemented in the national air pollution database EMIS.

Tab. 25 > Historical and projected key underlying assumptions used for the modelling of Switzerland's greenhouse gas emission projections. See section 6.3.9 for more details about heating degree days.

Key underlying assumptions	Historical							Projected		
	1990 [a]	1995 [a]	2000	2005	2010	2015	2020 [b]	2025	2030	2035
[1] Population (annual mean, million inhabitants)	NA	NA	7.18	7.44	7.83	8.28	8.71	9.11	9.49	9.82
[2] Gross domestic product (prices 2017, billion Swiss francs)	NA	NA	520	549	603	648	713	760	805	851
[3] Energy reference area (total, million square metres)	NA	NA	621	653	706	744	782	816	847	874
[4] Full-time equivalents (all sectors, million)	NA	NA	3.42	3.45	3.76	3.99	4.14	4.24	4.31	4.38

[61] https://www.bfs.admin.ch/bfs/en/home/statistics/population/population-projections/national-projections.html

[62] https://www.iea.org/reports/world-energy-outlook-2018

[63] The data table is named 'EP2050+_Ergebnissynthese_2020-2060_WWB_KKW50_aktuelleRahmenbedingungen_2022-04-12.xlsx'.

[5] Heating degree days (number)	NA	NA	3 081	3 518	3 586	3 075	3 182	3 135	3 089	3 042
[6] Average day temperature (degrees Celsius)	NA	NA	10.4	9.3	9.0	10.6	10.2	10.3	10.5	10.6
[7] Crude oil price (prices 2017, US dollars per megawatt-hour)	NA	NA	38.8	63.2	87.5	62.2	74.8	88.0	96.0	104.5
[8] Price for natural gas (prices 2017, US dollars per megawatt-hour)	NA	NA	13.3	20.9	28.5	22.4	24.4	26.7	28.0	29.4
[9] Passenger cars (billion vehicle kilometres)	42 649	41 324	45 613	48 040	52 066	56 620	52 055	61 749	63 691	65 335
[10] Freight transport (road) and buses (billion vehicle kilometres)	4 874	5 155	5 529	5 682	6 090	6 767	7 002	7 687	8 111	8 510

[a] The key underlying assumptions 1–8 stem from *Prognos et al.* (2020), no values are provided in the respective data table for the years 1990 and 1995 (relevant for the projections are in particular the values reaching beyond the latest inventory year).

[b] The values used by *Prognos et al.* (2020) for 2020 are based on projections and may differ from real historical values.

Prognos et al. (2020); *FOEN* (2022a)

5.1.3 Results

Tab. 26 and Tab. 27 provide a general overview of the projections of Switzerland's greenhouse gas emissions under the WEM, WOM and WAM scenarios, detailed by sector and by gas (the tables complement the results presented in BR CTF table 6, in particular they also show the projections up to 2035). For a direct comparison with Switzerland's emissions reduction targets, the total emissions presented in the tables and figures of this chapter are composed as follows:

- Emissions of all greenhouse gases from the sectors 1 'Energy', 2 'Industrial processes and product use', 3 'Agriculture' and 5 'Waste' are included;
- Emissions from sector 6 'Other' are excluded;
- Indirect CO_2 emissions are included (for details see section 3.2.4 and Annex B.3.3), with the exception of indirect CO_2 emissions from sector 6 'Other', as this sector is not included at all in Switzerland's emission reduction targets;
- With regard to Switzerland's quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol greenhouse gas emissions and removals from land use, land-use change and forestry are accounted for by an activity-based approach at the end of the commitment period (see Annex B.3.5). Therefore, the emissions from sector 4 'Land use, land-use change and forestry' are not included in the totals presented in this chapter, but the respective evolutions for the different scenarios are reported separately and briefly discussed;
- Greenhouse gas emissions from international transport are excluded, but to increase transparency, they are reported separately and briefly discussed;
- To be fully consistent with Switzerland's emission reduction targets, the values for Switzerland's base year emissions should actually be taken from the update to Switzerland's second initial report (*FOEN*, 2016d, see also FCCC/IRR/2016/CHE). However, relative evolutions in this chapter are provided with regard to the emissions in 1990 according to Switzerland's most recent greenhouse gas inventory submission, in consistency with the values reported in BR CTF Table 6(a) to 6(c).

The evolution of total greenhouse gas emissions under the WEM, WOM and WAM scenarios as relevant for Switzerland's emission reduction targets is displayed in Fig. 65, while the various panels in Fig. 66 and Fig. 67 present the disaggregation by sector and gas, respectively. To provide more details for the energy sector and to allow for a distinction of the contribution of transport[64], the evolution of the different source categories of sector 1 'Energy' (1A1, 1A2, 1A3, 1A4, 1A5, and 1B) under the WEM, WOM and WAM scenarios is shown in Fig. 68 and Fig. 69. Finally, Fig. 70 shows the evolution of indirect CO_2 emissions. In brief, the three scenarios are characterised as follows (emissions as relevant for Switzerland's emission reduction targets, see above):

- **'With existing measures' (WEM) scenario:** By 2025, 2030 and 2035, Switzerland's total greenhouse gas emissions under the WEM scenario are projected to decrease to 78.6 per cent, 72.7 per cent and 68.2 per cent of the emissions in 1990, respectively. While the source category covering residential and commercial/institutional

[64] In BR CTF table 6, 'energy' consists of the greenhouse gas emissions from the source categories 1A1, 1A2, 1A4, 1A5 and 1B (which are targeted with the policies and measures presented in section 4.3), while 'transport' consists of the greenhouse gas emissions from source category 1A3 (which are targeted with the policies and measures presented in section 4.4).

buildings (1A4) dominated total emissions in 1990, its emissions gradually decreased and are projected to continue on a decreasing pathway, reaching a reduction of 50.0 per cent by 2030 compared to 1990 (Fig. 69). Emissions from transport (1A3), on the other hand, increased considerably (by 13.3 per cent) between 1990 and 2008, exceeding emissions from residential and commercial/institutional buildings by 2007. Emissions from the transport sector are largely driven by passenger cars. In the course of about the last decade, efforts to reduce specific vehicle emissions have finally become effective. Thanks to the CO_2 emission regulations for newly registered vehicles (section 4.4.2), as well as thanks to the autonomous technological progress, greenhouse gas emissions from the transport sector are projected to further decrease over the coming years. The emission reduction projected to be achieved by 2030 is 23.5 per cent compared to the highest level in 2008, bringing the emissions from the transport sector to 86.7 per cent of the emissions in 1990. By 2030, Switzerland's total greenhouse gas emissions are projected to decrease by 14.8 million tonnes of CO_2 equivalents below the value in 1990. Emission reductions from the source categories covering residential and commercial/institutional buildings (1A4, reduction of 8.7 million tonnes of CO_2 equivalents), transport (1A3, reduction of 1.9 million tonnes of CO_2 equivalents) and manufacturing industries and construction (1A2, reduction of 1.9 million tonnes of CO_2 equivalents) contribute most to the projected decrease of total greenhouse gas emissions under the WEM scenario. Further contributions come from sector 2 'Industrial processes and product use' (overall reduction of 1.1 million tonnes of CO_2 equivalents, including an increase of F-gases by about 0.5 million tonnes of CO_2 equivalents[65]), sector 3 'Agriculture' (reduction of 0.9 million tonnes of CO_2 equivalents), sector 5 'Waste' (reduction of 0.5 million tonnes of CO_2 equivalents), and indirect CO_2 emissions (reduction of 0.3 million tonnes of CO_2 equivalents). Emissions from source category 1A1 are projected to increase by 0.8 million tonnes of CO_2 equivalents by 2030 compared to 1990. Finally, the source categories 1B and 1A5 are both projected to decrease by 0.1 million tonnes of CO_2 equivalents;

- **'Without measures' (WOM) scenario:** Under the WOM scenario, policies and measures are excluded as of the bifurcation points indicated in Tab. 30, i.e. with a few exceptions as early as 1990. Consequently, emissions under the WOM scenario increase by 9.5 per cent compared to 1990 until around 2010, slowly decreasing again to about the same emission level as in 1990 by 2030 to 2035. This decreasing trend after about 2010 is a result of autonomous technological progress improving the greenhouse gas efficiency also in the absence of (domestic) policies and measures. Under the WOM scenario (as under the WEM scenario), the source categories covering residential and commercial/institutional buildings (1A4) and transport (1A3) are mainly responsible for the general decrease in total greenhouse gas emissions in the coming years, to some extent also the source category manufacturing industries and construction (1A2; see Fig. 68 and Fig. 69). In contrast, emissions from energy industries (1A1) are projected to increase, in particular in 2029 and 2033, i.e. at the time when nuclear power plants are decommissioned and assumed to be replaced by gas-fired combined-cycle power plants (see also Fig. 21 in Switzerland's fourth biennial report). Accordingly, greenhouse gas emissions from energy industries (1A1) exceed, by 2030, the emissions in 1990 by about 3.9 million tonnes of CO_2 equivalents. A continuously increasing trend is also projected for emissions from sector 2 'Industrial processes and product use', which, driven by emissions of HFCs, increase by 1.6 million tonnes of CO_2 equivalents by 2030 compared to 1990;
- **'With additional measures' (WAM) scenario:** By 2030 and 2035, Switzerland's total greenhouse gas emissions under the WAM scenario are projected to decrease to 66.0 and 60.7 per cent of the emissions in 1990, respectively. Compared to the WEM scenario, emissions decrease faster, as new policies and measures are introduced and existing policies and measures are strengthened beyond the strengthening already stipulated under current legislation (i.e., under the WEM scenario). While the energy sector (in particular transport, but also the source categories covering residential and commercial/institutional buildings, manufacturing industries and construction as well as energy industries) is mainly responsible for the additional emission reductions, contributions also come from the agriculture sector and from the additional reduction of emissions of F-gases within the industrial processes and product use sector (Fig. 69).

Regarding **land use, land-use change and forestry**, the difference between the WEM and the WOM scenarios results from different assumptions in forest management practices, because all other parameters are identical for all scenarios (see section 5.3.4). Under the WEM scenario, harvesting is assumed to increase, making the land use, land-use change and forestry sector a net source, with differences between the WEM and the WOM scenarios of 1.5 to 2.3 million tonnes

[65] By 2030, emissions of F-gases are projected to remain above the level of 1990, but historical data and projections suggest the peaking of emissions before 2020 and a decline thereafter.

of CO_2 equivalents over the period from 2021 to 2035. The harvesting rates assumed under the WOM scenario, as derived from the continuation of recent forest management practices observed between 1990 and 2006 could lead to an unsustainable forest stand in the long run and, amongst other effects, jeopardise the capacity of forests to adapt to climate change. Therefore, despite the positive (short-term) effect with regard to carbon sequestration, the WOM scenario is not considered a preferable policy option. In more detail, the following emissions and removals from the land use, land-use change and forestry sector are projected under the different scenarios (see Tab. 36 for underlying assumptions):

- Under the WEM scenario, forest management practices on forest land lead to net removals in the order of –2.9 million to –1.1 million tonnes of CO_2 equivalents per year in the period from 2021 to 2035. In total, the land use, land-use change and forestry sector produces net removals of –2.3 million to –0.5 million tonnes of CO_2 equivalents per year in the period from 2021 to 2035 (Tab. 26);
- Under the WOM scenario, forest management practices on forest land lead to net removals of –4.4 million to –3.4 million tonnes of CO_2 equivalents in the period from 2021 to 2035. In total, the land use, land-use change and forestry sector produces net removals of –3.8 million to –2.8 million tonnes of CO_2 equivalents in the period from 2021 to 2035 (Tab. 26);
- Under the WAM scenario, forest management practices on forest land lead to net emissions in the order of 0.6 million to 1.1 million tonnes of CO_2 equivalents in the period from 2021 to 2035. In total, the land use, land-use change and forestry sector produces net emissions of 1.1 million to 1.7 million tonnes of CO_2 equivalents in the period from 2021 to 2035 (Tab. 26).

In Fig. 66, there is a distinctive shift from 2020 to 2021. There a several reasons for this:

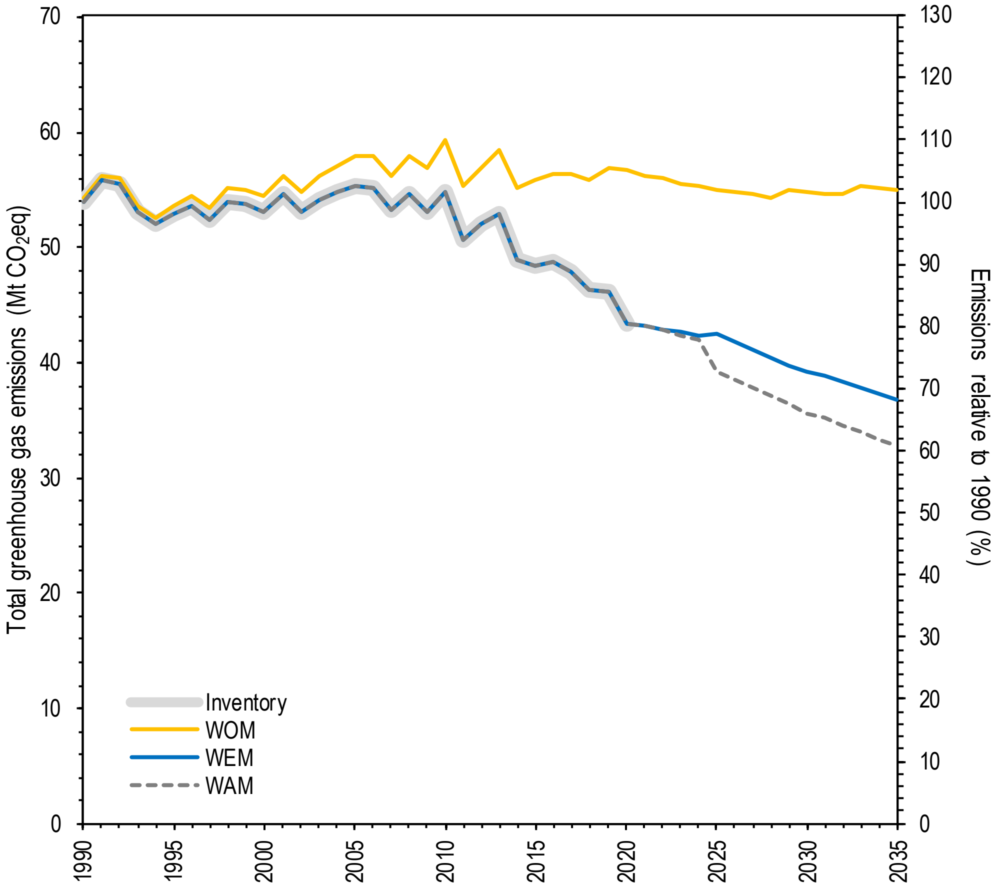
- Inventory data as reported in the Switzerland's most recent greenhouse gas inventory (*FOEN*, 2022a) include the years 1990–2020. From 2021 onwards, simulation results are shown for the three scenarios. However, in the forest sector, scenarios and simulation with the model Massimo start at 2006 (see section 5.3.4), leading to different pathways across the scenarios starting in 2006 and thus also differing from observed values for the period 2006–2020. The model Massimo calculates in 10-years intervals; in between the data are kept constant, explaining the step-wise output (values available for 2006, 2016, 2026 and 2036);
- The WEM scenario does not completely reflect reality. The scenarios used for this report were originally designed for forest development purposes, not for reporting under the UNFCCC. Swiss forest policy, the basis for the WEM scenario, defines goals to be reached, but the measures are not stringent in the sense that they do not include 'penalties' when goals are missed. The WOM scenario, which reflects recent management practices according to *Stadelmann et al.* (2021), is not a measured-based scenario, but a stochastic scenario. The forest management applied in reality lies somewhere between the forest management assumed under the WOM and WEM scenarios;
- Further, there are also methodological challenges which lead to a shift in the modelled and observed estimates (*Thürig et al.*, 2021). One of them is that the model runs on the forest plots common to second national forest inventory (NFI2/1994–1996) and third national forest inventory (NFI3/2004–2006), whereas the actual inventory data are valid for all plots being forest at the time of the inventory. Also, slightly different allometric functions are used for the simulation and the (more detailed) inventory estimates.

Regarding **international transport (bunkers)**, virtually all (more than 99 per cent, see Tab. 4) greenhouse gas emissions stem from aviation, while greenhouse gas emissions from navigation are of negligible importance. Greenhouse gas emissions from international transport are assumed to be the same under the WEM and WOM scenarios, while the planned sustainable aviation fuel policy (4.4.12) is projected to lead to lower emissions under the WAM scenario (see section 5.3.7 for details). By 2030 and 2035, emissions from international transport are projected to increase to 226.2 and 229.6 per cent of the emissions in 1990 under the WEM and WOM scenario, respectively (i.e. emissions more than double). Under the WAM scenario, emission are projected to increase to 215.0 and 186.1 per cent of the emissions in 1990 by 2030 and 2035, respectively (i.e. emissions about double).

In this chapter, solely projections of domestic emissions under the different scenarios are provided, in agreement with the target of the second CO_2 Act which is defined as a 20 per cent domestic reduction by 2020 compared to 1990 (Annex

B.3). While Switzerland's focus indeed lies on domestic emission reductions, international carbon credits play a subsidiary role in particular cases to reach international commitments (Annex B.3.6), but these international carbon credits are not taken into account for the scenarios presented here.

Fig. 65 > Total greenhouse gas emissions under the WEM, WOM and WAM scenarios as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Also shown are actual inventory data for the years 1990 to 2020. The vertical axis to the right indicates emissions relative to 1990. Values are provided in Tab. 26 and Tab. 27. Year-to-year variations visible in all scenarios for the years 1990 to 2020 reflect the impact of meteorological conditions on heating demand (see also section 3.2.3). For projections up to 2035, a smooth trend of meteorological conditions is assumed (in line with the temperature and heating degree days shown in Tab. 25).



Tab. 26 > Switzerland's greenhouse gas emissions under the WEM, WOM and WAM scenarios, by sector. The total is shown as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). From 1990 to 2020, the WEM and WAM scenarios correspond to actual inventory data.

		1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
		Mt CO_2eq									
Total as relevant for Switzerland's emission reduction targets	**WEM**	**54.0**	**52.9**	**53.1**	**55.4**	**54.8**	**48.5**	**43.4**	**42.4**	**39.2**	**36.8**
	WOM	**54.3**	**53.6**	**54.5**	**58.0**	**59.4**	**55.8**	**56.7**	**55.0**	**54.8**	**55.0**
	WAM	**54.0**	**52.9**	**53.1**	**55.4**	**54.8**	**48.5**	**43.4**	**39.3**	**35.6**	**32.8**
1 Energy	WEM	41.8	41.9	42.2	44.0	43.2	37.1	32.7	32.6	29.8	27.6
	WOM	42.1	42.4	43.3	45.9	46.7	43.1	44.0	42.3	42.1	42.1
	WAM	41.8	41.9	42.2	44.0	43.2	37.1	32.7	29.8	26.6	24.4
1A1 Energy industries	WEM	2.5	2.6	3.2	3.8	3.8	3.3	3.3	3.3	3.4	3.5
	WOM	2.5	2.7	3.2	3.8	4.0	4.1	5.1	5.2	6.5	7.7
	WAM	2.5	2.6	3.2	3.8	3.8	3.3	3.3	3.1	3.1	3.3
1A2 Manufacturing industries and construction	WEM	6.6	6.3	6.0	6.0	5.9	5.0	4.5	4.8	4.6	4.5
	WOM	6.6	6.3	6.0	6.1	6.0	5.6	5.6	5.3	5.1	5.1
	WAM	6.6	6.3	6.0	6.0	5.9	5.0	4.5	4.5	4.3	4.2
1A3 Transport	WEM	14.7	14.3	16.0	15.9	16.3	15.3	13.6	14.4	12.7	11.2
	WOM	14.7	14.3	16.1	16.2	17.0	16.1	15.8	15.2	14.8	14.3
	WAM	14.7	14.3	16.0	15.9	16.3	15.3	13.6	12.7	10.6	9.0
1A4 Other sectors	WEM	17.5	18.1	16.6	17.8	16.8	13.1	11.0	9.7	8.7	8.0
	WOM	17.7	18.5	17.5	19.4	19.3	16.9	17.1	16.2	15.4	14.7
	WAM	17.5	18.1	16.6	17.8	16.8	13.1	11.0	9.2	8.2	7.5
1A5 Military	WEM	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	WOM	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	WAM	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1B Fugitive emissions from oil and natural gas	WEM	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2
	WOM	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2
	WAM	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2
2 Industrial processes and product use	WEM	4.0	3.4	3.8	4.4	4.5	4.5	4.2	3.3	3.0	2.8
	WOM	4.0	3.4	3.8	4.7	5.1	5.2	5.3	5.5	5.6	5.7
	WAM	4.0	3.4	3.8	4.4	4.5	4.5	4.2	3.2	2.9	2.6
3 Agriculture	WEM	6.6	6.4	6.0	5.9	6.1	6.0	5.8	5.7	5.7	5.7
	WOM	6.6	6.4	6.0	5.9	6.1	6.0	6.1	6.0	6.0	6.0
	WAM	6.6	6.4	6.0	5.9	6.1	6.0	5.8	5.5	5.4	5.0
5 Waste	WEM	1.1	0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6
	WOM	1.1	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.7	0.7
	WAM	1.1	0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6
Indirect CO_2 (excluding sector 6)	WEM	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	WOM	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	WAM	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
4 LULUCF (not included in the total)	*WEM*	*–2.0*	*–3.9*	*5.2*	*–2.9*	*–2.9*	*–2.2*	*–1.7*	*–2.3*	*–0.5*	*–0.5*
	WOM	*–2.0*	*–3.9*	*5.2*	*–2.9*	*–2.9*	*–2.2*	*–1.7*	*–3.8*	*–2.8*	*–2.8*
	WAM	*–2.0*	*–3.9*	*5.2*	*–2.9*	*–2.9*	*–2.2*	*–1.7*	*1.1*	*1.7*	*1.7*
International transport (not included in the total)	*WEM*	*3.2*	*3.7*	*4.7*	*3.6*	*4.3*	*5.0*	*2.1*	*6.4*	*7.1*	*7.2*
	WOM	*3.2*	*3.7*	*4.7*	*3.6*	*4.3*	*5.0*	*2.1*	*6.4*	*7.1*	*7.2*
	WAM	*3.2*	*3.7*	*4.7*	*3.6*	*4.3*	*5.0*	*2.1*	*6.3*	*6.8*	*5.9*

Tab. 27 > Switzerland's greenhouse gas emissions under the WEM, WOM and WAM scenarios, by gas. Values are shown as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). From 1990 to 2020, the WEM and WAM scenarios correspond to actual inventory data. For all scenarios, the maximum value for NF_3 is reached in the year 2010 (12.7 thousand tonnes of CO_2 equivalents).

		1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
		Mt CO_2eq									
Total as relevant for Switzerland's emission reduction targets	**WEM**	**54.0**	**52.9**	**53.1**	**55.4**	**54.8**	**48.5**	**43.4**	**42.4**	**39.2**	**36.8**
	WOM	**54.3**	**53.6**	**54.5**	**58.0**	**59.4**	**55.8**	**56.7**	**55.0**	**54.8**	**55.0**
	WAM	**54.0**	**52.9**	**53.1**	**55.4**	**54.8**	**48.5**	**43.4**	**39.3**	**35.6**	**32.8**
CO_2 (excluding LULUCF, excluding sector 6, excluding international transport)	WEM	44.1	43.4	43.6	45.8	45.0	38.7	34.2	34.2	31.5	29.2
	WOM	44.4	43.9	44.7	47.7	48.5	44.7	45.5	43.8	43.6	43.6
	WAM	44.1	43.4	43.6	45.8	45.0	38.7	34.2	31.4	28.3	26.1
CH_4 (excluding LULUCF, excluding sector 6, excluding international transport)	WEM	5.8	5.5	5.1	5.1	5.0	4.8	4.6	4.5	4.5	4.5
	WOM	5.8	5.6	5.2	5.2	5.2	5.0	5.0	4.9	4.8	4.8
	WAM	5.8	5.5	5.1	5.1	5.0	4.8	4.6	4.4	4.3	4.0
N_2O (excluding LULUCF, excluding sector 6, excluding international transport)	WEM	3.4	3.3	3.3	3.1	3.1	3.0	2.9	2.4	2.4	2.4
	WOM	3.4	3.3	3.3	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	WAM	3.4	3.3	3.3	3.1	3.1	3.0	2.9	2.2	2.2	2.1
HFCs	WEM	0.0	0.2	0.6	1.0	1.3	1.5	1.4	1.1	0.6	0.6
	WOM	0.0	0.2	0.7	1.3	1.9	2.2	2.4	2.6	2.6	2.8
	WAM	0.0	0.2	0.6	1.0	1.3	1.5	1.4	1.0	0.6	0.4
PFCs	WEM	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	WOM	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	WAM	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
SF_6	WEM	0.1	0.1	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.1
	WOM	0.1	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2
	WAM	0.1	0.1	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.0
NF_3	WEM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WOM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	WAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indirect CO_2 (excluding sector 6)	WEM	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	WOM	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	WAM	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1

Fig. 66 > Switzerland's greenhouse gas emissions under the WEM, WOM and WAM scenarios, by sector as shown in Tab. 26. Also shown are actual inventory data for the years 1990 to 2020. See Fig. 68 for a more detailed disaggregation within the energy sector, in particular allowing for a distinction of the transport sector. For international transport, the WOM scenario (orange line hidden) is identical to the WEM scenario. The reason for the substantial reduction of emissions in sector 2 'Industrial processes and product use' from 2020 to 2021 under the WEM and WAM scenarios is that a chemical plant installed a new catalyst in the course of 2021, thereby substantially reducing N_2O emissions.

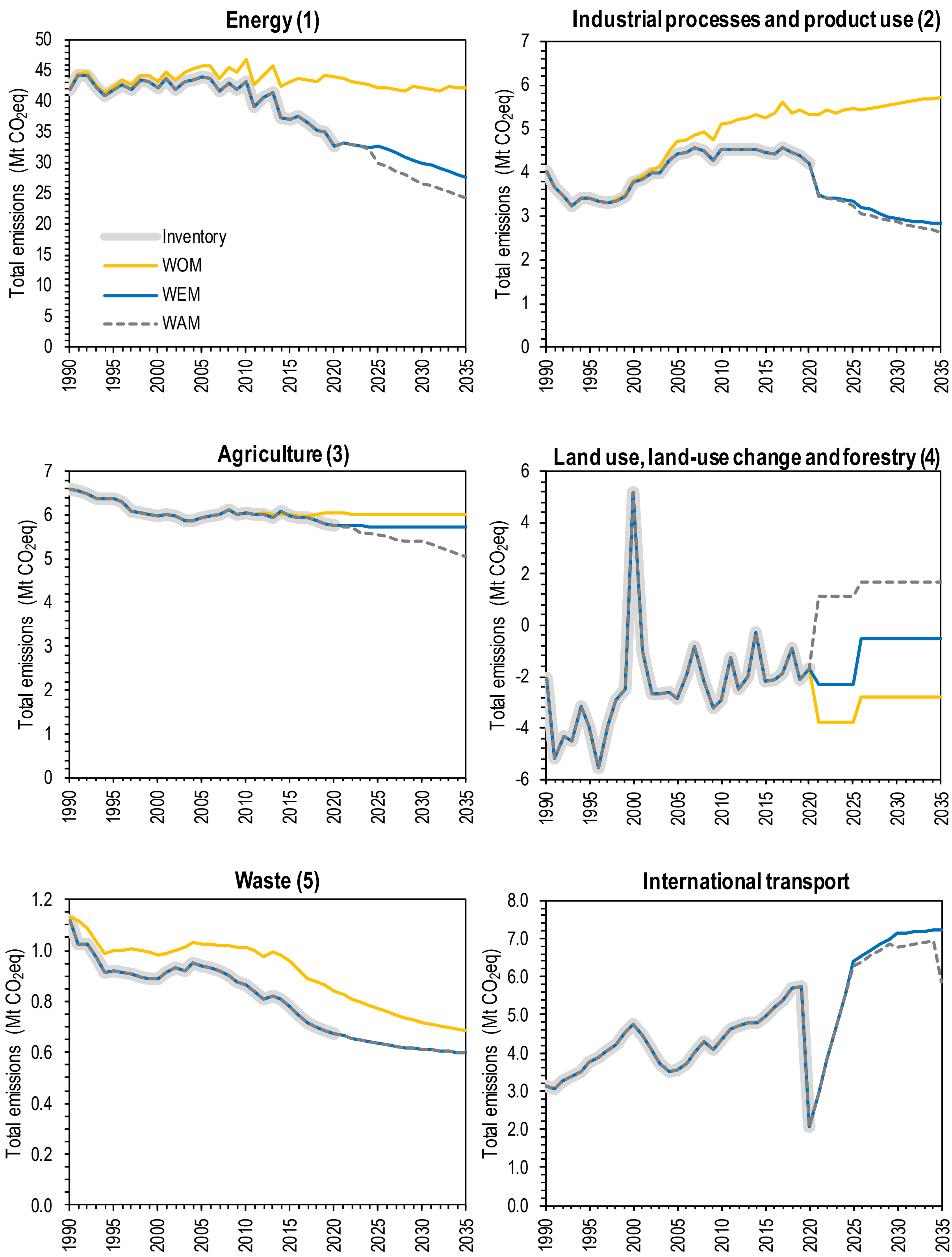


Fig. 67 > Switzerland's greenhouse gas emissions under the WEM, WOM and WAM scenarios by gas as shown in Tab. 27. Also shown are actual inventory data for the years 1990 to 2020. The panel for SF_6 and NF_3 shows the sum of the two gases (SF_6 strongly dominates, see Tab. 27 for the individual contributions). The reason for the substantial reduction of N_2O emissions from 2020 to 2021 under the WEM and WAM scenarios is that a chemical plant installed a new catalyst in the course of 2021.

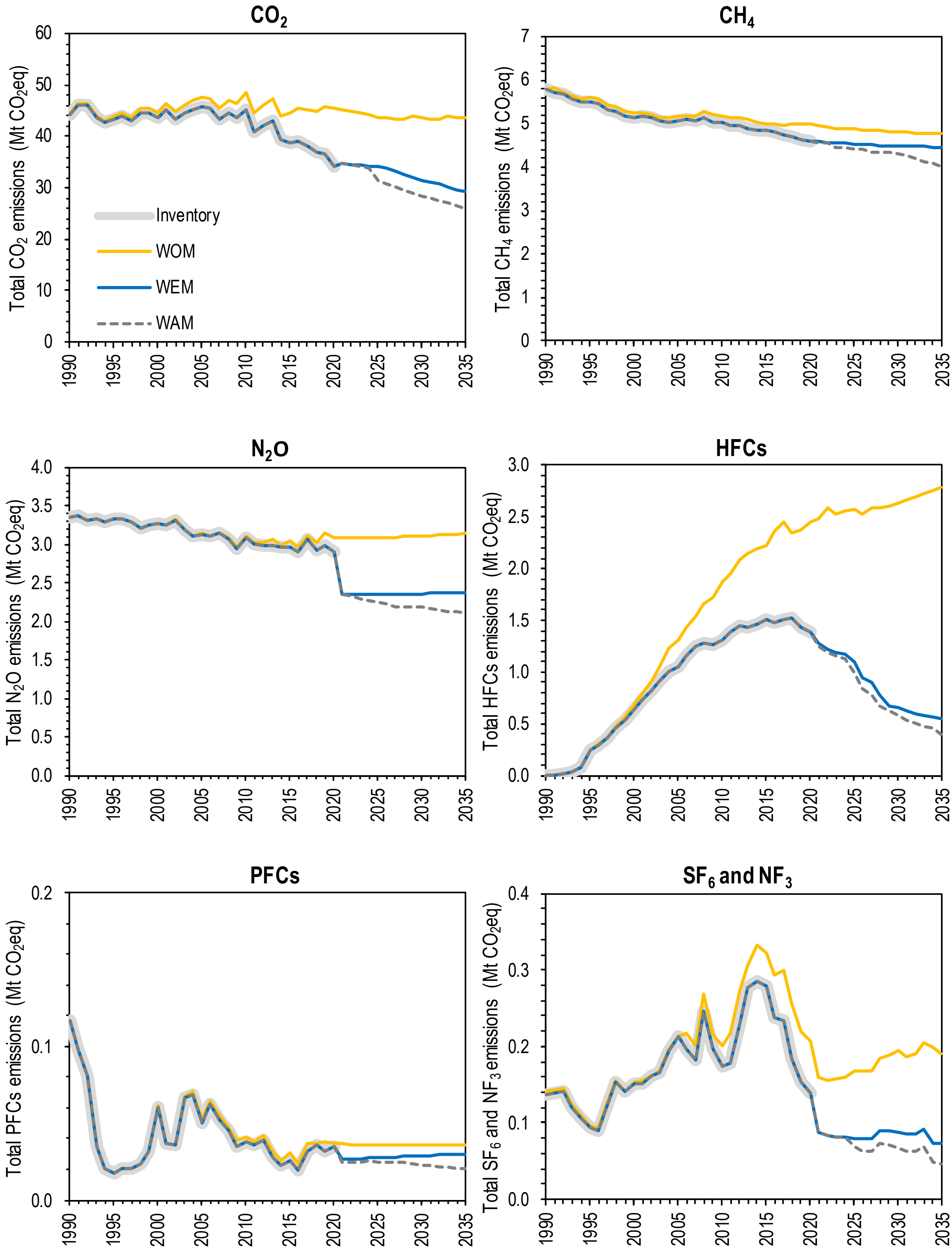


Fig. 68 > Switzerland's greenhouse gas emissions in the different source categories of the energy sector under the WEM, WOM and WAM scenarios as shown in Tab. 26. Also shown are actual inventory data for the years 1990 to 2020. 'Transport' corresponds to source category 1A3. Source category 1A4 is dominated by greenhouse gas emissions from residential and commercial use of fossil fuels, while source category 1A5 covers greenhouse gas emissions from non-road military vehicles including military aviation (see section 3.2.3 for more details). For the source categories 1A5 'Other' and 1B 'Fugitive emissions from oil and natural gas' the WOM scenarios (hidden orange lines) are identical to the WEM scenarios.

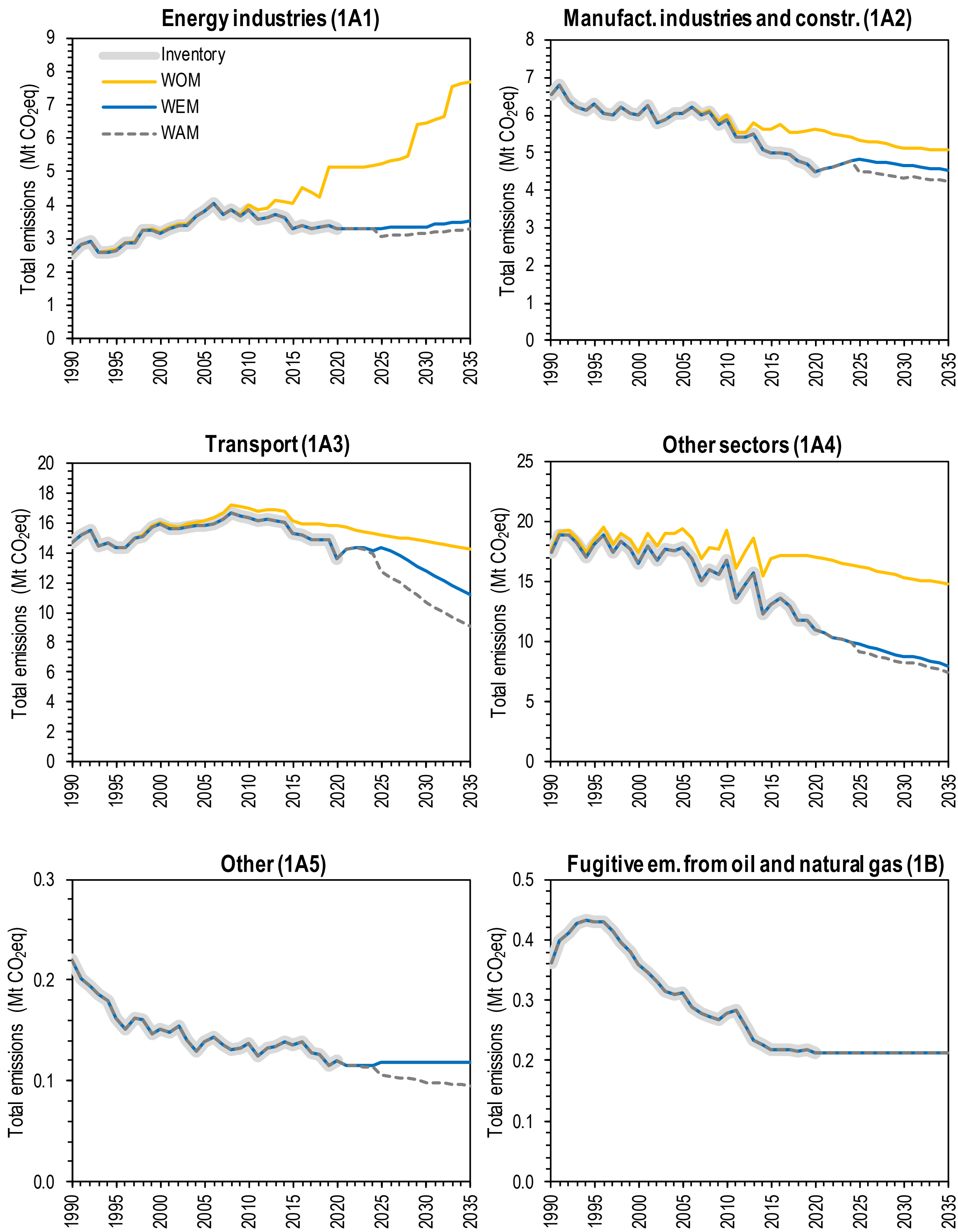


Fig. 69 > Contribution of the different sectors to the evolution of Switzerland's total greenhouse gas emissions under the WEM, WOM and WAM scenarios. Emissions are considered as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Contributions from the energy sector are further disaggregated (1A1, 1A2, 1A3, 1A4, 1A5, and 1B) to illustrate the most important source categories.

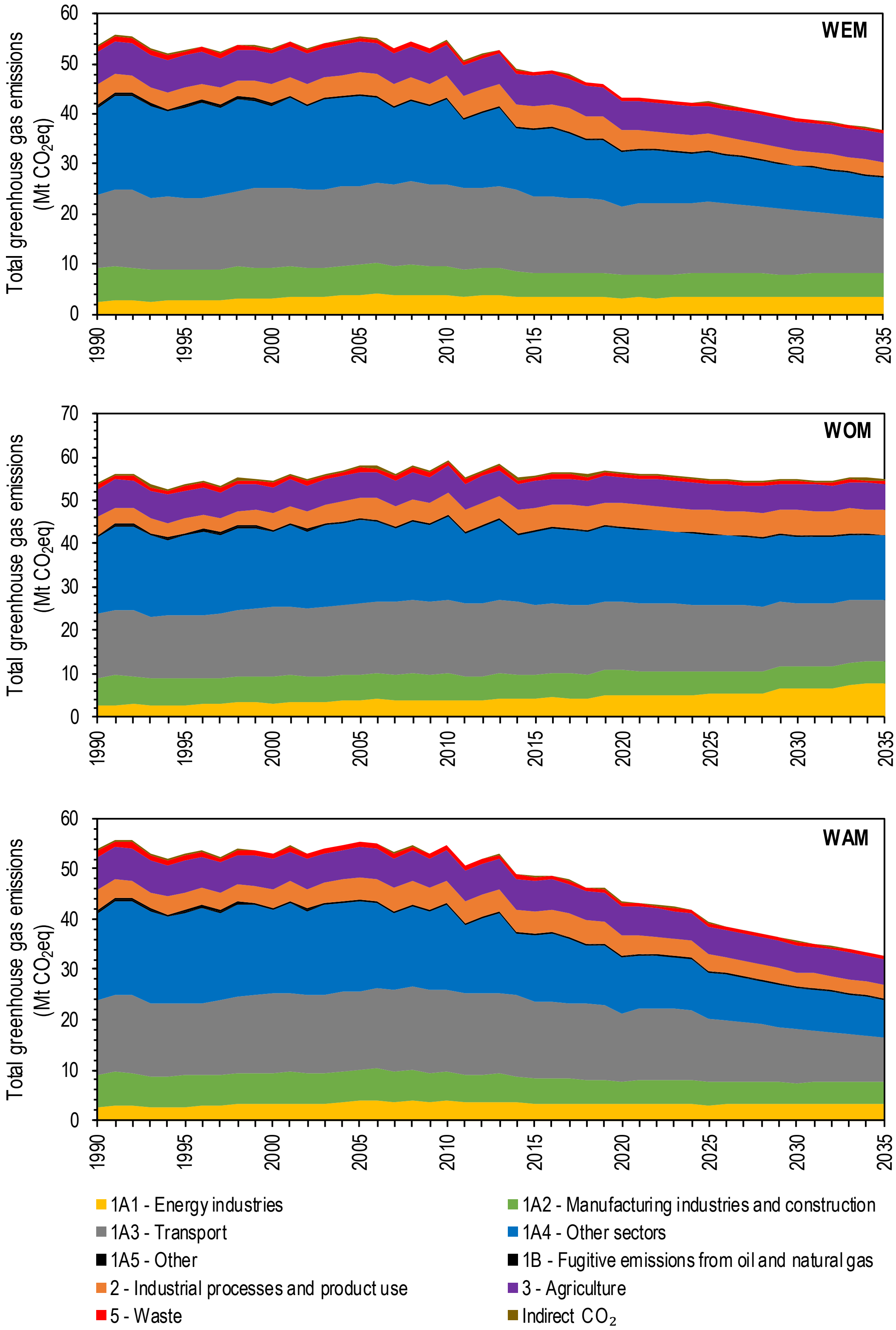
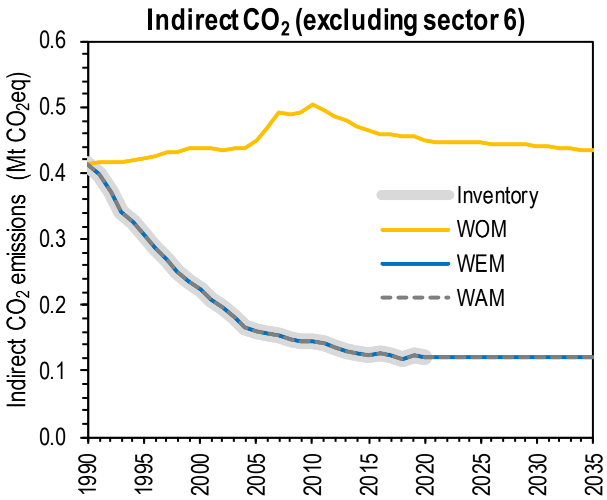


Fig. 70 > Switzerland's indirect CO_2 emissions under the WEM, WOM and WAM scenarios (excluding sector 6) as shown in Tab. 26. Also shown are actual inventory data for the years 1990 to 2020.



5.2 Assessment of aggregate effect of policies and measures

5.2.1 Total effect of currently implemented and adopted policies and measures

The total effect of currently implemented and adopted policies and measures – calculated based on the difference between the emissions under the WOM and WEM scenarios – is presented in Tab. 28 by gas and in Tab. 29 by sector. For 2020, the most recent inventory year, the total effect of currently implemented and adopted policies and measures is estimated at a reduction of 13.3 million tonnes of CO_2 equivalents (annual reduction, not cumulative). For 2025, 2030 and 2035, the total effect of currently implemented and adopted policies and measures is projected at 12.5, 15.6 and 18.1 million tonnes of CO_2 equivalents, respectively. These estimates depend on the assumptions regarding the evolution of the underlying drivers and contain considerable uncertainties (see sensitivity analysis in section 5.3.9). Further, the total effect of currently implemented and adopted policies and measures also depends on the bifurcation points of the WEM and WOM scenarios, which are shown in Tab. 30. The contributions of each sector are discussed in the following. Importantly, the total effect of policies and measures as presented in this chapter does not necessarily correspond to the sum of the mitigation impacts of individual policies and measures as reported in chapter 4. Among the reasons are (i) differences in the policies and measures considered as well as in the bifurcation points, (ii) differences in the methodologies applied, and (iii) interactions of policies and measures only considered when estimating the total effect but not the individual mitigation impact.

Tab. 28 > Total effect of currently implemented and adopted policies and measures, by gas. Emissions are considered as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Shown are the differences between the WOM and WEM scenarios as presented in Tab. 27.

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
	Mt CO_2eq (annual reduction, not cumulative)									
CO_2	0.3	0.5	1.0	1.9	3.5	6.0	11.2	9.6	12.1	14.4
CH_4	0.0	0.1	0.1	0.1	0.2	0.2	0.4	0.3	0.3	0.3
N_2O	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.7	0.8	0.8
HFCs/PFCs/SF_6/NF_3	0.0	0.0	0.0	0.3	0.6	0.8	1.1	1.6	2.1	2.3
Indirect CO_2	0.0	0.1	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Total as relevant for Switzerland's emission reduction targets	**0.3**	**0.7**	**1.4**	**2.6**	**4.6**	**7.3**	**13.3**	**12.5**	**15.6**	**18.1**

Tab. 29 > Total effect of currently implemented and adopted policies and measures, by sector. Emissions are considered as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Shown are the differences between the WOM and WEM scenarios as presented in Tab. 26.

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
	Mt CO_2eq (annual reduction, not cumulative)									
1 Energy	0.3	0.5	1.1	1.9	3.5	6.0	11.4	9.7	12.3	14.5
2 Industrial processes and product use	0.0	0.0	0.0	0.3	0.6	0.8	1.1	2.1	2.6	2.9
3 Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
5 Waste	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Indirect CO_2	0.0	0.1	0.2	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Total as relevant for Switzerland's emission reduction targets	**0.3**	**0.7**	**1.4**	**2.6**	**4.6**	**7.3**	**13.3**	**12.5**	**15.6**	**18.1**

Tab. 30 > Bifurcation points of the WEM and WOM scenarios for the individual sectors. For the WEM and WAM scenarios, historical data from the most recent greenhouse gas inventory are used, i.e. until 2020. After 2020, the WAM scenario starts to increasingly deviate from the WEM scenario as planned policies and measures (or the planned strengthening/adjustment of implemented policies and measures) come into force.

Sector	Bifurcation points of the WOM and WEM scenarios
Energy sector (including transport)	The bifurcation point is 1990. Some policies and measure in the energy sector already have a minor mitigation impact in 1990, see *EPFL and Infras* (2016) and *EPFL* (2017) for details.
Industrial processes and product use sector	No measures specifically targeting process emissions of CO_2 and CH_4 are considered under any of the scenarios. The WEM and WAM scenarios deviate from the WOM scenario as of 2021 as a result of the obligations in relation to chemical conversion processes (N_2O), see also section 4.5.5. Regarding F-gases, the bifurcation point is 1990.
Agriculture sector	The bifurcation point is 2011 (first calculation with different assumptions for the WEM and WOM scenarios for the following year, see section 5.3.3 for more explanations).
Land use, land-use change and forestry sector	The bifurcation point is 2020 (first values taken from the modelling starting in 2006 with different assumptions for the WEM and WOM scenarios for the following year, see section 5.3.4 for more explanations).
Waste sector	The bifurcation point is 1990.
Indirect CO_2	The bifurcation point is 1990.

Energy (including transport)

For 2020, the aggregate effect of currently implemented and adopted policies and measures in the energy sector (including transport) is estimated at 11.4 million tonnes of CO_2 equivalents (Tab. 29), i.e. the energy sector is expected to contribute about 85 per cent to the aggregate effect of currently implemented and adopted policies and measures. For 2025, 2030 and 2035, the aggregate effect of currently implemented and adopted policies and measures in the energy sector (including transport) is estimated at 9.7, 12.3 and 14.5 million tonnes of CO_2 equivalents, respectively. As required by the reporting guidelines, the estimated and expected effects of individual policies and measures are addressed in chapter 4. The aggregate effect of currently implemented and adopted policies and measures in the energy sector is strongly modulated by the introduction of renewable energy sources under the WEM scenario and the potential need for gas-fired combined-cycle power plants as a replacement for nuclear power plants under the WOM scenario.

Industrial processes and product use

As no policies and measures affecting process emissions of CO_2 and CH_4 from industry are distinguished between the WEM and WOM scenarios, no aggregate effects of policies and measures are expected for these gases. With regard to N_2O, the obligations in relation to chemical conversion processes (N_2O) is responsible for the substantial decrease of N_2O emissions of about 550 thousand tonnes of CO_2 equivalents as of 2021 under the WEM (and WAM) scenario (see also section 4.5.5). Further, policies and measures with regard to F-gases substantially influence emissions of HFCs, PFCs, SF_6, and NF_3 from sector 2 'Industrial processes and product use'. Mainly driven by the phase-out of fluorinated refrigerants assumed under the WEM scenario, a substantial reduction of total greenhouse gas emissions of 1.1 million tonnes of CO_2 equivalents in 2020 compared to the WOM scenario is estimated. For 2025, 2030 and 2035, the total impact resulting from policies and measures with regard to emissions of F-gases is further enhanced by the reduction of N_2O emissions under the WEM scenario, leading to an estimated mitigation impact of 2.1, 2.6 and 2.9 million tonnes of CO_2 equivalents, respectively (Tab. 28 and Tab. 29; annual reduction, not cumulative).

Agriculture

For 2020, the aggregate effect of currently implemented and adopted policies and measures in the agriculture sector is estimated at 0.3 million tonnes of CO_2 equivalents, remaining about constant for each year up to 2035 (Tab. 29). CH_4 emission reductions contribute about 60 per cent to the aggregate effect of currently implemented and adopted policies and measures in the agriculture sector (40 per cent stem from N_2O emission reductions). The bifurcation point of the WEM and WOM scenarios is 2011 and not 1990 as for other sectors (Tab. 30), because retrospectively it is impossible to elaborate meaningful WOM scenarios for this sector (see also section 5.3.3).

Waste

For the waste sector, the aggregate effect of currently implemented and adopted policies and measures can almost completely be attributed to the ban on landfilling of combustible waste (section 4.8.2), which is considered for the WEM and the WAM scenarios, but not for the WOM scenario (section 5.3.5). The effect of the ban on landfilling of combustible waste is slightly reduced due to incentives for increasing biogas production, which lead to somewhat increased fugitive CH_4 emission under the WEM and WAM scenarios, compared to the WOM scenario. Overall, emissions under the WOM scenario exceed emissions under the WEM scenario by 0.2 million tonnes of CO_2 equivalents in 2020 and by 0.1 million tonnes of CO_2 equivalents in 2025, 2030 and 2035 (slightly decreasing trend over the years, see Fig. 66).

5.2.2 Total additional effect of planned policies and measures

The total additional effect of planned policies and measures – calculated based on the difference between the emissions under the WEM and WAM scenarios – is presented by gas in Tab. 31 and by sector in Tab. 32. The starting points of the various planned policies and measures are detailed under the respective sections in chapter 4. For 2025, 2030 and 2035, the total additional effect of planned policies and measures is estimated at a reduction of 3.1, 3.6 and 4.1 million tonnes of CO_2 equivalents (annual reduction, not cumulative), where the main contributions come from the energy sector, followed by the agriculture sector.

Tab. 31 > Total additional effect of planned policies and measures, by gas. Emissions are considered as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Shown are the differences between the WEM and WAM scenarios as presented in Tab. 27.

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
	Mt CO_2eq (annual reduction, not cumulative)									
CO_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	3.2	3.2
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3
HFCs/PFCs/SF_6/NF_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Indirect CO_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total as relevant for Switzerland's emission reduction targets	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.1**	**3.6**	**4.1**

Tab. 32 > Total additional effect of planned policies and measures, by sector. Emissions are considered as relevant for Switzerland's emission reduction targets (i.e. including emissions of all greenhouse gases from the sectors 1, 2, 3 and 5, including indirect CO_2 emissions from these sectors, excluding direct and indirect emissions from sector 6, excluding emissions and removals from land use, land-use change and forestry, and excluding emissions from international transport). Shown are the differences between the WEM and WAM scenarios as presented in Tab. 26.

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
	Mt CO_2eq (annual reduction, not cumulative)									
1 Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	3.2	3.2
2 Industrial processes and product use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
3 Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.7
5 Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Indirect CO_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total as relevant for Switzerland's emission reduction targets	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.1**	**3.6**	**4.1**

5.3 Methodology

The methodologies applied to establish Switzerland's greenhouse gas emission scenarios are tailored to the particular characteristics of each sector, always ensuring consistency with actual data of the greenhouse gas inventory. To provide a basic understanding of the models and approaches used, details relevant for each sector are summarised in Tab. 33 and discussed in the following sections.

Tab. 33 > Overview of models and approaches used to project Switzerland's greenhouse gas emissions from different sectors.

	Gases	Type and characteristics of approach or model	Original purpose of approach or model	Strengths and weaknesses	Accounting of overlaps and synergies
1 Energy[66] (including international transport)	CO_2, CH_4, N_2O	Model network of various energy system models. The resulting energy demand is transferred to the national air pollution database EMIS to calculate emissions of greenhouse gases.	Energy perspectives 2050+ of the Swiss Confederation to develop an energy system that is compatible with the long-term climate goal of net-zero greenhouse gas emissions by 2050 and, at the same time, ensures a secure energy supply.	Comprehensive simulation of Switzerland's energy system (due to the level of detail, development takes several years), simultaneously taking into account the medium to long-term climate and energy policy targets.	Accounts implicitly for the overall interactions between the effects of different policies and measures, direct and indirect rebound effects, as well as spill-over effects in all economic sectors.
2 Industrial processes and product use	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	Bottom-up estimates according to the 2006 IPCC guidelines for national greenhouse gas inventories.	Greenhouse gas inventory (no fundamental adjustments needed).	Calculations at the level of single processes, requiring a full set of projections of activity data and emission factors.	Policies and measures are assumed to target distinct sources of greenhouse gases, i.e. overlaps and synergies are considered negligible.
3 Agriculture	CO_2, CH_4, N_2O				
4 Land use, land-use change and forestry		Stochastic empirical single tree forest management scenario model (Massimo) for CO_2, simple assumptions for CH_4 and N_2O.	Projections of the development of forest resources.	Specifically designed to reflect the characteristics of Swiss forests, based on data from the national forest inventories.	
5 Waste		Bottom-up estimates according to the 2006 IPCC guidelines for national greenhouse gas inventories.	Greenhouse gas inventory (no fundamental adjustments needed).	Calculations at the level of single processes, requiring a full set of projections of activity data and emission factors.	
Indirect CO_2	Indirect CO_2				

5.3.1 Energy

In its eighth national communication and fifth biennial report, Switzerland presents completely updated WEM and WAM scenarios for the energy sector. The scenarios are now based on the results from the energy perspectives 2050+ (*Prognos et al.*, 2020). As in previous submissions, the WOM scenario for the energy sector is based on the work of *EPFL and Infras* (2016) and *EPFL* (2017). An overview of the key steps performed to establish the WEM, WOM and WAM scenarios for the energy sector, including information on underlying assumptions, is provided in the following.

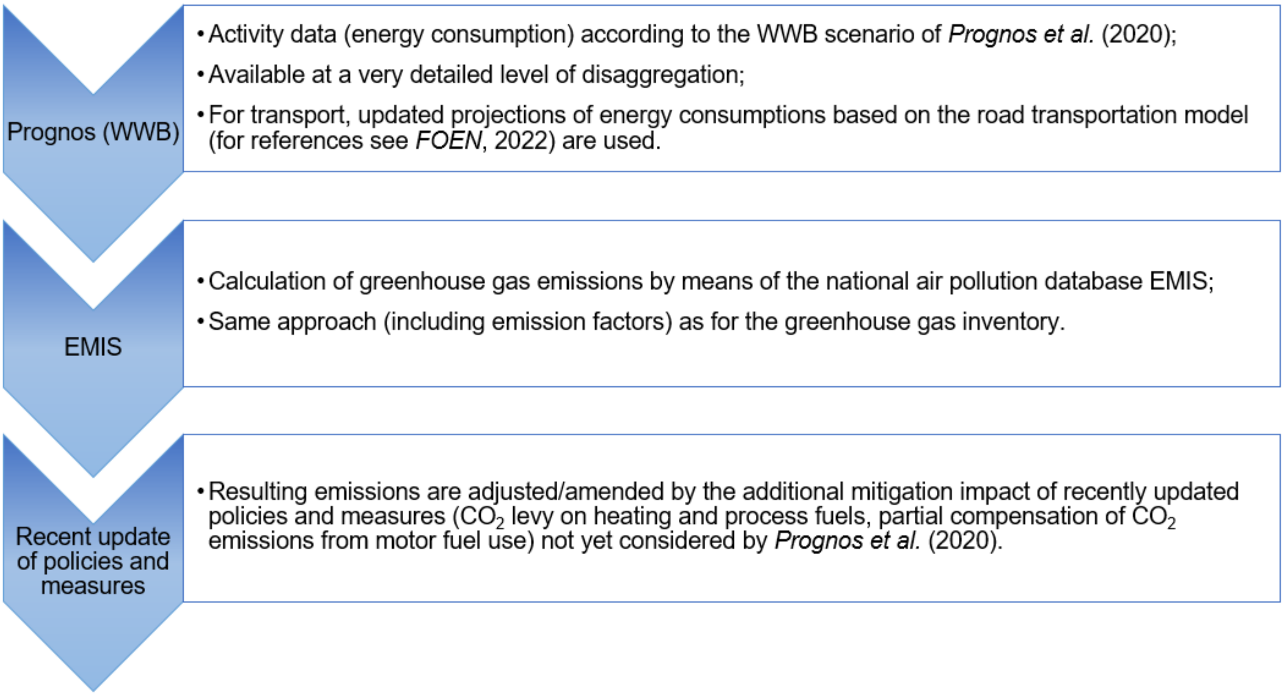
WEM scenario (energy)

The energy perspectives 2050+ (*Prognos et al.*, 2020) analyse how to develop an energy system that is compatible with the long-term climate goal of net-zero greenhouse gas emissions by 2050 and, at the same time, ensures a secure energy supply. Different versions of the net-zero emissions scenarios ('ZERO') – considering different combinations of technologies and varying paces of the transition to renewable energy in the electricity sector – are compared with the 'business as usual' ('continue as before', 'WWB') scenario to gain insights into the additional need for action and the additional technical measures required to achieve the 2050 target. The results of the energy perspectives 2050+ also assess necessary investments and additional or reduced costs.

Fig. 71 provides a schematic overview of the development of the WEM scenario for the energy sector, based on the WWB scenario of *Prognos et al.* (2020). In the following, the three essential steps are discussed.

66 The energy perspectives 2050+ as described in this table form the basis for the WEM and WAM scenarios. The WOM scenario relies and the model of *EPFL and Infras* (2016) and *EPFL* (2017), see Switzerland's fourth biennial report for details.

Fig. 71 > Schematic overview of the three steps performed to derive the WEM scenario for the energy sector based on the WWB scenario of *Prognos et al.* (2020).



As a first step, the WWB scenario of the energy perspectives 2050+ (*Prognos et al.*, 2020) forms the basis for the WEM scenario used for Switzerland's eight national communication and fifth biennial report. Comprehensive information regarding the different scenarios established in the framework of the energy perspectives 2050+, including methodologies applied, are available on the website of the Swiss Federal Office of Energy: *https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html*. The documentation includes an executive summary, a concise report (110 pages) and a technical report (501 pages).[67] Moreover, extensive tables with results and underlying assumptions are available, as well as additional commentaries that dive deeper into selected individual aspects (such as on electricity supply during winter, potential and use of biomass, power generation and heat-power cogeneration, etc.).

In brief, the scenarios of the energy perspectives 2050+ are calculated with different energy system models. The models follow a bottom-up approach with a detailed representation of the relevant technologies in each sector. The modelling is integrated for the entire energy system; results from the individual sector models thus flow directly into the modelling of the other sectors. This is particularly important for the interface of the energy demand sectors with the modelling of the electricity sector, district heating generation and other energy conversion. *Prognos et al.* (2020) implicitly include the mitigation impact of all implemented policies and measures, e.g. by estimating the overall technical progress.

Regarding the evolution of the transport sector, the WWB scenario of *Prognos et al.* (2020) relies on inputs from the road transportation model primarily used for the greenhouse gas inventory (see section 3.2.9 in *FOEN*, 2022a). The road transportation model is based on a bottom-up approach, taking into account the composition of the Swiss vehicle fleet and differentiating various vehicle classes, fuel types and emissions standards. For past and future years, energy consumption is then calculated based on parameters such as the composition of the fleet, the distances travelled, the fuel types used, and the specific fuel consumption. The road transportation model directly targets vehicle kilometres, i.e. passengers per vehicle are not quantified for this exercise.

At the time of preparing the energy perspectives 2050+, the greenhouse gas inventory up to and including the year 2018 was available. In order to gain results that are completely consistent with Switzerland's latest greenhouse gas inventory, slight corrections are applied in the second step where necessary (see below). A complete recalibration with most recent inventory data, i.e. historical emissions up to 2020, could not be performed, as the modelling exercise is very costly and took several years to be completed. However, as the road transportation model is annually updated, the WEM scenario

[67] *Executive summary*, *Concise report*, *Technical report*

includes projections of energy consumptions based on the version establish for Switzerland's latest greenhouse gas inventory (*FOEN*, 2022a). Overall, the WWB scenario of the energy perspectives 2050+, together with the latest version of the road transportation model, provide activity data (energy consumption) at a highly disaggregated level.

As a second step, the activity data (energy consumption) obtained from the first step are integrated into the national air pollution database EMIS. Therewith, greenhouse gas emissions (CO_2, CH_4, N_2O) can be calculated with exactly the same approach (including emission factors) as used for the greenhouse gas inventory, guaranteeing consistency between historical and projected data. The methodologies for each source category are described in detail in Switzerland's latest national inventory report (*FOEN*, 2022a). As the activity data based on *Prognos et al.* (2020) do not reflect the impact of measures to contain the corona virus pandemic, projected activity data are considered as of 2025 in most cases (with linear interpolation between 2020 and 2025). Therewith, the recovery from the observed decrease in the historical data for 2020 is probably more realistic (i.e. lasting several years instead of one year only), but the short-term evolution should be viewed with caution.

Prognos et al. (2020) do not provide explicit activity data of source category 1B. As greenhouse gas emissions from this source category are of minor importance, emissions are assumed to remain constant up to 2035.

As a third and final step, resulting emissions are adjusted/amended by the additional mitigation impact of recently updated policies and measures. In its original version, the WWB scenario of *Prognos et al.* (2020) considers – for past and future years – all energy and climate policy measures and instruments in force until the end of 2018, i.e. generally assuming that the policies and measures will be continued in a similar manner, without any strengthening or weakening, up to 2035. The development of technologies (efficiency, equipment, installations, vehicles, devices, etc.) and their use follow the autonomous technical progress and the legal basis existing at the end of 2018. To take into account the most recent developments in Switzerland's climate policy and, thus, to establish a WEM scenario that is fully consistent with the currently implemented and adopted policies and measures (Tab. 24), the following adjustments/amendments are made with regard to the WWB scenario:[68]

- **CO_2 levy on heating and process fuels** (section 4.2.5): The WWB scenario does not take into account the latest increase of the rate of the CO_2 levy from 96 to 120 Swiss francs per tonne of CO_2 introduced as of 1 January 2022. Therefore, for the WEM scenario, the additional mitigation impact realised as of 2022 is factored in. The additional mitigation impact is estimated at 250 thousand tonnes of CO_2 equivalents per year and is attributed to three quarters to the source categories 1A4a and 1A4b ('buildings') and to one quarter to the source categories 1A1 and 1A2 ('industry');
- **Partial compensation of CO_2 emissions from motor fuel use** (section 4.4.5): The WWB scenario does not take into account the increases of the compensation rate from 2021 to 2024. Therefore, for the WEM scenario, the additional mitigation impact realised for the years 2021 to 2024 is factored in. The additional domestic mitigation impact is estimated at 530 thousand tonnes of CO_2 equivalents per year.

The three steps discussed above provide detailed and up-to-date results for the WEM scenario. The strength of this approach is that it is based on a comprehensive simulation of Switzerland's energy system, including a very detailed representation of all relevant technologies. Resulting greenhouse gas emissions are fully consistent with the greenhouse gas inventory. Another advantage is that the modelling takes into account energy and climate policy at the same time, the results are thus consistent with the goals from both areas. However, the modelling does not explicitly represent single policies and measures, but takes into account the overall mitigation impact, e.g. based on assumptions regarding technical progress and energy use (expert judgements and empirical values thereby play a certain role). Due to the high complexity and the high level of detail, the development of projections takes several years, making this approach not suitable for short-term updates. These latter remarks may be considered as weaknesses of the approach.

WOM scenario (energy)

The WOM scenario was not updated in the framework of the energy perspectives 2050+. A new edition of the scenario would require considerable capacities and costs, but it is not expected to reveal any new insights. Accordingly, the WOM

[68] The adjustments/amendments were applied as a final step, i.e. at the level of resulting greenhouse gas emissions (and not at the level of energy consumption provided by *Prognos et al.*, 2020).

scenario for the energy sector is based on the work of *EPFL and Infras* (2016) and *EPFL* (2017) as in previous submissions.

Detailed information with regard to the WOM scenario – including methodologies, strengths and weaknesses – is available in Switzerland's fourth biennial report. The WOM scenario for this submission includes some updates and improvements in order to take into account recalculations that are also reflected in the greenhouse gas inventory as well as in the WEM and WAM scenarios. Accordingly, the WOM scenario now includes an adjustment in order to correctly attribute the energy consumption and related greenhouse gas emissions from heated greenhouses in source category 1A4c, as well as minor recalculations to some emission factors.

The computable general equilibrium model of *EPFL and Infras* (2016) and *EPFL* (2017) does not address emissions from source category 1B. Therefore, the WOM scenario for source category 1B is assumed to be identical to the WEM scenario for the full time period from 1990 to 2035.

WAM scenario (energy)

The WAM scenario is closely coupled to the WEM scenario, i.e. to the energy perspectives 2050+ (*Prognos et al.*, 2020; see above). However, compared to the WEM scenario, the WAM scenario additionally takes into account the impact of the planned strengthening/adjustment of currently implemented and adopted policies and measures and of new instruments as proposed in the third CO_2 Act (section 4.2.4). For the energy sector, the following adjustments of the most important measures are considered under the WAM scenario:

- **Negotiated reduction commitments (for exemption from the CO_2 levy)** (section 4.2.7): Continuation of negotiated reduction commitments (for exemption from the CO_2 levy), but planned expiration in 2040 (this should incentivise the transition to fossil-free energy consumption, giving operators 16 years to phase out fossil fuels; the remaining time is considered sufficient to allow for replacing existing fossil plants by CO_2-free technologies at the end of their technical lifetime). As of 2025, it is planned that each company with a negotiated reduction commitment (for exemption from the CO_2 levy) must depict a decarbonisation roadmap;
- **National buildings refurbishment programme** (section 4.3.3): Increase of the share of the revenues from the CO_2 levy on heating and process fuels earmarked for measures in the buildings sector from 33 to below 50 per cent. Continuation of the national buildings refurbishment programme with no cap on annual contributions (previously, the cap was 450 million Swiss francs per year). During the period 2025–2030, 40 million Swiss francs per year shall be allocated to the replacement of fossil heating systems;
- **CO_2 emission regulations for newly registered vehicles** (section 4.4.2): (i) 15 per cent reduction compared to the 2021 targets for new cars and vans from 2025 onward, (ii) 37.5 per cent reduction compared to the 2021 targets for new cars as well as 31 per cent reduction for new vans from 2030 onward, (ii) introduction of CO_2 emission regulations for heavy duty vehicles from 2025 onward;
- **Partial compensation of CO_2 emissions from motor fuel use** (section 4.4.5): Continuation of the domestic compensation rate of 10 per cent of CO_2 emissions from motor fuels from 2025 until 2030;
- **Mineral oil tax reduction on biofuels and natural gas (renewable transport fuels):** The mineral oil tax reduction on biofuels and natural gas shall be extended until the end of 2030. At the same time, importers of fossil fuels are obliged to reduce a certain proportion of CO_2 emissions from transport by placing renewable fuels on the market. The Swiss Federal Council is to determine this proportion within a range of five to ten per cent;
- **Third CO_2 Act (support for fossil-free public transport buses and ships):** Under the third CO_2 Act, the federal government wants to support the conversion of buses and ships to fossil-free electric or hydrogen drives, thereby accelerating the efforts already underway by the cantons and municipalities.

These adjustments are provisional in the sense that they reflect the propositions of the Swiss Federal Council. The additional mitigation impacts of the measures are generally calculated individually using bottom-up approaches. Where available (e.g. for the CO_2 emission regulations for newly registered vehicles), model simulations have been used to estimate the additional mitigation impacts. The planned adjustment of the partial compensation of CO_2 emissions from motor fuel use is interpreted as annual reduction objectives; the mitigation impact of these measures then corresponds to these objectives.

The calculations with regard to the strengthening/adjustment of policies and measures considered under the WAM scenario as described above provide the additional mitigation impact realised compared to the WEM scenario up to 2030 in most cases. The estimates of the additional mitigation impact are available in CO_2 equivalents and for highly aggregated subsets of the energy sector as defined under the CO_2 Ordinance (buildings, transport, industry, other). The distributions on individual gases (CO_2, CH_4, N_2O) and source categories (1A1, 1A2, 1A3, 1A4, 1A5) then follow the respective distributions of emissions under the WEM scenario in each single year. Where no additional polices and measures are planned, the additional mitigation impact equals zero (e.g. for source category 1B). Beyond 2030, no concrete policies and measures are planned yet (or the additional mitigation impact cannot be estimated yet, see sections 4.2, 4.3 and 4.4). Accordingly, between 2030 and 2035, it is assumed that the additional estimated mitigation impact remains constant (i.e. the WEM and WAM scenarios for the energy sector evolve in parallel). Finally, the WAM scenario is constructed by subtracting the estimates for the additional mitigation impacts from the WEM scenario.

The approach applied to derive the WAM scenario for the energy sector has strengths and weaknesses. The bottom-up approach allows for a targeted estimation of the mitigation impact of each measure, taking full account of their specific effects in each sector. A drawback of this approach is that interactions between measures can only be partially considered.

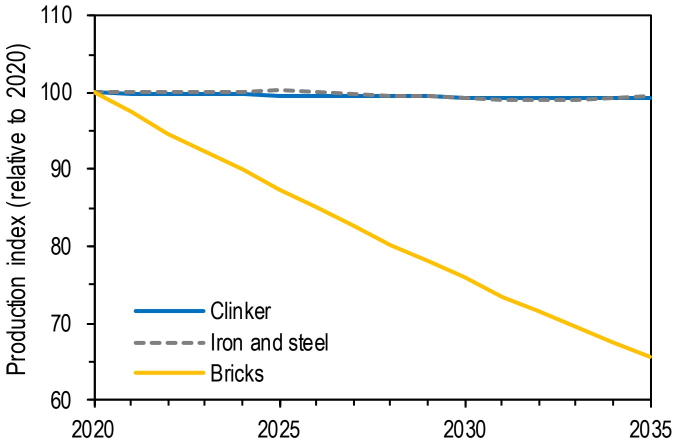
5.3.2 Industrial processes and product use

Greenhouse gas emission scenarios for the industrial processes and product use sector are based on exactly the same methodology as used for the greenhouse gas inventory, i.e. bottom-up estimates according to the 2006 IPCC guidelines for national greenhouse gas inventories (*IPCC*, 2006). Details about the methodologies, including relevant emission factors, are documented in *FOEN* (2022a). The strength of this approach is that greenhouse gas emission scenarios are calculated at the level of single processes. This, however, requires a full set of projections of activity data and emission factors (which may potentially be considered a weakness of the approach).

In Switzerland, there are few industrial branches that release relevant amounts of process-related greenhouse gases. The primary source of process-related greenhouses gases emitted from the industrial processes and product use sector is the cement industry, followed by emissions of F-gases from the use as refrigerants and by emissions of CO_2 from the thermal cracking process (production of ammonia and ethylene). Up to 2020, N_2O emissions from the chemical industry (production of niacin) were substantial as well. However, the WEM and WAM scenarios include a major and persistent decrease in N_2O emissions of about 550 thousand tonnes of CO_2 equivalents from 2020 to 2021. The reason is that the respective chemical plant installed a new catalyst in the course of 2021, therewith eliminating almost all emissions. Measures in the industry sector are primarily targeting energy-related emissions (section 4.3), which are included under the energy sector (for the respective methodology see section 5.3.1). However, the emissions trading scheme (section 4.2.6) also covers process-related emissions, permitting companies to reach their reduction obligations not only by more efficient use of energy, but also by optimisation of their production processes leading to reduced process-related emissions of greenhouse gases. Nevertheless, for most emitters of process-related greenhouse gases covered by the emissions trading scheme (in particular for the cement industry, the major emitter) this possibility hardly exists due to physical/chemical limits regarding further reductions of the emission factors. As the Ordinance on Air Pollution Control (section 4.5.3) and the NMVOC incentive fee (section 4.5.4) are exclusively considered regarding the scenarios for indirect CO_2 emissions, the following two policies and measures are solely responsible for the differences between the WEM, WOM and WAM scenarios for the industrial processes and product use sector: (i) provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3) (section 4.5.2), and (ii) obligations in relation to chemical conversion processes (N_2O) (section 4.5.5).

The relevant activity data for industrial production are inferred from production indices available from the energy perspectives of *Prognos et al.* (2020). Accordingly, the production of goods (such as clinker, cement, iron and steel, bricks, chemicals, etc.) underlying the activity data are consistent with the use of energy underlying the emissions reported in the energy sector. Fig. 72 provides a few examples of production indices applied under the WEM, WOM and WAM scenarios. Production indices of clinker as well as iron and steel are assumed to remain about constant over the coming decades. The decline in the production index of brick is substantial, but the effect on total geogenic CO_2 emissions from the industrial processes and product use sector is limited as these emissions are dominated by cement production. For some industrial processes whose emissions are of minor importance and for which detailed projections of production indices are unavailable, it is assumed that the activities remain constant at the level of past years (depending on the process, mean values over the last ten years or over the full time period since 1990 are used). Where projections are deduced from *Prognos et al.* (2020), values are calculated based on the production indices from 2025 onwards, with linear interpolation between the last inventory year and 2025.

Fig. 72 > Production indices for clinker, iron and steel as well as bricks until 2035 (relative to 2020). Identical production indices are used for the WEM, WOM and WAM scenarios.



Prognos et al. (2020)

Projections of emissions of F-gases are based on a well-established bottom-up model (see *Carbotech*, 2020). This model, described in detail in *FOEN* (2022a), is not only used to derive the emission estimates for the annual greenhouse gas inventory, but also serves to project future emissions. For historical years (i.e. from 1990 up to the most recent inventory year), the model is based on detailed statistics of F-gases imported into Switzerland, supplemented by information from the branch associations and companies concerned. The model makes assumptions about product life time as well as emission factors relevant for assembly, operation and disposal of appliances. For the projections, the two most important applications of fluorinated gases – refrigeration and electrical equipment – are considered in detail, while emissions from other applications are mostly hold constant over time. The main factors defining the scenarios are the phase-out of HFCs, decreasing emission factors in refrigeration, and the limit set on SF_6 emissions following the provisions relating to substances stable in the atmosphere (HFCs, PFCs, SF_6, NF_3) (section 4.5.2). Emissions of HFCs show a substantial change to a faster decrease rate at around 2025 under the WEM and WAM scenarios (Fig. 67). The reason is that the model assumes that HFCs with relatively high global warming potentials are disposed at this time as the respective appliances reach their end of life. Therewith, emissions from the remaining appliances (in operation as well as at their disposal) are lower. The large changes reflect past changes of filling amounts, as the lifetimes are assumes to be a fixed number without smoothening over several years. The WEM scenario was updated at the same time as the data for the most recent greenhouse gas inventory was compiled (*FOEN*, 2022a). Due to limited resources, the WOM and WAM scenarios correspond to the scenarios prepared for Switzerland's fourth biennial report. In order to be fully consistent with the most recent greenhouse gas inventory (and, thus, the WEM scenario), a few minor adjustments were made: (i) the WAM scenario for NF_3 is assumed to be identical to the WEM scenario, (ii) the WAM scenario for PFCs and SF_6 is assumed to show the same difference to the WEM scenario as in the previous submission, and (iii) the WOM scenario for SF_6 is assumed to show the same difference to the WEM scenario as in the previous submission. As visible in Fig. 67, the resulting scenarios are fully consistent with the most recent greenhouse gas inventory.

Tab. 34 provides an overview of assumptions in the industrial processes and product use sector with regard to the WEM, WOM and WAM scenarios. Regarding F-gases, *Carbotech* (2020) provides further details about underlying assumptions and methodologies.

Tab. 34 > Assumptions used for the projections of emissions from the industrial processes and product use sector under the WEM, WOM and WAM scenarios.

	WEM	WOM	WAM
Industrial production	In close correspondence with the assumptions on industrial production used in the energy perspectives of *Prognos et al.* (2020), the production indices for cement and metal are assumed to remain about constant up to 2035, while the production index for bricks declines over the coming decades. For other processes, which are of minor importance, it is assumed that activities remain at the level of past years.	As there are no policies and measures affecting the production rates, the evolution is identical for all scenarios.	As there are no policies and measures affecting the production rates, the evolution is identical for all scenarios.

HFCs	Existing restrictions on the use of F-gases (in concert with technological progress) are considered. This leads to a gradual replacement of HFCs used as refrigerants (*Carbotech*, 2020). Further, measures to reduce leakage (secure handling of refrigerants, monitoring etc.) are continuously introduced.	The WOM scenario assumes no forced phase-out and replacement of fluorinated gases and therefore emissions of HFCs keep increasing (*Carbotech*, 2020).	Similar but faster replacement of HFCs as refrigerants compared to the WEM scenario and more restrictive handling of exclusions in further applications is assumed. It is further assumed that optimisation of disposal leads to additional prevention of emissions (*Carbotech*, 2020). Overall, the implemented measures assure compliance with Switzerland's commitment under the Kigali Amendment to the Montreal Protocol.
SF_6	Agreements with relevant sectors, leading to reduction of emissions.	Constant use of SF_6 and higher emission factors compared to the WEM and WAM scenarios.	Stepwise prohibition of SF_6, leading to a replacement for use in electrical equipment.
Gases from other industrial processes and solvent use	Other process-related emissions (e.g. from ammonia/ethylene production, nitric acid production) and emissions from solvent use are assumed to maintain the level of past years (depending on the process, mean values over the last ten years or over the full time period since 1990 are used). The evolution of N_2O emissions from the chemical industry is dominated by a major and persistent downward shift from 2020 to 2021, as a chemical plant installed a new catalyst in the course of 2021, leading to a substantial reduction of the corresponding emission factor (to only about two per cent of its original value).	Identical evolution as for the WEM scenario, with the only exception that it is assumed that the chemical plant continues to operate its niacin production without catalyst (i.e. N_2O emissions do not decrease as under the WEM and WAM scenarios from 2020 to 2021).	Identical evolution as for the WEM scenario.

5.3.3 Agriculture

Greenhouse gas emission scenarios for the agriculture sector are based on projected activity data, e.g. livestock numbers, crop production data (amount of crops harvested, areas of crop cultures, meadows and pastures) and use of synthetic fertilisers and recycling fertilisers from different agricultural policy evaluation models. The productivity of mature dairy cows (i.e. milk yield) and its influence on CH_4 emissions are also considered in all scenarios. For the WAM scenario the impact of additional technological measures on model parameters such as nitrogen excretion rates, ammonia emission factors and nitrate leaching and runoff are modelled.

Generally, time series beyond 2020 (WEM, WAM) and 2011 (WOM) are extended by continuing the time series according to the development of the respective reference parameters in the models used. Some data such as e.g. crop yields may exhibit considerable year-to-year variability and this may lead to somewhat arbitrary projections due to an arbitrary starting point. However, observing the overall behaviour of the projections, no indication that this would lead to a systematic misalignment is found. Hence, it is concluded that the eventual offsets of individual time series projections cancel each other out.

In the following, the most important aspects relevant under the WEM, WOM and WAM scenarios are presented:

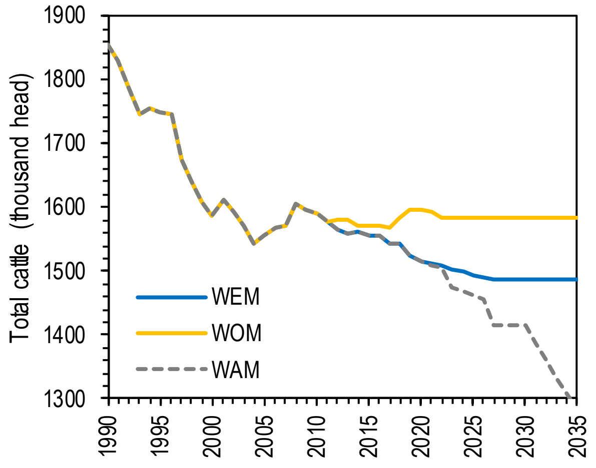
- **Animal livestock population:** The development of livestock populations depends on price scenarios and consequently on policies concerning market price support and free trade agreements with other countries, particularly the European Union, as well as on consumer demand (*Peter et al.*, 2009; *Peter et al.*, 2010; *Möhring et al.*, 2015). Furthermore, the design of the agricultural subsidy and direct payments system is an important driver for the development of livestock populations;
- **Feeding regimes:** Feeding regimes are generally assumed to remain unchanged in the WOM scenario (from 2011 onward) and the WEM scenarios (from 2020 onward) with the single exception of dairy cows whose feed energy intake depends on milk production. Two important measures related to livestock feeding are the governmental programme for grassland-based milk and meat production (*Mack et al.*, 2017) which is currently under revision, and the further promotion of phase feeding with protein-reduced feed for swine (NPr). Both measures are considered under the WAM scenario;
- **Manure management:** Manure management is governed by the stable system, which is again mainly influenced by requirements for animal-friendly livestock husbandry and the respective incentives and label programmes. Different modes of (financial) incentives and legal provisions may promote low-emission stable and manure

management systems in the future. A report by the Swiss Federal Office for the Environment and the Swiss Federal Office for Agriculture regulates the respective requirements at present (*FOEN and FOAG*, 2012). Technical measures for a further reduction of emissions from housing and manure storage are currently investigated in the Agroscope 'emission research stable' (*Schrade et al.*, 2018);

- **Nitrogen excretion by animals:** Nitrogen excretion rates determine the amount of manure nitrogen managed and applied to soils and hence govern N_2O emissions. Nitrogen excretion rates varied in the past mainly due to increasing productivity of dairy cows and due to the feeding of protein-reduced animal feeds for swine and poultry. It is most likely that nitrogen excretion rates will continue to decrease in the future although a precise change rate is hard to predict due to partially contrary developments in livestock management. For cattle, the governmental programme for grassland-based milk and meat production (*Mack et al.*, 2017) might be decisive, while for monogastrics environmental regulations as well as financial constraints and subsidy systems may be most influential;
- **Crop cultures:** An important driver for the future development of the cropping areas and the respective agricultural portfolio is the upcoming design of direct payments. Accordingly, trends in the development of individual crop cultures may differ due to differential governmental incentives. The current system of direct payments contains several mechanisms to incentivise more sustainable production such as support for environmental-friendly production systems (e.g. organic agriculture), promotion of ecological compensation areas (biodiversity) or advancement of extensive crop management (*Möhring et al.*, 2016). In addition to the governmental subsidy system, macroeconomic price levels particularly related to possible free-trade agreements as well as the need for animal fodder will determine the portfolio of crop cultures in the future;
- **Fertilisers and nutrient management:** Fertiliser management depends primarily on the standards of the Suisse-Bilanz (fertiliser management plan) that have to be observed in order to fulfil the proof of ecological performance and to get access to direct payments (*Swiss Federal Council*, 2009; *Herzog and Richner*, 2005). The Suisse-Bilanz might be a convenient tool to promote nitrogen use efficiency in the future by altering the determination of the maximum fertiliser allowance and lowering the respective permits. For the new agricultural policy (AP22+) it was planned to revise the nutrient balance tool (Suisse-Bilanz). More stringent provisions for maximum surplus allowances and a stronger enforcement of the standards defined in the new tool could have substantial effects on fertiliser management and promote nitrogen use efficiency;
- **Nitrogen use efficiency:** Nitrogen use efficiency is strongly related to agricultural greenhouse gas emissions and nitrogen surplus can be used as proxy for N_2O emissions (e.g. *Schils et al.*, 2007). Parameters determining the nitrogen surplus and hence the nitrogen use efficiency are primarily the ammonia emission factors and the share of nitrogen lost as nitrate (leaching and runoff). Nitrogen use efficiency in Switzerland is influenced mainly by the general requirements under the proof of ecological performance (Suisse-Bilanz and possible follow-up tools), by the programmes for resource efficiency (e.g. *Swiss Federal Council*, 2009) as well as by the Ordinance on the Promotion of Quality and Sustainability in the Agrifood Sector (*Swiss Confederation*, 2013). Compared to the actual situation, various measures such as precision-farming, breeding of new crop varieties, use of nitrification and urease inhibitors or an increased share of leguminous crops in crop rotations may further enhance nitrogen use efficiency.

In the following, the circumstances and sources of information relevant for the WEM, WOM and WAM scenarios are discussed. Fig. 73 shows the evolution of the most relevant key parameters under the different scenarios.

Fig. 73 > Evolution of the most relevant key parameters under the WEM, WOM and WAM scenarios for agriculture: Total cattle (left) and total commercial fertiliser (right).



Based on *FOEN* (2022a), *Mack and Möhring et al.* (2021) and *Peter et al.* (2010)

WEM scenario

The basis of the WEM scenario is the continuation of the agricultural policy 2018–2021 (section 4.6.5). As of 2022, the new agricultural policy (AP22+) should have entered into force. Due to its suspension by the Swiss Parliament, central elements of the policy are planned to be implemented through a parliamentary initiative instead (*Swiss Confederation*, 2019). *Mack and Möhring* (2021) investigated the repercussions of the parliamentary initiative 19.475 with the multi-agent model SWISSland. As the ordinances under the parliamentary initiative have not yet passed legislation, the reference scenario of *Mack and Möhring* (2021) is used as basis for the calculations of the WEM scenario. Projections are thus based on data and information available by 2021 on (i) the development of the macroeconomical variables (gross domestic product, population, crop yields), (ii) the expected development of the domestic producer prices, and (iii) the actual agricultural policy with the respective subsidy system.

Development of animal populations, productivity of dairy cows (milk yield), development of cropping areas and fertiliser use are projected until 2027. For the subsequent years, all values are kept constant at the levels projected for 2027.

WOM scenario

The WOM scenario for agriculture is based on the continuation of the agricultural policy 2011. The great number of drivers that has influenced the development of agricultural structures since 1990 (e.g. technological progress, breeding programmes, macro-economic framework, agricultural policy, etc.) does not allow to distinguish the specific mitigation impacts of individual policies and measures retrospectively. Accordingly, 2011 is chosen as bifurcation point since concrete projections were made for the agricultural policy 2011 at this time (Tab. 30). The fundamental assumption is that the scheme of the direct payments and the requirements under the proof of ecological performance would have been maintained as established in 2011. Greenhouse gas emissions are projected according to *Peter et al.* (2010), as expected after the implementation of the agricultural policy 2011. *Peter et al.* (2010) projected the future development of the agricultural portfolio and structures according to calculations made with the S-Integral model. The S-Integral model is a comprehensive agricultural supply model which simultaneously takes into account economic, agronomic and ecological aspects and interrelationships (*Peter*, 2008). Projections are available for three agricultural price scenarios of which the high price level scenario is used here. The portfolio of agricultural operations (i.e. the production levels of the individual livestock animals and crop cultures) develops according to the macroeconomic development exogenously represented in the model. Technical, organisational and structural framework conditions are assumed to remain largely unchanged. The time horizons of the projections reach in most cases until 2022, and all values are kept constant for subsequent years.

WAM scenario

For the WAM scenario it is assumed that the parliamentary initiative 19.475 (*Swiss Confederation*, 2019) will be implemented as planned. The respective impacts are implemented stepwise in the agricultural greenhouse gas inventory model:

- First, structural data are projected to evolve until 2027 according to the parliamentary initiative scenario in *Mack and Möhring* (2021) (structural data comprise animal populations, productivity of dairy cows (milk yield), cropping areas, and synthetic fertiliser use);
- Second, a main goal of the parliamentary initiative 19.475 is a reduction of the nitrogen surplus by 20 per cent until 2030 as compared to the mean over the years 2014–2016. Accordingly, planned measures as described in the 'Explanatory report on the opening of the consultation procedure' (*FOAG*, 2021) are modelled to take effect between 2021 and 2027;
- Third, the targeted reduction of 20 per cent of the nitrogen surplus is not reached with the measures under point two; rather, the 'Explanatory report on the opening of the consultation procedure' (*FOAG*, 2021) estimates a reduction of 7.7 per cent only. Consequently, an additional reduction of the ammonia and nitrate losses is modelled until 2030 without further specification of the concrete measures. The 'Explanatory report on the opening of the consultation procedure' of the parliamentary initiative 19.475 (*FOAG*, 2021) provides that these reductions would be achieved by additional measures taken by the industry and producer organisations;
- In a final step, greenhouse gas emissions are projected to decline, beyond 2030, according to the target of Switzerland's long-term climate strategy to 2050 (*Swiss Federal Council*, 2021a). A substantial reduction of agricultural greenhouse gas emissions of 40 per cent until 2050 as compared to 1990 is aspired. These reductions are modelled by reducing the amount of synthetic fertilisers and the livestock populations. A reduction of the consumption of animal products should accompany the reduction of the livestock populations in order to prevent the imports of greenhouse gas intensive animal products.

The Swiss long-term climate strategy and the climate strategy for agriculture (section 4.6.4) are not legally binding, but encompass some general hints on the future roadmap of a climate-friendly agriculture. Up to date, very few concrete measures are available that could be taken into account under the WAM scenario in addition to the measures of the parliamentary initiative 19.475. However, tools and measures are being investigated and consolidated at the moment. For this purpose, two instruments intended to financially support relevant projects by agricultural stakeholders, namely the resource programme (section 4.6.3) and the Ordinance on the Promotion of Quality and Sustainability in the Agrifood Sector (*Swiss Confederation*, 2013), were implemented by the Swiss Federal Office for Agriculture in the past. Under these voluntary programs several pilot projects were financed that implement and test technical greenhouse gas reduction measures on the farms (e.g. AgroCO2ncept Flaachtal, KLIR-project of Aaremilch AG, IP-Suisse programme for the climate; *Alig et al.*, 2015; *Furrer et al.*, 2021; section 4.6.6). Furthermore, several cantons and organisations of the food and agriculture industry started to develop projects to promote climate-friendly farming. Experiences and insights from these projects may be used to guide the further development of the agricultural policy framework. Promising measures and strategies may be further incentivised by financial contributions for environment-friendly production systems and for the efficient use of resources.

Tab. 35 provides an overview of specific assumptions in the agriculture sector with regard to the WEM, WOM and WAM scenarios.

Tab. 35 > Assumptions used for the projections of emissions from the agriculture sector under the WEM, WOM and WAM scenarios.

	WEM	WOM	WAM
Animal livestock population	The continuation of the agricultural policy 2018–2021 influences animal population as predicted in the reference scenario in *Mack and Möhring* (2021). The cattle population is projected to decline slightly, whereas the number of swine and poultry remain more or less constant. Beyond 2027 (the time horizon of *Mack and Möhring, 2021*) animal populations are assumed to remain constant for all animal categories.	Overall, *Peter et al.* (2010) expected rather constant livestock populations until 2022. Beyond 2022, constant populations are assumed for most animal categories.	Until 2027, livestock populations are projected to develop according to the general agricultural policy framework assumed in the parliamentary initiative scenario in *Mack and Möhring* (2021). Additionally, the cattle population is projected to further decline due to the concrete sustainability measures promoted by the parliamentary initiative 19.475 (approximately by another five per cent; *FOAG*, 2021). Between 2027 and 2030, all animal populations are held constant. After 2030, livestock populations are projected to decrease until overall agricultural greenhouse gas emissions reach the 40 per cent target of Switzerland's long-term climate strategy to 2050 (*Swiss Federal Council*, 2021a). This means that livestock populations would have to fall by 38 per cent between 2030 and 2050.

Feeding regime	For most animal categories, energy intake and CH_4 rates remain constant at the value of 2020, i.e. no technical measures concerning animal diets are implemented. Milk yield and hence gross energy intake of mature dairy cattle are assumed to slightly increase until 2027 (*Mack and Möhring*, 2021). Accordingly, the CH_4 emission factor for both enteric fermentation and manure management increases proportionally. An important political measure could be the promotion of extensive milk and meat production based on grassland diets. It is planned that the respective incentives implemented during the agricultural policy 2018–2021 will be maintained and eventually developed further. A first evaluation by *Mack et al.* (2017) concluded that so far the programme mainly led to a preservation of the current feeding regime and had only limited influence on environmental issues as e.g. the nitrogen surplus. This is hence consistent with the assumptions made for the WEM scenario.	With the exception of mature dairy cows, energy intake and CH_4 rates remain constant at the value of 2011, i.e. no technical measures concerning animal diets are implemented. Milk production and hence gross energy intake of mature dairy cattle level off approximately around 2011 (*Peter et al.*, 2010). Accordingly, the CH_4 emission factors for both enteric fermentation and manure management of mature dairy cows also remain more or less at the level of 2011.	With the exception of mature dairy cows, energy intake and hence CH_4 emission factors for enteric fermentation and the excretion rate for volatile solids are assumed to remain constant at the value of 2020. Milk yield and hence gross energy intake of mature dairy cattle are assumed to slightly increase until 2027 (*Mack and Möhring*, 2021). The maintenance and eventual further development of the governmental programme for grassland-based milk and meat production may alter feeding regimes of ruminants. The respective developments have been included in the WAM scenario. New scientific developments might help to define alternative cattle feeding strategies with low emission intensities in the future that reduce CH_4 emissions by 10–20 per cent (see e.g. *Kreuzer*, 2020). However, although first programmes are being started in practice, it is still too early to assess their impact on overall greenhouse gas emissions. Accordingly, the respective emission reductions are not yet included explicitly in the inventory model scenario.
Manure management	In the past, Swiss agriculture experienced a transition from tied to loose housing systems that led to an increasing share of animal manure stored in liquid systems. Additionally, the time animal spend on pastures increase considerably. However, this trend towards more animal-friendly livestock husbandry took place mainly during the 1990's and little changes could be observed in the more recent past. Also the governmental programme for grassland-based milk and meat production is thought to have little influence on these structures (*Mack et al.*, 2017). Accordingly, parameters affecting manure management are kept constant in the WEM scenario model.	All parameters affecting manure management are assumed to remain constant (distribution as in 2011).	Further reductions of the gaseous losses from animal housing and manure management are aspired in the future (*Swiss Confederation*, 2019). Specific measures considered in the WAM scenario are the obligation for coverage of slurry tanks and the 'promotion of environmental friendly production (Strukturverbesserungsmassnahmen)' (*FOAG*, 2021). Implementation of these measures between 2020 and 2027 are thought to lower CH_4 and N_2O emissions from manure management and particularly NH_3 volatilisation from animal housing and manure storage. Due to the projected reduction of the respective nitrogen losses, the amount of applied synthetic nitrogen fertiliser was reduced accordingly. As these measures do not yet lead to the aspired reduction of the nitrogen surplus (i.e. –20 per cent until 2030; *FOAG*, 2021), loss rates of NH_3 and NO_3^- are further reduced by more than 10 per cent between 2020 and 2030.
Nitrogen excretion by animals	All nitrogen excretion rates are assumed to remain constant at the level of 2019 (last census of farm management techniques; *Kupper et al., 2022*). Without further incentives, neither the governmental programme for grassland-based milk and meat production (*Mack et al.*, 2017) nor the feeding with protein-reduced feed (NPr) for swine and poultry are thought to lower animal nitrogen excretion rates significantly.	Nitrogen excretion rates of all animal except mature dairy cattle are assumed to remain constant at the level of 2011. Nitrogen excretion rates of mature dairy cattle depend on milk production and are assumed to level off around 2011 as no further increase of milk yield is projected (*Peter et al.*, 2010).	The parliamentary initiative 19.475 plans to promote of the use of protein-reduced feed (NPr) for swine (*FOAG*, 2021). Accordingly, the nitrogen excretion rates for swine were reduced by seven per cent between 2020 and 2027. Eventual effects of the further development of the governmental programme for grassland-based milk and meat production (*Mack et al.*, 2017) are not considered, as a first evaluation showed little impacts on the nitrogen excretion rates.
Crop cultures	Developments of the harvested amounts of individual crop cultures is projected according to the reference scenario in *Mack and Möhring* (2021). In general, arable crop production is projected to slightly decline particularly due to a reduction of leys, whereas feed production from grasslands remains more or less constant. Beyond 2027, constant yields and areas are assumed.	Development of crop cultures between 2011 and 2022 is calculated according to *Peter et al.* (2010). Areas of arable crops are slightly declining while land use for meadows and pasture is slightly increasing. Between 2022 and 2050, areas and yields are assumed to remain constant.	Developments of the harvested amounts of individual crop cultures are projected according to the parliamentary initiative scenario in *Mack and Möhring* (2021). In general, the total amount of arable crops produced is projected to develop similarly as in the WEM scenario (i.e. slight decline). Some differences concerning individual cultures can be observed mainly due to the effect of restrictions in the use of pesticides and due to measures to promote biodiversity. Noticeable is particularly the decline in leys and an increase in cereals and silage corn. Feed production from grasslands is somewhat lower than in the WEM scenario. The area affected by measures promoting biodiversity increases considerably.

Fertilisers and nutrient management	Use of commercial fertilisers is projected to decrease only slightly by two per cent between 2020 and 2027 (*Mack and Möhring*, 2021). Beyond 2027, constant fertiliser use is assumed.	After 2011, the total amount of applied commercial fertiliser is assumed to remain constant as total agricultural area and total dry matter production is not changing significantly.	As compared to the WEM scenario, the use of commercial fertilisers is projected to further decline considerably by another 14 per cent until 2030. The effect is due to various measures to increase nitrogen use efficiency of mainly manure nitrogen. In addition to the measures mentioned under 'manure management' above, the parliamentary initiative 19.475 mentions specifically: (i) the abolition of the 10 per cent error margin in the Swiss fertiliser balance (Suisse-Bilanz), (ii) lower nitrogen application rates in arable crops in order to promote biodiversity, and (iii) the promotion of the efficient use of nitrogen in special crops (*FOAG*, 2021). Between 2030 and 2050, the amount of synthetic fertiliser is projected to fall by another 15 per cent due to further promotion of nitrogen use efficiency.
Nitrogen use efficiency	Under the current agricultural policy 2018–2021, a further development of the scheme of direct payments with adjustments in the proof of ecological performance is aspired. Programmes for resource efficiency in agriculture will be further developed and shall be designed to increase nutrient use efficiency in order to fulfil the environmental goals for agriculture (*FOEN and FOAG*, 2008). For the future, additional concrete measures are suggested in the parliamentary initiative 19.475 that replaces the suspended new agricultural policy (AP22+; *Swiss Confederation*, 2019). However, so far, the respective decisions have not been passed officially by the Swiss Parliament and the planned measures are hence not considered in the WEM scenario. Accordingly, ammonia emission factors and nitrogen loss rates are projected to remain constant at the level of 2020 in the inventory model.	Since total amount of applied commercial fertiliser as well as total nitrogen available from animal manure are assumed to remain constant, no increase in nitrogen use efficiency is achieved.	Falling commercial fertiliser levels combined with more or less stable crop yields immediately implies that nitrogen use efficiency must substantially increase. Measures to promote the efficient use of nitrogen are planned in the parliamentary initiative 19.475 (*FOAG*, 2021) and are mentioned under 'manure management' and 'Fertilisers and fertiliser management' above. In total, the nitrogen surplus shall fall by 20 per cent until 2030 as compared to the mean 2014–2016 (*Swiss Confederation*, 2019). Additional efficiency gains could be achieved by plant breeding, precision farming or the increased use of leguminous crops in crop rotations. The respective efforts are projected to lead to an additional reduction of the use of synthetic fertilisers of 15 per cent between 2030 and 2050.

5.3.4 Land use, land-use change and forestry

To project greenhouse gas emissions for the forestry sector, the stochastic empirical single tree forest management scenario model (Massimo), which is based on data from the three successive national forest inventories (see section 2.12), is used (*Stadelmann et al.*, 2019; *Stadelmann*, 2020). The model is specifically designed to reflect the characteristics of Swiss forests. Massimo is also used for the calculation of Switzerland's forest management reference level for accounting for forest management under the Kyoto Protocol for the second commitment period (2013–2020) and of Switzerland's forest reference level (FRL) for accounting of forest land under the Paris Agreement. The model mainly consists of a single tree growth component, a wood harvesting component, and a component on ingrowth. These model components as well as mortality rates are empirically derived from data of the national forest inventories (*Stadelmann et al.*, 2019), as detailed in the following:

- **Single tree growth:** Single tree growth is estimated using a single tree model. It depends on the diameter at breast height, on the basal area of the stand under consideration, on a competition index, on site fertility, on the elevation, and on the stand age. The estimate of stand age is based on a model that has been derived from tree ring analysis on the sample plots of the national forest inventory. Ingrowth rates are considered as well;
- **Wood harvesting component:** To calculate annual clearcut areas in even-aged forest (which occupy 80 per cent of the forest area), the following rotation periods are assumed: 90–110 years on very good sites, 110–130 years on good sites, 130–150 years on medium sites, and 180 years on poor sites in alpine regions. Mature stands are harvested within a time span of 20–30 years in order to promote natural regeneration. This is common practice in the Swiss forestry sector and is reflected in the data of the national forest inventory. Stands are thinned as soon as their basal area has increased by ten per cent since the last thinning event. This criterion guarantees that a stand reaches the development stage of mature timber during a rotation period. The thinning techniques implemented in the model runs are derived from the national forest inventories;

- **Ingrowth:** By not simulating regeneration pools but directly simulating ingrowth (i.e., trees growing over the 12 centimetres calliper threshold of the Swiss national forest inventory), the number, diameter and main tree species based on stand, site and environmental characteristics are simulated (*Zell et al.*, 2019);
- **Mortality rates:** The updated mortality model formulates mortality depending on tree species, basal area and diameter at breast height as a quadratic term (for details cf. *Stadelmann et al.*, 2021). The mortality model accounts for density-dependent (i.e. increasing basal area results in increasing mortality) and age-dependent mortality (i.e. the U-shaped dependence on diameter at breast height shows both large mortality in the self-thinning phase of a forest and as well as for old trees).

Massimo produces a time series of carbon stocks, harvest rates, and gross growth for Swiss forests per decade starting in 2006. The model thus gives information on changes in carbon stored in productive forests. Changes in emissions or in removals of non-CO_2 gases are not calculated by the model. No changes are expected in the occurrence of wildfires. Also, there are no assumptions made for the development of the areas under afforestation and deforestation. Accordingly, it is assumed that, until 2035, the non-CO_2 emissions from productive forests as well as emissions and removals from afforestation and deforestation equal the mean value of the emissions and removals in the period between 1990 and 2020.

For the land use, land-use change and forestry sector, only detailed projections for the forestry sector are available, as described above. As greenhouse gas net emissions and removals in the land use, land-use change and forestry sector are dominated by greenhouse gas fluxes in category 4A1 ‘Forest land remaining forest land’, projections are focussing on this category, assuming that all other categories in the sector keep their current level of net emissions and removals, respectively, i.e. the mean of the period 1990–2020. Category 4A1 directly represents the managed forest land (MFL) under the Paris Agreement (land-based accounting) and is closely related to the forest management activity under the Kyoto Protocol. Using Massimo and defining future harvesting rates to derive forest management scenarios, greenhouse gas balances under the WEM, WOM and WAM scenarios are calculated. The scenarios presented include net emissions and removals from all pools as reported under the UNFCCC. For accounting purposes, the net emissions and removals from forest management have to be considered in relation to the forest management reference level (FMRL) under the Kyoto Protocol and in relation to the forest reference level (FRL) under the Paris Agreement. The characteristics of the WEM, WOM and WAM scenarios, which deviate from the scenarios presented in Switzerland’s previous submission, are detailed in Tab. 36.

The existing policies and measures (WEM) define a distinct increase in harvesting rates up to the level of the potential sustainable wood supply in Swiss forests (objective 1 in *FOEN*, 2021). Without political measures (WOM), Swiss forests would act as a considerable CO_2 sink because standing volume in Swiss forests would further increase, thereby leading to an instable forest structure with regard to future challenges of climate change and not fulfilling the objectives of sustainable forest management. The scenario with additional measures (WAM) is based on objective 2 in *FOEN* (2021), which aims at improving the resilience of Swiss forests, to create forest stands with optimal conditions for adaptation to climate change and optimizing the mitigation potential. The forest policy (*FOEN*, 2021) includes a general description of forest adaptation, but concrete measures, to be used for modelling purposes, are not yet defined in detail.

Tab. 36 > Assumptions used for the projections of emissions from the land use, land-use change and forestry sector under the WEM, WOM and WAM scenarios.

	WEM	WOM	WAM
Forest area, afforestation, deforestation	The forest area as well as the changes in forest area (afforestation, deforestation) are calculated using an extrapolation of the trend 1990–2009 (values derived from the Swiss land use statistics AREA, *SFSO*, 2021).	Identical assumptions for all scenarios.	Identical assumptions for all scenarios.
Forest management, political measures	In order to reach the optimal combination of the objectives identified in Switzerland’s Forest Policy (section 4.7.4), it is important that Swiss forests are managed in a sustainable way. The WEM scenario reflects all policies and measures adopted until 2009.	Policies and measures are not explicitly considered in this scenario.	In the WAM scenario, a steep decline decrease in carbon stocks is established through increased harvesting rates, to create forest stands with optimal conditions for adaptation to climate change and improving the resilience through natural regeneration or planting. This long-term objective is generally described in objective 2 in *FOEN* (2021). Further, all climate services of the forest (sequestration in forest biomass, carbon storage in wood products and substitution effects) are optimised.

Harvesting rates	Objective 1 in *FOEN* (2021) aims at exploiting the potential sustainable wood supply: harvesting rates have to further increase to 8.2 million cubic metres in 2030. Afterwards, harvesting rates are assumed to stay at this level (*Stadelmann et al.*, 2021). This aim is also based on Switzerland's wood policy: increase wood production by 2025 (*FOEN/SFOE/SECO*, 2021).	Under the WOM scenario, it is assumed that the management practices observed between 1990–2009 (periods of NFI1/1983–1985, NFI2/1993–1995 and NFI3/2004–2006) are continued. The harvesting rates correspond to the continuation of these recent management practices and are strongly related to the age class distribution. This scenario is also used for calculation of Switzerland's forest reference level for accounting for forest land under the Paris Agreement (*Stadelmann et al.*, 2021).	Under the WAM scenario, harvesting rates are strongly increased until 2035 in order to lower growing stock to 300 cubic metres (*Stadelmann et al.*, 2021).
Other categories and greenhouse gases	As greenhouse gas net emissions and removals in the land use, land-use change and forestry sector are dominated by greenhouse gas fluxes in category 4A1 'Forest land remaining forest land', projections are focussing on this category, assuming that emissions by sources and removals by sinks from all other land uses (including emissions of CH_4 and N_2O) remain constant (at the level of the respective mean over the years 1990–2020).	Identical assumptions for all scenarios.	Identical assumptions for all scenarios.

5.3.5 Waste

Greenhouse gas emission scenarios for the waste sector are calculated following exactly the same methodology as used for the greenhouse gas inventory, i.e. bottom-up estimates according to the 2006 IPCC guidelines for national greenhouse gas inventories (*IPCC*, 2006). Details about the methodologies are documented in *FOEN* (2022a). The underlying assumptions used under the different scenarios to project greenhouse gas emissions are described in Tab. 37. As in the waste sector policies and measures are rather limited, the WEM, WOM and WAM scenarios are largely based on the same underlying assumptions, with differences for the WOM scenario regarding landfilling of combustible waste and emissions from biogas production. For all scenarios, it is assumed that waste generation per capita remains at current levels.

Tab. 37 > Assumptions used for the projections of greenhouse gas emissions from the waste sector under the WEM, WOM and WAM scenarios. In consistency with the greenhouse gas inventory, greenhouse gas emissions from waste incineration facilities are reported under public heat and electricity generation in the energy sector.

	WEM	WOM	WAM
Landfilling of combustible waste	As landfilling of combustible waste was only of secondary importance and is prohibited completely since the year 2000 (section 4.8.2), greenhouse gas emissions from solid waste disposal sites are small, further decreasing, and only result from waste deposited before the implementation of the ban on landfilling of combustible waste. The WEM scenario is thus based on a continuation of the model for landfilling of combustible waste until 2035 (*IPCC*, 2006; *FOEN*, 2022a). The share of CH_4 flared (current value 10 per cent) is assumed to reach 11 per cent by 2025 and again 10 per cent by 2030, followed by a linear decrease to zero by 2050 as the remaining emissions are getting to small to be flared.	It is assumed that the ban on landfilling of combustible waste was not implemented. Consequently, the amount of waste disposed of at waste disposal sites under the WOM scenario follows the same evolution as under the WEM and WAM scenarios until 1999, but then only decreases to 10 per cent of this value by 2020, remaining constant thereafter.[69] It is further assumed that the share of CH_4 recovered for power production (on total CH_4 produced) is the same under the WOM scenario as under the WEM and WAM scenarios (the share decreases disproportionately as the cost-income ratio is changing for the worse with decreasing CH_4 production of the waste disposal site). Finally, it is assumed that the share of CH_4 flared remains constant at 3.5 per cent from 1990 to 2030, and then declines to zero by 2050.	Same as for the WEM scenario.
Wastewater handling	Emissions from wastewater handling are assumed to scale with the evolution of population.	Same as for the WEM scenario.	Same as for the WEM scenario.

[69] The reasoning for this assumption is a decreasing public acceptance of waste disposal sites (odour, need of space, pollution, etc.), leading to the closing of waste disposal sites (where practicable) even without an official ban.

Biogas production	It is assumed that the projected increase in the use of biogas (*Prognos et al.*, 2020) can only be provided if additional biogas facilities are constructed. As *Prognos et al.* (2020) do not explicitly model the number of biogas facilities, the trend over the years 2011–2020 is extrapolated. Accordingly, the total number of biogas facilities increases from 146 in 2020 to 165, 184 and 203 by 2025, 2030 and 2035, respectively. The additional biogas facilities lead to a related increase of fugitive emissions over the coming years.	It is assumed that the amount of biogas upgraded under the WOM scenario compared to the amount of biogas upgraded under the WEM and WAM scenarios corresponds to half of the amount by 2020 and to one third of the amount by 2030 and thereafter. The additional number of biogas facilities constructed after 2010 under the WOM scenario is then derived assuming the same amount of additionally upgraded biogas per facility as under the WEM and WAM scenarios. Consequently, reduced emissions from biogas facilities result under the WOM scenario compared to the WEM and WAM scenarios.	Same as for the WEM scenario.

The strength of this approach is that greenhouse gas emission scenarios are calculated at the level of single processes. This, however, requires a full set of projections of activity data and emission factors (which may potentially be considered a weakness of the approach).

5.3.6 Indirect CO_2 emissions

For the WEM and WAM scenarios, projections of indirect CO_2 emissions are based on the same assumptions and methodologies as the projections of direct greenhouse gas emissions in the respective sectors (see above). For the WOM scenario, it is assumed that due to the absence of policies and measures the emission factors for precursor emissions do not improve over time and, thus, remain constant at the values in 1990 (see section 4.5.4). The same activity data as under the WEM and WAM scenarios are then used to derive precursor emissions and subsequently indirect CO_2 emissions under the WOM scenario. For all scenarios, only fossil emissions and only emissions not already included elsewhere are considered (see section 3.2.4 for more details).

5.3.7 International transport

The scenarios for international aviation are based on the WWB scenario of *Prognos et al.* (2020). As described in the info box on page 37 of the concise report (see footnote 67), the following assumptions are underlain:

- The development of fuel consumption is extrapolated on the basis of a projection of passenger numbers; until 2030 according to *Intraplan* (2015), thereafter parallel to the development of the population, taking into account an increase in the efficiency of flights in relation to passenger numbers. The increase in efficiency results from technical improvements of aircraft, but also through an increase in the load factor and the use of larger aircraft. Overall, efficiency is assumed to increase with a rate of 0.57 per cent per year, based on scenario 5 in *ICAO* (2016). This increase in efficiency also reflects the effect of the CO_2 emissions standard for aircraft (section 4.4.9).[70] These assumptions lead to the passenger numbers and fuel consumption shown in Tab. 38;
- As the activity data based on *Prognos et al.* (2020) do not reflect the impact of measures to contain the corona virus pandemic, projected activity data were considered as of 2025, with linear interpolation between 2020 and 2025. Therewith, the recovery from the observed decrease in the historical data for 2020 is probably more realistic (i.e. lasting several years instead of one year only), but the short-term evolution should be viewed with caution;
- The inclusion of aviation in the emissions trading scheme (section 4.2.6) as well as the carbon offsetting and reduction scheme for international civil aviation (CORSIA; section 4.4.10) overall enforce a carbon neutral growth on the basis of 2019. However, since both systems involve compensation outside the aviation sector and possibly also outside Switzerland, they cannot be offset against emissions in the logic of the energy perspectives (*Prognos et al.*, 2020);
- With regard to the share of biofuels in international aviation from Switzerland, *Prognos et al.* (2020) assume for the WWB scenario that it rises continuously from zero per cent in 2030 to three per cent in 2045 (corresponding to an increase rate of 0.2 per cent per year starting in 2030);

70 As this policy and measure is of global significance, it is assumed that it does not lead to differences between the WEM, WOM and WAM scenarios.

- For the WEM and WOM scenarios the resulting fuel consumption as described above – including the increase in the share of biofuels of 0.2 per cent per year as of 2030 – is directly used to project greenhouse gas emissions from international aviation. As for the energy sector, the calculations are performed by means of the national air pollution database EMIS, i.e. the same emission factors are applied as for the greenhouse gas inventory;
- The greenhouse gas emissions under the WAM scenario are calculated based on the same methodology and assumptions as for the WEM and WOM scenarios. However, to include the planned sustainable aviation fuel policy (section 4.4.12), it is assumed that the introduction of sustainable aviation fuels increases stepwise, reaching shares of two per cent in 2025, five per cent in 2030, and 20 per cent in 2035.

For Switzerland, emissions from international transport are dominated by international aviation. The minor emissions from international navigation are assumed to remain constant at the level of emissions in 2020 up to 2035 (for the WEM, WOM and WAM scenarios).

Tab. 38 > International aviation: Passenger numbers and fuel consumption used for the WEM, WOM and WAM scenarios.

	2025	2030	2035
Departing passengers (million)	71	81	85
Aviation fuels (PJ)	87	97	100
thereof biofuels, WEM and WOM scenarios (PJ)	0	0	1
thereof biofuels, WAM scenario (PJ)	2	5	20

Prognos et al. (2020)

5.3.8 Main differences compared to previous submissions

Compared to the greenhouse gas emission scenarios presented in Switzerland's last submission (i.e. Switzerland's fourth biennial report), the following most important changes and improvements regarding methodology and assumptions were implemented in the calculations for the different sectors:

- For the energy sector, Switzerland completely updated its WEM and WAM scenarios. The scenarios are now based on the results from the energy perspectives 2050+ (*Prognos et al.*, 2020). Therewith, the WEM and WAM scenarios now reflect the results of very detailed energy system models while a computable general equilibrium model was previously applied;
- In the industrial processes and product use sector, the same methodology for process emissions is used, but the relevant activity data for industrial production are inferred from production indices available from the energy perspectives 2050+ of *Prognos et al.* (2020). With regard to F-gases, a minor update (mainly of input parameters) ensures consistency with the most recent greenhouse gas inventory, but emissions projections remain very similar to the previous submission;
- Projections for the agriculture sector now include new scenarios from *Mack and Möhring* (2021) as well as provisions in *Swiss Confederation* (2019), *FOAG* (2021) and *Swiss Federal Council* (2021a). Further adjustments ensure consistency with the latest greenhouse gas inventory;
- The WAM scenario for international transport now takes into account the planned sustainable aviation fuel policy (section 4.4.12), while the inclusion of aviation in the emissions trading scheme (section 4.2.6) as well as the carbon offsetting and reduction scheme for international civil aviation (CORSIA; section 4.4.10) are assumed to develop its mitigation impact outside the aviation sector;
- In the land use, land-use change and forestry sector, updated results for all three scenarios have become available, leading to several recalculations (improvements) compared to the previous submission. First, the same methodological improvements were implemented as for the technical correction of Switzerland's forest management reference level, see *Thürig et al.* (2021) and section 11.5.2.4 in *FOEN* (2022a) for a detailed description. Second, in the context of the development of Switzerland's forest reference level (FRL), several scenarios were defined and tested (*Stadelmann et al.*, 2021), from which three are used for this report (see Tab. 36). The definition of the scenarios differs from the assignment in the previous submission.

In Fig. 74, the projections as reported in Switzerland's eighth national communication and fifth biennial report are compared to the projections as reported in Switzerland's fourth biennial report. Compared to the previous submission, the most recent WEM scenario is 5.6 per cent and 8.3 per cent lower by 2030 and 2035, respectively. The most recent WOM scenario is 2.4 per cent and 2.6 per cent higher by 2030 and 2035, respectively. The most recent WAM scenario is 1.6 per cent higher and 1.5 per cent lower by 2030 and 2035, respectively. Altogether, the overall differences are of minor importance (see Fig. 74). Changes may result from updated methodologies and assumptions, but they also reflect actual changes in underlying legislation (the individual contributions from these two parts could not be disentangled). Fig. 75 shows the same comparison for international transport. Apart from the substantial impact in consequence of the corona virus pandemic, projections for the WEM and WOM scenarios as presented in Switzerland's eighth national communication and fifth biennial report are very similar to the projections presented in Switzerland's fourth biennial report. However, the revision of the WAM scenario leads to some differences compared to the previous report.

Fig. 74 > Total emissions without LULUCF: Changes in projections as reported in Switzerland's eighth national communication and fifth biennial report (thicker lines) and Switzerland's fourth biennial report (thinner lines). The overall differences are of minor importance.

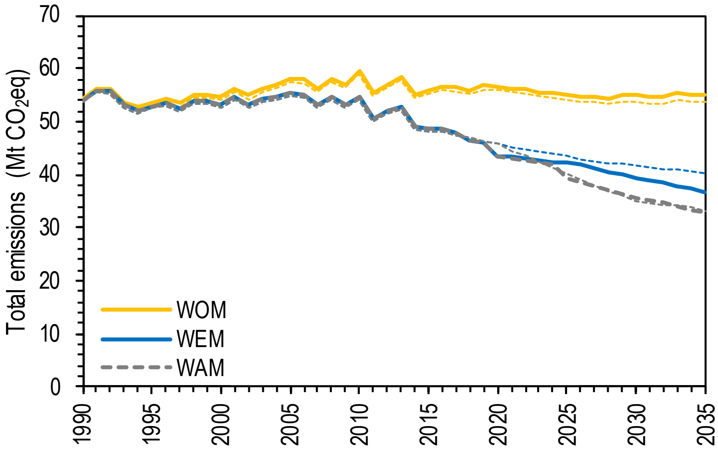
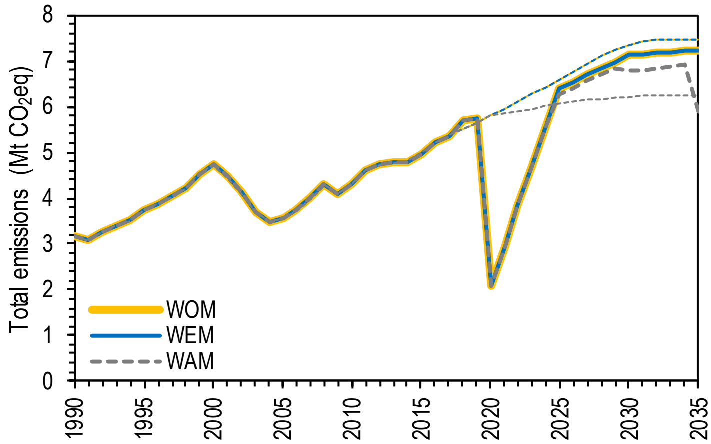


Fig. 75 > International transport: Changes in projections as reported in Switzerland's eighth national communication and fifth biennial report (thicker lines) and Switzerland's fourth biennial report (thinner lines). Major differences occur for the years 2020 to 2025 as the consequences of the corona virus pandemic are now taken into account. Further, the WAM scenario was revised compared to the previous submission.



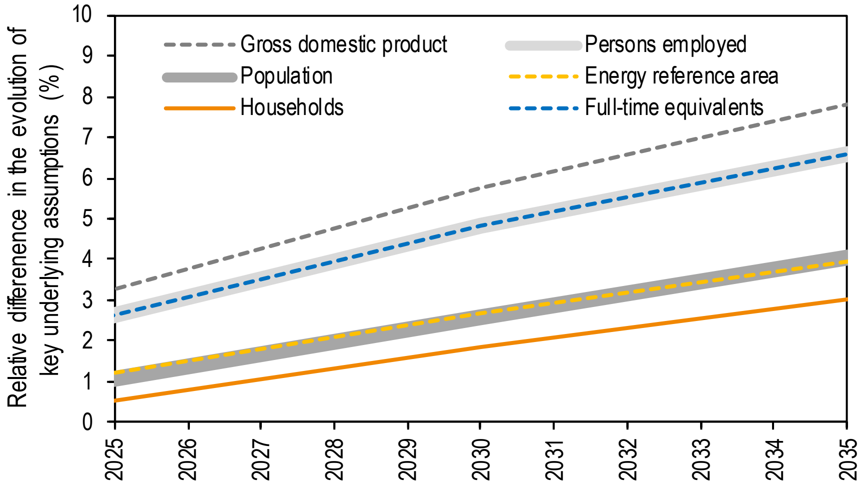
5.3.9 Sensitivity analysis

In the context of the development of the energy perspectives 2050+, *Prognos et al.* (2020) also performed a sensitivity analysis. Thereby, the potential impacts of higher growth rates of population and gross domestic product were estimated.[71] Detailed information is available in section 11.1 of the technical report (see footnote 67).

In brief, higher growth rates in population and gross domestic product lead to an increased number of employed persons. Due to the larger population, the higher number of employed persons and the higher gross value added, the quantity factors derived from this, such as the energy reference area, the transport performance and the production quantities, increase as well. The sensitivity analysis examines how these changed quantity factors affect energy consumption and greenhouse gas emissions. All other factors – including efficiency developments and substitution relationships – are left unchanged compared to the main scenario.

The evolutions of various key underlying assumptions (population, households, gross domestic product, persons employed, full-time equivalents, energy reference area) is shown in Fig. 76, where the given values provide the relative difference (in per cent) between the sensitivity scenario and the main scenario. The basis for population is the 'high scenario' (B-00-2015) of the Swiss Federal Statistical Office (*SFSO*, 2015). In the sensitivity scenario, the population rises to 9.7 million (main scenario: 9.5 million) in 2030 and to 10.2 million in 2035 (main scenario: 9.8 million). In 2035, this corresponds to a difference of 4.0 per cent. The differences between the sensitivity scenario and the main scenario for the total energy reference area evolves very similar as for population. The development of the household structure is also based on the scenario BM-00-2015 of the Swiss Federal Statistical Office. The differences in the mean household size compared to the main scenario are minor, but the mean household size is slightly higher in the sensitivity. Due to the slightly larger mean household size, the relative difference between the sensitivity scenario and the main scenario in the number of households is slightly smaller than in the population. In 2035, the number of private households in the sensitivity scenario is by 3.5 per cent higher than in the main scenario. Persons employed and full-time equivalents evolve in parallel and reach a value, in the sensitivity scenario and by 2035, of 6.6 per cent above the main scenario. The largest relative difference is assumed for the gross domestic product, with the sensitivity scenario being 7.8 per cent higher than the main scenario (by 2035).

Fig. 76 > Evolution of various key underlying assumptions under the sensitivity scenario. Shown are the relative differences between the sensitivity scenario and the main scenario. Additional parameters are available in the technical report and the corresponding data tables (*Prognos et al.*, 2020).



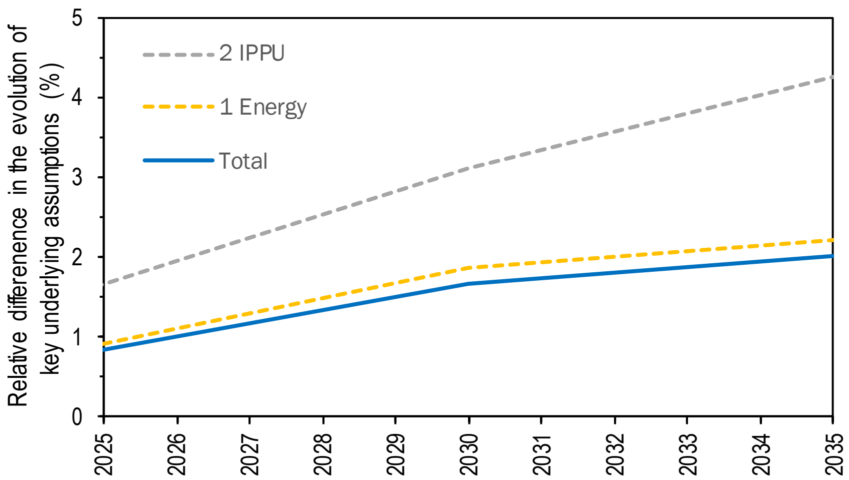
[71] In addition, the sensitivity to energy price assumptions was analysed, but only for the net-zero emissions scenarios ('ZERO'), while energy prices for the scenario 'WWB' (used here as the basis for the WEM scenario) remained unchanged.

The main results of the sensitivity analysis are as follows:

- Final energy consumption in the sensitivity scenario decreases from 783 petajoules in 2000 to 727 petajoules in 2030 and to 708 petajoules in 2035. In 2035, the energy consumption is thus 25 petajoules higher than in the main scenario. The additional 25 petajoules correspond to an increase in consumption of around four per cent;
- A large part of the additional consumption is accounted for by electricity (18 petajoules). The additional electricity demand is not offset by higher domestic generation, but by additional imports. There also results an additional consumption of fossil energy sources, which amounts to about five petajoules for petroleum products and about four petajoules for natural gas in 2035;
- The additional consumption of fossil energy sources in the sensitivity scenario leads to slightly higher emissions of greenhouse gases compared to the main scenario (see Fig. 77). Process emissions in sector 2 'Industrial processes and product use' are also slightly higher in the sensitivity scenario compared to the main scenario. For simplification, an identical development was assumed for agriculture and waste as in the main scenario;
- Overall, the sensitivity scenario results in additional greenhouse gas emissions of 0.7 and 0.8 million tonnes of CO_2 equivalents in 2030 and 2035, respectively, compared to the main scenario. CO_2 is responsible for the dominant share (about 98 per cent) of the resulting difference. The additional emissions mainly occur in industry (energy and process emissions) and transport. In contrast, additional emissions from services and private households are negligible;
- In relative terms, total greenhouse gas emissions are 2.0 per cent higher under the sensitivity scenario compared to the main scenario in 2035. The relative difference is 2.2 per cent for the energy sector and 4.3 per cent for process emissions in sector 2 'Industrial processes and product use' (Fig. 77).

A further discussion as well as additional figures are available in section 11.1 of the technical report (see footnote 67).

Fig. 77 > Evolution of greenhouse gas emissions (sum of all gases) under the sensitivity scenario. Shown are the relative differences between the sensitivity scenario and the main scenario. Additional parameters are available in the technical report and the corresponding data tables of *Prognos et al.* (2020).



References

Alig, M., Prechsl, U., Schwitter, K., Waldvogel, T., Wolff, V., Wunderlich, A., Zorn, A., Gaillard, G., 2015: Ökologische und ökonomische Bewertung von Klimaschutzmassnahmen zur Umsetzung auf landwirtschaftlichen Betrieben in der Schweiz. Agroscope Science, 29. Agroscope, Ettenhausen. *https://ira.agroscope.ch/de-CH/Page/Einzelpublikation/Download?einzelpublikationId=35396* [18.07.2022]

Carbotech, 2020: Emissionsperspektiven F-Gase: HFKW, PFKW, NF_3 und SF_6 (Update 2020). Carbotech AG, Basel. [confidential/internal]

EPFL and Infras, 2016: Emissions scenarios without measures, 1990–2030. Swiss Federal Institute of Technology in Lausanne, ENAC IA LEURE, Lausanne / Infras, Zurich (mandated by the Swiss Federal Office for the Environment, Bern). 04.05.2016. *http://goo.gl/5na6D2* [18.07.2022]

EPFL, 2017: Updated emissions scenarios without measures, 1990–2035. Swiss Federal Institute of Technology in Lausanne, ENAC IA LEURE, Lausanne (mandated by the Swiss Federal Office for the Environment, Bern). 12.10.2017. *http://goo.gl/ySao2s* [18.07.2022]

FOAG, 2021: Verordnungspaket Parlamentarische Initiative 19.475 «Das Risiko beim Einsatz von Pestiziden reduzieren». Erläuternder Bericht zur Eröffnung des Vernehmlassungsverfahrens. Bern, Schweiz. *https://www.blw.admin.ch/dam/blw/de/dokumente/Politik/Agrarpolitik/Agrarpakete aktuell/verordnungspaket_parliv_28-4-21.pdf* [18.07.2022]

FOEN and FOAG, 2008: Umweltziele Landwirtschaft (Hergeleitet aus bestehenden rechtlichen Grundlagen). Swiss Federal Office for the Environment, Bern / Swiss Federal Office for Agriculture, Bern. *https://www.bafu.admin.ch/uw-0820-d* [18.07.2022]

FOEN and FOAG, 2012: Baulicher Umweltschutz in der Landwirtschaft. Ein Modul der Vollzugshilfe Umweltschutz in der Landwirtschaft. Swiss Federal Office for the Environment, Bern / Swiss Federal Office for Agriculture, Bern. UV-1101-D. *https://www.bafu.admin.ch/uv-1101-d* [18.07.2022]

FOEN, 2016d: Switzerland's Second initial report under the Kyoto Protocol. Update following the in-country review by an expert review team coordinated by the UNFCCC secretariat. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

FOEN, 2021: Forest Policy: objectives and measures 2021–2024. For the sustainable management of forests in Switzerland. Swiss Federal Office for the Environment, Bern. UI-2119-E, 20.12.2021. *www.bafu.admin.ch/ui-2119-e* [18.07.2022]

FOEN, 2022a: Switzerland's greenhouse gas inventory 1990–2020: National inventory report, as well as reporting tables (CRF) and SEF tables. Submission of April 2022 under the UNFCCC and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

FOEN/SFOE/SECO, 2021: Wood Resource Policy. Strategy, Objectives and Wood Action Plan 2021–2026. Swiss Federal Office for the Environment, Bern / Swiss Federal Office of Energy, Bern / Swiss State Secretariat for Economic Affairs, Bern. UI-2103-E, 20.06.2021. *www.bafu.admin.ch/ui-2103-e* [18.07.2022]

Furrer, C., Stüssi, M., Bystricky, M. 2021: Umweltbewertung ausgewählter Klimaschutzmassnahmen auf Landwirtschaftsbetrieben. Agroscope Science, 121. Zürich, Switzerland. *https://bit.ly/3wVJVBB* [18.07.2022]

Herzog, F. and Richner, W., 2005: Evaluation der Ökomassnahmen: Bereich Stickstoff und Phosphor. Herzog, F., Richner, W. (eds). Schriftenreihe der FAL Nr. 57, 17662. Agroscope FAL Reckenholz, Zurich. *http://goo.gl/2XKX7r* [18.07.2022]

ICAO, 2016: ICAO Environmental Report 2016 – Chapter 1: Aviation and environmental outlook, environmental trends in aviation to 2050. International Civil Aviation Organization (ICAO). 2016. *https://www.icao.int/environmental-protection/Pages/env2016.aspx* [18.07.2022]

Intraplan, 2015: Entwicklung des Luftverkehrs in der Schweiz bis 2030 – Nachfrageprognose. Intraplan Consult GmbH, München. Juni 2015. *https://bit.ly/34lsZ7D* [18.07.2022]

IPCC, 2006: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. *https://www.ipcc-nggip.iges.or.jp/public/2006gl* [18.07.2022]

Kreuzer, M. 2020: Milchviehfütterung: Wie kann man gezielt gegen Methanemissionen vorgehen? Handout zum Milchviehforum 2020. 31.01.2020. BBZN Hohenrain, LU. Hohenrain, Schweiz. [18.07.2022]

Kupper, T., Häni, Ch., Bretscher, D., Zaucker, F., Bencheikh, M., Kohler, F., Menzi, H. 2022: Ammoniakemissionen der schweizerischen Landwirtschaft 1990–2020. Berner Fachhochschule, Hochschule für Agrar-, Forst- und Lebensmittelwissenschaften HAFL, Zollikofen (mandated by the Swiss Federal Office for the Environment). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/luft/externe-studien-berichte/Kupper_2022_Ammoniakemissionen%20Schweiz%201990-2020.pdf* [18.07.2022]

Mack, G., Heitkämper, K., Käufeler, B., Möbius, S. 2017: Evaluation der Beiträge für Graslandbasierte Milch- und Fleischproduktion (GMF). Agroscope Science Nr. 54, 1–99. Agroscope. Tänikon-Ettenhausen, Schweiz. *https://ira.agroscope.ch/de-CH/publication/37016* [18.07.2022]

Mack, G., Möhring, A. 2021: SWISSland-Modellierung zur PaIv 19.475: «Das Risiko beim Einsatz von Pestiziden reduzieren». Agroscope. Tänikon-Ettenhausen, Schweiz. *https://www.agroscope.admin.ch/agroscope/de/home/themen/wirtschaft-technik/oekonomische-modellierung-politikanalyse.html* [18.07.2022]

Möhring, A., Ferjani, A., Mack, G., Mann, S., Zimmermann, A., 2016: Modellprojektionen mit SWISSland zum Zahlungsrahmen 2018–2021. Agroscope Science, 35. Agroscope, Ettenhausen. *https://ira.agroscope.ch/de-CH/publication/35836* [18.07.2022]

Möhring, A., Mack, G., Ferjani, A., Kohler, A., Mann, S., 2015: Swiss Agricultural Outlook. Agroscope Science Nr. 23. Agroscope, Ettenhausen. *https://ira.agroscope.ch/de-CH/publication/34903* [18.07.2022]

Peter, S., 2008: Modellierung agrarökologischer Fragestellungen unter Berücksichtigung des landwirtschaftlichen Strukturwandels. Dissertation. Swiss Federal Institute of Technology in Zurich. *https://bit.ly/2XCHdOy* [18.07.2022]

Peter, S., Hartmann, M., Weber, M., Lehmann, B., Hediger, W., 2009: THG 2020 – Möglichkeiten und Grenzen zur Vermeidung landwirtschaftlicher Treibhausgase in der Schweiz. Gruppe Agrar-, Lebensmittel und Umweltökonomie des Interdepartementalen Instituts für Umweltentscheidungen. Swiss Federal Institute of Technology in Zurich. *http://goo.gl/vzkUwZ* [18.07.2022]

Peter, S., Valsangiacomo, A., Lehmann, B., Weber, M., 2010: Stickstoff 2020 – Möglichkeiten und Einschränkungen zur Vermeidung landwirtschaftlicher Stickstoffemissionen in der Schweiz. Gruppe Agrar-, Lebensmittel und Umweltökonomie des Interdepartementalen Instituts für Umweltentscheidungen. Swiss Federal Institute of Technology in Zurich. *https://bit.ly/35i3jbY* [18.07.2022]

Prognos et al., 2020: Energy Perspectives 2050+. Prognos, Basel / TEP Energy, Zurich / Infras, Zurich / Ecoplan, Bern (mandated by the Swiss Federal Office of Energy, Bern). *https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html* [18.07.2022]

Schils, R.L.M., Olesen, J.E., del Prado, A., Soussana, J.F., 2007: A review of farm level modeling approaches for mitigating greenhouse gas emissions from ruminant livestock systems. Livestock Science 112 (3): 240–251. *http://www.sciencedirect.com/science/article/pii/S187114130700474X* [18.07.2022]

Schrade, S., Keck, M., Zähner, M. 2018: Emissionsversuchsstall für Milchvieh: Konzept und Messmethode. In: Swiss -Future-Farm-Eröffnung. 21.09., Hrsg. Swiss Future Farm. Tänikon, Schweiz. *https://ira.agroscope.ch/de-CH/publication/39430* [18.07.2022]

SFSO, 2015: Szenarien zur Bevölkerungsentwicklung der Schweiz 2015–2065. Swiss Federal Statistical Office, Neuchâtel. *https://www.bfs.admin.ch/bfs/en/home/statistics/population/population-projections/national-projections.assetdetail.350324.html* [18.07.2022]

SFSO, 2021: Supply of data of the AREA Land Use Statistics. Written communication from Michael Bühler (Swiss Federal Statistical Office, Neuchâtel) to Martin Lindenmann (Sigmaplan, Bern), 14.07.2021. [confidential/internal, queries from database]

Stadelmann, G., 2020: Quantifizierung der Waldbiomasse und des Holznutzungspotenzials in der Schweiz. Schweizerische Zeitschrift für Forstwesen 171, 124–132. *https://doi.org/10.3188/szf.2020.0124* [18.07.2022]

Stadelmann, G., Portier, J., Didion, M., Rogiers, N., & Thürig, E., 2021: From Paris to Switzerland: four pathways to a Forest Reference Level. Frontiers in Forests and Global Change, Volume 4, 148. *https://doi.org/10.3389/ffgc.2021.685574* [18.07.2022]

Stadelmann, G., Temperli, C., Rohner, B., Didion, M., Herold, A., Rösler, E., Thürig, E., 2019: Presenting MASSIMO: A Management Scenario Simulation Model to Project Growth, Harvests and Carbon Dynamics of Swiss Forests. Forests 10 (2), 94. *https://www.dora.lib4ri.ch/wsl/islandora/object/wsl%3A19354* [18.07.2022]

Swiss Confederation, 2013: Verordnung über die Förderung von Qualität und Nachhaltigkeit in der Land- und Ernährungswirtschaft (QuNaV) vom 23.10.2013 (Stand am 01.01.2014). Swiss Confederation. *https://www.admin.ch/opc/de/classified-compilation/20130238/index.html* [18.07.2022]

Swiss Confederation, 2019: Parlamentarische Initiative 19.475: Das Risiko beim Einsatz von Pestiziden reduzieren. Swiss Confederation. *https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20190475* [18.07.2022]

Swiss Federal Council, 2009: Weiterentwicklung des Direktzahlungssystems: Bericht des Bundesrates (in Erfüllung der Motion der Kommission für Wirtschaft und Abgaben des Ständerates vom 10.11.2006 (06.3635)). Swiss Federal Council, Bern. 730.750.d. *http://goo.gl/sZp5N7* [18.07.2022]

Swiss Federal Council, 2021a: Switzerland's Long-Term Climate Strategy. Swiss Federal Council. Bern, Switzerland. *https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/emission-reduction/reduction-targets/2050-target/climate-strategy-2050.html* [18.07.2022

Thürig, E., Stadelmann, G., Didion, M. 2021: Estimating carbon stock changes in living and dead biomass and soil for the technical correction of Switzerland's Forest Management Reference Level for the Swiss NIR 2021 (1990–2019) – modeling methodology and results, including supplemental information on updated Yasso data for technical correction of the Swiss FMRL in the Swiss NIR 2022. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf (commissioned by the Swiss Federal Office for the Environment, Bern). *http://www.climatereporting.ch* [18.07.2022]

Zell, J., Rohner, B., Thürig, E., Stadelmann, G., 2019: Modeling ingrowth for empirical forest prediction systems. Forest Ecology and Management 433, 771–779. *https://doi.org/10.1016/j.foreco.2018.11.052* [18.07.2022]

6 Vulnerability assessment, climate change impacts and adaptation measures

Contents of this chapter have been updated to reflect the new climate change scenarios for Switzerland (*CH2018*, 2018), recent impact studies based on these scenarios, as well as latest developments with regard to the Swiss adaptation strategy and its implementation. The chapter structure has been slightly changed compared to Switzerland's seventh national communication.

6.1 Climate modelling, projections and scenarios

6.1.1 Update on the state of models and scenarios

The official scenarios on climate change currently used in Switzerland (CH2018 Climate Scenarios for Switzerland) were launched in 2018 (*CH2018*, 2018). CH2018 and its follow-up activities are a focus area of the National Centre for Climate Services established in 2015 (*http://www.nccs.ch*, see also section 6.4.2). The CH2018 scenarios were realised in a co-design framework including the Swiss Federal Institute of Technology in Zurich (ETH Zurich), with the Centre for Climate Systems Modelling (C2SM) and MeteoSwiss as the two leading institutions, and also integrating further partners such as the University of Bern.

The CH2018 climate scenarios present a consolidated view on projected future climate change in Switzerland. The products, design and communication of CH2018 closely followed the results and advice of an end-user oriented survey carried out beforehand (*Perch-Nielsen et al.*, 2016). CH2018 has thus closed many gaps and further facilitated the use of climate scenario information and data in practice, with end-user targeted products addressing lay to expert users. The scenarios are based on a large number of state-of-the-art European-scale regional climate model experiments available at the time of their preparation (EURO-CORDEX; *Jacob et al.*, 2014; *Kotlarski et al.*, 2014). Statistical methods were used to produce probabilistic multi-model estimates of future change for a range of meteorological variables. Summarised results are available for five representative Swiss regions, three scenario time periods (represented by 30-year periods around the years 2035, 2060 and 2085) and three emission scenarios.

CH2018 is based on the RCP emission scenarios that were used for the fifth assessment report of the Intergovernmental Panel on Climate Change (*IPCC AR5*, 2014). CH2018 also provides statistically downscaled products at two kilometres horizontal and daily temporal resolution for precipitation and temperature using a methodology that dissolved some of the limitations of the CH2011 statistical downscaling approach. For eight meteorological variables, CH2018 additionally provides ready-to-use data for 84 to 399 stations (depending on variable) in Switzerland. A major advancement with respect to the preceding CH2011 scenarios is the transient character of the data for impact applications. Results and data are available through the internet page *http://www.climate-scenarios.ch*.

The CH2018 scenarios serve as a basis for climate change impact studies in Switzerland. The currently most comprehensive study, 'Hydro-CH2018', was led by the Oeschger Centre for Climate Change Research and the Swiss Federal Office for the Environment. It investigated quantitative impacts of climate change with a focus on hydrology (*FOEN*, 2021). The CH2018 scenarios also were an important input for the further development of the national climate adaptation strategy (see section 6.3).

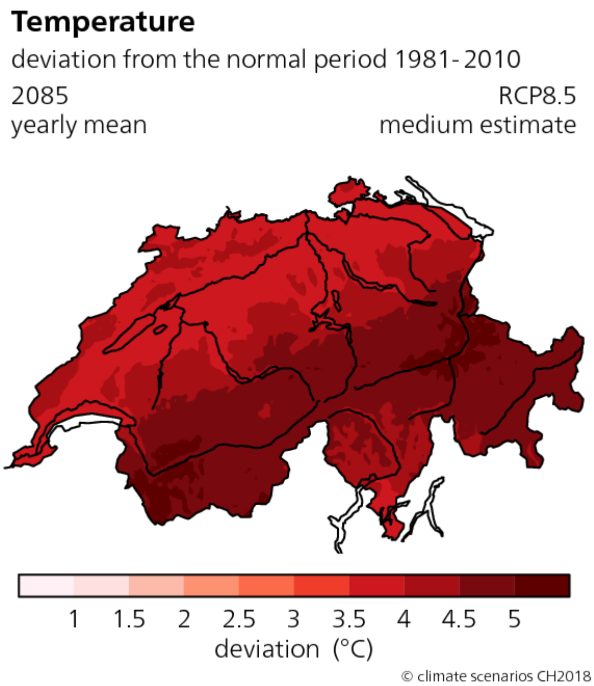
With the sixth assessment report of the Intergovernmental Panel on Climate Change (*IPCC AR6*, 2021) and additional global and regional climate model projections available, current efforts relate to the integration of most recent state-of-the-art knowledge and data resources into the Swiss climate scenario landscape. In addition, output from novel climate model projections that allow to simulate the sub-daily (i.e. hourly) character of climate change at high spatial resolution is increasingly becoming available. In the Swiss follow-up scenario project, such simulations will be integrated and will improve understanding of high-impact extreme events under changing climatic conditions. This project will again be realised in a co-design framework between MeteoSwiss and the Swiss Federal Institute of Technology in Zurich (ETH Zurich), and is planned to involve several partner institutions and stakeholders from academia and federal offices.

6.1.2 Main results for temperature, precipitation and climate extremes

Temperature and precipitation

In line with the observations of recent decades, a further warming of the climate is projected for Switzerland (see also Fig. 78 and Fig. 79). Expected changes in the climate system are significant with respect to present-day and pre-industrial conditions and will further depart from present-day conditions, with a magnitude depending on the emissions scenario considered. Mean temperature will further increase in all regions and seasons, most prominently in summer and in high altitudes. Summer mean precipitation will likely decrease by the end of the century, while winter precipitation will likely increase. Both of these seasonal characteristics are particularly pronounced for strong-warming scenarios. Despite these particular, significant changes in cold and warm season precipitation, annually integrated precipitation amounts show no clear change.

Fig. 78 > Future change in temperature (degree Celsius) according to CH2018 climate scenarios and based on the emission scenario RCP8.5 of the fifth assessment report of the Intergovernmental Panel on Climate Change (*IPCC AR5*, 2014) by the end of the century (2085: 2070–2099). The changes are relative to the reference period 1981–2010. The figure is based on a novel localised product of CH2018 (two kilometres gridded bias-corrected and localised scenario data).



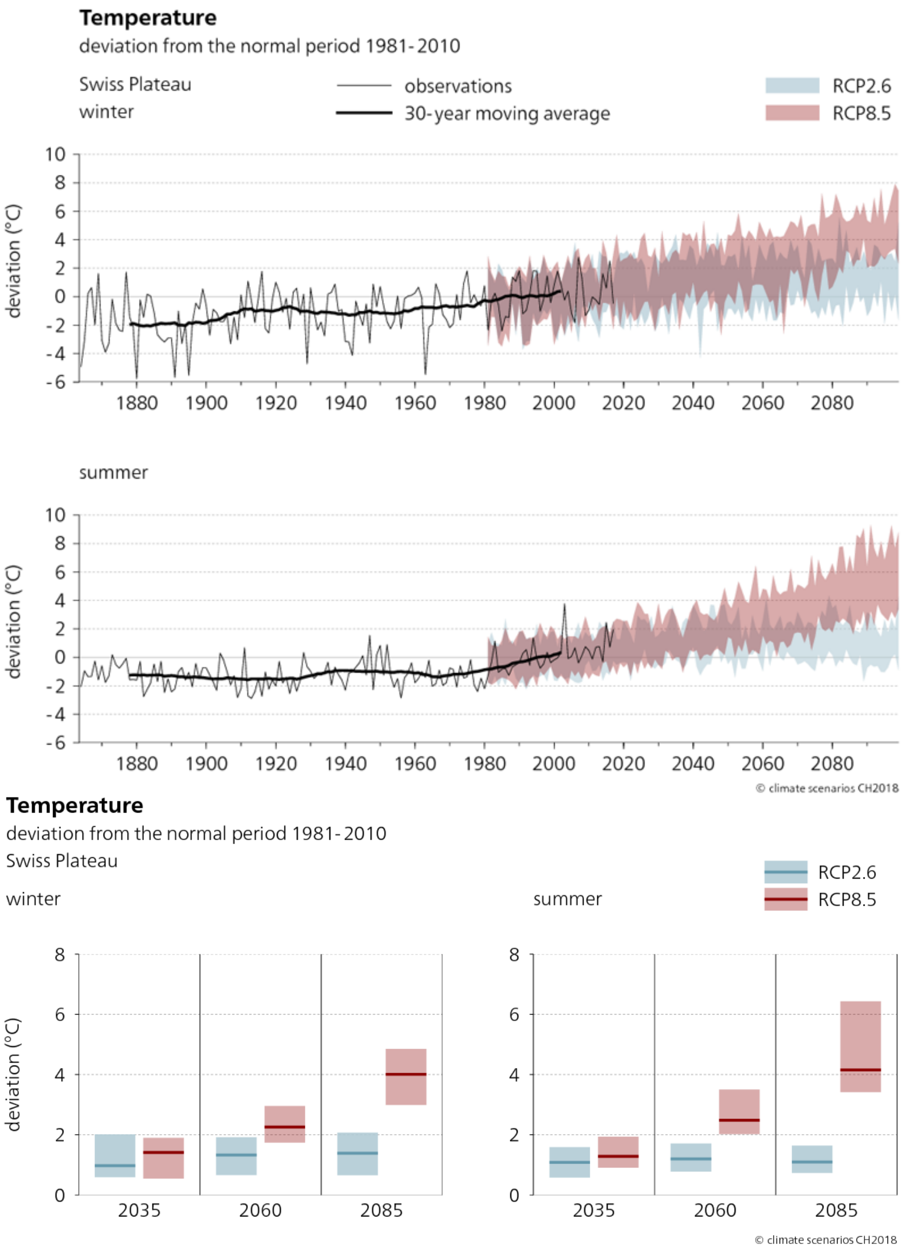
CH2018 (2018) and NCCS (*www.nccs.admin.ch*)

The future Swiss climate depends heavily on the development of global greenhouse gas emissions. This effect is particularly marked towards the end of the 21st century. As an example, Fig. 79 shows the observed seasonal temperature evolution (winter and summer) over the Central Plateau (i.e. the lower-lying, densely populated areas of Switzerland) and its future projection with (RCP2.6, blue colour) and without climate change mitigation (RCP8.5, red colour). Temperature is expressed as the deviation from the reference period 1981–2010. Along with large inter-annual variability (especially in winter), the observed record clearly shows that temperatures in Switzerland have risen over the last century with an accelerated warming trend since the 1980s.

The future climate of Switzerland will not only be determined by the pure thermodynamic effect of rising greenhouse gas concentrations but also by corresponding changes in the large scale circulation. However, the latter have a large uncertainty and little model consensus exists so far.

With respect to the pre-industrial period (1871–1900) the observed warming amounts to approximately two degrees Celsius for Switzerland, while the global mean temperature change in this period has warmed by about one degree Celsius. It is expected that future warming in Switzerland will still be larger than the global mean, but that the future relationship between global and regional warming could look different than it does today. While the scenarios with and without mitigation show similar warming rates over Switzerland for the near-term (next 10–20 years), they clearly depart from each other in the mid- to long-term (i.e. after around 2040). In a scenario with resolute climate mitigation measures, the additional temperature increase in Switzerland would be limited to around 1.5 degrees Celsius (relative to the reference period 1981–2010). In contrast, a scenario without climate change mitigation yields a temperature increase of four degrees Celsius, and partly even distinctly more, for both seasons (see also Fig. 79 bottom panels).

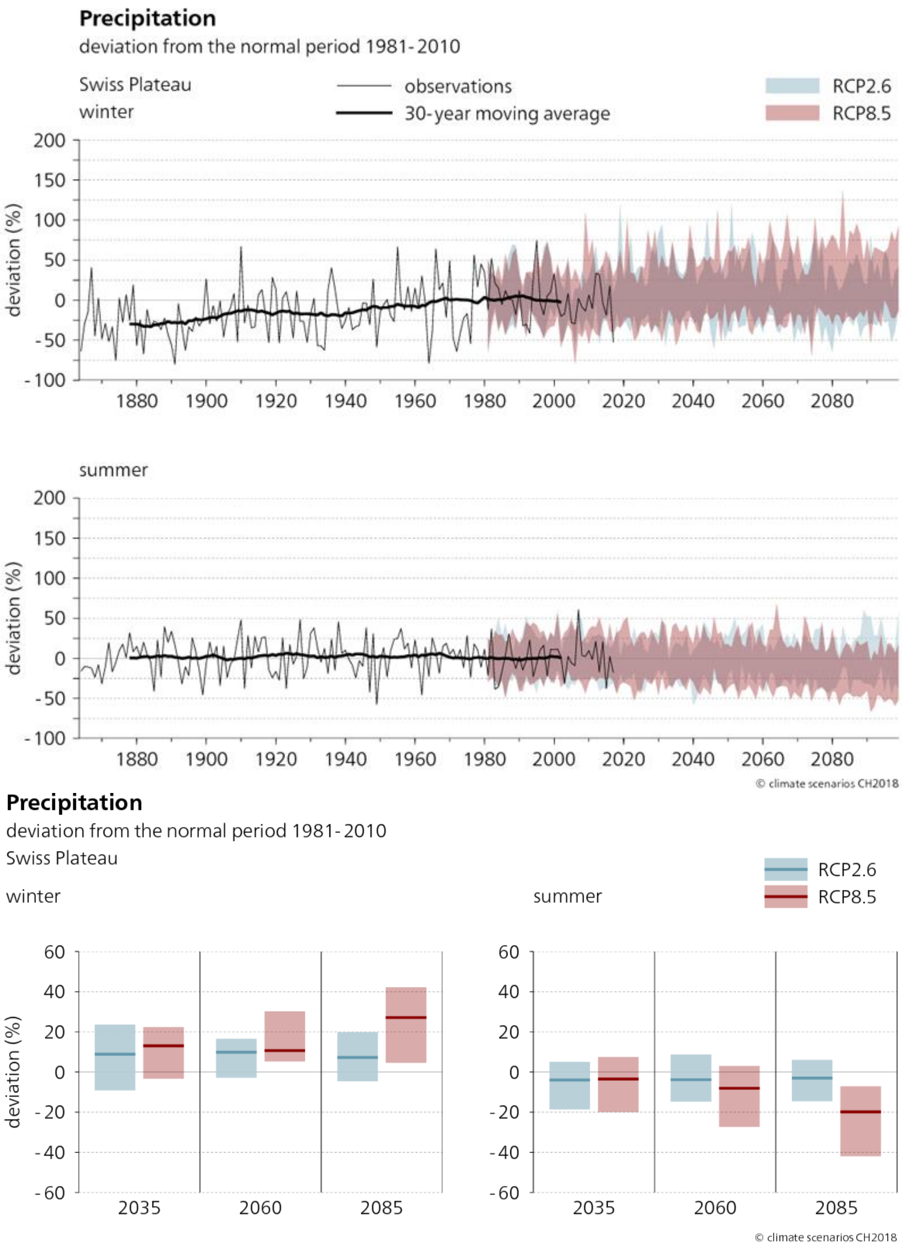
Fig. 79 > Past observed variability and future projected changes in winter and summer temperature (degree Celsius) over the Central Plateau (top and middle panel) and summarised change signals for three future reference periods in winter (bottom left panel) and summer (bottom right panel). The changes are relative to the reference period 1981–2010 and represent the RCP2.6 (with resolute mitigation, blue) and RCP8.5 (without mitigation, red) emission scenarios.



CH2018 (2018) and NCCS (*www.nccs.admin.ch*)

Past variability and projected future changes in seasonal precipitation are presented in Fig. 80. While summer precipitation has shown no trend for more than 100 years, winter precipitation has increased. Year-to-year precipitation variability is expected to stay large and winter precipitation is projected to further increase. In particular for the without mitigation scenario and towards the end of the century, further increases are significant and in a range between +5 and +40 per cent (median signal about +25 per cent). In summer, significant changes are projected to emerge from present-day variability during the second-half of the 21st century and a clear reduction in summer precipitation in a range between –5 and –40 per cent (median signal about –20 per cent) is projected for the end of the century (RCP8.5). Consistent with temperature projections, the divergence of with and without mitigation scenarios by the end of the century is distinct. In the case of precipitation, the mitigation pathway could help prevent a significant decrease in summer precipitation (see Fig. 80, bottom right).

Fig. 80 > Past observed variability and future projected changes in winter and summer precipitation (per cent) over the Central Plateau (top and middle panel) and summarised change signals for three future reference periods in winter (bottom left panel) and summer (bottom right panel). The changes are relative to the reference period 1981–2010 and represent to the RCP2.6 (with resolute mitigation, blue) and RCP8.5 (without mitigation, red) emission scenarios.



CH2018 (2018) and NCCS (*www.nccs.admin.ch*)

The projected increase in temperature for Switzerland is consistent with large-scale warming over Europe for all seasons. In winter there is increased warming in northern Europe, partly due to a decrease in snow cover (polar amplification). In summer, stronger warming is projected to take place in southern Europe, partly driven by drier surface conditions and changes in atmospheric stratification and circulation (Mediterranean amplification, see also *Brogli et al.*, 2019). Northern Europe will likely get wetter and southern Europe is expected to get drier, which is consistent with global-scale patterns and processes that find a drying in the subtropics and wetter conditions in high latitudes. In between those opposing trends, precipitation in the alpine region could either increase or decrease at the annually integrated scale, but show significant changes in the individual seasons (see also *Rajczak and Schär*, 2017). In summer, the Mediterranean drying will likely encompass the Alps and Central Europe and will significantly affect Switzerland. The expected decrease in mean summer precipitation is primarily due to a lower number of wet days, while the average intensity of precipitation remains at a balanced to slightly increasing level. Consequently, the probability of prolonged periods of consecutive dry days increases. In winter, a tendency for increasing precipitation amounts is already identifiable in the observed records (see also Fig. 80). This increase is expected to further continue as the climate warms.

Temperature extremes

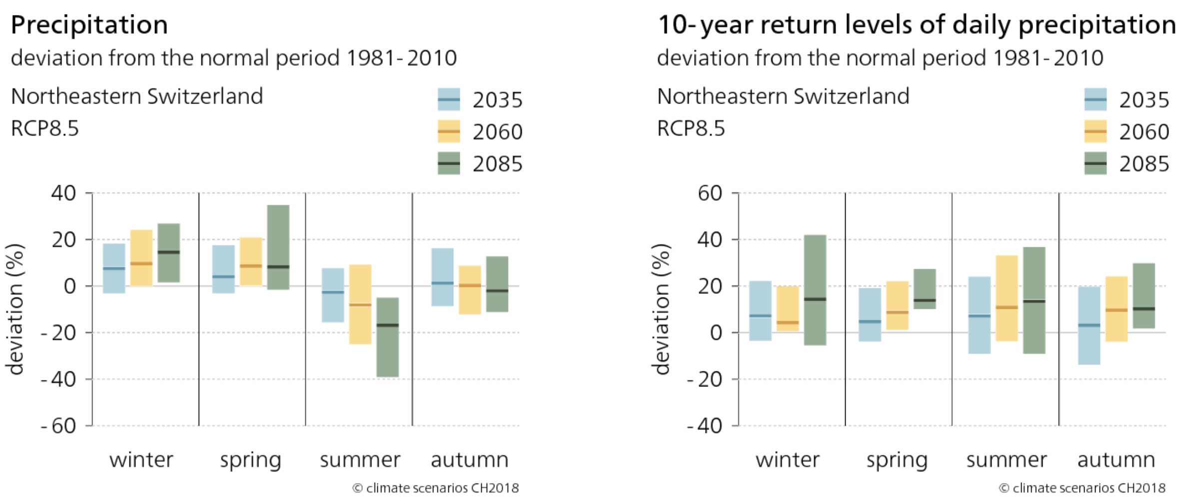
The CH2018 climate scenarios are the first scenario generation that explicitly addresses projected changes in extreme events. State-of-the-art knowledge and data was screened and processed in order to provide novel end-user oriented products for temperature and precipitation extremes.

By the end of the 21st century it is very likely that the frequency, duration and intensity of summer warm spells and heat waves in Switzerland will increase significantly. The projected intensification is strongest for the RCP8.5 scenario. Extreme temperatures in Switzerland are expected to rise stronger than mean seasonal temperatures. CH2018 provides a set of threshold based climatic indicators that describe hot conditions (e.g. present-day and future projected numbers of tropical nights and hot days for specific locations and regions). For the city of Zurich, for example, the number of hot days (maximum temperature above 30 degrees Celsius) is expected to increase from 5.4 to 30.1 days per year by the end of the century based on the RCP8.5 scenario. During winter, the number of cold nights and days is likely to decrease significantly (e.g. frost and ice days). Consistent with the aforementioned example, in Zurich the amount of frost days (minimum temperature below zero degrees Celsius) is projected to fall from 74 days to 27.1 days per year. These numbers do not yet reflect the urban heat island effect and, in particular, underestimate the frequency of heat stress conditions in larger agglomerations of Switzerland. Based on *Burgstall et al.* (2021), an extension of the 'NCCS Web Atlas' (see section 6.4.2) due for implementation in the course of 2022 will fill this gap.

Heavy precipitation and droughts

Consistent with theory and assessments at global to European level, heavy to extreme precipitation events are projected to intensify (*Rajczak and Schär*, 2017). Some of this intensification is already evident in observational records of recent decades (*Scherrer et al.*, 2016) and is in line with physical principles that imply an increased moisture absorption capacity of the atmosphere under warming conditions. While the relative intensification of heavy precipitation events is consistent with projected changes in mean precipitation in winter, sign and magnitude of changes in heavy and mean precipitation are not proportionate or even opposite in summer (see Fig. 81), illustrating the complexity of changes in precipitation characteristics.

Fig. 81 > Projected change in seasonal mean (left panel) and seasonal 10-year return levels of daily precipitation (right panel) in Northeastern Switzerland for the RCP8.5 emission scenario and three future scenario reference periods with respect to 1981–2010. Please note the different axis scaling in both panels and that the panels only refer to the RCP8.5 (without mitigation) emission scenario.



CH2018 (2018)

In line with decreasing mean summer precipitation, the potential for longer summer dry spells is likely to increase (*CH2018*, 2018), indicating a growing risk of drought for Switzerland. However, model uncertainties in projected changes of droughts are larger than for changes in temperature and precipitation extremes. Parallel to the general changes in precipitation and a rising zero degree line over Switzerland, a shift from solid (snow) to liquid (rain) precipitation is expected as temperatures rise. This has implications for Swiss hydrology, e.g. with regard to water storage, runoff and seasonal hydropower production (*FOEN*, 2021; *NCCS and FOEN*, 2021; see also section 6.3.1).

Winter storms

Confidence in projections of windiness in Central Europe remain relatively low and no robust projection for changes in wind or extreme wind storms – originating from either Föhn[72] or winter storms – can be made.

6.2 Assessment of risks and opportunities

As stipulated in the Swiss adaptation strategy (*Swiss Confederation*, 2012a) (see section 6.4), Switzerland shall minimise the risks of climate change, take advantage of opportunities arising as a result of climate change and increase its adaptive capacity by implementing targeted measures. In order to do so, Switzerland has assessed its current climate-related risks and opportunities as well as their alteration under future conditions.

Between 2010 and 2017, a comprehensive, nationwide assessment of climate-related risks and opportunities was performed. It consisted of the development of a methodology for assessing risks and opportunities, of eight case studies in different regions of Switzerland[73], and of a synthesis report (*FOEN*, 2017a) prioritising the identified risks and opportunities at the national level. More details about the approach chosen and the method used can be found in *Holthausen et al.* (2013).

The synthesis report (*FOEN*, 2017a; see *FOEN*, 2018a for an extended summary in English) documents risks and opportunities of climate change for the 2060 time horizon and assesses their relative importance from today's perspective. The main result is a list of all risks and opportunities potentially affecting Switzerland and a shorter list of key risks and opportunities that adaptation efforts should focus on. Those key risks and opportunities include (see Fig. 82):

- Impairment of human health, loss of performance at work and increase in cooling energy needs due to greater heat stress;
- Water shortages, danger of forest fire and the exacerbation of water use conflicts due to increasing levels of drought;
- Threat to the economic viability of lower-lying winter sports areas due to rising snowline;
- Increase in personal injury and property damage due to the greater risk of flooding, deceasing slope stability and more frequent wasting;
- Increase in personal injury and property damage due to more frequent or extended mass wasting as a result of the retreat of glaciers and thawing of permafrost due to the increase in heavy precipitation;
- Mostly negative impacts on biodiversity due to the change in habitats, species composition and landscapes;
- Impairment of human and animal health due to the spread of harmful organisms, diseases and alien species;
- Increase in crop yields, lower heating energy demand, and increase in summer tourism revenues in mountain areas due to improvement of site conditions;
- Increase in winter energy production and decrease in snow-related property damage and maintenance costs due to rising snowline.

The assessment confirmed that Switzerland is already today affected by climate change and will be more so in the future. Although climate change related opportunities may occur, there are a lot more risks to be expected and to prepare for.

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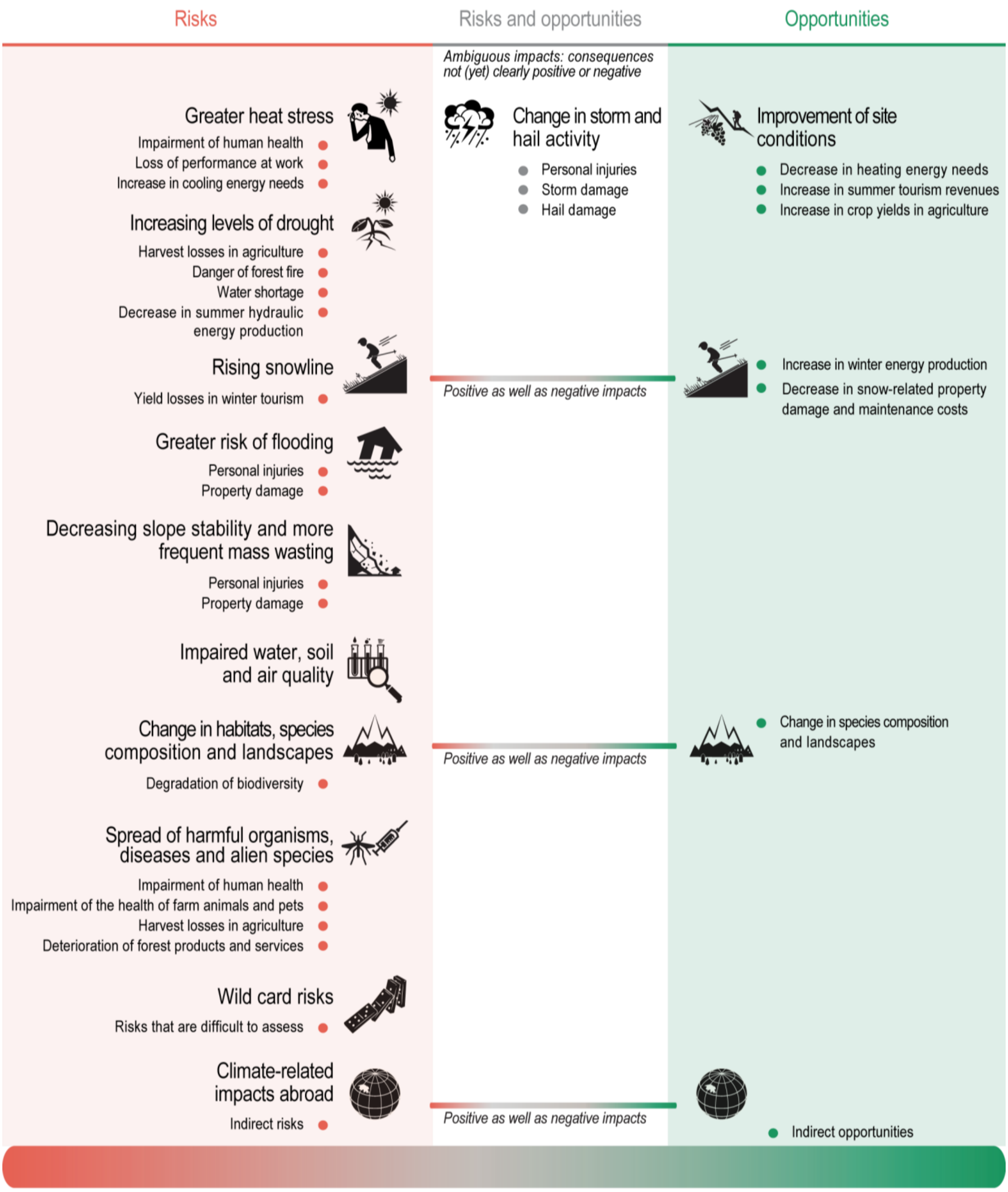
72 https://en.wikipedia.org/wiki/Foehn_wind

73 For references see section 6.3 of Switzerland's seventh national communication.

Fig. 82 organises the twelve challenges of climate change by risks (left column) and opportunities (right column). Hail and storm activity is placed in the column in the middle, as it is unclear yet whether climate change will soften or intensify future impacts. Key risks and opportunities are allocated to the respective challenges. Certain challenges, such as the rising snow line, changes in habitats, species composition and landscape, as well as climate-related impacts abroad, contain risks and opportunities at the same time. This is illustrated by a connecting line between the left-hand side and the right-hand side columns. The umbrella term 'Improvement of site conditions' encompasses various opportunities linked to climate change.

Fig. 82 > Overview of all climate-related challenges and corresponding key risks and opportunities (bullet points) affecting Switzerland.



FOEN (2018a)

The nationwide assessment shows that the state of knowledge today is sufficient for developing and undertaking adequate adaptation measures. Nonetheless, further research is expected to help reducing uncertainties and to improve understanding of the natural processes and affected systems. In order to close knowledge gaps on climate-related impacts abroad on Switzerland and on compound climate risks, two distinct research projects were initiated.

The research project about climate-related impacts abroad (*FOEN*, 2020a) has shown that Switzerland, with its intensive international linkages, could be strongly affected by the consequences of climate change in other countries. Important sectors of the Swiss economy (especially the financial sector and the insurance industry) as well as the import and export of goods and services (in particular food and energy) are concerned. Impacts are also expected in the areas of security, migration and development cooperation.

The research project on compound climate risks focussed on a protective forest in the alpine region (*Niggli et al.*, forthcoming) and on a Swiss urban area (*Vaghefi et al.*, 2022; *Neukom et al.*, in prep.). The findings of the first study show that drought, beetle infestation and windthrow can only impair the protective function of a forest if they happen in combination, while exceptional forest fires can lead to a partial loss of the protective function without other natural hazards occurring. The second study investigates whether persistent heat and drought can bring health, water and energy supply or other important subsystems of a city to their limits. Preliminary results indicate that under the CH2018 climate scenarios, medium to severe impairments may occur in the areas studied and that there is a need for adaptive action. Further insights for dealing with climate-relevant risks and opportunities are expected from the 2022–2025 research programme ‘NCCS-Impacts’ conducted under the umbrella of the National Centre for Climate Services (see section 6.4.2).

The results of the nationwide assessment of climate-related risks and opportunities, together with the new CH2018 climate scenarios, formed the main basis for the development of the second action plan (*Swiss Confederation, 2020a*) implementing the national adaptation strategy (see section 6.4.1). Regarding adaptation to climate change at the sub-national level, the assessment serves as a sound basis for regional strategies and more specific measures.

6.3 Climate change impacts on nature, society and economy

The CH2018 climate scenarios published in 2018 (see section 6.1) provide an up-to-date climatological basis for more reliable and detailed assessments of the expected impacts of climate change on nature, society and the economy in Switzerland. In 2021 they were supplemented by the results of the Hydro-CH2018 project, which offers consistent bases for the hydrological domain (see section 6.3.1 below). In 2020, the current state of knowledge on the already observed impacts of climate change was also comprehensively documented in a data-based manner by *FOEN, MeteoSwiss, NCCS* (2020a/2020b). Taken together, these sources open up far-reaching possibilities for classifying past developments and assessing future ones.

6.3.1 Hydrological cycle and water resources

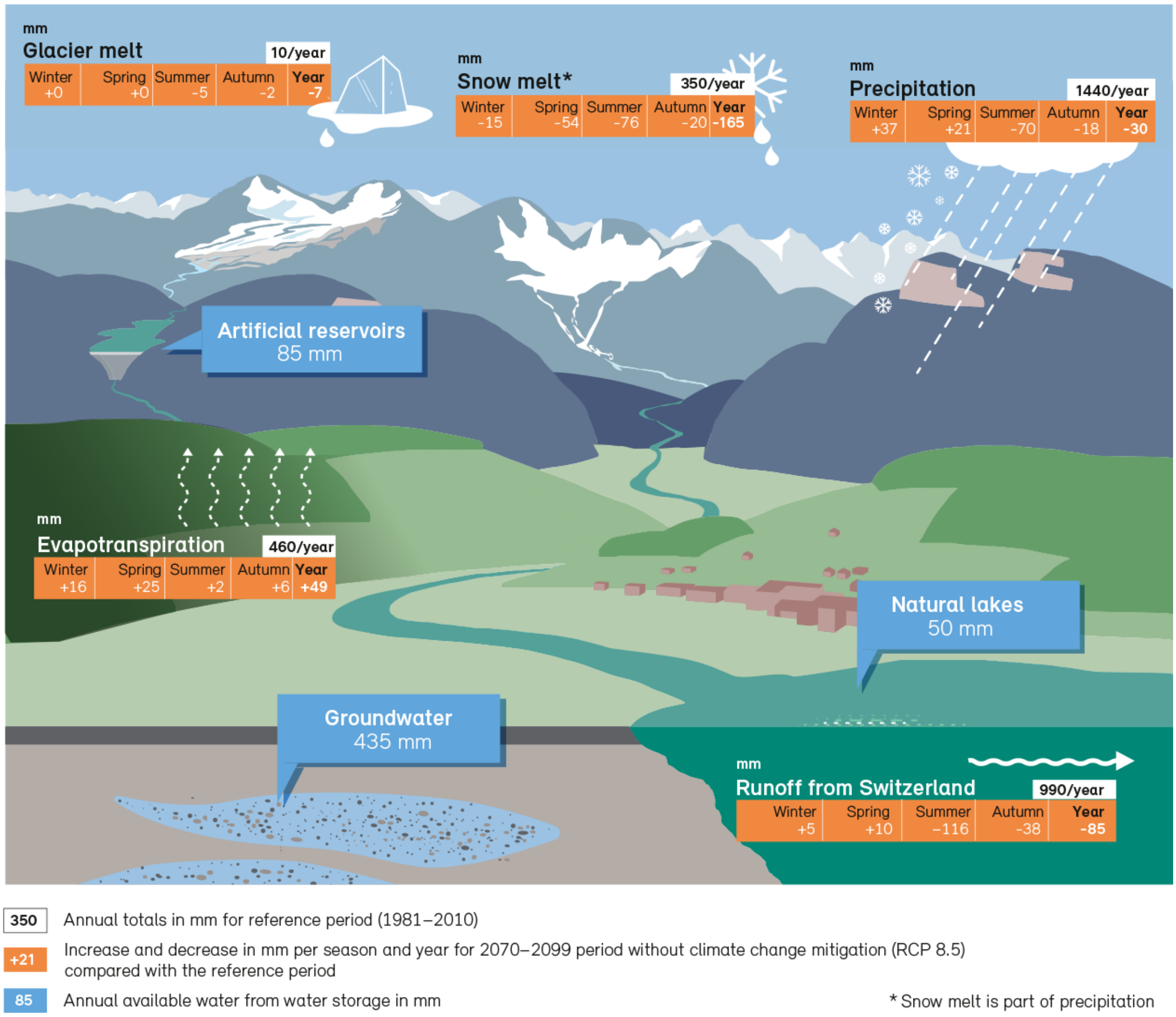
Within the National Centre for Climate Services priority theme ‘Hydrological basis for climate change’, run by the Swiss Federal Office for the Environment, the effects of climate change on the water balance in Switzerland during the 20th and 21st centuries were studied (*NCCS and FOEN*, 2021). The primary aim of this project was to present scenarios with enhanced spatial and temporal resolution for the hydrological cycle and runoff in the different climate regions and altitudes in Switzerland up to 2100, taking into account the most recent climate scenarios (*CH2018*, 2018). On this basis, changes in extreme runoff values (high and low water), water temperatures, water resources and their annual distribution and finally the consequences for water management could be assessed.

From the CH2018 climate scenarios (see section 6.1.1), up to 22 climate model chains were selected. They correspond to an increase in greenhouse gas emissions based on the emission scenarios RCP2.6 (resolute mitigation action in line with the Paris agreement target) and RCP8.5 (no additional climate change mitigation) of the fifth assessment report of the Intergovernmental Panel on Climate Change. Several hydrological models were used to model snow and glacier melt, runoff, groundwater recharge or water temperature.

Water balance

Climate change affects the entire water balance: precipitation and runoff alter, temperatures and evaporation increase, the glaciers melt ever faster, less snow falls in winter, causing a lack of water from snowmelt in the summertime (Fig. 83). Climate change is also altering the filling rate of water reservoirs over the year, and the contribution from snow and glacier melt is generally decreasing. The climate-related storage changes are overlaid in the short term by the prevailing weather conditions and human abstraction.

Fig. 83 > Modelled water balance variables for Switzerland for the reference period 1981–2010 (white background) and expected change in the distant future (2070–2099; orange background boxes) without climate change mitigation (RCP8.5). The sustainably usable annual water storage volume (blue background boxes) is specified for the reference period.



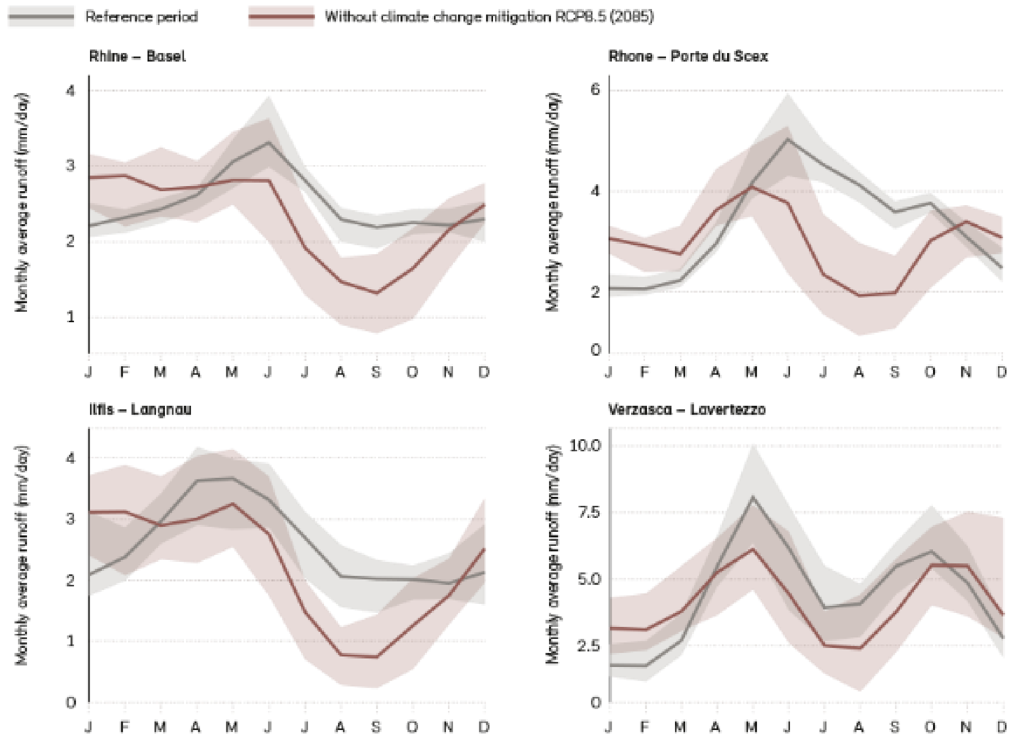
FOEN (2021)

Changes in runoff

Annual runoff amounts have hardly changed in the past 100 years. However, the seasonal runoff distribution has already changed in recent decades. Runoff has decreased in summer and increased in winter. This development will continue in a changing climate.

In addition to the above-mentioned changes, the snowpack will form later in the year and melt earlier. As a result, runoff and groundwater recharge will increase in the winter months, whereas there will be less meltwater in spring and summer. In summer, higher temperatures will cause the glaciers to melt faster, meaning that the watercourses supplied by these glaciers will carry more water. However, this will only be a temporary phenomenon: meltwater from small glaciers is already starting to decrease again, with large glaciers expected to follow suit by 2050 at the latest. The combined effect of these developments is that in the future almost all watercourses will carry more water in winter. Fig. 84 shows exemplary changes in the seasonal runoff of four rivers with different runoff regimes.

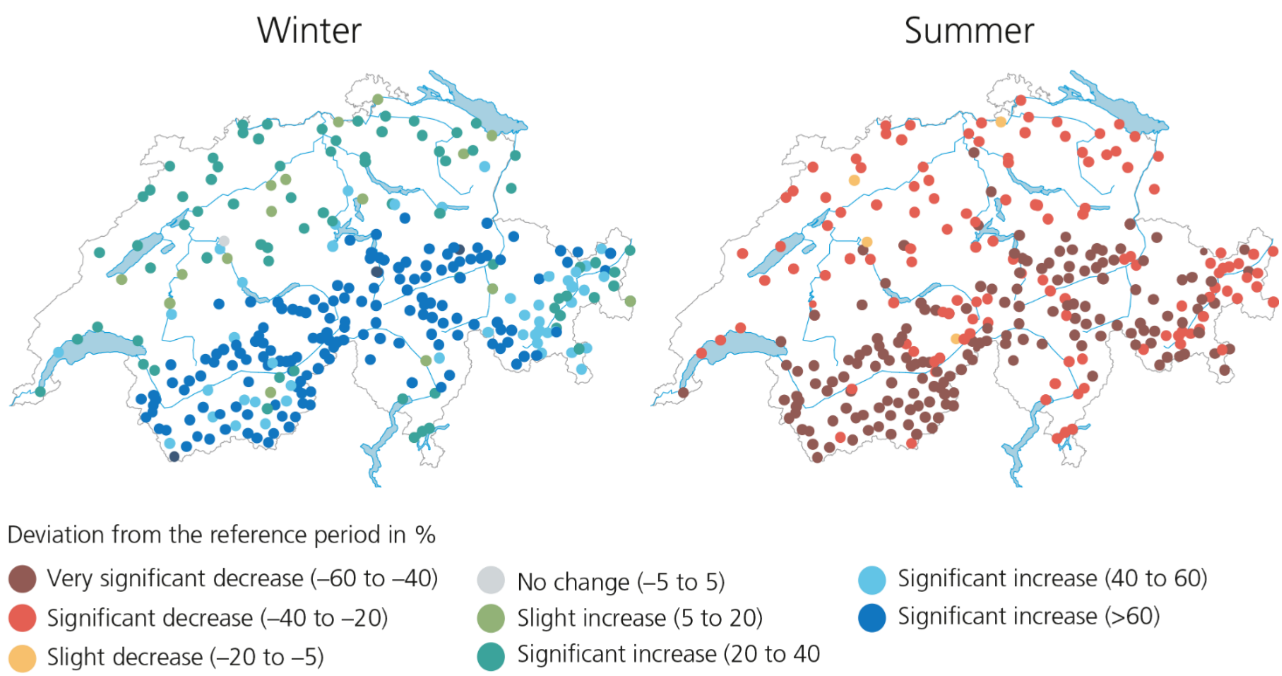
Fig. 84 > Change in average monthly runoff in four typical catchments. The hydrological scenarios (median and range of uncertainty) were calculated for the reference period 1981–2010 (grey) and the scenario without climate change mitigation (RCP8.5) for the end of the 21st century (red). A considerable decrease in runoff in summer and an increase in winter can be expected in every region.



FOEN (2021)

In the absence of climate change mitigation measures, winter runoff will increase by between 10 and 50 per cent by the end of the century, while in summer (and autumn, not depicted below) it will decline by 30 to 50 per cent compared to today (Fig. 85).

Fig. 85 > Expected changes in seasonal runoff for various catchments by the end of the century (2070–2099) compared to the reference period 1981–2010 if no climate change mitigation takes place (RCP8.5).



NCCS and FOEN (2021)

With resolute climate change mitigation the changes can be largely limited (Tab. 39). The change in seasonal inflows will also affect the water levels of the lakes. However, total annual runoff will probably only decline by around 10 per cent. The seasonal dynamics of groundwater levels and spring discharge rates will also change, with high and low phases becoming more pronounced. Water levels and discharge rates will become higher in winter and lower in summer.

Tab. 39 > Possible range (simulation) of changes for the period 2070–2099 in comparison to the reference period 1981–2010. 30-year averages across Switzerland rounded to five per cent.

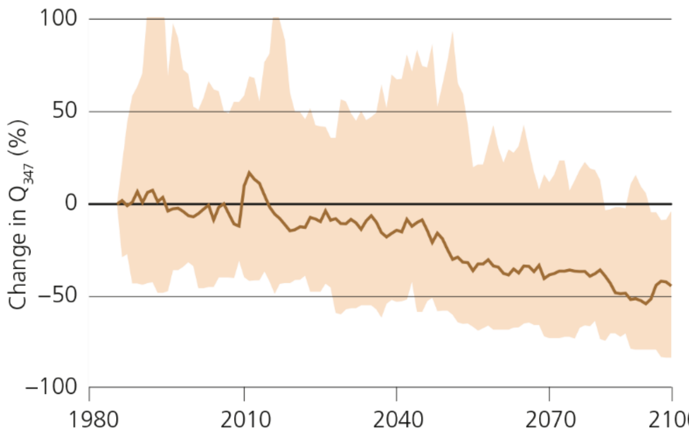
	With resolute climate change mitigation, end of the century (RCP2.6)	Without climate change mitigation, end of the century (RCP8.5)
Runoff from snowmelt	–0 to –30%	–30 to –60%
Annual runoff	–5 to +5%	–0 to –20%
Winter runoff	+0 to +20%	+10 to +50%
Summer runoff	–0 to –20%	–30 to –50%

NCCS and FOEN (2021)

Water shortages in summer

The hydrological scenarios show that, in general, water levels will drop significantly in summer and autumn. This applies to both surface waters and groundwater. All altitudes and regions will be affected by the decline, but especially the Alps and alpine foothills. In the absence of climate change mitigation measures, summer runoff will be on average 30 to 50 per cent lower than today by the end of the century and up to 60 per cent lower than present-day glacier streams. At the same time, dry spells and heat waves will become more frequent in summer and last for longer. Without climate change mitigation, summer low flow at altitudes below 1,500 metres above sea level will decrease by 30 per cent during dry spells by the end of the century. This increases the risk that springs, wetlands, streams and smaller rivers will dry up more frequently during periods of low rainfall. In addition, life in and around waters will be impacted more often by insufficient water depth and high temperatures. Some streams and rivers are likely to dry up completely during dry periods in the summer, especially small and medium size watercourses and those in karst areas such as the Jura mountains. The amount of usable water will diminish in summer due to climate change. If, at the same time, more river water or groundwater is used for irrigating crops or for cooling purposes, this may trigger temporary regional water shortages. Already today, these two types of water use are restricted during dry spells in summer. Until now, high-altitude alpine streams and rivers have usually had low flow in winter, when the water is stored in snowpack. In the future, regions above 2,000 metres above sea level will see runoff increase when water levels are low in winter. At altitudes between 1,500 and 2,000 metres above sea level, climate change may shift the low flow season from winter to summer and autumn.

Fig. 86 > Low flow in the Thur river at Halden (canton of Thurgau). Change of the low flow discharge rate in areas below 1,500 metres above sea level in a scenario without climate change mitigation (RCP8.5). The value Q347 represents the discharge exceeded by the river on 347 days a year on average. The light area represents the simulation range.

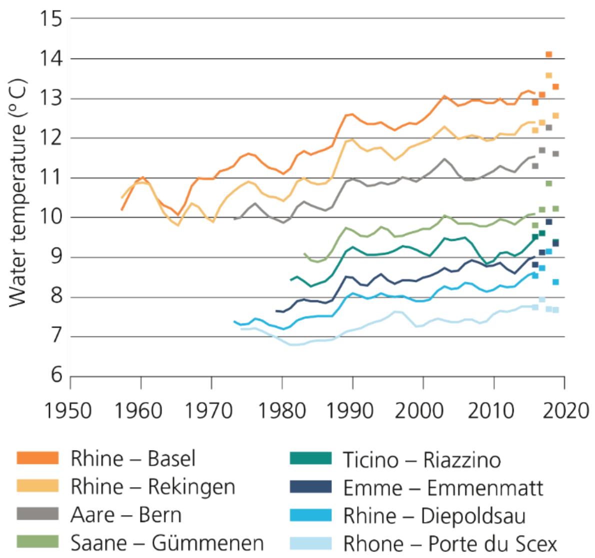


NCCS and FOEN (2021)

Impacts on water temperature in surface waters

Watercourses and lakes have become significantly warmer in recent decades. Mean water temperatures in Swiss rivers and streams have risen by between one and two degrees Celsius since 1970 (Fig. 87). The hot summers of 2003, 2015 and 2018 saw record-breaking temperatures at many stations and in summer 2018 there were new records at 25 out of 83 monitoring stations (*FOEN et al.*, 2019). Temperatures well over 25 degrees Celsius were recorded in the Upper Rhine, Limmat, Thur and the Rhone below Lake Geneva, among others. High water temperatures can cause stress in many aquatic organisms and in extreme cases can be fatal. Outbreaks of certain diseases are also linked to higher water temperatures. Since the 1980s, more and more water bodies have experienced temperatures that are critical for outbreaks such as Proliferative Kidney Disease (PKD) in trout. In addition, these warm periods are lasting longer and longer. The total number of days per year with temperatures above 15 degrees Celsius has increased by an average of 20 days in four decades, with even greater warming observed in some regions (*Michel et al.*, 2019).

Fig. 87 > Water temperature of rivers. Mean annual water temperatures in Swiss watercourses have risen significantly in recent decades. Moving averages (over seven years) for a number of examples are shown as lines; the last four annual averages are shown as dots.



NCCS and FOEN (2021)

Rivers and streams in all parts of Switzerland are expected to continue warming. Without climate change mitigation, summer water temperatures in watercourses could rise by three to nine degrees Celsius by the end of this century (Fig. 88). However, if resolute climate change mitigation measures are implemented, warming in summer is likely to remain below three degrees Celsius compared with present levels. In winter, too, warming will be less pronounced. Climate change will also result in more low flow periods in summer, with streams and river sections drying up more and more frequently. The combined effect of warming and water scarcity is likely to lead to major changes in ecosystems very quickly.

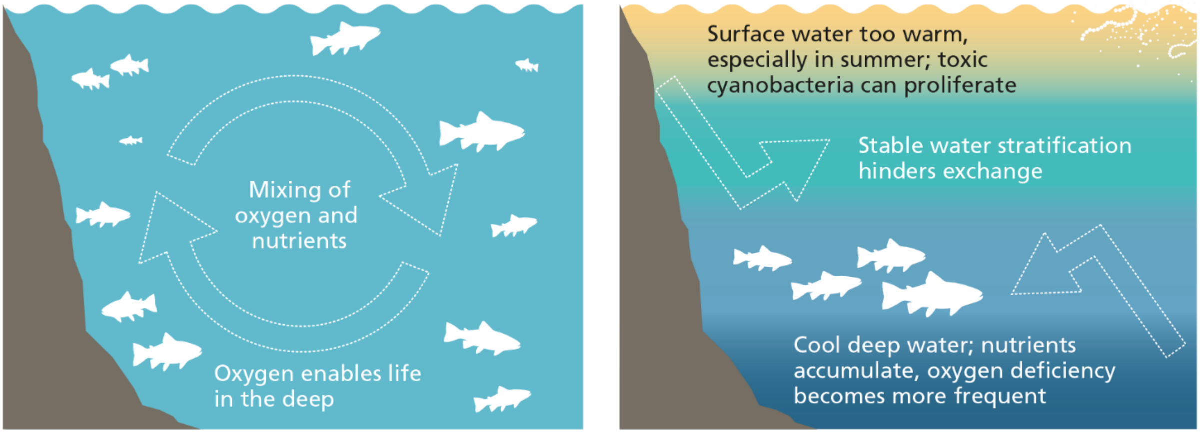
Fig. 88 > Expected development of average temperatures of Swiss watercourses in summer for the RCP2.6 (green) and for the RCP8.5 (orange) scenarios (projected deviations in the periods 2045–2074 and 2070–2099 from the reference period 1981–2010). The light areas indicate the simulation range.

NCCS and FOEN (2021)

The average warming of the surface water layers of Swiss lakes in recent decades is approximately 0.4 degrees Celsius per decade and around two degrees Celsius from 1960–2010 (*Råman Vinnå et al.*, 2021), and changes in mixing have been observed. For example, heat waves like in summer 2003 caused increased and extended summer stratification. Mild winters such as in 2006 and 2007 prevented the seasonal mixing down to the deep water in some lakes. The total freezing of Swiss lakes has become much rarer since the 1960s, particularly on the Central Plateau (*Hendricks Franssen and Scherrer*, 2008).

The future development of the temperature and stratification regime was modelled for 29 lakes (*FOEN*, 2021). The annual average water temperature on the surface of lakes could increase by three to four degrees Celsius by the end of the century due to climate change. This will hinder the exchange between surface and deep water. As a result of the altered water temperatures, the mixing regimes of the lakes are changing in various ways: The stable stratification conditions in summer are lasting longer but winter stratification is occurring less often and the formation and duration of lake ice is decreased. As a result, the distribution of oxygen and nutrients in lakes will alter, which will have consequences for the entire food web (Fig. 89).

Fig. 89 > Effects of global warming on natural processes in lakes. Today, most Swiss lakes mix completely once a year in winter or twice a year in spring and autumn ('turnover'; left-hand panel). Climate change could result in less frequent turnover in some lakes in the future (right-hand panel). For all lakes, the duration of stable stratification will increase in summer and water temperatures will rise.



NCCS and FOEN (2021)

6.3.2 Cryosphere

Snow and zero degree isotherm

The snowpack is a natural water reservoir which is crucially important for the seasonal water balance in Switzerland. According to model calculations, in the 1981–2010 reference period some 40 per cent (22 cubic kilometres) of the total annual runoff came from the snowpack (*FOEN*, 2021). The snowpack builds up in the alpine region over the winter and normally reaches its peak in March. The ensuing snowmelt dominates discharge in many catchments in spring and early summer.

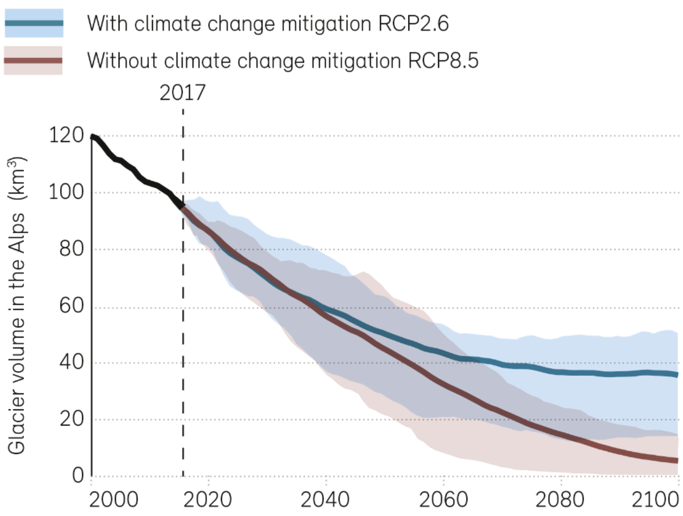
The zero degree isotherm largely determines whether precipitation falls as snow, which is stored, or as rain, which immediately contributes to runoff. It also defines the elevation below which snow and glacier melt can occur. The average zero degree isotherm in winter has risen by 300 to 400 metres since 1961 (*CH2018*, 2018). The percentage of days with snowfall below 500 metres above sea level has fallen by some 40 per cent since 1961. The water quantity stored in snow in spring (snow water equivalent) below 1000 metres above sea level dropped by as much as 75 per cent in the same period (*Marty et al.*, 2017a). As winter temperatures rise, so does the zero degree isotherm – by around 150 metres per degree Celsius temperature increase (*CH2018*, 2018). Consequently, the proportion of snow in total precipitation is further reduced. The addition of new snow to the permanent snowpack starts later in the year and is limited to higher elevations, while snowmelt starts earlier in spring. The maximum snow volume will shift from March to February. While temperature rises, the expected increase in winter precipitation will only have a positive impact on the snowpack at very high elevations. It will not compensate for the general decrease in snow volumes. With resolute climate change mitigation, the hydrological scenarios show a 42 per cent decrease in the average annual amount of water stored in the snowpack by the end of the century. Without climate change mitigation, the decrease is expected to reach 78 per cent.

Glaciers

The retreat and massive loss of volume of glaciers in the Alps is the best visible indicator of the recent increase in atmospheric temperature. The changes of the glaciers in the Swiss Alps are measured every year and compiled by the network GLAMOS (see section 8.3.4). In recent years, evidence of severe impacts on glaciers has accumulated, including collapse structures on the glacier surface, disintegration into pieces, separation of glacier tongues from the main ice body at steep slopes, leaving dead ice in formerly ice-covered areas. At various locations all over the Swiss Alps, glacier lakes have formed or grown as a result of continuing glacier retreat. By the end of the Little Ice Age around 1850, the ice volume in the Swiss Alps is estimated to have been around 130 cubic kilometres. In 2010 it was around 60 cubic kilometres (*Fischer et al.*, 2015) and in 2019 just 53 cubic kilometres (*Langhammer et al.*, 2019). In total, therefore, the glaciers have lost around 60 per cent of their volume since 1850. Glacier volume has decreased by 10 per cent in the last five years alone (2015–2019).[74]

Glacier scenarios show that a large percentage of the ice sheets in the Alps will have disappeared by the end of the century (Fig. 90). With resolute climate change mitigation, some 37 per cent of the 2017 glacier volume will remain in this time horizon. In contrast, without climate change mitigation the remaining volume will be around 5 per cent. Since glaciers often take decades to adapt to a new climate, some of the glacier retreat cannot be prevented in the future because, even for the current climate, the glacier volume is too large to be in equilibrium (*Zekollari et al.*, 2019). 52 per cent of the very small glaciers in Switzerland, which account for more than 80 per cent of the total number of glaciers in mid- to low-latitude mountain ranges, are expected to completely disappear within the next 25 years (*Huss and Fischer*, 2016). Evidence of impacts of vanishing glaciers on the high-mountain landscapes and processes – including effects on the water cycle, sediment processes and slope stability, and thus on tourism, energy and natural hazards – has increased and will continue to increase in the future (*Haeberli et al.*, 2013).

Fig. 90 > Changes in volume (mean value and range of uncertainty) of all alpine glaciers under different climate scenarios. Up to 2017, observation data are used. Without climate change mitigation, 95 per cent of the 2017 glacier volume is expected to melt by 2100.



FOEN (2021), adapted from *Zekollari et al.* (2019)

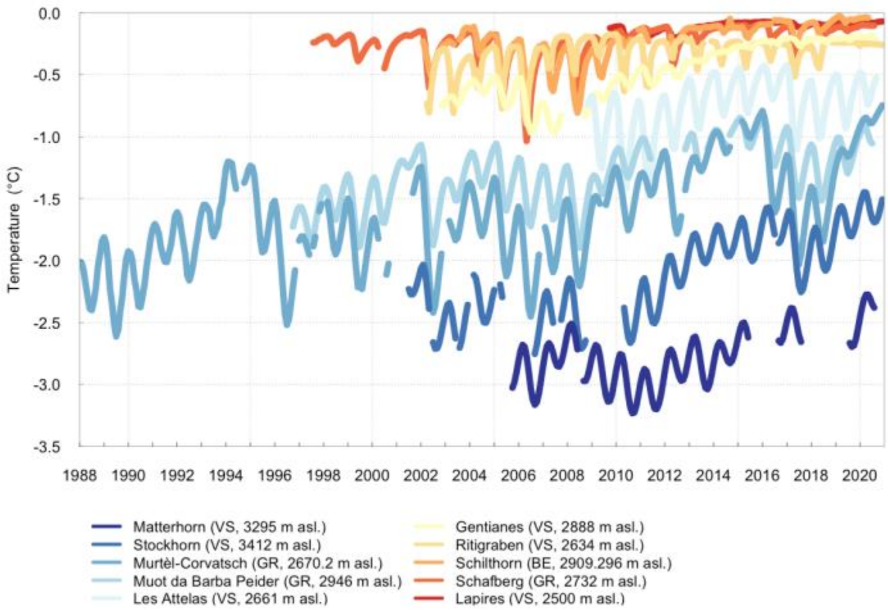
Permafrost

Permafrost is defined as subsoil with a temperature below zero degrees Celsius throughout the year. Permafrost is widespread in the Alps above an altitude of around 2,500 metres. It lies hidden in icy talus slopes and moraines, rock glaciers and steep rock faces with ice-filled pores and clefts. Systematic monitoring of permafrost is performed since the year 2000 by the Swiss Permafrost Monitoring Network (PERMOS). It now also includes other landforms like debris or steep rock slopes (see also section 8.3.4). Observations in the Swiss Alps over the past two decades show a general rise in permafrost temperatures (Fig. 91), a decrease in the ice content and an increase in rock glacier flow rates (*PERMOS*,

74 www.glamos.ch

2021). Analyses of documented rockfall events (*PERMOS*, 2016) with starting zones at high elevations indicate that the frequency of events with volumes of one million cubic kilometres or more has increased since the beginning of the 21st century, as compared to the 20th century (*Huggel et al.*, 2012; see also section 6.3.3). A further temperature increase in line with the CH2018 scenarios will cause warming or complete thawing of cleft ice in rock faces. Temperatures in ice rich debris slopes and rock glaciers will rise as well, increasing the depth of the active layer. The warming of the outer 50 metres of frozen rock faces can be attributed to the temperature rise in the 20th century. In the future, it will penetrate into greater depths and increase the thermal imbalance. For summits and ridges, such effects will be particularly pronounced as the warming may penetrate from different sides (*Noetzli and Gruber*, 2009).

Fig. 91 > Permafrost temperatures measured in selected boreholes at a depth of 10 metres (monthly means).



PERMOS (2021)

6.3.3 Natural hazards

In many parts of Switzerland, natural hazards pose a major threat to human life, infrastructure and material assets. The increase in the value of infrastructure, settlement expansion in hazard prone areas and the impact of climate change increase the potentially devastating effects of already existing hazards. The main climate change factors influencing natural hazards are an increase in hydro-meteorological extreme events (frequency and intensity of heavy rainfall) and the effects of higher temperatures. The currently available knowledge on the effects of climate change on natural hazard processes in Switzerland is compiled in a report mandated by the Swiss Federal Office for the Environment (*geo7*, 2020).

Floods

Floods in Switzerland are predominantly caused by extreme precipitation, sometimes in connection with snowmelt and/or high lake levels. In the last 500 years, flood-rich and flood-poor periods have alternated. Since the 1970s, Switzerland is in a period of high flood frequency. However, no direct relationship was found between flood frequency and mean air temperature (*Schmocker-Fackel and Naef*, 2010). The comparison of flood patterns in different European countries suggests that changes in the large-scale atmospheric circulation are responsible for variations in flood frequency. Clear statements about future changes in atmospheric circulation and thus about changes in extreme and very rare precipitation events in the Alpine region are not yet possible (*CH2018*, 2018). In recent times, an increased number of floods has also been observed in many other parts of Europe. The last 30 years have seen the most floods in Europe for 500 years. This is all the more remarkable because flood phases in Europe in the past tended to occur in cool climatic periods, while the last 30 years have been warmer than average. The current flood phase is unique in climatic terms (*Blöschl et al.*, 2020).

As climate change progresses, the precipitation potential increases. Global climate models also show that in the future, without climate change mitigation, more atmospheric humidity will be transported towards the Alps. Thus, the potential for more intensive precipitation and floods will increase (*Brönnimann et al.*, 2018).

A high zero degree line during the event is necessary for the occurrence of large floods in the alpine catchments and the major Swiss rivers. In most Swiss catchments, floods therefore now mainly occur in summer and autumn. The projected temperature increase will lead to a rise in the zero degree line, which in turn will extend the flood season and tend to increase the volume and extent of floods in the alpine region (*FOEN*, 2021). The hydrological scenarios do not yet provide any reliable information on how the frequency of floods and flood runoff will change. Nevertheless, various climate-related processes indicate that floods and surface runoff will increase in the course of climate change (*FOEN*, 2021).

Rock falls, debris flow and landslides

Changes in temperature and precipitation are likely to have a range of secondary effects on the occurrence of natural hazards, in particular in mountain environments. However, while there is theoretical evidence for increased mass movement activity as a result of projected climate change, the effects are currently difficult to demonstrate in observational data (*Stoffel and Huggel*, 2012).

Processes related to warming of permafrost (*Hasler*, 2011) may increase the frequency and magnitude of rock fall. In combination with the increasing availability of sediments, the deepening of active layers, the downwasting of glaciers and the possibility of flood waves from mountain lakes due to rock falls, new and complex hazardous situations may arise in regions where they have not been observed before. A prominent example is the Moosfluh landslide, which was triggered by the retreat of the Aletsch glacier (canton of Valais). Around 150 million cubic metres of rock were mobilised. Satellite radar data allowed early detection of terrain movements. Affected hiking trails had to be closed and new ones were built.[75]

One of the most obvious consequences of climate change at higher elevations is the glacier retreat and related formation of ice-marginal lakes, ice avalanches and gravitational processes originating from the debuttressing of previously glaciated walls and hillslopes (*Linsbauer et al.*, 2015; *NELAK*, 2013; *Schaub*, 2015). Within the next few decades, glacier downwasting is likely to lead to more rock slope failures. Important effects on slope stability are also related to the warming and thawing of permafrost (see section 6.3.2). The probability of rock instability and the incidence of large (more than 1 million cubic metres) rock falls is likely to increase in a warming climate (*Huggel*, 2009).

Changes in sediment supply and land use are other key factors in the frequency and magnitude of mass movements. Recent observations in the Swiss Alps indicate that sediment supply can indeed change significantly as a result of permafrost degradation of rock and boulder slopes or due to mass movements associated with other processes (*Huggel et al.*, 2012). As such, warming has been reported to indirectly affect the magnitude and frequency of debris flows, as greater amounts of sediment become available (*Lugon and Stoffel*, 2010). The volume of debris flows in many parts of the Swiss Alps has risen by one order of magnitude since the early 20th century (*Stoffel*, 2010) and is likely to further increase with ongoing permafrost degradation. The actual triggering conditions of debris flows have been shown to occur less frequently today as compared to most of the 20th century (*Schneuwly-Bollschweiler and Stoffel*, 2012) and are not expected to increase in the future (*Stoffel et al.*, 2014). Despite uncertainties, recent developments at high-elevation sites clearly show that events beyond historical experience are likely to occur as climate change continues.

At lower elevations, landslides could occur more frequently in winter and spring as a result of warmer temperatures and larger precipitation sums (*Lopez Saez et al.*, 2013). The occurrence of debris flows and shallow landslides in the Prealps, Plateau and Jura mountains depends on the incidence of intense thunderstorms or long-lasting, persistent rainfall. Such conditions are likely to become more frequent, in particular in winter and spring. As a consequence, in the decades to come a shift might be expected not only in the frequency but also in the seasonality of debris flows and shallow landslides.

6.3.4 Damage due to extreme events

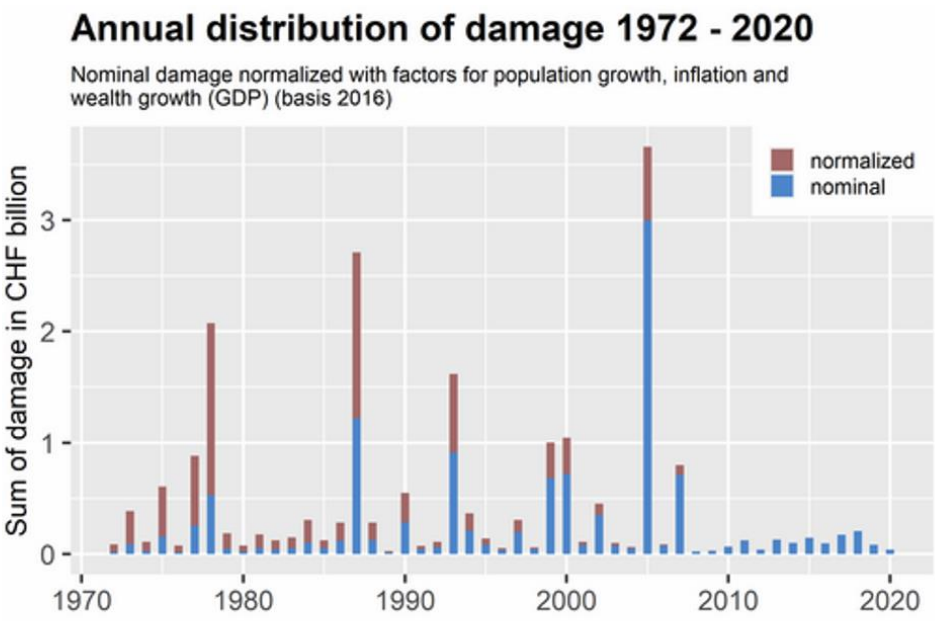
In Switzerland, floods and debris flows caused damage amounting to 13.4 billion Swiss francs between 1972 and 2020. A further billion Swiss francs in damage was caused by landslides and other fall processes, with total damage corresponding to an average loss of around 295 million Swiss francs per year. A few individual events were mainly responsible for the extent of the damage. The floods of August 2005 caused damage of around 3 billion Swiss francs. Half of the total damage since 1972 can be attributed to five major events.[76] According to the available data, about 1.8 million people

[75] https://www.bafu.admin.ch/bafu/fr/home/themes/dangers-naturels/dossiers/glissement-de-terrain-Moosfluh.html

[76] https://www.wsl.ch/en/natural-hazards/understanding-and-forecasting-floods/flood-and-landslide-damage-database.html

(about 20 per cent of the Swiss population) live in flood-prone areas. At the same time, about 1.7 million (about 30 per cent) of the jobs and about 25 per cent of the material assets are exposed to potential flooding. Existing measures protect these areas from the more frequent events. Without protective infrastructures, the damage would be significantly higher.

Fig. 92 > Total annual losses in billion Swiss francs (nominal and normalised) arising from floods, debris flows, landslides and rock falls since 1972.



Swiss Federal Institute for Forest, Snow and Landscape Research

6.3.5 Water management

The results of the Hydro-CH2018 project (*FOEN*, 2021; *NCCS and FOEN*, 2021) show that climate change will intensify the pressure on management of the Swiss water resources. All three divisions of water management – water use, water protection and flood protection – are significantly affected by climate change. Measures already implemented contribute to preparing the water sector for the future climate. Further adaptations to climate change must follow.

Water use

Water is among the most vital resources for life and the economy. It is used as drinking water, for irrigation, for energy production and in industry. Around 80 per cent of Switzerland’s drinking water is obtained from groundwater resources and 20 per cent from lakes. Switzerland’s groundwater resources are under pressure due to settlement development and diffuse substance inputs, particularly on the Central Plateau and in the main alpine valleys. More frequent and prolonged droughts pose additional challenges for the various water-consuming sectors, as they will compete for limited resources during such periods.

Due to water-saving measures in households and in the industry, and despite population growth, water consumption from public water suppliers has been slightly declining since the 1990s. In the near future, water demand from households and the industry is expected to remain at the current level (*Freiburghaus*, 2015). Serious water shortages in public water supply are not expected over the next decade. However, dry and hot spells can temporarily lead to high peak demand and thus to local problems for public water supplies. Where necessary, peak demand must be reduced during dry periods, e.g. by temporarily restricting secondary water uses such as watering green areas, filling swimming pools, or washing cars.

Climate change also affects Switzerland’s agricultural production. In the past decade, irrigated areas for agricultural production have significantly increased. During the past dry spells in 2015 and 2018, public drinking water networks were also used for agricultural irrigation. This led to problems for suppliers, as their infrastructure is not designed for the peak demand of the agriculture sector. To avoid such problems, water for agriculture must be provided by separate water distribution infrastructure, which is independent from public drinking water networks (see section 6.6.3). With an increasing demand for service water for agricultural irrigation, the Central Plateau including the Jura mountains as well as the inner alpine dry valleys of the Valais and Engadin will potentially be most affected by water deficits and related water conflicts (*Brunner et al.*, 2019a/2019b). The need for irrigation must be reduced through climate-smart agricultural production, taking into account the water availability in the region.

In Switzerland, more than half of the electricity is generated by hydropower (*FOEN*, 2021; see also section 6.3.9). In the second half of the century, climate change will lead to a seasonal shift of runoff to winter and therefore affect electricity production, especially for run-of-river power plants. By the end of the century, the annual production from run-of-river power plants is expected to decrease slightly; winter production will increase by about 8 per cent (SCCER-SoE, 2019). In order to strengthen security of electricity supply, especially in winter, Switzerland will increase its renewable electricity production, including hydropower. Existing hydropower plants will be expanded and new plants will be constructed in the forthcoming decades.

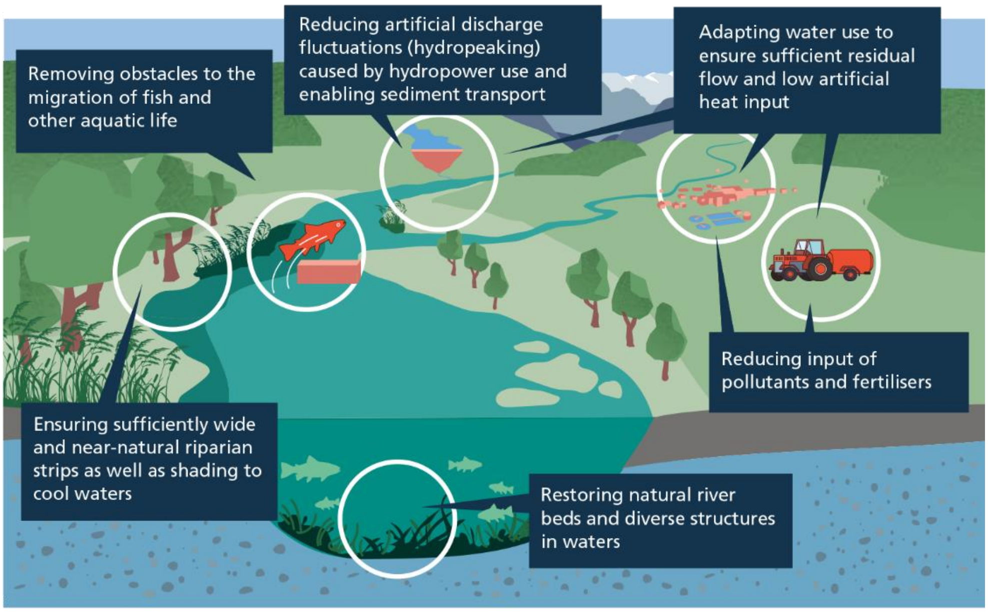
Importantly, surface waters as well as groundwater resources are increasingly used for cooling and heating purposes in many regions. High river water temperatures in summer negatively affect aquatic organisms. Especially during heat waves, cooling capacities for industrial purposes are limited due to water protection regulations. During the hot summers 2015 and 2018, for example, the nuclear power plants Mühleberg and Beznau had to temporarily reduce their energy output to limit the additional heating of river water. With Switzerland's decision to phase out nuclear energy, these heat inputs into the rivers will cease in the longer term and release pressure from aquatic ecosystems.

Water protection

Ecologically intact water bodies will be better able to cope with climate change and meet the diverse demands of society. It is therefore important to protect water resources from overexploitation and from contamination by pollutants and fertilisers. In addition, rivers, lakes and groundwater must be kept in, or restored to, a state that is as natural as possible.

Rising water temperatures are further increasing the pressure on natural resources, such as biotopes, thus endangering indispensable ecosystem services (*SCNAT*, 2021). The existence of cold-loving fish species such as trout and grayling is threatened in large parts of the Central Plateau. Over a fifth of endangered or extinct species in Switzerland are linked to water bodies, and a further fifth to riparian areas and wetlands (*FOEN*, 2017b).

Fig. 93 > Measures to strengthen surface water bodies. Near-natural watercourses are better able to cope with the challenges of climate change than those heavily modified by humans. The implementation of water protection measures, promoting near-natural watercourses, will become even more important.



NCCS and FOEN (2021)

Flood Protection

More frequent and intense heavy precipitation as well as the climate-related increase in sediment transport intensify the risks from flood and surface runoff. As the population grows and the landscape is used more intensively, more and more assets and property will be at risk from natural hazards. Integrated risk management has proven an effective way of dealing with risks from natural hazards in Switzerland. The federal government, cantons and municipalities have drawn conclusions from past flood events and introduced additional flood protection measures that have proven effective in recent years (see Fig. 92 and section 6.6.3).

6.3.6 Biodiversity

Despite continued and enhanced efforts for protection and recovery, the biodiversity in Switzerland still is not in a satisfactory state. Since 1900, biodiversity has been steadily declining. More than one third of all analysed species are threatened, the quality and area of valuable habitats has declined, and regional characteristics are disappearing (*FOEN*, 2019). Climate change is aggravating ongoing stressors for habitats, species and within species diversity (i.e. genetic diversity) also in Switzerland. In turn, stopping and reversing habitat loss and environmental degradation are recognised as the most cost-effective measures for slowing biodiversity decline and greenhouse gas emissions (*IPBES*, 2018).

Diversity of habitats

Switzerland is rich in diverse habitats, but almost half of them are threatened (*Delarze et al.*, 2016). Out of the 167 habitat types evaluated, 59 per cent are of national priority. The list of National Priority Habitats includes 98 habitat types from 8 different ecosystem types, of which 39 per cent have a high to very high priority, 81 per cent are on the national Red List, and for 28 per cent Switzerland has a medium to high responsibility at the international level. Ecosystems with an above-average proportion of priority habitat types include wetlands (including raised bogs), water bodies (of which mainly watercourses) as well as extensively used habitats on ruderal, agricultural, and forest land (*FOEN*, 2019). By placing biotopes of national importance (national mires, alluvial zones, amphibian spawning sites, dry meadows and pastures) under protection, area losses in these particularly valuable habitats have been slowed. However, quality losses are ongoing as a result of nitrogen inputs, changes in the water regime, abandonment, improper management and other pressures. Current evaluations show that raised bogs have become significantly dryer, and thus lose their carbon storage function and become sources of CO_2 emissions (*Bergamini et al*, 2019; *Heer*, 2021). The woody cover has also increased on dry meadows and pastures as well as on fens, which decreases their biological quality (*Bergamini et al*, 2019).

The Alps are home to a wide range of habitats and species. Biodiversity in the Alps is also particularly affected by climate change due to the wide altitudinal zonation and the related significance of temperature for the habitat. Climatic changes displace the ranges of species and modifies habitats. Climate change also indirectly affects biodiversity in the Alps by enabling more intensive agriculture at higher altitudes and altering patterns of use for leisure and tourism (four season recreation). Also, more renewable energy infrastructure such as hydropower dams are built in areas previously devoid of constructions (*FOEN*, 2017b).

Changes in climate indicator values (mean temperature and humidity) are particularly pronounced in settlement areas. Today, the vegetation in this habitat increasingly consists of species that are heat and drought indicators. Settlement areas are heating up faster than forests and agricultural areas (*Heer*, 2021).

Diversity of species

A clear trend toward warmer temperatures can be seen when looking at the long-term changes in water temperatures in Swiss waterbodies (*FOEN*, 2021). In standing waters, for example, 11 per cent of water beetle species and 33 per cent of dragonflies are threatened with extinction as a result of temperature increase, while 63 per cent of dragonflies benefit from temperature warming (*FOEN*, 2021). Climate change requires some species to shift their range to cooler water bodies that tend to be higher up. However, the streams are not always ecologically connected, especially when infrastructure blocks species movements. In a changing climate, good connectivity is particularly important for the survival of many species (*Altermatt et al.*, 2013). As cold-blooded animals, fish cannot regulate body temperature, but are directly dependent on water temperature. Typically, cold-water species cannot tolerate temperatures above 25 degrees Celsius (*Lessard and Hayes*, 2003). The brown trout is an example of how climate change affects fish that depend on cool and oxygen-rich waters. Their population has declined sharply in Switzerland in recent years (*FOEN*, 2021). Because physical barriers restrict longitudinal migration in mountain regions, an upward habitat shift in effect implies habitat reduction, suggesting the likelihood of an overall population decrease. Extensive brown trout catch data documenting an altitude-dependent decline indicate that such a climate-related population decrease has in fact already occurred (*Hari et al.*, 2005).

Climate change also strongly alters phenology, i.e. the temporal occurrence of certain development processes over the course of the year (*Altermatt*, 2010; *Vitasse et al.*, 2021). For example, an earlier hatching of aquatic insects and an earlier spring bloom of phyto- and zooplankton are already observed today as a result of the temperature increase (*Everall et al.*, 2015). This can disrupt interactions between different species within an ecosystem. If higher animals in the food chain – such as fish, birds or mammals – are not able to adapt their development processes to the new food supply in time, the necessary food will be missing, e.g. for the rearing and development of offspring. Such effects of climate change across several levels of the food pyramid are complex and operate on longer-term time scales (*Van Asch et al*., 2013). In alpine watercourses, the overall diversity of habitat conditions is decreasing as a result of the increase in water temperature and the decrease in meltwater (*FOEN*, 2021).

In general, a tendency towards earlier phenological spring phases is observed in various plant species throughout Switzerland. Climate change also alters the distribution of plant species. When periods of water shortage become more frequent, this favours drought-resistant species and allows them to spread at the expense of less tolerant species. Some species may colonise higher elevation sites to avoid heat stress. Such developments have the effect of changing the species composition. A comparison of early biodiversity monitoring surveys (2003–2007) with the most recent ones (2013–2018) shows that the number of both native and non-native plants is increasing at the milder sites of the Central Plateau and Pre-Alps. However, the increase is greater for non-native species. Higher temperatures favour the spread of alien plants in particular (*Scherrer et al.*, 2022).

The spread of alien plants in meadows and pastures of the mountain area is a relatively new phenomenon (*FOEN, MeteoSwiss, NCCS*, 2020a/2020b). Data are available on the composition of the alpine flora, covering a period of more than 100 years. Over this observation period, the number of plant species on mountain peaks has increased significantly (*Rixen and Wipf*, 2017). Under the pressure of climate change, which is particularly pronounced in the alpine region, mountain plants of lower altitudes are expanding their range to higher altitudes, causing an increase in the number of species there. This development has accelerated in recent years (*FOEN, MeteoSwiss, NCCS*, 2020a/2020b).

The effects of climate change on birds and other animal groups are complex. On the one hand, direct physiological mechanisms are at work; on the other hand, there are indirect effects as a result of altered habitats, shifted competitive relationships, or phenological shifts (*SCNAT*, 2021a). Interactions between species in an ecosystem are disrupted or interrupted, for example when the activity of pollinators no longer coincides with the flowering season or when predators miss their prey in terms of time or space (*FOEN*, 2021; *SCNAT*, 2021). The effects are both species-specific and age-dependent. For example, a warmer and drier summer can have a positive or negative effect. The chicks of nest fledglings such as the rock ptarmigan survive better, but the adult rock ptarmigan become heat stressed (*SCNAT*, 2021a). Climate change is already causing substantial changes in native breeding birds. A comparison of the altitudinal distribution of the 71 most common Swiss bird species between 1995 and 2015 shows that around two thirds of the species have significantly expanded their range upwards within 20 years. The centre of the average altitudinal occurrence increased by 24 metres. Alpine species in particular show strong changes: Those 10 species that had the highest mean distribution in the first study period increased by an average of 51 metres in altitude towards the summit (*SCNAT*, 2021a).

As with breeding birds and the Swiss Bird Index (SBI)[77], the trend for butterfly species studied has been diverging over the last 30 years. It is mainly the warmth-loving species that have increased. The cold-loving species of the high mountains, such as the glacier butterfly, on the other hand, are decreasing. As a result of climate warming, species that prefer higher temperatures tend to expand their distribution, while species that are adapted to low temperatures decline. As the area, and thus also the available habitat, in the mountains decreases towards the top, the populations of upward-migrating species inevitably decrease (*SCNAT*, 2021a). For specialised and cold-loving species, survival is becoming increasingly difficult as climate change progresses. The winners include generalists and warmth-loving species.

Overall, biodiversity is coming under additional pressure as climate change progresses (*FOEN*, 2021). A comprehensive review of more than 2000 species of animals, plants and fungi shows that most species in the European alps are not able

[77] *www.vogelwarte.ch/en/projects/population-trends/sbi-state/*

to overcome the 60 to 70 metres of altitude per decade that would be necessary for them to continue living under their normal climatic conditions. Furthermore, earlier snowmelt and increasingly warmer spring days lead to asynchronies in spring activities, which threatens species interactions and long-term ecosystem functioning (*Vitasse et al.*, 2021).

Diversity of genes

Climate change means that many species have to adapt to changing climatic conditions or migrate to new areas where they find a climate that suits them (*Holderegger and Segelbacher*, 2016). Only those individuals can cope with the new environmental conditions that have the appropriate genetic make-up with matching alleles in sufficient frequency and when they can be inherited. But even if a species persists in climate change, it will have much lower genetic diversity. For example, while 67 per cent of the macroinvertebrate species studied will survive, only 16–35 per cent of the genetic variation within species will survive (*FOEN*, 2021). High genetic diversity thus is one of the basic prerequisites to adapt to new environmental conditions (*Guntern*, 2016; *Holderegger and Segelbacher*, 2016). If a population has greater genetic diversity, it has a higher chance that one of its alleles will be well adapted to future changes in environmental conditions. In addition, populations with low genetic diversity are more susceptible to the consequences of inbreeding and genetic drift in the longer term than large populations are (*Holderegger and Segelbacher*, 2016).

Fig. 94 > Swiss stone pine forest at Laegh da Cavloc.

Photo: M. Bolliger

The Swiss stone pine is the ‘queen’ of the upper timberline – gnarled trees up to 500 years old with fragrant wood (Fig. 94). If climate continues to get warmer and drier, the Swiss stone pine is in danger of being displaced by fast-growing competitors from lower altitudes – spruces, firs, pines and deciduous trees. Checks by researchers indicate that young trees at high altitude sites have the genetic equipment for both the current and the future climate. In contrast, the majority of young trees at low altitudes had the ‘wrong’ gene variants, which would no longer be advantageous in a warmer and drier climate. Combined with other challenges – such as damage from game or skiers and disease-causing fungi that benefit from the warmer climate – the Swiss stone pine could become locally extinct in some places. This makes exchange between populations more difficult and can lead to inbreeding. Because the Swiss stone pine, together with the larch, characterises the typical forest ecosystem at the upper tree line, an entire biocoenosis would become unbalanced. In addition to the pine jay, this would affect a large number of fungi, lichens and insects that are native to these forests (*Dauphin et al.*, 2020; *WSL*, 2021).

Projections for biodiversity

On the basis of existing observations and model results, it is possible to make some projections concerning the future climate change impacts on biodiversity in Switzerland. The tree line will shift upwards by about 400 metres in altitude with a global temperature increase of 2.2 degrees Celsius on average (*Körner*, 2021). Many species will not be able to keep pace with the rapidly advancing climate change. Species with low genetic variation, low reproduction rates, poor dispersal abilities and narrow ecological niches are the most vulnerable (*SCNAT*, 2021). Moreover, disruptions in species interactions caused by individual migration rates or phenological shifts are likely to have consequences for biodiversity (*SCNAT*, 2021a). The vulnerable species are displaced by more adaptable, increasingly common species, leading to a homogenisation of ecosystems. Under the current path of global warming averaging 3.2 degrees Celsius by 2100, about 49 per cent of insect species, 44 per cent of plant species and 26 per cent of vertebrate species would lose more than half of their range (*Warren et al.*, 2018). Native species are more at risk, while non-native invasive species benefit. Peatlands, forests, dry meadows, springs, water bodies and rocks have a high proportion of species with narrow ecological niches and are therefore considered climate-sensitive (*SCNAT*, 2021).

Biodiversity in Switzerland depends on protected areas, priority areas, ecological networking and sustainable land use. The federal government and cantons have already taken several specific measures to conserve and promote biodiversity. Examples include the inventories of biotopes of national importance, the financing of forest reserves and biodiversity priority areas in agricultural areas and participation in the renaturation of bodies of water. Although the area designated for biodiversity has increased in the last 25 years, it is still not large enough to stop the population losses of endangered species and the decline of rare habitats. The Swiss Federal Council recognised the need for action and financing and adopted the Swiss Biodiversity Strategy (*Swiss Confederation*, 2012) in 2012. The development of an ecological infrastructure composed of all protected and connected areas is one of the main measures of the related action plan (*Swiss Federal Council*, 2017a). For that purpose, protected areas should be enhanced and remediated, area loss and fragmentation trends inverted, and habitat functionality increased.

6.3.7 Agriculture

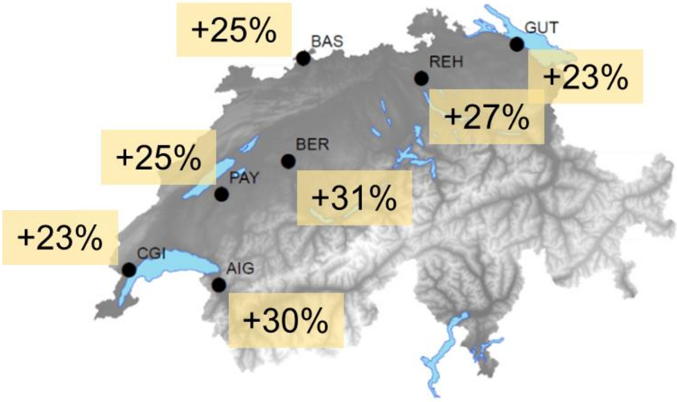
Plant production

Rising temperatures are expected to accelerate plant development. In wheat, advancement rates of the heading date could range between 0.2 days per decade, under moderate warming, and 2.6 days per decade, under emission scenarios that do not foresee an effective abatement of greenhouse gas emissions (*Rogger et al.*, 2021). By the mid of the century, developmental stage sensitive to heat stress could thus occur five to ten days earlier in the season, which would allow current wheat varieties to partially escape from future heat periods.

In maize, faster accumulation of growing degree-days would allow the crop to be harvested earlier than under current conditions (10 to 20 days by 2060, depending on emission scenario and location) (*Buzzi et. al.*, 2021). Higher temperatures would also provide opportunities for cultivating maize in areas today still unfavourable and switching in places from early-maturing varieties to mid- to late-maturing varieties. Under rainfed cultivation, maize grain yields are projected to increase until about 2060 but to decline thereafter if climate protection measures are not implemented (*Holzkämper*, 2020). The beneficial effects of elevated atmospheric CO_2 concentrations could partially offset the negative impacts of heat and water stress, in wheat more than in maize (*Webber et al.*, 2018).

Because of the projected changes in the hydrological cycle with, in particular, a decline in summer precipitation amounts and the more frequent occurrence of drought conditions (*FOEN*, 2021), irrigation water demand for crop production is anticipated to increase considerably. In a case study for western Switzerland, irrigation requirements for maize cultivation were simulated to increase by as much as to 40 per cent until the end of the century, with large variations depending on chosen varieties and management (*Holzkämper*, 2020). More recently, the potential increase in irrigation water requirements was assessed for a range of crops (*Eisenring et al.*, 2021). In potato cultivation, for instance, the expected increase in water requirements until 2060 was estimated in between 10 and 40 per cent, depending on emission scenario and location (Fig. 95).

Fig. 95 > Relative increase between 1981–2010 and 2045–2074 in irrigation water demand for potato cultivation. Results for an emission scenario without climate change mitigation (RCP8.5).



Eisenring et al. (2021)

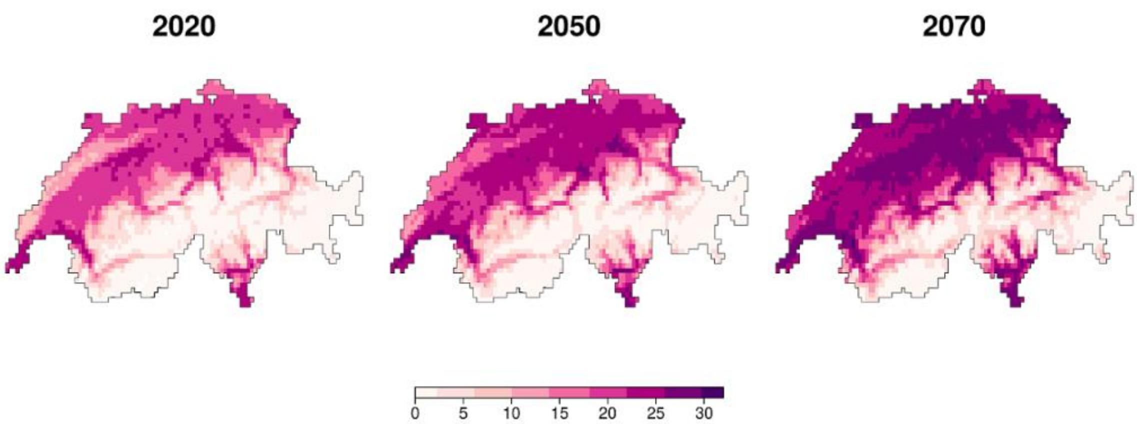
Climate change will have significant impacts on grassland ecosystem services (*Lavorel*, 2019). Fodder production would profit from a projected lengthening of the growing season (*NCCS*, 2018), but extreme temperatures in spring and more prolonged and intense droughts in summer are likely to negatively affect grassland productivity and increase yield instability. As production stability and grassland multi-functionality are related to plant species richness (*Haughey et al.*, 2018; *Suter et al.*, 2021), larger impacts of drought are likely to occur in species-poor grasslands than in botanically diverse pastures and meadows. In numerical experiments, management was found to significantly control grassland responses to drought, with vegetation dynamics less affected by increasing aridity under extensive management (*Moulin and Calanca*, 2021).

More frequent and intense heavy precipitation events could aggravate problems in plant production associated with soil erosion (*Borrelli et al.*, 2020). An earlier high-resolution assessment for current climatic conditions indicated that about 12 per cent of the current agricultural area is exposed to moderate potential erosion risk, while 43 per cent is exposed to high potential erosion risk (*Prasuhn et al.*, 2013).

Insect pests

It is likely that plant production will face higher pest pressure under future climatic conditions. An increase in the number of generations per year is expected for many native pest species, but a few could also suffer from higher temperatures. An example of the latter is the carrot fly (*Chamaepsila rosae*) whose developmental cycle was found to be significantly hampered by critically high soil temperatures on the Central Plateau during 2006, 2013, 2015 and 2017 (*Agroscope*, 2018).

Fig. 96 > Modelling study on the number of non-indigenous insect pests (out of 64) that would find a suitable climate in Switzerland at different time horizons (RCP8.5 scenario).



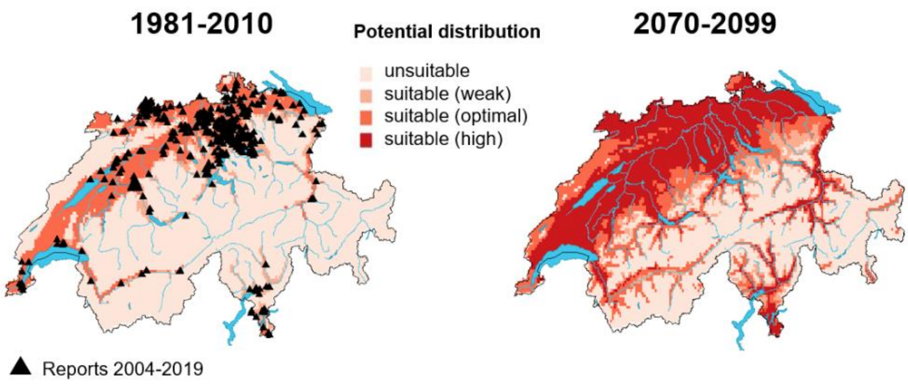
Based on *Grünig et al.* (2020a)

Climate change probably will lead to the establishment of non-indigenous, potentially invasive insect pests. A Europe-wide study of the effects of warming on the potential range of 64 agricultural insect pests found that current climatic conditions in Switzerland are already suitable for the establishment of 30 of these species, and that an additional 12 species could prosper under conditions projected for the second half of the century (*Grünig et al.*, 2020a). The study also indicated that the number of overlaps of insect pests with their host plants would increase with climate change, and that the area of regions where these overlaps are possible would also grow significantly in the future (Fig. 96).

A second study (*Grünig et al.*, 2020b) examined the climate niches of quarantine organisms and already established insect pests. The study identified two main groups of pests: those undergoing winter diapause and those that lack strategies for overwintering. The results further indicated a critical lower threshold (close to minus one degree Celsius) for the average monthly mean temperature of the coldest month for the second group. It was concluded that rapid rise in pest pressure could take place in areas where warming leads to average minimum winter temperatures above this threshold.

As with native insect pests, invasive insect pests are expected to have larger habitats and higher development rates under future climate conditions. A species that is currently under close monitoring is the highly polyphagous brown marmorated stinkbug (*Halyomorpha halys* Stål). Native to East Asia and invasive in Europe and North America, it can damage a wide variety of fruit and vegetable crops. In Switzerland, it has been of concern to farmers since about 2015. A model-based assessment of the potential distribution and seasonal occurrence of the marmorated stink bug (*Stoeckli et al.*, 2020) disclosed that the potential range is likely to expand further in the future, allowing the marmorated stink bug to find suitable living conditions throughout north-western Switzerland and in many alpine valleys (Fig. 97).

Fig. 97 > Potential distribution of the marmorated stink bug under present (1981–2010) and future (2070–2099) climatic conditions. Results of simulations with the CLIMEX model, using the IPCC SRES non-intervention emission scenario A2. Locations where the marmorated stink bug was found in the period 2004–2019 (left-hand graph).



Stoeckli et al. (2020)

6.3.8 Forests and Forestry

Forest ecosystems and the goods and services they provide can be significantly affected by climate change through drought, heat waves, forest fires, storms or biotic calamities such as bark beetle infestations. Compared to the slow processes that occur in forests (tree growth, seed dispersal, genetic adaptation, etc.), climate change is occurring at a speed that overwhelms potential natural adaptation processes of forests. Important forest products and services such as wood production and protection against natural hazards could be reduced as a result. This also has implications for the Swiss forestry and timber industries, which together currently employ almost 80,000 people.

Tree growth, mortality and vegetation shifts

Climate change acts in different ways on tree species and the composition of forests. It weakens the vigour of drought sensitive species and favours the competitiveness of more drought resistant species. Because the tree line is mainly determined by summer temperatures (*Körner and Paulsen*, 2004), warmer conditions induce an upward shift. However, the upward shift of the tree line observed since 1900 is not only driven by climatic changes but also by the abandonment of pastures at high altitudes (*Gehrig-Fasel et al.*, 2007; *Vittoz et al.*, 2008). Due to changes in minimum air temperature in spring (less extreme cold events), European ash (*Fraxinus excelsior*), silver fir (*Abies alba* Mill.), wild cherry (*Prunus avium* L.), sycamore (*Acer pseudoplatanus* L.), sessile oak (*Quercus petraea*), and European beech (*Fagus sylvatica* L.)

are successfully regenerating at and beyond the upper elevation limits of adult individuals (*Vitasse et al.*, 2012), but this implies an enhanced risk due to late frost events (*Vitasse et al.*, 2014; *Vitasse et al.*, 2018).

In the inner-alpine dry valleys climate variability is now the main driving factor for vegetational changes (*Rigling and Dobbertin*, 2011; *Rigling et al.*, 2013). Whereas the scots pine (*Pinus sylvestris* L.) now shows high mortality related to enhanced drought events (*Etzold et al.*, 2016), the sub-Mediterranean pubescent oak (*Quercus pubescens* Willd.) has locally increased in abundance. The growth of pines in drought events is not only reduced, but also the quality of the wood built under water stress is lower, as the hydraulic properties are more vulnerable to drought (*Eilmann et al.*, 2011).

On the Central Plateau, the Norway spruce (*Picea abies* L.) covers wide areas outside its natural limits, which are characterised by a colder and wetter climate. In the dry year 2003, growth in the lowlands was reduced, whereas it was enhanced at higher and hence colder elevations (*Dobbertin*, 2005). In the hot and dry year 2018, even sudden drought-induced mortality of Norway spruce was observed (*Arend et al.*, 2021). European beech (*Fagus sylvatica* L.) (*Braun et al.*, 2021) and the silver fir (*Abies alba*) showed serious drought damages, too (*FOEN et al.*, 2019).

Considerable drought induced tree damage and mortality was detected after 2018 in large parts of Europe (*Schuldt et al.*, 2020). The symptoms included exceptionally low foliar water potentials crossing the threshold for xylem hydraulic failure in many species, widespread leaf discoloration and premature leaf shedding. Strong drought-legacy effects were detected in 2019, which implies that the physiological recovery of trees was impaired after the 2018 drought event, leaving them highly vulnerable to secondary drought impacts such as insect or fungal pathogen attacks. Mortality of trees triggered by the 2018 events is likely to continue for several years.

An important factor enhancing the impacts of drought on trees is the deposition of nitrogen in forests. Evaluations reveal that the combination of drought stress and nitrogen deposition amplifies the effects of drought on trees (*Braun et al.*, 2017). The mean annual nitrogen deposition in forests in Switzerland is about 20 kilograms (*Meteotest*, 2019), with much higher rates in agricultural regions in the lowlands.

In some cases, climate change increases the ability of neophytes to invade forests and to act as 'invasive aliens'. The tree-of-heaven (*Ailanthus altissima*) becomes invasive in the south-alpine region of Switzerland (Ticino and Grisons). In the northern regions, the tree-of-heaven is found mainly in areas influenced by the warm Föhn winds or in towns (*Gurtner et al*., 2015). It is especially successful on shallow, rocky and dry sites, where other tree species are less competitive (*Knüsel et al*., 2019). The leaves of the tree-of-heaven are toxic and game avoid to feed on them, which is an advantage for invasive spreading into the forests.

The reported findings are consistent with current knowledge on the ecophysiology of trees (*Arend et al.*, 2016). However, the future forest composition is difficult to predict, since the influence of climate change on the forests is modified by a lot of other factors like local and regional site conditions, the influence of pests, diseases, insects and, especially at higher elevations, changes in agricultural practices (*Zimmermann et al.*, 2016). In Switzerland, for planning forest management, site types developed for the altitudinal vegetation belts are used. The altitudinal vegetation belts are now modelled on the basis of climate change scenarios (*Zischg et al.*, 2021) to guide practitioners in the choice of feasible future tree species (*Frehner et al.*, 2018). If the development proceeds as observed and predicted by climate models (*CH2018*, 2018), a substantial shift in tree species composition will occur, favouring more drought tolerant trees like oak species, whereas trees adapted to colder and wetter climate like the Norway spruce will be restricted to sites at higher elevations.

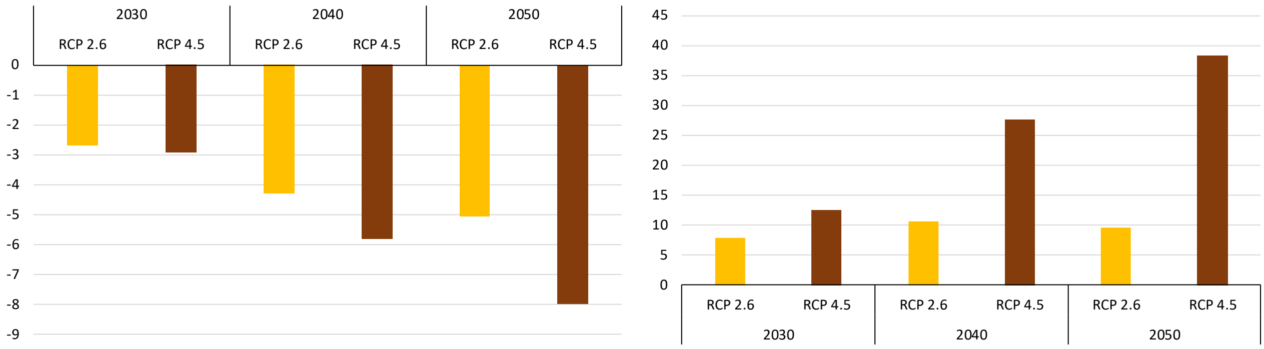
6.3.9 Energy

In the energy domain, relevant impacts include the changing needs for cooling and heating as well as changes in the productivity of hydropower plants. These are discussed below. Other relevant impacts have not been analysed in detail, e.g., the impact of extreme events on energy infrastructures (*Forzieri et al.*, 2018).

Impact of climate change on heating and cooling demand

Heating degree days provide an indication of the heating requirement for buildings. For a particular year, heating degree days are defined as the sum of the daily differences between the mean outside temperature from a room temperature of 20 degrees Celsius for days with an outside temperature of 12 degrees Celsius or less. Cooling degree days are counted when the mean daily temperature exceeds 18.3 degrees Celsius. They provide an indication of the energy demand for air conditioning. Climate change is likely to modify both heating degree and cooling degree days. Fig. 98 shows the expected evolution of heating degree days and cooling degree days computed from the CH2018 scenarios (*CH2018*, 2018) for the years 2030, 2040 and 2050 using two emissions scenarios (RCP2.6 and RCP4.5) in respect to the reference year 2020.

Fig. 98 > Changes in per cent of heating degree days (left) and cooling degree days (right) in respect to the reference year (2020) in scenarios with resolute and with moderate climate change mitigation, respectively (PCP2.6, RCP4.5).



Prognos et al. (2020)

Generally speaking, global warming leads to a decrease in heating energy demand in Switzerland, which is partly countered by an increased energy demand for space cooling.

Impacts of changes in heating and cooling degree days on energy consumption and economic welfare

Using an economic model, a study by *Vöhringer et al*. (2019) simulated the impacts of the future changes of heating degree days and cooling degree days for the year 2060. Tab. 40 presents the results of these simulations for three global emissions scenarios (IPCC SRES RCP3PD, A1B, A2). Decrease in heating demand will lower the energy consumption of oil and natural gas, which are mostly used in Switzerland for heating. In contrast, the increase of cooling demand will boost electricity consumption. The aggregated impacts are a decrease of oil and gas use, and an increase of electricity use. The actual impact on electricity consumption depends heavily on the spread of air conditioning in Switzerland in future decades.

Tab. 40 > Impacts of climate change on the Swiss economy in 2060. Energy consumption is shown as percentage change with respect to the baseline scenario.

	RCP3PD	A1B	A2
Energy consumption	–1.0%	–1.7%	–1.7%
Petroleum products	–2.1%	–3.4%	–3.4%
Natural gas	–2.0%	–3.5%	–3.4%
Electricity	2.5%	3.8%	3.7%
District heating	–4.4%	–7.1%	–7.0%
CO_2 emissions	–2.1%	–3.4%	–3.4%
Welfare impact in million Swiss francs, 2016	963	1 599	1 569
Welfare impact as percentage of total household consumption	0.1%	0.2%	0.2%

Vöhringer et al. (2019)

From an economic point of view, the effect of decreasing heating energy consumption strongly outweighs the effect of increasing cooling energy demand. Thus, the net effect leads to lower household expenditures in the order of 963 million to 1,599 million Swiss francs in 2060, depending on the underlying emissions scenario. In addition to the economic benefits, CO_2 emissions are reduced by 2.1 to 3.4 per cent. These results are in line with the findings of other studies that expect climate change to lead to decreasing energy demand in colder regions and increasing energy demand in warmer regions of the world (*Isaac and van Vuuren*, 2009).

Influence of climate change on hydroelectric power production in Switzerland

More than half of the electricity in Switzerland is produced from hydropower. Both storage and run-of-river power plants are used. The impacts of climate change on hydropower production were investigated as part of a study on the impacts of climate change on Swiss water bodies (*FOEN*, 2021). The hydrological scenarios Hydro-CH2018 formed the basis for the study. Hydropower is dependent on the volumes of water flowing in watercourses and their seasonal distribution, and is thus strongly affected by the impacts of climate change. Discharges are determined on one hand by precipitation and on the other hand by atmospheric temperature. Climate change affects both aspects. Higher temperatures lead to more evaporation and thus to reduced runoff. In addition, higher temperatures change the seasonal distribution of runoff (*Lanz and Wechsler*, 2020).

It is currently expected that the climate-induced change in evaporation, amount and duration of snow cover and glacier melt will have a rather positive impact on the operation of run-of-river power plants in the coming decades. In winter, they should benefit from increased inflow, as precipitation falls more as rain and less as snow. This will potentially allow them to produce more electricity (*Savelsberg et al.*, 2018). As reservoirs at lower altitudes (below 2,000 metres above sea level) refill more quickly (or empty more slowly) in winter with the transition to a rainfall-dominated runoff regime, this strengthens production in the winter period. For reservoirs with a catchment area above 2,000 metres above sea level (KWO, Mattmark, Grand Dixence, Mauvoisin, etc.), the changes in winter are likely to be smaller, because at this altitude no fundamental changes in the discharge regime are expected during the 21st century (*Lanz and Wechsler*, 2020).

The run-of-river power plants on the rivers of the alpine valleys and the Central Plateau will also benefit from a winter increase in discharge (*SCCER-SoE*, 2019). Above 1,400 metres elevation, the increase could be more than 30 per cent (*Schaefli et al.*, 2018, *SCCER-SoE*, 2019), but starting from a relatively low level. Despite the winter increase, annual production will tend to decrease, as both precipitation and snowmelt water will decrease significantly in summer (*SCCER-SoE*, 2019). Run-of-river power plants are directly affected by summer drought because, unlike storage power plants, they can only use the currently flowing water volumes.

Until the middle of the century, melting glaciers will most probably dampen the summer runoff decline to some extent. Their runoff contribution, which is fed by precipitation accumulated over centuries, provided about 4 per cent of Switzerland's hydropower generation in the years 1980–2010. The relative importance of glacier water for the discharge of the Rhone river at Geneva (7.8 per cent) was much greater than for the Rhine river in Basel (2.2 per cent). In the years 2040–2060, the glacier contribution is expected to decrease to 7.1 per cent in the Rhone area and to 0.4 per cent in the Rhine area. Later in the century (2070–2090), glaciers will contribute hardly anything to hydropower production in the Rhine area (0.1 per cent), while the Rhone area will benefit from its large glaciers, which will continue to contribute 3.8 per cent. Due to the reduced ice volume, production volumes are estimated to decrease by approximately 0.54 terawatt-hours per year in the period 2040–2060 and by approximately 1 terawatt-hour per year in 2070–2090 (*Schaefli et al.*, 2018).

The statements above apply to average years, but large year-to-year fluctuations are common. The change between dry and wet years could have a greater impact on hydropower production than the long-term changes due to climate change (*Savelsberg et al.*, 2018). The Swiss Federal Office for the Environment (*FOEN*, 2016) has examined the impact of the dry summer and autumn of 2015 on hydropower production. After an above-average spring, the run-of-river power plants produced significantly less electricity than usual in the second half of 2015 due to the drought. Thanks to higher natural inflows from glaciated catchment areas and the early use of water stored in reservoirs in the autumn of 2015, overall electricity production from hydropower was still above the average of the previous years. An analysis of the impacts of the summer 2018, which was also hot and dry, showed a similar result. However, there was a small shortfall in production of 0.8 per cent compared to the average of the last ten years (*FOEN et al.*, 2019). This experience has to be taken into account with regard to supply security during winter months, when Switzerland depends on electricity imports.

Influence of climate change on the thermal use of waters

Rivers, lakes and groundwater represent enormous heat reservoirs. In autumn and winter, they can be used as a heat source and thus form a CO_2-neutral option for the replacement of fossil energies. A positive consequence of global warming is that more heating energy can be extracted from warmer waters during the cold season. Depending on the season, water bodies warm up to different degrees. In general, the conditions for heat extraction from lakes are likely to improve in winter (higher flow, higher temperature). The heat utilisation potential of watercourses should also increase slightly in winter (higher average winter temperature, higher winter discharge) (*Lanz*, 2020). In addition to rivers and lakes, also groundwater is used thermally. Groundwater bodies react very differently to changes in atmospheric temperature, depending on how strongly they are influenced by infiltration from surface waters (*Figura*, 2013). Groundwater with a stable temperature throughout the year makes the most sense for thermal use and is also suitable for combined cooling and heating. Although these mostly lower-lying groundwater sources will also gradually warm with climate change, they will still be significantly cooler than the atmosphere in mid-summer and significantly warmer in winter. In contrast, the extraction of heat for heating buildings can have a positive effect, as it contributes to the cooling of groundwater bodies. The canton of Basel-Stadt is considering the introduction of monetary incentives for the expansion of groundwater use for heating purposes (*AUE*, 2017). However, it became apparent in 2018 that the thermal usability of groundwater can also be impaired by drought. For example, the canton of St. Gallen reported that some heat pumps had operating problems in November and December 2018 due to low groundwater levels. Such problems also occurred in the canton of Glarus (*EBP*, 2019).

Water bodies can also be used for cooling, but not all cantons in Switzerland allow cooling with groundwater. Due to the warming of the water bodies, their cooling potential dwindles in summer. This mainly affects the river water, which can no longer be used for cooling in hot summers when the water temperature approaches 25 degrees Celsius. In addition, the demand for building and process cooling may increase in warmer summers and during hot spells. However, most existing cooling systems can still be optimised in terms of construction and energy consumption, so that cooling energy demand does not necessarily have to increase significantly even at higher temperatures (*Lanz*, 2020). Despite climate change, the demand for cooling remains many times lower than the demand for heating. According to the Energy Perspectives 2050+, the demand for heating in 2050 is expected to be between 74 and 85 terawatt-hours while the demand for cooling is expected to be between three and four terawatt-hours (*Prognos et al.*, 2020[78]).

6.3.10 Health

Extreme events

The projected increase in the frequency and intensity of heat waves (section 6.1.2) in combination with high tropospheric ozone concentrations represents the greatest direct risk of climate change to public health in Switzerland. The potential impact first became apparent during the hot summer of 2003. High ambient temperatures caused almost 1000 additional deaths between June and August 2003. The 2003 heat wave mostly affected the elderly and was more pronounced in cities where it was exacerbated by the urban heat island effect (*Grize et al.*, 2005). Excess deaths due to heat were also observed during the hot summers of 2015, 2018, and 2019 (see Tab. 41). Most of the extra deaths occurred in people aged 75 years and older (*Ragettli and Röösli*, 2020; *Ragettli and Röösli*, 2021b).

Tab. 41 > Excess mortality during the four warmest summers in Switzerland (June, July, August). For 2018, excess mortality was limited to August (3.4 [0.5–6.4] per cent).

Summer	Ranking of warmest summers	Excess deaths (n)	Excess mortality including 95 per cent confidence interval
2003	1	975	6.9 [4.9–8.8] %
2015	2	804	5.4 [3.0–7.9] %
2018	4	185	1.2 [–0.7–3.1] %
2019	3	521	3.5 [1.6–5.3] %

Ragettli and Röösli (2020), *Ragettli and Röösli* (2021b)

Heat waves and single hot days are not only related to excess mortality but also to increased morbidity. In Switzerland, the summer of 2015 was the second warmest summer (after 2003) since the beginning of measurements 150 years ago (*MeteoSwiss*, 2016). A study which analysed daily counts of emergency hospital admissions in 2015 in relation to previous years (*Ragettli et al.*, 2019) reported close to 2,800 additional cases (+2.4 [1.6–3.2] per cent, 95 per cent confidence interval) in the period June–August 2015. Highest excess emergency hospital admission estimates were found where registered temperatures had been highest, namely in the canton of Ticino (8.4 [5.1–11.7] per cent, 95 per cent confidence interval), in the Lake Geneva region (4.8 [3.0–6.7] per cent, 95 per cent confidence interval) and among the population aged 75 years and older (5.1 [3.7–6.5] per cent, 95 per cent confidence interval). During days with most extreme temperatures, increased emergency hospital admissions were observed mainly for pneumonia, certain infection diseases and

[78] Scenarios ZERO Basis and WWB

diseases of the genitourinary system. A recent study on short-term associations between ambient temperature and mental health hospitalizations in the city of Bern (*Bundo et al.*, 2021) also reported that high temperatures negatively affect the mental status in psychiatric patients.

Additional direct effects of climate change on health are expected from the increase of other extreme events such as floods, mudslides and, possibly, storms. In view of the well-developed emergency measures of civil protection in Switzerland, the health effects should be manageable. However, extreme events may entail severe psychological consequences for the directly affected population which are often underestimated and may last longer.

Allergies and vector-borne diseases

Throughout Switzerland, the starting dates of the pollen season have shifted between 1990 and 2020 to earlier periods of the year for several allergenic pollen types (hazel, oak, grasses, nettle/hemp) (*Glick et al.*, 2021). In addition to these species, significant trends were found in a 50-year analysis (1969–2020) of Basel pollen levels (*Gehrig and Clot*, 2021). The same two analyses found an overall increase in pollen season intensity (calculated as the annual pollen integral) for most trees (hazel, birch, oak, beech, alder, yew, ash, hornbeam, plane, poplar) and nettle/hemp (*Glick et al.*, 2021; *Gehrig and Clot*, 2021). Similar trends in pollen season onset, duration and intensity were reported in an analysis which included data from across Europe (*Ziska et al.*, 2019), where pollen season shifts have been attributed to temperature rise and CO_2 increase. Moreover, due to climate change related habitat changes, highly allergenic non-native species (e.g. mugwort and ragweed) may settle in Switzerland, further intensifying the pollen season. People sensitised to a variety of different pollen may start suffering earlier from hay fever or asthma symptoms and for a prolonged period of the year, as pollen production starts earlier in the year and the amount of pollen increases.

The latest comprehensive representative surveys date from the 1990’s and early 2000’s. These showed a clearly increasing trend in prevalence of intermittent allergic rhinitis (pollen allergy symptoms) in both children (*Asher et al.*, 2006) and adults (*Bjerg et al.*, 2011; *Huovinen et al.*, 1999) in many westernised countries, including Switzerland, until the 1990’s. Since then, several Swiss studies have reported that this trend flattened out among children and adolescents around the year 2000 (*Braun-Fahrländer et al.*, 2004; *Grize et al.*, 2006), but no studies on trends in the prevalence of pollen-sensitization are known since this time. However, estimated prevalence remains high at around 20 per cent in Switzerland (*Ballmer-Weber and Helbing*, 2017) and worldwide as one of the most common chronic diseases (*Bousquet et al.*, 2009). To date, there is no clear evidence that an increase in the prevalence of allergic diseases is causally linked to increasing pollen concentrations in the air. However, it is to be expected that the combination of widespread prevalence and increased intensity of the pollen season would adversely affect the quality of life of many.

Another important potential health risk of climate change is the occurrence of vector-borne diseases. The diseases result from a transmission of an infectious agent through an animal vector (mosquito, tick) usually through biting or touching. Increasing temperatures favour growth of vectors and replication rates of infectious agents, e.g. viruses. In Switzerland, the most common vector-borne diseases are tick-borne encephalitis (FSME) and Lyme disease. In recent years, outbreaks of some vector-borne diseases, such as Dengue and Chikungunya fever have been observed in neighbouring countries such as Italy and France, and the respective vector (the mosquito *Aedes aegypti*) is present in Switzerland, too. However, future developments are still highly uncertain as many other factors such as human behaviour, population density, international trade and global tourism affect disease transmission.

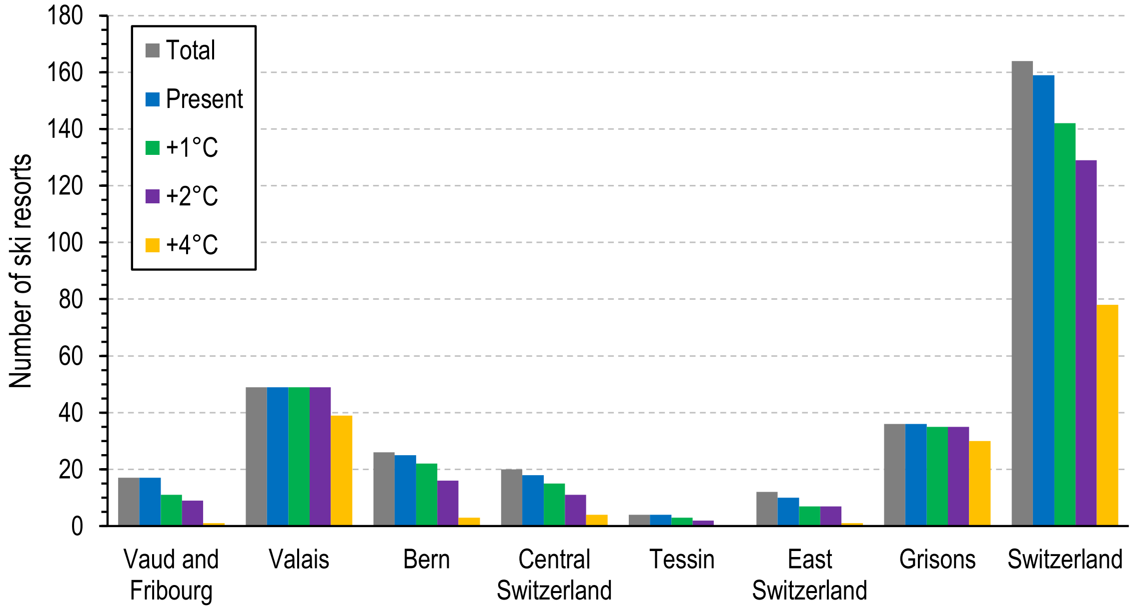
6.3.11 Tourism

In Switzerland, tourism is one of the most important sectors directly affected by climate change. This implies that ski resorts in the foothills of the Prealps may not operate profitably in the future (*Lehmann Friedli*, 2011; *Serquet et al.*, 2013; *Klein et al.*, 2016). With climate change progressing, the altitudinal threshold for snow-reliability will continue to rise. Without climate mitigation measures, the natural snow cover will be reduced by around 40 per cent at an altitude of 1500 to 2000 metres above sea level by 2060 (*CH2018*, 2018). Numerous ski resorts in Switzerland are located at higher altitudes and therefore likely to be less severely affected by climate change than ski resorts in other parts of the Alps. However, profitability is decreasing everywhere due to the shortening of the ski season, the increasing cost of artificial snow production, the decreasing number of guests due to uncertain snow conditions and the decreasing motivation for winter sports, triggered by the lack of wintery atmosphere on the Central Plateau (*Bandi*, 2021).

Based on the altitude of the station, the Swiss ski resorts currently considered to be snow-reliable have been assessed for an average temperature increase of one, two and four degrees Celsius. It appears that the number of ski resorts with economically sufficient snow conditions may drop by at least one fifth for a regional temperature rise of two degrees Celsius. Under this scenario and seen from a national tourism perspective, the number of affected resorts is not so significant (Fig. 99). In case of a regional four degrees Celsius rise in temperature, low elevation ski resorts will be extremely affected while many high-altitude ski resorts remain snow-reliable. Therefore, the loss expected in Switzerland is below average in comparison with neighbouring alpine countries (*Abegg et al.*, 2007).

Climate change scenarios show that by the end of the century, compared to the reference period 1999–2012, snow depth will decrease by around 50 per cent even for altitude levels as high as 3000 metres above sea level if no preventive measures are taken. At that time, snow days may decline by 50 per cent at an altitude of 1500 metres and in the lowlands snow is predicted to disappear almost entirely (*Marty et al.*, 2017b). Already today, small ski resorts at low altitudes only operate when snow cover is sufficient. Their room for manoeuvre but also the pressure to generate revenue are comparatively low. Medium-sized ski resorts are most affected by the decreasing snow reliability in terms of profitability, as they cannot easily afford to invest in artificial snow compared to larger ski resorts at higher altitudes (*Bandi*, 2021).

Fig. 99 > Snow-reliability in Swiss ski resorts. Total number of ski resorts (grey) and number of ski resorts that were snow reliable in the early 2000s (blue) and are expected to remain snow reliable under an increase in average temperature of one degree Celsius (green), two degrees Celsius (purple) and four degrees Celsius (orange), respectively.



Abegg et al. (2007)

Changing conditions in summer may create new opportunities for the tourism sector. Pleasant temperatures at higher altitudes and a tendency towards less rainfall can help reposition the alpine region as a summer holiday destination. At the same time, numerous places at lakes and rivers might become an alternative to seaside holiday resorts at the Mediterranean Sea, which tend to lose attractiveness as excessive heat and drought conditions become more frequent (*Swiss Confederation*, 2020a). Yet, more tourists in summer will not compensate for the loss of income of mountain resorts in winter. Currently, these places are heavily dependent on winter tourism to maintain their profitability (*NELAK*, 2013; *Lehmann Friedli*, 2013).

Destinations dependent on glaciers as tourist attractions will be affected as glacier retreat continues (see section 6.3.2). By 2100, the glaciers of the Alps will lose approximately 95 per cent of their current volume without measures to mitigate climate change. Other changes in natural scenery (rivers running dry in late summer, lack of winter atmosphere in the absence of snow) may further reduce the attractiveness of some alpine tourist areas.

Even though the loss of natural landscape caused by the disappearance of a glacier is irreplaceable, the emergence of new mountain lakes can in some cases have a positive impact on tourism. An example of this is the valley of Gadmen, where a lake formed after the retreat of the Trift glacier in the late 1990s. This lake, together with a new suspension bridge built to bypass the obstacle, led to an increase in the number of tourists hiking to the nearby hut (*NELAK*, 2013).

Climate-related changes in natural hazards are another element that is important for tourist destinations in the mountains. The melting of permafrost destabilises the subsoil. This can affect infrastructures located at high altitudes. Hotel and restaurant buildings, cable car masts, avalanche barriers, etc. are at risk if they are anchored in permafrost (*FOEN*, 2017a). A related problem is the frequency of rock fall and debris flows which will increase due to the combination of melting glaciers, melting permafrost, rising snow line and more intense precipitation (see section 6.3.3). This may pose an additional risk to mountaineers and hikers at high altitudes. As the potential damage costs (e.g. from glacial lake outbursts) can be much higher than the costs of adaptation measures, it is important to invest in strategies that minimise the risk. Furthermore, possible operational disruptions and a negative image due to safety issues could cause additional economic damage (*Swiss Confederation, 2020a*).

6.4 Domestic adaptation polices and strategies

6.4.1 Update on the Swiss adaptation strategy

The impacts of climate change involve both risks and opportunities for Switzerland (see section 6.2). In order to minimise the risks posed and to benefit from the opportunities provided by climate change, adaptation measures need to be planned and implemented in the coming decades.

The Swiss Federal Council adopted its strategy 'Adaptation to Climate Change in Switzerland' in 2012 (*Swiss Confederation*, 2012a). The strategy describes goals, challenges and fields of action in adapting to climate change in Switzerland and provides the framework for the federal offices to pursue a coordinated course of action in responding to the expected climate change impacts. For the implementation of the strategy, a first action plan for the period 2014–2019 comprising of 63 adaptation measures was adopted in 2014 (*Swiss Confederation*, 2014). A second action plan for the period 2020–2025 with 75 measures was adopted by the Swiss Federal Council in 2020 (*Swiss Confederation*, 2020a).

The legal basis for adaptation action taken by the national government and key elements of the adaptation strategy are described in Switzerland's sixth national communication.[79] The action plan for the period 2020–2025 considers the results of the nationwide climate change risk assessment (*FOEN*, 2018a; *FOEN*, 2017a; see section 6.2) and addresses the major risks and opportunities identified therein. The need for action for each risk or opportunity was evaluated, taking into account the urgency and the deficit in adaptation to climate change in the sectors affected. Where the need for action was classified as moderate or high, adaptation measures were developed and included in the second action plan. The new plan now also covers storm and hail, 'wild card' risks and indirect risks caused by climate-related impacts abroad, where the main task consists of further improving the knowledge base.

The action plan for the period 2020–2025 contains 63 adaptation measures in 12 sectors. Another 12 cross-sectoral measures aim to improve the knowledge base for adaptation, e.g., by providing updated regional climate scenarios or by improving the hydrological knowledge base. Cross-sectoral measures support the implementation of the adaptation strategy and the coordination of adaptation measures between both, federal offices (horizontal coordination) and the federal and cantonal levels (vertical coordination).

Additional information on the state of implementation of the national adaptation strategy and its action plans may be found in sections 6.6.1 and 6.6.2, respectively. As many adaptation measures are implemented at regional and local level, it is the responsibility of the cantons to assess the specific climate-related risks and opportunities on their territory and to take measures to mitigate the risks.

Based on the provisions of Article 7, paragraphs 9, 10 and 11, and Decision 9/CMA.1, Switzerland submitted its First Adaptation Communication under the UNFCCC on 9 December 2020. The communication contains the national adaptation strategy and the two associated action plans, as adopted by the Swiss Federal Council (*Swiss Confederation*, 2020c).

[79] available for download at the website *www.climatereporting.ch*

6.4.2 Measures supporting the implementation of the adaptation strategy

The Swiss Federal Office for the Environment takes the lead in coordinating the implementation of the adaptation strategy at the federal level and periodically assesses progress made (see sections 6.5, 6.6.1 and 6.6.2). In addition, the Office promotes awareness raising, adaptation capacity building and innovation through the organisation and management of a pilot programme and the development of tools to support small and medium-sized municipalities (see further below in this section). It also implements targeted initiatives under the ‘Climate Programme Training and Communication’ (see section 9.2.3). Since 2015, the National Centre for Climate Services has served as a national coordination body and knowledge hub in support of the implementation of the adaptation strategy.

National Centre for Climate Services (NCCS)

In response to the Global Framework for Climate Services’ call for the establishment of national coordination mechanisms, Switzerland founded its National Centre for Climate Services in 2015. The centre is a concerted national effort comprised of nine federal offices and institutes as well as partners from academia.[80] The participating institutions are committed to creating synergies at national to subnational level. Based on the national adaptation strategy and the associated action plans, the NCCS is organised as a nationwide network and virtual centre. It addresses the entire climate services value chain, ranging from pure climate data to tailored support for a wide range of actors engaged in adaptation and mitigation action.

The co-creation and dissemination of climate services is vital for effective climate mitigation, adaptation and societal transformation. To overcome fragmentation and strengthen capacities leading to increased resilience, the NCCS acts as a network agent and knowledge broker. It pursues three main goals: (i) bundle the existing climate services of the federal government, (ii) foster dialogue among stakeholder communities, and (iii) co-produce new tailored solutions. These goals are reflected in the centre’s strategy[81] that revolves around nine activity fields, all of which recognise the importance of promoting knowledge exchange.

To achieve its goals, the NCCS has engaged key stakeholders, gathered the requirements of different providers and interest groups, and set priorities accordingly. Concrete studies address issues such as human and animal health, natural hazards and risk management, pest spread and forest functions. Overarching climate services include the new generation of Swiss climate scenarios (*CH2018*, 2018) and hydrological scenarios (Hydro-CH2018, see *FOEN*, 2021; *NCCS and FOEN*, 2021). All focal topics are designed to be user-oriented. Jointly developed communication tactics promote their use.

The ‘NCCS-Impacts’[82] programme was launched with a focus on the cross-sectoral analysis of climate impacts, with a first call for projects in 2021. The aim of the programme is to obtain a comprehensive overview of future climate impacts in Switzerland and the associated key challenges for the environment, economy and society. The programme will transform the results into actionable and user-oriented products (‘climate services as decision support’). In this way, the programme strives to close the gap between basic scientific research and measures in the field of climate adaptation and mitigation. The programme is carried out as a cross-sectoral and cross-departmental undertaking within the federal administration.

To gain further traction, a multi-level network and communication strategy has been developed and is currently being implemented. The NCCS web portal *www.nccs.ch* was launched in late 2018. It aims to serve as a one-stop-shop for the provision of climate services and information on adaptation measures and best practices. In its ‘Web Atlas’ section[83], the portal provides access to the data from the CH2018 and Hydro-CH2018 projects, including all regions and locations, all seasons, all future time periods, and all emission scenarios for which calculations were made.

80 Swiss Federal Office of Meteorology and Climatology, Swiss Federal Office for the Environment, Swiss Federal Office for Agriculture, Swiss Federal Office for Civil Protection, Swiss Federal Office of Public Health, Swiss Federal Food Safety and Veterinary Office, Swiss Federal Office of Energy, ETH Zurich, Swiss Federal Institute for Forest, Snow and Landscape Research.

81 *https://www.nccs.admin.ch/nccs/en/home/the-nccs/about-the-nccs/mandate-and-goals/strategy.html*

82 *https://www.nccs.admin.ch/nccs/en/home/climate-change-and-impacts/nccs-impacts.html*

83 *https://www.nccs.admin.ch/nccs/en/home/data-and-media-library/data/ch2018-web-atlas.html*

Other information platforms related to adaptation to climate change

At the Swiss Federal Office for the Environment website, the national adaptation strategy and both action plans are available. A brief overview of the core elements of Swiss adaptation policy and its fields of action is given, too.[84] This site, together with information provided by the Swiss Academy of Sciences[85], complements the NCCS web portal.

Pilot programme Adaptation to climate change

As climate change adaptation – apart from relevant activities in the traditional field of natural hazards management – still is a relatively new issue, activities and experiences on regional and local level are widely lacking. Therefore, the pilot programme 'Adaptation to climate change'[86] was set up under the leadership of the Swiss Federal Office for the Environment together with the Swiss Federal Offices of Meteorology and Climatology, Civil Protection, Public Health, Agriculture, Spatial Development, Energy, Roads, Housing as well as the Food Safety and Veterinary Office. Its main purpose is to serve as a national funding initiative to support cantons, regions and municipalities in tackling climate change-related challenges. The programme's goals are:

- To contribute to putting the Swiss adaptation strategy into practice;
- To raise awareness for climate change adaptation in cantons, regions and municipalities;
- To trigger and implement innovative, cross-sectoral pilot projects;
- To capitalise climate change-related opportunities, minimise risks, and increase adaptive capacity in the pilot areas;
- To enhance vertical and horizontal collaboration as well as to initiate and foster knowledge exchange between cantons, regions and municipalities.

31 projects were selected for implementation during the first programme period 2014–2016. The results are documented in a synthesis report (*FOEN*, 2017). Following a programme evaluation (*Landis et al.*, 2017b), a second call for projects was launched in 2018. 50 out of 140 project proposals were selected for funding (50 per cent funding rate, as a general rule). For an overview of the main topics covered and the related projects, see *https://www.nccs.admin.ch/nccs/en/home/measures/pak/projekte-phase2.html*. 2022, the final year of the programme, will comprise the synthesis of results, dissemination activities and an evaluation.

Online-Tool Adaptation to Climate Change for Municipalities

In Switzerland, adaptation strategies and concepts for adaptation in individual sectors are mostly developed at the federal and cantonal level. However, the municipal level is crucial for the implementation of measures. On 1 January 2022, Switzerland counted 2,148 municipalities. Their size and thus the available resources vary greatly. While large cities have their own services for climate change adaptation, in smaller municipalities a few civil servants take care of all municipal tasks, leaving them little time to deal with climate change adaptation.

To support smaller and medium-sized municipalities in adapting to climate change, the Swiss Federal Office for the Environment is developing an online tool. The tool is designed to help municipalities identify the main risks of climate change and assess possible adaptation measures to these risks. It offers two main functions:

- The tool asks in a systematic way what climate change risks a municipality is facing today or might face in the future and what measures it has already taken or intends to take to address future challenges. The tool summarises the answers in a clear and concise manner;
- The tool contains a collection of good practice examples. For instance, if a municipality indicates that it expects more frequent flooding, it will be shown examples of how other municipalities protect themselves from flooding.

[84] *https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/adaptation.html*

[85] *http://www.proclim.ch*, *https://naturalsciences.ch/topics/climate*

[86] *https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/adaptation/pilot-programme.html*

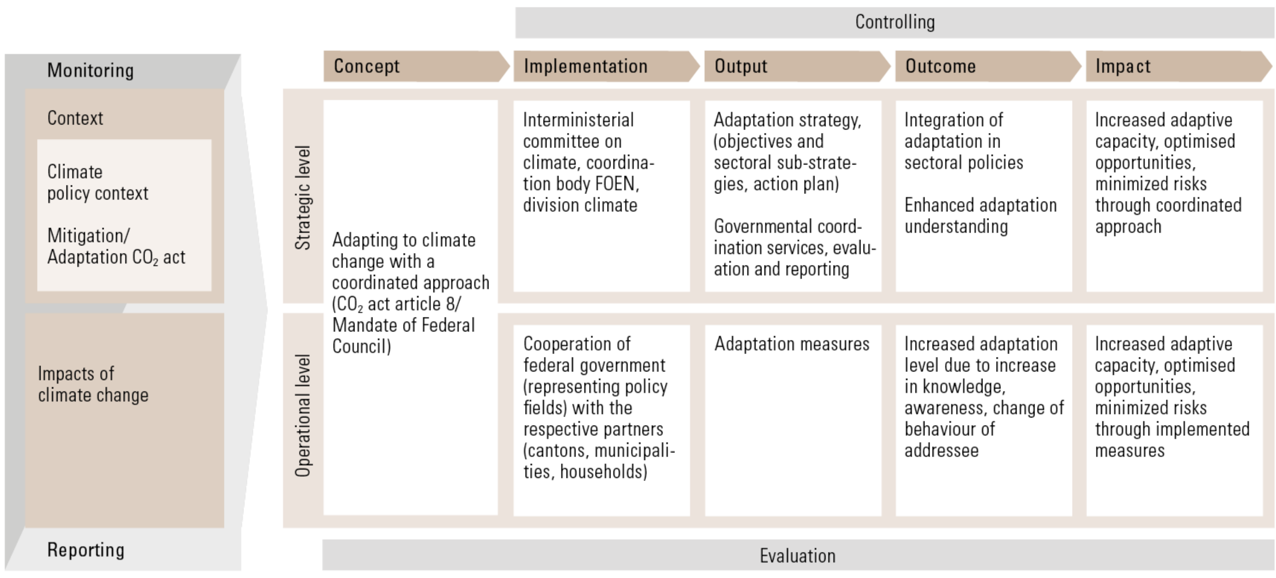
Each municipality can add further measures so that the collection of good practices grows and the other municipalities can benefit from the experience gained.

The tool is currently under development. In order to adapt it to the needs of the municipalities, municipal representatives have participated in the design and testing of a prototype. The release of the tool is planned for the end of 2022.

6.5 Monitoring and evaluation framework

With the adoption of the first action plan of the Swiss adaptation strategy (*Swiss Confederation*, 2014), the Swiss Federal Office for the Environment was mandated to report to the Swiss Federal Council on the progress made and the effects achieved with the implementation of the adaptations measures contained in the action plan by the end of 2017. In response to this mandate, a monitoring and evaluation scheme for the systematic assessment of climate change adaptation in Switzerland was developed. An impact model (see Fig. 100) is used as the basis of the system. The model consists of five 'evaluation objects' (concept; implementation; output; outcome; impact) and sets out the logic underlying the flow from one object to another. Furthermore, the model distinguishes between the strategic level (setting up of a coordination framework for adaptation) and the operational level (implementation of adaptation measures).

Fig. 100 > Impact model for monitoring, reporting and evaluation.



Swiss Confederation (2014)

On the basis of the impact model, the development process of the strategy, the progress of implementation, the effectiveness of the implementation of measures as well as the coordination by the Swiss Federal Office for the Environment were evaluated at the federal level. The results are documented in *Boesch et al.* (2015), *FOEN* (2015), *FOEN* (2017) and *Landis et al.* (2017a). They have been included in the development of the second action plan. As recommended by *Landis et al.* (2017a) and *FOEN* (2017), the cross-sectoral perspective has been strengthened and the objectives of the measures and cross-sectoral challenges have been specified in the second action plan.

The impact model is an effective tool to demonstrate, communicate and facilitate discussions on the complex relationships associated with climate change adaptation. It supports learning and helps optimizing the use of existing knowledge and experiences of stakeholders within Switzerland. However, a number of challenges were identified including (i) setting objectives and thresholds for evaluating adaptation, (ii) capturing the causality between the expected and the actual outcome of an adaptation measure, and (iii) the short time between the adoption of the action plan and its evaluation.

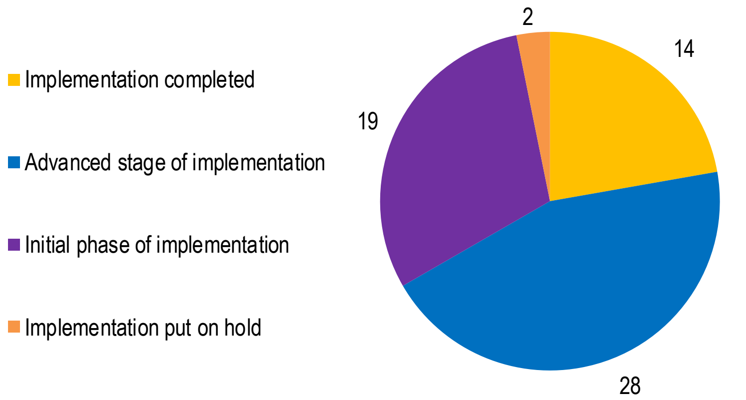
6.6 Progress and outcomes of adaptation action

6.6.1 State of implementation of adaptation action at the federal level

The first action plan of the Swiss adaptation strategy for the period 2014–2019 contained 63 adaptation measures. A survey of the federal offices responsible for development and implementation of these measures showed an encouraging state of implementation at the end of the action plan period (Fig. 101). 14 measures had been fully completed, 28 were advanced in their implementation, 19 were in the initial phase of implementation, and only two were put on hold. Detailed information about the implementation in the different sectors is available online.[87] 46 out of the 63 measures were carried forward into the second action plan because their implementation had not been completed or because the measures need to be implemented continuously.

The second action plan for the period 2020–2025 contains 75 adaptation measures. 63 of these are situated within the sectors and 12 are cross-sectoral measures. A first survey assessing the state of implementation is due in 2023.

Fig. 101 > State of implementation of adaptation measures at the federal level, 2020.



Swiss Confederation (2020a)

6.6.2 State of implementation of adaptation action at the cantonal level

According to Article 15 of the CO_2 Ordinance, the cantons are required to inform the Swiss Federal Office for the Environment every five years about the measures they undertake to adapt to climate change. The information shall serve as basis for the further development of the Swiss Federal Council's adaptation strategy and for the coordination between the federal and cantonal levels. In the second reporting, which took place in 2021/2022, all but three cantons participated (23 out of 26). Of the three cantons that did not respond to the survey, two are currently developing an adaptation strategy. Thus, the results provide a nearly complete overview of the state of planning and implementation of adaptation measures at the cantonal level. The results of the reporting are summarised briefly in this section.

Most of the 26 cantons addressed the topic of adaptation in one way or another. 15 cantons – nine more than in the first reporting in 2015 – already developed an adaptation strategy or an adaptation plan. In nine cantons such a strategy or plan is currently under development. 19 cantons reported on coordination of their adaptation activities across different sectoral policies. Only one canton reported that climate change is not addressed politically. Therefore it had not undertaken any adaptation action yet and no such action was planned for the time being.

So far, only one canton has included a specific legal basis for climate adaptation in the cantonal constitution. Three cantons are developing a climate law. With regard to the budget and staff, dedicated resources vary greatly between the cantons. While some cantons do not have extra budget or staff for climate adaptation, others are equipped with up to 7.4 full time employees for mitigation and adaptation.

Since autumn 2020 a group of ten cantons led by the canton of Aargau is developing an indicator set. The goal is to define at least one impact indicator and one response indicator for each sector of the national adaptation plan. The impact indicator is used as a proxy to show the influence of climate change on each sector, e.g. water temperature in small rivers. The response indicator shows a response to these changes, e.g. kilometres of revitalised rivers. A first draft of an indicator set was sent to all 26 cantons for consultation in autumn 2021. The consultation showed that most of the proposed indicators are relevant for the cantons, but that they need to be further developed.

87 www.bafu.admin.ch/implementation-adaptation-strategy

6.6.3 Update on adaptation in the sectors most affected by climate change

Natural hazard management

In the Swiss Federal Council's adaptation strategy (*Swiss Confederation*, 2012a), five fields of action for the natural hazards management sector are identified. These fields of action address floods in the Alps, on the Central Plateau and in the Jura mountains, torrential and gravitational processes, and impacts on protective forests in the alpine region.

The lessons learned and findings from the events of recent decades are the basis for current legislation and the new Swiss natural hazards strategy (*PLANAT*, 2018) of the National Platform for Natural Hazards (PLANAT).[88] The strategy of integrated risk management[89] was incorporated in order to tackle and overcome the additional challenges resulting from climate change. This approach is consistent with the 'Alpine strategy for adaptation to climate change in the field of natural hazards' of the Alpine Convention (*PLANALP*, 2012).

As part of the pilot programme 'Adaptation to Climate Change'[90] (see section 6.4.2), the Swiss Federal Office for Civil Protection, together with a wide range of partnering institutions, investigated the most important challenges of climate change for the integrated civil protection system in Switzerland and the resulting need for action (*EBP and FOCP*, 2021a). The results are summarised in *EBP and FOCP*, 2021b.

Implementation of the integrated risk management strategy presents a major challenge. Besides ongoing measures, new measures that reduce the potential of damage due to climate change are becoming increasingly important. According to the Swiss adaptation strategy, measures are to focus on the following areas:

- Monitoring of natural hazard processes: New processes and their evolution as well as changes in known processes need to be recognised in due time and be closely monitored. Systematic monitoring of hazard processes ensures that imminent hazards and general changes in the hazard situation can be identified at an early stage. With the Warning of Mass Movement Hazards (WARMA) project, the periodic monitoring and evaluation of permanent landslides is established and a methodology for the nationwide assessment of mass movement disposition is developed. The warning system is expected to be operational in 2025;
- Comprehensive knowledge of hazards and risks: Systematic nationwide hazard and risk assessments need to be established on a regular basis. In order to do this, a comprehensive knowledge base is needed. Key elements are up-to-date hazard maps, the development of missing hazard fundamentals and the assessment of the damage potential at the national and cantonal level;
- Protective structures designed to accommodate excess loads: The overload case already be taken into account in the planning phase of protective infrastructures, and constant maintenance must ensure their functionality. In addition, protective forests need to be constantly regenerated and climate-related changes need to be considered and reflected in the selection of tree species;
- Implementation of land use planning measures: The goals and principles of living with natural hazards have to be defined and implemented at all levels of land use planning. In line with the Swiss natural hazards strategy, the creation of new risks must be avoided and risk-based considerations including climate change scenarios need to be applied in land use planning. Risk-based protection goals need to be defined and considered. In the project 'Risk-based spatial planning', land use planning was complemented with hazard maps by focusing on existing uses in an area at risk. Examples and practical experiences are documented in a report commissioned by *FOEN and ARE* (2019);
- Successful response to natural disasters (*FOCP*, 2013): Up-to-date emergency planning and emergency concepts need to be developed for all cantons and communities. They need to be regularly exercised and adapted to site specific conditions and climate-induced changes. The coordination of all parties involved in the management of an emergency situation needs to be ensured. Through timely early warnings, appropriate measures can be taken

88 https://www.planat.ch/en/

89 https://www.planat.ch/en/specialists/risk-management

90 https://www.nccs.admin.ch/nccs/en/home/measures/pak.html

in an emergency. Since 2017, relevant measurements and observation data, predictions, warnings, models and bulletins are made available centrally to federal, cantonal and local natural hazard experts via the Common Information Platform for Natural Hazards (GIN).[91] A periodically updated platform of federal agencies issuing warnings on natural hazards for the public and cantonal and/or communal authorities exists at the internet address *http://www.natural-hazards.ch*;

- Awareness, education and research in the field of natural hazards is improved: House owners, architects, planners and the public need to be educated about natural hazards. Local natural hazards advisors are needed to ensure that local knowledge is available for the intervention teams in case of an emergency. Intervention and emergency teams have to be adequately trained in response measures. In the context of the pilot programme 'Adaptation to climate change', three short films have been produced to illustrate strategies for protection against natural hazards;[92]
- Analyses of major events and their management: Extreme events and the subsequent response activities need to be well documented and evaluated at all levels. A harmonised data collection allows the comparison of events and interventions in order to ensure continuous improvement and, if needed, adjustment of management processes. A collection of hydrological event analysis reports is available at the Swiss Federal Office for the Environment website.[93]

An extensive study on how to deal with more frequent and intense heavy precipitation events and how to best manage rain water in densely populated areas is available (*FOEN and ARE*, 2022).

Weather hazard alerts

According to the established federal legal framework, MeteoSwiss warns authorities and the population of weather hazards. Severe weather warnings are a public service of the government and part of the basic meteorological services. In 2001, MeteoSwiss introduced a comprehensive severe weather warning system, which since has been continuously developed and optimised. The current warning system is embedded in a natural hazard warning concept (LAINAT[94]) coordinated with the Swiss Federal Office for the Environment, the Swiss Federal Office for Civil Protection, the Institute for Snow and Avalanche Research and the Swiss Seismological Service. MeteoSwiss warns in all national languages and in English of rain, snow, slippery roads, wind, heat, thunderstorms and ground frost.[95]

Recently, MeteoSwiss started with the exploration and development of impact-based and user-tailored warnings (*MeteoSwiss*, 2021). The former heat warning system was revised and a new heat warning concept was put in place in summer 2021. Heat is considered a serious natural hazard, especially for human health. With the new warning system, the evidence available on the effects of temperature on mortality in Switzerland is taken into account. Threshold values and criteria are based on epidemiological evaluations, making it possible to issue impact-based warnings. On this basis, the authorities, the health system and the population can more effectively be alerted of an impending hot spell.[96] Besides heat warnings, an interdisciplinary and comprehensive programme aimed at redesigning all meteorological warnings currently analyses further ideas concerning impact-based warning concepts. The generation of a comprehensive drought warning system is under discussion.

Water Management

At present, Switzerland abstracts only about seven per cent of its annually sustainably usable groundwater volume for drinking and process water purposes. Thus, water quantity is not the limiting factor in the water management sector. This also holds true if climate changes may turn out to be more severe than today's projections suggest. It is the change in the

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91 *https://www.info.gin.admin.ch/bafu_gin/en/home/gin/uebersicht.html*

92 *https://www.youtube.com/watch?v=e5RHODOfOIc*, *https://www.youtube.com/watch?v=YL9EauScOJ0*, *https://www.youtube.com/watch?v=N_IIXvqjaSw*

93 *https://www.bafu.admin.ch/bafu/de/home/themen/wasser/dossiers/hydrologische-ereignisse.html*; *https://www.bafu.admin.ch/bafu/de/home/themen/naturgefahren/fachinformationen/schaeden-und-lehren-aus-naturereignissen/naturgefahren--ereignisanalysen.html*

94 *https://www.bafu.admin.ch/bafu/en/home/office/lainat-and-gin-secretariats.html*

95 *https://www.meteoswiss.admin.ch/home/weather/gefahren/explanation-of-the-danger-levels.html*

96 *https://www.meteoswiss.admin.ch/home/weather/wetterbegriffe/heat/heat-warnings.html*

hydrological regimes, the rise in water temperature combined with water quality aspects, and the increase of extreme events that need particular attention.

In 2020, in the context of the second climate change adaptation action plan 2020–2025 (*Swiss Confederation*, 2020a), the government also reported on progress of measures related to water management. As stipulated in the revised Federal Act on the Protection of Waters (*Swiss Confederation*, 2021), sufficient space needs to be provided for surface waters in order to safeguard their natural functions in the interest of, inter alia, flood protection and water use. While space shall be provided for all water bodies, it is foreseen to rehabilitate about 25 per cent (4,000 kilometres) of the water courses that are currently in a bad ecological state.

The rehabilitation of water bodies has started but will take several generations for full implementation. In the period from 2011–2019, mainly small watercourses and water bodies on the Central Plateau have been revitalised, with a total of 160 kilometres to date (*FOEN*, 2021a). In addition to the rehabilitation of waters, other water protection measures such as the rehabilitation of hydropower plants or the definition of space provided for waters represent important pillars of water protection policy in Switzerland. Water bodies in a nearly natural state are more resilient to extreme events such as floods and droughts. Therefore, from an ecological as well as from a flood risk management point of view, the rehabilitation of water bodies is a valuable contribution towards adaptation to climate change.

Integrated Water Resources Management (IWRM) aims to achieve cross-sectoral and regional management of water resources. Water bodies are considered as a comprehensive system that needs to be managed at catchment level. This enables efficient and goal-oriented water management with regional coordination, transparent weighing of interests and facilitated setting of priorities (*Water Agenda 21*, 2011; *FOEN*, 2012; *FOEN*, 2013; *Schmid et al.*, 2014).

According to the Federal Constitution, the cantons are responsible for the sustainable management of their water resources. The lessons learned from past droughts have led to about half of the cantons applying IWRM principles or having started to create the necessary planning instruments. Such planning includes the consideration of both the water supply side (e.g. construction of water pipes to interconnect municipalities) and the demand side (e.g. reduction of water consumption through more efficient irrigation technologies or setting priorities among competing water users).

The Swiss Federal Office for the Environment has supported the cantons in applying IWRM by issuing guiding principles (*Water Agenda 21*, 2011; *FOEN*, 2013). In addition, the Office has published three specific modules on drought management (*Dübendorfer et al.*, 2015; *Chaix et al.*, 2016; *Wehse et al.*, 2017), covering the topics of identification of risk areas (module 1), long-term management of water resources (module 2) and management of exceptional situations (module 3). Furthermore, a platform for early detection of and information about droughts has been developed.[97]

When applying IWRM principles, the cantons need to pay special attention to service water for agricultural production. Irrigated areas have considerably increased in the past decade. The Swiss Federal Office for Agriculture promotes and financially supports the application of efficient irrigation technologies. In addition, the use of drought-resistant varieties and water-saving cultivation is promoted in Switzerland's agricultural policy. These efforts need to be intensified in view of the more frequent droughts in the future (see also the section on Agriculture below).

The peak demand of the agriculture sector during dry periods cannot be met by the infrastructure of the public drinking water suppliers, as it is not designed for the required water quantities. In the past, situations arose in several cantons where local water resources were temporarily overused. The supply of service water to agriculture must therefore take place via an infrastructure that is independent of the public drinking water supply. In several cantons, additional infrastructure such as water pipes has been built to facilitate provision of sufficient service water for irrigation.

In recent years, the cantons have made progress in developing regional drinking water supply plans. These aim to prevent or reduce supply bottlenecks through forward-looking water distribution. Important aspects are the interconnection of neighbouring water networks and the extraction of water from hydrogeologically independent aquifers. As a rule, public water suppliers should have a second mainstay in order to have sufficient drinking water available in case of need.

[97] https://www.trockenheit.ch/ (German only)

Thanks to the cantons' efforts, no severe drinking water shortages were reported during the dry spell in 2018 (*FOEN et al.*, 2019). Through the new Ordinance on Securing the Drinking Water Supply in Severe Shortages (*Swiss Confederation*, 2020b) that entered into force on 1 October 2020, the importance of communal, regional and cantonal water supply planning was further emphasised.

In conclusion, Switzerland's main challenges in water management lie in the application of IWRM principles in all cantons in view of the projected seasonal water shortages. Special attention needs to be given to the service water use by the agriculture sector, which must be assured by infrastructure independent from the public drinking water networks.

Biodiversity and Landscape

In parallel to the national strategy on the adaptation to climate change, a national biodiversity strategy (*Swiss Confederation*, 2012) with an accompanying action plan (*Swiss Federal Council*, 2017a) has been elaborated. The measures contained in the biodiversity action plan aim to improve the capacity of biodiversity to adapt to a modest change in climate parameters. With regard to a more pronounced warming scenario, additional measures are presented in the second action plan (2020–2025) of the national adaptation strategy (*Swiss Confederation, 2020a*).

Biodiversity management includes measures to improve the vertical connectivity of habitats across different altitudinal levels as well as risk analyses of the most vulnerable species and ecosystems with regard to climate change. In addition, since biodiversity losses often have an irreversible character, it is important to avoid the impairment of biodiversity by adaptation measures in other sectors (*Swiss Confederation, 2020a*). The measures in the action plan target the most affected ecosystems such as aquatic habitats and alpine areas but also habitat connectivity. Furthermore, the implementation of the national strategy on invasive alien species (*Swiss Federal Council*, 2016) is under way. At the landscape level, the Swiss Landscape Concept (*FOEN*, 2020) defines the framework for the coherent, quality-oriented development of Swiss landscapes. The federal government's landscape policy is based on strategic and landscape quality objectives that are binding for the authorities. Spatial planning principles and sectoral objectives specify these objectives for the various sectoral policies of the federal government.

Agriculture

Adaptation measures in agriculture include, among others, the selection of crop varieties and livestock breeds which perform better under future climatic conditions. Based on the Swiss plant breeding strategy (*FOAG*, 2016), an action plan was drawn up for the main fields of action. It includes a business plan for the establishment of a competence and innovation network and a report on the further development of the portfolio of public breeding programmes.[98] Implementation is to take place within the agricultural policy from 2022 (see section 4.6.5). The conservation and sustainable use of genetic crop diversity is an ongoing task of the Swiss Federal Office for Agriculture. In the period 2019–2022, the sixth funding phase of the National Action Plan for the Conservation of Crop Diversity (NAP-PGREL) was underway.

According to the Swiss animal breeding strategy (*FOAG*, 2018), animal breeding measures should increasingly focus on characteristics such as animal health, environmental impact or resource efficiency. The implications of climate change for animal health and performance are investigated in the broader context of the "One Health" approach.[99] Key research questions have been identified in a preliminary study commissioned by the Swiss Federal Food Safety and Veterinary Office (*SAFOSO*, 2019). The report includes a qualitative assessment of the relevance of climate change for aspects connected to animal production, ranging from forage quality to animal diseases.

Plant protection is also gaining in importance with climate change. The government's action plan for risk reduction and sustainable use of plant protection products (*Swiss Federal Council*, 2017b) stipulates that risks are to be halved and alternatives to chemical crop protection are to be promoted. In the framework of the National Centre for Climate Services, quantitative information has been provided on the proliferation and spread of insect pests under future climatic conditions.[100] It should serve as a basis for the development and implementation of novel crop protection strategies. The Swiss

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[98] For further information, see *https://www.blw.admin.ch/blw/en/home/nachhaltige-produktion/pflanzliche-produktion/pflanzenzuechtung.html*.

[99] *https://en.wikipedia.org/wiki/One_Health*

[100] See *https://www.nccs.admin.ch/nccs/en/home/sectors/agriculture/impacts-pests.html*

Plant Health Network[101] was founded in 2021. Its aim is to better protect the health of cultivated and forest plants in Switzerland against the introduction and spread of new pests and diseases with the help of coordinated communication measures.

Soils play a vital role in climate change adaptation. The 2014–2017 agricultural policy (see section 4.6.5) introduced direct payments (resource efficiency contributions) for minimal soil disturbance. In addition, the provisions on erosion control, which is part of the proof of ecological performance, have been clarified. Further improvements regarding soil protection are planned within the agricultural policy from 2022.

With regard to water use, irrigation efficiency has been included as a criterion in the assessment of irrigation infrastructure projects. Furthermore, higher contributions are granted for the use of resource-saving technologies. Some regional projects under the agricultural resource programme deal with soil protection and irrigation efficiency. These initiatives, for the most part supported by the government, are testing innovative management options on the ground that have the potential for scaling up.

Within the second phase of the pilot programme 'Adaptation to climate change'[102], various projects are supported, inter alia:

- Heat stress in grazing cattle: The goal of this project is to develop a method for early and reliable detection of heat stress in grazing cattle and to evaluate effective strategies for minimizing heat stress;
- Water storage for irrigation: This project seeks a way to meet the increasing water demand of agricultural enterprises. Farmers, fishermen and other stakeholders collect data from selected watercourses with the help of a smartphone app. This data is incorporated into a balance sheet of agricultural water demand and helps to clarify whether and how water deficits could be met with additional local or regional water reservoirs;
- Climate change as an opportunity for agriculture: The project develops a broad-based strategy for climate- and site-adapted production for a valley in the canton of Aargau. The focus is on the question of what opportunities and limits exist for agricultural development under drier climatic conditions;
- Viticulture in the canton of Neuchâtel: This project evaluates the variations of climatic parameters over the course of the year and the corresponding bioclimatic indices relevant to viticulture.

Several measures can be taken on different levels (farm, regional, national) to cope with extreme events like drought. A study was conducted to assess the need for action in relation to risk management measures (*Rohrer and Tombez*, 2019). The study concluded that in principle suitable agricultural insurance products are available in Switzerland. However, market penetration is low, especially for large-scale risks that can affect many actors simultaneously. Based on this, as part of the agricultural policy from 2022, it was proposed to create the legal basis for the federal government to co-finance crop insurance premiums. With regard to the resilience of agriculture and the food system to climate change, initial studies have been supported (e.g., *Monastyrnaya*, 2020).

Forests and forestry

The Swiss Federal Council's adaptation strategy (*Swiss Confederation*, 2012a) with its action plan 2020–2025 (*Swiss Confederation, 2020a*) as well as the Forest Policy with its action plan 2021–2024 (*FOEN*, 2021b) focus on three forest categories which are considered to be at high risk due to climate change. These are (i) protective forests with insufficient regeneration and reduced stability (covering approximately 68,000 hectares), (ii) forests with a high percentage of conifers in the Swiss lowlands which are susceptible to drought, wind throw and bark beetle infestations (covering approximately 50,000 hectares), and (iii) climate-sensitive forests in the Central Alps and other parts of Switzerland which are especially drought prone or sites with large amounts of dry wood in areas at risk from forest fires, e.g. in Ticino, Valais or Grisons (covering roughly 50,000 hectares) (*Brändli* et al., 2020). The aim is to avoid that forest functions and services can no longer be fulfilled.

[101] *https://www.blw.admin.ch/blw/en/home/nachhaltige-produktion/Pflanzengesundheit/ihrbeitrag/netzwerk.html*

[102] *https://www.nccs.admin.ch/nccs/en/home/measures/pak.html*

Adaptation measures focus on taking care of the young forest stands, aiming at the reduction of future risks and increasing the adaptive capacity of forests, e.g. through appropriate and sufficient regeneration. This includes the promotion of tree species with potentially high adaptive capacity with a view to possible future climates. These measures are implemented by public and private forest owners, with the technical and financial support from the federal government as well as the cantons (regulated in the Environmental Programme Agreement 2020–2024, *FOEN*, 2018b). A web-based tool[103] provides technical guidance for the most climate-fit tree species on a specific forest location. In addition, the Swiss Federal Office for the Environment and the cantons support a scientific demonstration project with over 55,000 tree plants.[104] The project is being carried out by the Swiss Federal Institute for Forest, Snow and Landscape Research with experimental plantations at 59 sites in Switzerland. In the process, 18 different tree species from 7 different provenances are subjected to a long-term test.

Energy and Transport

Energy supply and demand in Switzerland are affected by climate change in multiple ways. Regarding the generation of electricity from hydropower, the following climate change adaptation goals have been defined (*Swiss Confederation*, 2012a):

- Ensuring the contribution of hydropower to maintaining the security of electricity supply;
- Making optimal use of hydropower potential under changing hydrological and water management conditions through increased cooperation between industry players;
- Where necessary, monitoring of new climate-related security risks (e.g. due to thawing of permafrost).

The second action plan implementing Switzerland's adaptation strategy (*Swiss Confederation, 2020a*) reiterates the importance of the energy sector. The two main fields of action identified as the most relevant for climate change adaptation in the energy sector are (i) energy demand for air conditioning and cooling of buildings and (ii) generation of electricity from hydropower. Within these fields of action, several adaptation measures have already been implemented or are being planned at the national level, e.g.:

- Studies and information campaigns on measures to maintain comfortable indoor temperatures in buildings in a warmer climate while reducing energy demand for cooling. Amongst other initiatives, a study was commissioned (*HSLU*, 2021) and recommendations for building developers, architects and planners were published. Likewise, options for efficient cooling of office and commercial space were assessed (*SwissEnergy*, 2019) and a brochure was prepared for the target audience;
- Consideration of the changing climate in the monitoring of dams and reservoirs and provision of information and study results on the impact of climate change on hydropower.[105]

Both land-based and water-based transport are subject to temporal disruptions during extreme weather events. Due to its great importance for the transport of bulk goods, special attention is paid to navigation on the river Rhine. Around nine per cent of Switzerland's foreign trade volume – 6 million tonnes of goods in 2019 – are transported on the Rhine from Rotterdam (Netherlands) to the Swiss border port at Basel. Due to extremely low water levels in 2018, the volume of goods handled in the port of Basel was 19 per cent below the previous year (*FOEN et al.*, 2019). In the future, navigation might be increasingly affected by more frequent low water levels and higher winter discharges. In 2019, the Rhine channel in Basel was deepened to enable navigation during extreme low water level conditions.

Health

Climate change poses similar risks to human and animal health and requires similar measures to minimise these risks. This is why the Swiss adaptation strategy deals with the impacts of climate change on both, humans and animals. The focus is put on three fields of action requiring adaptation to climate change:

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103 *www.tree-app.ch* (German and French)

104 *https://www.wsl.ch/en/projects/experimental-plantations-of-tree-species.html*

105 See *https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/research-programmes/hydropower.html* for research priorities.

- Effects of heat (humans and animals): Hot days and heat waves can lead to cardiovascular conditions, dehydration, overheating, impaired performance, mental disorders and even to death. Summer heat increases ozone levels, which causes respiratory ailments and impairs lung function;
- Foodborne and waterborne diseases (humans): Infectious germs in water and food, in particular in dairy and meat products, thrive at higher temperatures;
- Vector-borne diseases (humans and animals): Climate change affects the emergence and re-emergence of vector-borne disease transmission and distribution as both pathogens and vectors depend on ambient temperature.

The fields of action listed above are addressed with the following adaptation measures:

- Updating the recommendations to health care services and the public on adequate behaviour during heat waves on the basis of new scientific results[106], fostering synergies between actors, coordinating actions among federal offices; periodic dialogue between experts from administration and science, evaluating the effectiveness of adaptation strategies;
- Informing employers and employees about heat-related health effects, errors, aggression and violence at workplaces (e.g. *SECO*, 2020);
- Improving and coordinating monitoring systems for vector-borne diseases, potential vectors, and infectious animal diseases; notification of selected infectious diseases based on the Federal Act on Controlling Communicable Human Diseases (*Swiss Confederation*, 2021a). Through the Swiss Mosquito Network[107], the Swiss Federal Office for Environment coordinates the surveillance of invasive *Aedes* mosquitoes across the cantons and runs a national surveillance programme (*Müller et al.*, 2020). Other vectors and the circulation of pathogens in vectors are not yet routinely monitored in Switzerland but were subject to several research projects (e.g. *Wipf et al.*, 2019; *Kaufmann et al.*, 2012; *Lommano et al.*, 2014).

Since the hot summer of 2003, the federal and cantonal authorities have taken measures to inform the population about expected heatwaves and about protective measures. For example, a heat protection toolkit aimed at professionals and authorities was developed in 2017 and updated in 2021. This toolbox contains concrete tips and makes visible what other actors (especially in the health sector) have already implemented (*Ragettli and Röösli*, 2021a) (for recent improvements to the public heat warning system see the section above on Weather hazard alerts).

Various studies in Switzerland and abroad indicate that public health measures such as cantonal heat action plans have contributed to a decrease in heat-related mortality. In Switzerland, heat-associated excess mortality was significantly lower in 2018 and 2019 compared to the warmest summers to date (2003 and 2015) (*Ragettli and Röösli*, 2021b; *Ragettli and Röösli*, 2020). From a meteorological perspective, the summers of 2018 and 2019 were only slightly less warm. This indicates successful measures by the authorities, including increased public awareness of heat-related health risks. However, the effectiveness of the various adaptation measures requires further assessment.

No additional measures are planned for food- and water-borne diseases. The existing measures, i.e. water treatment and food control, are expected to be effective in dealing with a potential increase of the risk for these diseases due to climate change.

Measures in the area of urban planning can also contribute to reducing the health impacts by reducing heat stress. Preventing the creation or reducing the magnitude of urban heat islands renders better living and working conditions for the population. Suitable measures include the unsealing of paved areas, the preservation and development of green areas and water bodies, the protection and promotion of urban trees, increased shading, the preservation of fresh air corridors and the use of heat-reducing building materials.

In recent years, numerous projects and analyses have been carried out in this area by the federal government, the cantons and the municipalities. At the national level, an extensive study on how to handle heat stress in cities (*FOEN and ARE*, 2018) was published in 2018. The current phase of the pilot programme 'Adaptation to climate change' (see section 6.4.2)

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[106] See the dedicated web page *http://www.hitzewelle.ch* / *http://www.canicule.ch*.

[107] *https://www.zanzare-svizzera.ch/en/home_en/*

includes 15 projects that deal with heat stress. Furthermore, many Swiss cantons and cities (among others Geneva, Basel, Zurich and Aargau) are making extensive efforts to address the exacerbation of heat stress in urban areas.

Tourism

In 2021, the Swiss government adopted a new tourism strategy (*Swiss Federal Council*, 2021). With this strategy, contributing to sustainability became an explicit goal of tourism policy, and adaptation to climate change is considered one of the key challenges for Switzerland as a tourist destination.

Based on the main impacts of climate change on Swiss tourism (*Lehmann Friedli*, 2011), three key fields of action requiring adaptation to climate change were identified in 2012 in the national adaptation strategy (*Swiss Confederation*, 2012a). These fields of action are (i) the development of the tourism offer, (ii) hazard minimisation, and (iii) communication. Adaptation efforts should help Switzerland to remain an attractive and successful tourist destination and to exploit its exceptional potential as a travel destination in the long term.

A coordinated approach to adapting tourism to climate change is essential. The federal tourism policy developed in the State Secretariat for Economic Affairs therefore relies on continued, structured cooperation with the Swiss Federal Office for the Environment in implementing the measures set out in the national adaptation action plan 2020–2025 (*Swiss Confederation*, 2020a). Adaptation measures include the repositioning of summer tourism and the safeguarding and development of winter sports. Through its funding instruments, tourism policy supports the development of new offers and diversification in Swiss tourism. The promotion of summer, autumn and year-round tourism plays an important role. At the same time, snow sports are also promoted and further developed, for instance through the Swiss Snowsports Initiative.[108]

Other adaptation measures address the information and knowledge gaps related to climate change adaptation and tourism. For example, as part of the Tourism Forum Switzerland 2021, which was dedicated to the topic of sustainability, a workshop was held on the strategic options for climate neutrality in Swiss tourism. Climate change experts discussed with tourism stakeholders, raising awareness of the issue among a wider audience. In addition, the Swiss State Secretariat for Economic Affairs plans to develop a knowledge base on the effects of climate change. Particular attention will be paid to the rising snowline, to other framework conditions that are changing with the climate and to the future prospects for skiing and snow sports areas.

6.7 Implementation of Article 4, paragraph 1(b) and (e), of the Convention

In relation to action taken to implement Article 4, paragraph 1(b) and (e), of the Convention with regard to adaptation, support of developing countries is an essential part of bilateral programmes and projects implemented through Switzerland’s climate change cooperation. The aim is to assist countries in reducing their vulnerability to the unavoidable and increasing consequences of climate change while giving particular attention to the social and economic costs of the adverse effects of climate change. Information on such initiatives is reported in chapter 7, in particular under the heading ‘Adaptation’ (see section 7.1.3). There, several examples of support to developing countries in adapting to climate change, including support through cooperative action, are highlighted.

[108] https://gosnow.ch/ (German and French)

References

Abegg, B. et al., 2007: Climate Change Impacts and Adaptation in Winter Tourism. In: OECD (2007): Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management, Organisation for Economic Co-operation and Development, Paris, p. 25–60. *http://dx.doi.org/10.1787/9789264031692-en* [18.07.2022]

Agroscope, 2018: Klimaerwärmung bremst Gemüseschädling. Press Release. Wädenswil, 10.04.2018. *https://www.admin.ch/gov/de/start/dokumentation/medienmitteilungen.msg-id-70369.html* [18.07.2022]

Altermatt, F., 2010: Climatic warming increases voltinism in European butterflies and moths. In: Proceedings of the Royal Society B: Biological Sciences, 277, p. 1281–1287. *http://rspb.royalsocietypublishing.org/content/royprsb/early/2009/12/18/rspb.2009.1910.full.pdf* [18.07.2022]

Altermatt, F., Seymour, M., Martinez, N., 2013: River network properties shape α-diversity and community similarity patterns of aquatic insect communities across major drainage basins. Journal of Biogeography, 40(12): 2249–2260. *https://doi.org/10.1111/jbi.12178* [18.07.2022]

Arend, M. et al., 2016: Ökophysiologie: Reaktionen von Waldbäumen auf Klimaänderungen. In: Plüss, A.R., Augustin, S., Brang, P. (Red.): Wald im Klimawandel. Grundlagen für Adaptationsstrategien. Haupt (Bern, Stuttgart, Wien). pp.77-91. [hardcopy]

Arend, M. et al., 2021: Rapid hydraulic collapse as cause of drought-induced mortality in conifers. PNAS 2021 Vol. 118. *https://doi.org/10.1073/pnas.2025251118* [18.07.2022]

Asher, M. et al., 2006: Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC Phases One and Three repeat multicountry cross-sectional surveys. The Lancet, Volume 368, Issue 9537, 733–43. *https ://www.sciencedirect.com/science/article/pii/S0140673606692830* [18.07.2022]

AUE, 2017: Bericht über den Umsetzungsstand der Massnahmen zur Anpassung an den Klimawandel im Kanton Basel-Stadt. Amt für Umwelt und Energie, Basel-Stadt. *https://www.bs.ch/dam/jcr:04d28f69-1aca-4e1c-bdce-d29664aeb5bc/Klimafolgenbericht-Umsetzungsstand-Massnahmen-2017.pdf* [18.07.2022]

Ballmer-Weber, B.K. and Helbing, A., 2017: Rhinite allergique. Un mal du 20e siècle. Swiss Medical Forum, 17 (2017), pp. 179-186 (also available in German). DOI: *https://doi.org/10.4414/fms.2017.02897* [18.07.2022]

Bandi, M., 2021: Klimawandel: Strategische Optionen für den Tourismus 2030. unpublished manuscript.

Bergamini A., Ginzler C., Schmidt B.R. et al., 2019: Resultate der Wirkungskontrolle Biotopschutz – Kurzfassung. Swiss Federal Office for the Environment, Bern. *https://www.wsl.ch/fileadmin/user_upload/WSL/Publikationen/Kurzfassung_WBS_2019.pdf* [18.07.2022]

Bjerg, A. et al., 2011: Increased Prevalence of Symptoms of Rhinitis but Not of Asthma between 1990 and 2008 in Swedish Adults: Comparisons of the ECRHS and GA2LEN Surveys. PLOS ONE, Volume 6, Issue 2, e16082. *https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0016082* [18.07.2022]

Blöschl, G., Kiss, A., Viglione, A. et al., 2020: Current European flood-rich period exceptional compared with past 500 years. Nature, 583(7817), 560–566. *https://doi.org/10.1038/s41586-020-2478-3* [18.07.2022]

Boesch, H.-J. et al., 2015: Evaluation der Anpassung an den Klimawandel, Evaluationsgegenstände Konzept, Umsetzung und Output. Ernst Basler and Partner, Zurich (mandated by the Swiss Federal Office for the Environment, Bern). 71 pp. [internal/confidential]

Borrelli, B. et al., 2020: Land use and climate change impacts on global soil erosion by water (2015–2070). PNAS, 117(36), 21994–22001. *www.pnas.org/cgi/doi/10.1073/pnas.2001403117* [18.07.2022]

Bousquet, J. et al., 2009: GA²LEN (Global Allergy and Asthma European Network) addresses the allergy and asthma 'epidemic'. Allergy, Volume 64, Issue 7, July 2009, pp. 969–997. *https://doi.org/10.1111/j.1398-9995.2009.02059.x* [18.07.2022]

Brändli, U.-B., Abegg, M. and Allgaier Leuch, B. (Red.), 2020: Schweizerisches Landesforstinventar – Ergebnisse der vierten Erhebung 2009–2017. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Swiss Federal Office for the Environment, Bern. *https://lfi.ch/publikationen/publ/ergebnisberichte/LFI4_Ergebnisbericht.pdf* [18.07.2022]

Braun, S. et al., 2017: Growth trends of beech and Norway spruce in Switzerland: The role of nitrogen deposition, ozone, mineral nutrition and climate. Science of the Total Environment 599–600. *https://doi.org/10.1016/j.scitotenv.2017.04.230* [18.07.2022]

Braun, S. et al., 2021: 37 Years of Forest Monitoring in Switzerland: Drought Effects on Fagus sylvatica. Front. For. Glob. Change 4:765-782. *https://dx.doi.org/10.3389/ffgc.2021.765782* [18.07.2022]

Braun-Fahrländer, C. et al., 2004: No further increase in asthma, hay fever and atopic sensitisation in adolescents living in Switzerland. European Respiratory Journal 2004 23: 407-413. *https://erj.ersjournals.com/content/23/3/407* [18.07.2022]

Brogli, R. et al., 2019: The Role of Hadley Circulation and Lapse-Rate Changes for the Future European Summer Climate. Journal of Climate, 32 385–404. *https://journals.ametsoc.org/downloadpdf/journals/clim/32/2/jcli-d-18-0431.1.xml* [18.07.2022]

Brönnimann, S., Rohr, C., Stucki, P. et al., 2018: 1868 – the flood that changed Switzerland. Causes, consequences and lessons for the future. Geographica Bernensia G94: 52. *http://dx.doi.org/10.4480/GB2018.G94.04* [18.07.2022]

Brunner, M. et al., 2019a: Welchen Beitrag leisten Mehrzweckspeicher zur Verminderung zukünftiger Wasserknappheit? On behalf of the Swiss Federal Office for the Environment, Bern. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/hydrologie/externe-studienberichte/Mehrzweckspeicher-Verminderung-Wasserknappheit.pdf* [18.07.2022]

Brunner, M. et al., 2019b: Present and Future Water Scarcity in Switzerland: Potential for Alleviation through Reservoirs and Lakes. Science of The Total Environment, 666. *https://www.sciencedirect.com/science/article/pii/S0048969719306576* [18.07.2022]

Bundo, M. et al., 2021: Ambient temperature and mental health hospitalizations in Bern, Switzerland: A 45-year time-series study. PLoS ONE 16(10). *https://doi.org/10.1371/journal.pone.0258302* [18.07.2022]

Burgstall, A. et al., 2021: Urban multi-model climate projections of intense heat in Switzerland. Climate Services (22), *https://www.sciencedirect.com/science/article/pii/S2405880721000169* [18.07.2022]

Buzzi, F. et al., 2021: Maize Cultivation: Maps of Accumulated Temperatures Support the Choice of Varieties. Swiss Agricultural Research 12, 1–8. *https://www.agrarforschungschweiz.ch/en/2021/01/maize-cultivation-maps-of-accumulated-temperatures-support-the-choice-of-varieties/* [18.07.2022]

CH2018, 2018: CH2018 – Climate Scenarios for Switzerland, Technical Report. National Centre for Climate Services (NCCS), Zurich. 271. ISBN: 978-3-9525031-4-0. *https://www.nccs.admin.ch/nccs/de/home/klimawandel-und-auswirkungen/schweizer-klimaszenarien/technical-report.html* [18.07.2022]

Chaix, O. et al., 2016: Bestimmung von Regionen mit Handlungsbedarf bei Trockenheit. Expertenbericht zum Umgang mit lokaler Wasserknappheit in der Schweiz (mandated by the Swiss Federal Office for the Environment, Bern). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/wasser/externe-studien-berichte/bestimmung_von_regionenmithandlungsbedarfbeitrockenheit.pdf* [18.07.2022]

Dauphin, B. et al., 2020: Genomic vulnerability to rapid climate warming in a tree species with a long generation time. Global Change Biology, 27, 6: 1181–1195. *https://www.dora.lib4ri.ch/wsl/islandora/object/wsl:25945* [18.07.2022]

Delarze, R., Eggenberg, S., Steiger, P. et al., 2016: Rote Liste der Lebensräume der Schweiz. Aktualisierte Kurzfassung zum technischen Bericht 2013 im Auftrag des Bundesamtes für Umwelt (BAFU), Bern: 33 S. *https://www.infoflora.ch/de/assets/content/documents/download/CH_RL_Lebensraeume_2017_v171130.pdf* [18.07.2022]

Dobbertin, M., 2005: Tree growth as indicator of tree vitality and of tree reaction to environmental stress: a review. Europ. J. of Forest Research 124: p. 319–333. *https://link.springer.com/article/10.1007/s10342-005-0085-3* [18.07.2022]

Dübendorfer, C. et al., 2015: Umgang mit Wasserressourcen in Ausnahmesituationen. Expertenbericht zum Umgang mit lokaler Wasserknappheit in der Schweiz. Ernst Basler und Partner, Zollikon / RWB Jura SA, Porrentruy (mandated by the Swiss Federal Office for the Environment). *https://tinyurl.com/Dueben15* [18.07.2022]

EBP and FOCP, 2021a: Auswirkungen des Klimawandels auf den Bevölkerungsschutz in der Schweiz. Projektdokumentation. EBP AG, Zürich, Swiss Federal Office for Civil Protection, Bern. *https://bit.ly/3zpscnM* [18.07.2022]

EBP and FOCP, 2021b: Was der Klimawandel für den Schweizer Bevölkerungsschutz bedeutet. EBP AG, Zürich, Swiss Federal Office for Civil Protection, Bern (also available in French). *https://tinyurl.com/EBPFOCP21b* [18.07.2022]

EBP, 2019: Trockenheit im Sommer und Herbst 2018 – Auswirkungen und deren Bewältigung in der Schweizer Wasserwirtschaft. EBP Schweiz AG. Mandated by the Swiss Federal Office for the Environment, Bern. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/wasser/externe-studien-berichte/Trockenheit_im_Sommer_und_Herbst_2018.pdf* [18.07.2022]

Eilmann, B. et al., 2011: Drought alters timing, quantity, and quality of wood formation in Scots pine. Journal of Experimental Botany, p. 1–9. *https://academic.oup.com/jxb/article/62/8/2763/474373* [18.07.2022]

Eisenring, S., Holzkaemper, A. and P. Calanca, 2021: Berechnung der Bewässerungsbedürfnisse unter aktuellen und zukünftigen Bedingungen in der Schweiz. Agroscope Science, 107, 2021, 1–55. *https://www.agrarforschungschweiz.ch/wp-content/uploads/2021/11/47710-50912-de-pub.pdf* [18.07.2022]

Etzold, S. et al., 2016: Mortalität von Waldbäumen: Ursachen und Trends. In: Plüss, A.R., Augustin, S., Brang, P. (Red.): Wald im Klimawandel. Grundlagen für Adaptationsstrategien. Haupt (Bern, Stuttgart, Wien). pp.177-196. [hardcopy]

Everall, N.C. et al., 2015: Detecting phenology change in the mayfly Ephemera danica: responses to spatial and temporal water temperature variations. Ecological Entomology, 40(2): 95–105. *https://doi.org/10.1111/een.12164* [18.07.2022]

Figura, S. et al., 2013: Klima und Grundwasser – Rückblicke und Vorhersagen von Temperatur und Sauerstoff mittels historischer Aufzeichnungen. Aqua & Gas, No. 7/8. *https://tinyurl.com/Figura13* [18.07.2022]

Fischer, M. et al., 2015: Surface elevation and mass changes of all Swiss glaciers 1980–2010. The Cryosphere, 2(2): 525–540. *https://doi.org/10.5194/tc-9-525-2015* [18.07.2022]

FOAG, 2016: Strategy for Plant Breeding 2050. Swiss Federal Office for Agriculture, Bern. *https://www.blw.admin.ch/dam/blw/en/dokumente/Nachhaltige%20Produktion/Pflanzliche%20Produktion/Pflanzenzuechtung/Z%C3%BCchtungsstrategie.pdf* [18.07.2022]

FOAG, 2018: Strategie Tierzucht 2030. Swiss Federal Office for Agriculture, Bern. *https://www.newsd.admin.ch/newsd/message/attachments/52496.pdf* [18.07.2022]

FOCP, 2013: Leitfaden KATAPLAN – Grundlage für kantonale Gefährdungsanalysen und Vorsorge. Swiss Federal Office for Civil Protection, Bern. *http://www.babs.admin.ch/de/aufgabenbabs/gefaehrdrisiken/ktgefanalyse.html* [18.07.2022]

FOEN and ARE, 2018: Hitze in Städten. Grundlage für eine klimaangepasste Siedlungsentwicklung. Umwelt-Wissen, Nr. 1812. Swiss Federal Office for the Environment, Bern, and Swiss Federal Office for Spatial Development, Bern (also available in French). *www.bafu.admin.ch/uw-1812-d* [18.07.2022]

FOEN and ARE, 2019: Risikobasierte Raumplanung. Risiken abwägen: Instrumente, Chancen und Erfahrungen aus Sicht von Kantonen, Gemeinden, Raumplanern und Architekten (also available in French). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/naturgefahren/externe-studien-berichte/risikobasierte-raumplanung.pdf* [18.07.2022]

FOEN and ARE, 2022: Regenwasser im Siedlungsraum. Starkniederschlag und Regenwasserbewirtschaftung in der klimaangepassten Siedlungsentwicklung. Umwelt-Wissen, UW-2201-D. Swiss Federal Office for the Environment, Bern / Swiss Federal Office for Spatial Development, Bern. *www.bafu.admin.ch/uw-2201-d* [18.07.2022]

FOEN et al., 2019: Hitze und Trockenheit im Sommer 2018. Auswirkungen auf Mensch und Umwelt. Umwelt-Zustand Nr. 1909. Swiss Federal Office for the Environment, Bern (available in German, French and Italian). *www.bafu.admin.ch/uz-1909-d* [18.07.2022]

FOEN, 2012: Einzugsgebietsmanagement. Anleitung für die Praxis zur integralen Bewirtschaftung des Wassers in der Schweiz. Umwelt-Wissen Nr. 1204. Swiss Federal Office for the Environment, Bern (also available in French). *www.bafu.admin.ch/uw-1204-d* [18.07.2022]

FOEN, 2013: Koordination wasserwirtschaftlicher Vorhaben. Die Abstimmung wasserwirtschaftlicher Vorhaben in und zwischen den Bereichen, den Staatsebenen und im Einzugsgebiet. Ein Modul der Vollzugshilfe Renaturierung der Gewässer. Umwelt-Vollzug Nr. 131. Swiss Federal Office for the Environment, Bern (also available in French). *www.bafu.admin.ch/uv-1311-d* [18.07.2022]

FOEN, 2015: Stand der Umsetzung bei der Anpassung an den Klimawandel, Fortschrittsbericht. Swiss Federal Office for the Environment, Bern. 107 pp, 30.11.2015. [internal/confidential]

FOEN, 2016: Hitze und Trockenheit im Sommer 2015. Auswirkungen auf Mensch und Umwelt. Umwelt-Zustand Nr. 1629. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/uz-1629-d* [18.07.2022]

FOEN, 2017: Impulse für eine klimaangepasste Schweiz – Erkenntnisse aus 31 Pilotprojekten zur Anpassung an den Klimawandel. Swiss Federal Office for the Environment, Bern (also available in French). *http://www.bafu.admin.ch/ui-1703-d* [18.07.2022]

FOEN, 2017a: Klimabedingte Risiken und Chancen. Eine schweizweite Synthese. Swiss Federal Office for the Environment, Bern (also available in French). *http://www.bafu.admin.ch/uw-1706-d* [18.07.2022]

FOEN, 2017b: Biodiversity in Switzerland: Status and Trends. Results of the biodiversity monitoring system in 2016. State of the environment no. 1630. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/uz-1630-e* [18.07.2022]

FOEN, 2018a: Climate-related risks and opportunities. A synthesis for Switzerland – short version. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/uw-1706-e* [18.07.2022]

FOEN, 2018b: Handbuch Programmvereinbarungen im Umweltbereich 2020 – 2024. Mitteilung des BAFU als Vollzugsbehörde an Gesuchsteller. Umwelt-Vollzug Nr. 1817. Swiss Federal Office for the Environment, Bern (also available in French). *www.bafu.admin.ch/uv-1817-d* [18.07.2022]

FOEN, 2019: Liste der National Prioritären Arten und Lebensräume. In der Schweiz zu fördernde prioritäre Arten und Lebensräume. Umwelt-Vollzug Nr. 1709. Swiss Federal Office for the Environment, Bern (also available in French). *www.bafu.admin.ch/uv-1709-d* [18.07.2022]

FOEN, 2020: Swiss Landscape Concept. Landscape and nature in federal policy areas. Environment Information Nr. 2011. Swiss Federal Office for the Environment, Bern. *http://www.bafu.admin.ch/ui-2011-e* [18.07.2022]

FOEN, 2020a: Effects of climate change abroad – risks and opportunities for Switzerland. Swiss Federal Office for the Environment, Bern. *http://www.bafu.admin.ch/ui-2002-e* [18.07.2021]

FOEN, 2021: Effects of climate change on Swiss water bodies. Hydrology, water ecology and water management. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/uw-2101-e* [18.07.2021]

FOEN, 2021a: Renaturierung der Schweizer Gewässer. Stand Umsetzung Revitalisierungen 2011–2019. Swiss Federal Office for the Environment, Bern (also available in French). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/wasser/fachinfo-daten/bericht_umsetzung_revitalisierung.pdf* [18.07.2022]

FOEN, 2021b: Forest Policy: Objectives and measures 2021–2024. For the sustainable management of forests in Switzerland. First revised edition 2021. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/ui-2119-e* [18.07.2022]

FOEN, MeteoSwiss, NCCS, 2020a: Klimawandel in der Schweiz. Indikatoren zu Ursachen, Auswirkungen, Massnahmen. Umwelt-Zustand Nr. 2013. Swiss Federal Office for the Environment, Bern (also available in French). *www.bafu.admin.ch/uz-2013-d* [18.07.2022]

FOEN, MeteoSwiss, NCCS, 2020b: Management summary: Climate change in Switzerland. Indicators of driving forces, impact and response. State of the environment no. 2013. Swiss Federal Office for the Environment, Bern. *www.bafu.admin.ch/uz-2013-e* [18.07.2022]

Forzieri, G. et al., 2018: Escalating impacts of climate extremes on critical infrastructures in Europe, Global Environmental Change 48, 97-107. *https://www.sciencedirect.com/science/article/pii/S0959378017304077/pdfft?isDTMRedir=true&download=true* [18.07.2022]

Frehner, M. et al., 2018: Standortkundliche Grundlagen für die Waldbewirtschaftung im Klimawandel. WSL Berichte, 66. 49 p. *https://www.dora.lib4ri.ch/wsl/islandora/object/wsl%3A17218/datastream/PDF/view* [18.07.2022]

Freiburghaus, M., 2015: Wasserverbrauch. Sinkender Wasserabsatz im Schweizer Haushalt. Aqua & Gas, Nr. 3, 2015. *http://wasserqualitaet.svgw.ch/fileadmin/resources/svgw/web/Aktuell-Actualite/WV_Verbracuh_pers.pdf* [18.07.2022]

Gehrig, R. and Clot, B., 2021: 50 Year of Pollen Monitoring in Basel (Switzerland) Demonstrate the Influence of Climate Change on Airborne Pollen. Front. Allergy 2:677159. *https://www.frontiersin.org/articles/10.3389/falgy.2021.677159/full* [18.07.2022]

Gehrig-Fasel, J. et al., 2007: Tree line shifts in the Swiss Alps: Climate change or land abandonment? Journal of Vegetation Science, 18, 571–582. *http://www.wsl.ch/staff/niklaus.zimmermann/papers/JVegSci_Gehrig_2007.pdf* [18.07.2022]

geo7, 2020: Naturgefahren und Klimawandel in der Schweiz. Stand des Wissens. Report mandated by the Swiss Federal Office for the Environment. *https://geo7.ch/site/assets/files/2234/geo7_bericht_ng_klima_schweiz.pdf* [18.07.2022]

Glick et al., 2021: Multi-decade changes in pollen season onset, duration, and intensity: A concern for public health? Science of The Total Environment, Volume 781, 146382. *https://doi.org/10.1016/j.scitotenv.2021.146382* [18.07.2022]

Grize, L. et al., 2005: Heat wave 2003 and mortality in Switzerland. Swiss Medical Weekly 2005, 135, 200–205. *https://www4.ti.ch/fileadmin/DSS/DSP/GOSA/documenti/smw2005-135-200-205.pdf* [18.07.2022]

Grize, L. et al., 2006: Trends in prevalence of asthma, allergic rhinitis and atopic dermatitis in 5–7-year old Swiss children from 1992 to 2001. Allergy, Volume 61, Issue 5, May 2006. *https://doi.org/10.1111/j.1398-9995.2006.01030.x* [18.07.2022]

Grünig, M. et al., 2020a: Crop and forest pest metawebs shift towards increased linkage and suitability overlap under climate change. Communications biology, 3(1), 1–10. *https://doi.org/10.1038/s42003-020-0962-9* [18.07.2022]

Grünig, M. et al., 2020b: Inflection point in climatic suitability of insect pest species in Europe suggests non-linear responses to climate change. Global Change Biology. *https://doi.org/10.1111/gcb.15313* [18.07.2022]

Guntern, J., 2016: Klimawandel und Biodiversität. Auswirkungen und mögliche Stossrichtungen für Massnahmen im Kanton Zürich (im Auftrag der Fachstelle Naturschutz). Forum Biodiversität Schweiz *https://www.zh.ch/mcs3redirect/1-71538477948-Uo-wEQGcX2DRcKo2vqFPi1kI4mY=* [18.07.2022]

Gurtner, D. et al., 2015: Der Götterbaum dringt in die Wälder nördlich der Alpen vor. Wald Holz 7: 22–24. *https://www.waldwissen.net/assets/waldwirtschaft/schaden/invasive/wsl_goetterbaum_verbreitung_schweiz/download/wsl_goetterbaum_verbreitung_schweiz_originalartikel.pdf.pdf* [18.07.2022]

Haeberli, W., Paul, F. and Zemp, M., 2013: Vanishing Glaciers in the European Alps. Pontifical Academy of Sciences, Scripta Varia 118. *http://www.geo.uzh.ch/~mzemp/Docs/Haeberli_etal_PASSV_2013.pdf* [18.07.2022]

Hari, R.E. et al., 2005: Consequences of climatic change for water temperature and brown trout populations in Alpine rivers and streams. Global Change Biology, 2(1) *https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2005.001051.x* [18.07.2022]

Hasler, A., 2011: Thermal conditions and kinematics of steep bedrock permafrost (PhD thesis, University of Zurich). Zurich, Switzerland. *https://doi.org/10.5167/uzh-59731* [18.07.2022]

Haughey E. et al., 2018: Higher species richness enhances yield stability in intensively managed grasslands with experimental disturbance. Scientific Reports, 8:15047, *https://www.nature.com/articles/s41598-018-33262-9* [18.07.2022]

Heer, N., 2021: BDM dokumentiert Klimawandel vor unserer Haustür. Hotspot – Die Zeitschrift des Forums Biodiversität Schweiz. 44 (2021), p.28. *https://tinyurl.com/Heer21* [18.07.2022]

Hendricks Franssen H.-J. and Scherrer S.C., 2008: Freezing of lakes on the Swiss Plateau in the period 1901–2006. International Journal of Climatology, 28(4): 421–433. *https://doi.org/10.1002/joc.1553* [18.07.2022]

Holderegger, R. and Segelbacher, G., 2016: Naturschutzgenetik. Ein Handbuch für die Praxis. Haupt, Bern, 247p. [hardcopy]

Holthausen, N. et al., 2013: Risiken und Chancen des Klimawandels in der Schweiz, Methodenbericht. Ernst Basler + Partner, Zollikon / Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf / Institute for Snow and Avalanche Research, Davos (mandated by the Swiss Federal Office for the Environment, Bern). 49 pp. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/externe-studien-berichte/risiken_und_chancendesklimawandelsinderschweiz.pdf* [18.07.2022]

Holzkämper, A., 2020: Varietal adaptations matter for agricultural water use – a simulation study on grain maize in Western Switzerland. Agricultural Water Management 237, 106202. *https://doi.org/10.1016/j.agwat.2020.106202* [18.07.2022]

HSLU, 2021: Bereit für den Klimawandel? Handlungsempfehlungen für Bauherrschaften und Planende. Lucerne University of Applied Sciences and Arts HSLU, Luzern. *https://zenodo.org/record/5639295/files/202103%20Klimawandel%20-%20Handlungsempfehlungen%20f%C3%BCr%20Bauherrschaften%20und%20Planende.pdf* [18.07.2022]

Huggel, C. et al., 2012: Ice thawing, mountains falling – are alpine rock slope failures increasing? Geol. Today 28, p. 98–104. *http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2451.2012.00836.x/abstract* [18.07.2022]

Huggel, C., 2009: Recent extreme slope failures in glacial environments: effects of thermal perturbation. Quaternary Science Reviews 28: p. 1119–1130. *https://doi.org/10.1016/j.quascirev.2008.06.007* [18.07.2022]

Huovinen, E. et al., 1999: Incidence and Prevalence of Asthma Among Adult Finnish Men and Women of the Finnish Twin Cohort From 1975 to 1990, and Their Relation to Hay Fever and Chronic Bronchitis. Chest*,* volume 115, Issue 4, pp 928-936. *https://doi.org/10.1378/chest.115.4.928* [18.07.2022]

Huss, M. and Fischer, M., 2016: Sensitivity of Very Small Glaciers in the Swiss Alps to Future Climate Change. Frontiers in Earth Science 4:34. *https://www.frontiersin.org/articles/10.3389/feart.2016.00034/full* [18.07.2022]

IPBES, 2018: Summary for policy makers of the IPBES assessment report on land degradation and restoration. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services IPBES. Bonn, Germany. *https://www.fs.fed.us/research/publications/misc/94550_2018_scholes.pdf* [18.07.2022]

IPCC AR5, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva. *https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf* [18.07.2022]

IPCC AR6, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. *https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf* [18.07.2022]

Isaac, M. and van Vuuren, D.P., 2009: Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy, 37(2): 507–521. *https://www.sciencedirect.com/science/article/pii/S0301421508005168#* [18.07.2022]

Jacob, D. et al., 2014: EURO-CORDEX: new high-resolution climate change projections for European impact research, Regional Environmental Change,14, 563-578, DOI: 10.1007/s10113-013-0499-2 [18.07.2022]

Kaufmann, Ch. et al., 2012: Spatio-temporal occurrence of Culicoides biting midges in the climatic regions of Switzerland, along with large scale species identification by MALDI-TOF mass spectrometry. Parasites Vectors 5, 246 (2012). *https://doi.org/10.1186/1756-3305-5-246* [18.07.2022]

Klein, G. et al., 2016: Shorter snow cover duration since 1970 in the Swiss Alps due to earlier snowmelt more than to later snow onset. Climatic Change 139: 637–649. *https://doi.org/10.1007/s10584-016-1806-y* [18.07.2022]

Knüsel, S. et al., 2019: Low litter cover, high light availability and rock cover favour the establishment of Ailanthus altissima in forests in southern Switzerland. Neobiota 46: 91–116. *https://doi.org/10.3929/ethz-b-000349496* [18.07.2022]

Körner, C. and Paulsen, J., 2004: A world-wide study of high altitude treeline temperatures. Journal of Biogeography, 31, 713–732. *https://onlinelibrary.wiley.com/doi/10.1111/j.1365-2699.2003.01043.x* [18.07.2022]

Körner, C., 2021: Alpine Plant Life. Functional Plant Ecology of High Mountain Ecosystems. 3rd Edition. Springer Nature Switzerland. 500 pp. [hardcopy]

Kotlarski, S. et al., 2014: Regional climate modeling on European scales: a joint standard evaluation of the EURO-CORDEX RCM ensemble, Geosci. Model Dev., 7. *https://gmd.copernicus.org/articles/7/1297/2014/gmd-7-1297-2014.pdf* [18.07.2022]

Landis, F. et al., 2017a: Evaluation der Strategie zur Anpassung an den Klimawandel – Modul A. Interface, Luzern and Oeschger Centre for Climate Change Research, Bern. 120 pp. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/externe-studien-berichte/Evaluation-Strategie-Anpassung-Klimawandel-ModulA.pdf* [18.07.2022]

Landis, F. et al., 2017b: Evaluation Pilotprogramm zur Anpassung an den Klimawandel – Modul B. Interface, Luzern: 67 pp. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/externe-studien-berichte/Evaluation-Pilotprogramm-Anpassung-Klimawandel-ModulB.pdf* [18.07.2022]

Langhammer L. et al., 2019: Glacier thickness estimation of alpine glaciers using data and modeling constraints. The Cryposphere, 13(8): 2189–2202. *https://doi.org/10.5194/tc-13-2189-2019* [18.07.2022]

Lanz, K. and Wechsler, T., 2020: Wasserkraft. In: Lanz, K. (Hrsg.) Auswirkungen des Klimawandels auf die Wasserwirtschaft der Schweiz. Studie im Auftrag des Bundesamts für Umwelt. 213–253. *https://doi.org/10.5281/zenodo.4133364* [18.07.2022]

Lanz, K., 2020: Thermische Nutzung. In: Lanz, K. (Hrsg.) Auswirkungen des Klimawandels auf die Wasserwirtschaft der Schweiz. Studie im Auftrag des Bundesamts für Umwelt. 131–163. *https://doi.org/10.5281/zenodo.4133364* [18.07.2022]

Lavorel S., 2019: Climate change effects on grassland ecosystem services. In: Gibson D. J. and J. A. Newton (eds.), Grasslands and Climate Change, Cambridge University Press, Cambridge, 131–146. [hardcopy]

Lehmann Friedli, T., 2011: Der Schweizer Tourismus im Klimawandel. Auswirkungen und Anpassungsoptionen. Research Unit Tourism, Centre for Regional Economic Development, University of Bern (mandated by the Swiss State Secretariat for Economic Affairs, Bern). 64 pp. *https://www.newsd.admin.ch/newsd/message/attachments/24181.pdf* [18.07.2022]

Lehmann Friedli, T., 2013: Ökonomische Relevanz von Klimaanpassung im Tourismus – Qualitative und quantitative Kosten-Nutzen-Bewertungen von Anpassungsmassnahmen im Schweizer Alpenraum. Berner Studien zu Freizeit und Tourismus, Heft 58, Bern. [hardcopy]

Lessard, J.L., Hayes, D.B., 2003: Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. River Research and Applications, 19(7):721–732. *https://onlinelibrary.wiley.com/doi/10.1002/rra.713* [18.07.2022]

Linsbauer, A. et al., 2015: Modelling glacier-bed overdeepenings and possible future lakes for the glaciers in the Himalaya-Karakoram region. Annals of Glaciology, 17(71): 119 –130. *http://www.zora.uzh.ch/id/eprint/112593/1/2015_Linsbauer_etal_2015_HK_overdeepenings.pdf* [18.07.2022]

Lommano, E. et al., 2014: Tick-borne pathogens in ticks collected from breeding and migratory birds in Switzerland. Ticks and Tick-borne Diseases, Volume 5, Issue 6, pp871-882. *https://doi.org/10.1016/j.ttbdis.2014.07.001* [18.07.2022]

Lopez Saez, J. et al., 2013: Climate change increases frequency of shallow spring landslides in the French Alps. Geology 41: 619–622. *https://dendrolab.ch/wp-content/uploads/2018/10/Lopez-Saez_etal_Geology_2013.pdf* [18.07.2022]

Lugon, R. and Stoffel, M., 2010: Rockglacier dynamics and magnitude–frequency relations of debris flows in a high-elevation watershed: Ritigraben, Swiss Alps. Global and Planetary Change 73: 202–210. *http://www.sciencedirect.com/science/article/pii/S0921818110001311* [18.07.2022]

Marty, C. et al., 2017a: Recent Evidence of Large-Scale Receding Snow Water Equivalents in the European Alps. Journal of Hydrometeorology, 18(4): 1021–1031. *https://doi.org/10.1175/JHM-D-16-0188.1* [18.07.2022]

Marty, C. et al., 2017b: How much can we save? Impact of different emission scenarios on future snow cover in the Alps. Cryosphere, 11, 1: 517-529. *https://tc.copernicus.org/articles/11/517/2017/tc-11-517-2017.pdf* [18.07.2022]

MeteoSwiss, 2016: Klimareport 2015. MeteoSwiss, Zurich: 84 pp. *http://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/klimareport_2015.pdf* [18.07.2022]

MeteoSwiss, 2021: Von den Warnungen bis zur Klimatologie – das Thema Hitze an der MeteoSchweiz. Fachbericht MeteoSchweiz Nr. 276. *https://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/Fachbericht_MeteoSchweiz_Nr.276.pdf* [18.07.2022]

Meteotest, 2019: Mapping Nitrogen Deposition 2015 for Switzerland. Technical Report on the Update of Critical Loads and Exceedance. Meteotest AG, Bern (commissioned by the Swiss Federal Office for the Environment). *https://www.bafu.admin.ch/dam/bafu/en/dokumente/luft/externe-studien-berichte/mapping-nitrogen-deposition-2015-for-switzerland.pdf* [18.07.2022]

Michel, A. et al., 2019: Stream temperature evolution in Switzerland over the last 50 years. Hydrology and Earth System Sciences, 24(1): 115–142. *https://doi.org/10.5194/hess-24-115-2020* [18.07.2022]

Monastyrnaya, E. et al., 2020: Resilience of the Swiss food systems. Final project report. Swiss Federal Institute of Technology in Zurich (ETH Zurich). *https://ethz.ch/content/dam/ethz/special-interest/usys/ias/enhancing-resilience-dam/images/Schlussbericht_Resilienz%20des%20Schweizer%20Ern%C3%A4hrungssystems_eng.pdf* [18.07.2022]

Moulin, T. and Calanca, P., 2021: Modélisation de la réponse des prairies permanentes aux changements climatiques. Fourrages, 246, 11–20. *https://afpf-asso.fr/revue/non-thematique-263?a=2296* [18.07.2022]

Müller, P. et al., 2020: Surveillance of invasive *Aedes* mosquitoes along Swiss traffic axes reveals different dispersal modes for *Aedes albopictus* and *Ae. japonicus*. PLoS neglected tropical diseases. *https://doi.org/10.1371/journal.pntd.0008705* [18.07.2022]

NCCS and FOEN, 2021: Swiss Water Bodies in a Changing Climate. National Centre for Climate Services, Zurich, and Swiss Federal Office for the Environment, Bern. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/hydro-ch2018/Broschuere/broschuere.pdf* [18.07.2022]

NCCS, 2018: CH2018 – Climate Scenarios for Switzerland. National Centre for Climate Services, Zurich. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/klima/CH2018_broschure.pdf* [18.07.2022]

NELAK, 2013: Neue Seen als Folge des Gletscherschwundes im Hochgebirge – Chancen und Risiken. Forschungsbericht NFP 61. Haeberli W, Bütler M, Huggel C, Müller H, Schleiss A (eds.). vdf Hochschulverlag. *https://goo.gl/fm4LDq* [18.07.2022]

Neukom, R. et al., in prep.: Effects of combined drought extremes on protective forests – A case study from the southern Swiss Alps.

Niggli, L. et al., forthcoming: Towards improved understanding of cascading and interconnected risks from concurrent weather extremes: Analysis of historical heat and drought extreme events. PLOS Climate

Noetzli, J. and Gruber, S., 2009: Transient thermal effects in Alpine permafrost. The Cryosphere, 3, 85–99. *http://www.the-cryosphere.net/3/85/2009/tc-3-85-2009.pdf* [18.07.2022]

Perch-Nielsen, S. et al., 2016: Analyse der Nutzerbedürfnisse zu nationalen Klimaszenarien (Ernst Basler + Partner AG im Auftrag der MeteoSchweiz), Fachbericht MeteoSchweiz Nr. 258. *https://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/FB258_EBP.pdf* [18.07.2022]

PERMOS, 2016: Permafrost in Switzerland 2010/2011 to 2013/2014. Glaciological Report (Permafrost) No. 12–15 of the Cryospheric Commission of the Swiss Academy of Sciences. *http://www.permos.ch/downloads/permos10-14.pdf* [18.07.2022]

PERMOS, 2021: Swiss Permafrost Bulletin 2019/2020. *http://www.permos.ch/downloads/PERMOS_bulletin_2019-20.pdf* [18.07.2022]

PLANALP, 2012: Alpine strategy for adaptation to climate change in the field of natural hazards. Developed by the Platform on Natural Hazards of the Alpine Convention PLANALP. *https://www.planat.ch/fileadmin/PLANALP/planalp_pdf/2012_PLANALP_Alpine_Strategy.pdf* [18.07.2022]

PLANAT, 2018: Management of risks from natural hazards. Strategy 2018. National Platform for Natural Hazards PLANAT. *http://www.planat.ch/fileadmin/PLANAT/Strategie2018/Strategie_en.pdf* [18.07.2022]

Prasuhn, V. et al., 2013: A high resolution soil erosion risk map of Switzerland as strategic policy support system. Land Use Policy, 32: 281–291. *https://doi.org/10.1016/J.LANDUSEPOL.2012.11.006* [18.07.2022]

Prognos et al., 2020: Energy Perspectives 2050+. Prognos, Basel / TEP Energy, Zurich / Infras, Zurich / Ecoplan, Bern (mandated by the Swiss Federal Office of Energy, Bern). *https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html* [18.07.2022]

Ragettli M.S., and Röösli, M., 2021a: Hitze-Massnahmen-Toolbox 2021. Massnahmenkatalog für den Schutz der menschlichen Gesundheit vor Hitze. SwissTPH, Basel (mandated by the Swiss Federal Office of Public Health, Bern, also available in French). *https://www.nccs.admin.ch/dam/nccs/de/dokumente/website/sektoren/gesundheit/hitze-massnahmen-toolbox-2021.pdf* [18.07.2022]

Ragettli, M.S. and Röösli, M., 2020: Gesundheitliche Auswirkungen von Hitze in der Schweiz und die Bedeutung von Präventionsmassnahmen. Hitzebedingte Todesfälle im Hitzesommer 2019 – und ein Vergleich mit den Hitzesommer 2003, 2015 und 2018. Swiss TPH, Basel. *https://www.nccs.admin.ch/dam/nccs/de/dokumente/website/sektoren/gesundheit/swisstph-2020-gesundheitliche-auswirkungen-von-hitze-2019-vergleich.pdf* [18.07.2022]

Ragettli, M.S. and Röösli, M., 2021b: Hitzebedingte Sterblichkeit im Sommer 2019. Die Bedeutung von Präventionsmassnahmen. Prim Hosp Care Allg Inn Med. 2021;21(3):90-95 (also available in French). DOI:*10.4414/phc-d.2021.10296* [18.07.2022]

Ragettli, M.S. et al., 2019: Impact of the warm summer 2015 on emergency hospital admissions in Switzerland. Environmental Health (2019) 18:66. *https://doi.org/10.1186/s12940-019-0507-1* [18.07.2022]

Rajczak, J. and Schär, C.,, 2017: Projections of Future Precipitation Extremes Over Europe: A Multimodel Assessment of Climate Simulations. JGR Atmospheres, 122 (20), *https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/2017JD027176?download=true* [18.07.2022]

Råman Vinnå, L. et al., 2021: The vulnerability of lakes to climate change along an altitudinal gradient. Nature Communications Earth & Environment 2, 35. *https://www.nature.com/articles/s43247-021-00106-w.pdf* [18.07.2022]

Rigling, A. and Dobbertin, M., 2011: Trockenheit als Auslöser von Absterbeprozessen in inneralpinen Waldföhrenwäldern. In: Waldtypen, Vegetation und Klimawandel im Vinschgau, einem inneralpinen Trockental, Jürg Ewald (eds). Verlag Kessel, 118 p. [hardcopy]

Rigling, A. et al., 2013: Driving factors of a vegetation shift from Scots pine to pubescent oak in dry Alpine forests. Glob. Change Biol. 19: 229–240. *http://onlinelibrary.wiley.com/doi/10.1111/gcb.12038/abstract* [18.07.2022]

Rixen, C. and Wipf, S., 2017: Non-equilibrium in alpine plant assemblages: Shifts in Europe's summit floras. In J. Catalan, J. M. Ninot, & M. M. Aniz (Eds.), Advances in global change research: Vol. 62. High mountain conservation in a changing world (pp. 285–303). *https://doi.org/10.1007/978-3-319-55982-7_12* [18.07.2022]

Rogger, J. et al., 2021: Can Swiss wheat varieties escape future heat stress? European Journal of Agronomy 131, 126394, *https://doi.org/10.1016/j.eja.2021.126394* [18.07.2022]

Rohrer, B. and Tombez, G., 2019: Analyse des solutions d'assurances agricoles pour la Suisse. Étude mandatée par l'Office Fédéral de l'Agriculture. WARM Consulting Group Ltd, Salavaux. *https://www.newsd.admin.ch/newsd/NSBExterneStudien/1044/attachment/de/4436.pdf* [18.07.2022]

SAFOSO, 2019: Abschätzung des Einflusses des Klimawandels auf die Tiergesundheit und Lebensmittelsicherheit. Eine One Health-Perspektive. Vorstudie für das Bundesamt für Lebensmittelsicherheit und Veterinärwesen, Bern. *https://www.blv.admin.ch/dam/blv/de/dokumente/das-blv/auftrag/bericht-einflusses-klimawandel-one-health.pdf* [18.07.2022]

Savelsberg, J. et al., 2018: The Impact of Climate Change on Swiss Hydropower. In: Sustainability No. 10, 2541. *https://doi.org/10.3390/su10072541* [18.07.2022]

SCCER-SoE, 2019: Climate change impact on Swiss hydropower production: synthesis report. Swiss Competence Centre for Energy Research – Supply of Electricity. Zürich, 28 Seiten. *https://www.researchgate.net/publication/351153593_Climate_change_impact_on_Swiss_hydropower_production_synthesis_report* [18.07.2022]

Schaefli, B. et al., 2018: The role of glacier retreat for Swiss hydropower production. In: Renewable Energy No. 132, Seiten 615-627 *https://www.researchgate.net/publication/327475196_The_role_of_glacier_retreat_for_Swiss_hydropower_production* [18.07.2022]

Schaub, Y., 2015: Outburst Floods from High-Mountain Lakes: Risk Analysis of Cascading Processes under Present and Future Conditions. Doctoral thesis, Department of Geography, University of Zurich, 292 pp. *https://www.researchgate.net/publication/278673012_Outburst_Floods_from_High-Mountain_Lakes_Risk_Analysis_of_Cascading_Processes_under_Present_and_Future_Conditions* [18.07.2022]

Scherrer, D. et al., 2022: Abundance changes of neophytes and native species indicate a thermophilisation and eutrophisation of the Swiss flora during the 20th century. Ecological Indicators 135 (2022). *https://doi.org/10.1016/j.ecolind.2022.108558* [18.07.2022]

Scherrer, S.C. et al., 2016: Emerging trends in heavy precipitation and hot temperature extremes in Switzerland, JGR Atmospheres,121. *https://doi.org/10.1002/2015JD024634* [18.07.2022]

Schmid, F. et al., 2014: Nachhaltige Wassergouvernanz: Herausforderungen und Wege in die Zukunft. Thematische Synthese 4 im Rahmen des Nationalen Forschungsprogramms NFP 61 «Nachhaltige Wassernutzung», Bern (also available in French). *http://www.nfp61.ch/SiteCollectionDocuments/nfp61_thematische_synthese_4_d.pdf* [18.07.2022]

Schmocker-Fackel, P. and Naef, F., 2010: Changes in flood frequencies in Switzerland since 1500. Hydrol. Earth Syst. Sci. 14, 1–14. *https://www.hydrol-earth-syst-sci.net/14/1581/2010/hess-14-1581-2010.pdf* [18.07.2022]

Schneuwly-Bollschweiler, M. and Stoffel, M., 2012: Hydrometeorological triggers of periglacial debris flows in the Zermatt valley (Switzerland) since 1864. Journal of Geophysical Research – Earth Surface 117: F02033, 12 pp. *https://dendrolab.ch/wp-content/uploads/2018/10/Schneuwly-Bollschweiler_Stoffel_JGeophysRes_2012.pdf* [18.07.2022]

Schuldt, B., Buras, A., Arend, M. et al., 2020: A first assessment of the impact of the extreme 2018 summer drought on Central European forests. Basic and Applied Ecology 45: 86-103. *https://www.sciencedirect.com/science/article/pii/S1439179120300414* [18.07.2022]

SCNAT, 2021: Tackling climate change and biodiversity loss jointly. Swiss Academies Factsheet 16 (3). *https://scnat.ch/en/uuid/i/4bb62ca1-4819-570d-beb1-ee58eabea746-Tackling_climate_change_and_biodiversity_loss_jointly* [18.07.2022]

SCNAT, 2021a: Biodiversität und Klimawandel. Hotspot – Die Zeitschrift des Forums Biodiversität Schweiz. 43 (2021) (also available in French) *https://scnat.ch/de/uuid/i/d3c54217-7322-5a4a-954f-dfbb6b919a7d-HOTSPOT_4321_Biodiversit%C3%A4t_und_Klimawandel* [18.07.2022]

SECO, 2020: Büroarbeit bei Hitze. Informationen für Arbeitgeber und Arbeitnehme Flyer. Swiss State Secretariat for Economic Affairs, Bern. *https://www.seco.admin.ch/dam/seco/de/dokumente/Publikationen_Dienstleistungen/Publikationen_Formulare/Arbeit/Arbeitsbedingungen/merkblaetter_checklisten/merkblatt_bueroarbeit_hitze_a5.pdf* [18.07.2022]

Serquet, G. et al., 2013: Monthly trends and the corresponding altitudinal shift in the snowfall/precipitation day ratio. Theoretical and Applied Climatology 114: 437–444. *https://link.springer.com/article/10.1007%2Fs00704-013-0847-7* [18.07.2022]

Stoeckli, S., Felber, R. and Haye, T., 2020: Current distribution and voltinism of the brown marmorated stink bug, Halyomorpha halys, in Switzerland and its response to climate change using a high-resolution CLIMEX model. International Journal of Biometeorology, 64, 2019–2032. *https://link.springer.com/article/10.1007/s00484-020-01992-z* [18.07.2022]

Stoffel, M. and Huggel, C., 2012: Effects of climate change on mass movements in mountain environments. Progress in Physical Geography 36: 421–439. *http://journals.sagepub.com/doi/pdf/10.1177/0309133312441010* [18.07.2022]

Stoffel, M. et al., 2014: Possible impacts of climate change on debris-flow activity in the Swiss Alps. Climatic Change 122: 141–155. *https://doc.rero.ch/record/325020/files/10584_2013_Article_993.pdf* [18.07.2022]

Stoffel, M., 2010: Magnitude-frequency relationships of debris flows – A case study based on field surveys and tree-ring records. Geomorphology 116: 67–76. *https://dendrolab.ch/wp-content/uploads/2018/10/Stoffel_Geomorphology_2010.pdf* [18.07.2022]

Suter, M. et al., 2021: Multispecies for multifunctions: combining four complementary species enhances multifunctionality of sown grassland. Scientific Reports, 11:3835. *https://doi.org/10.1038/s41598-021-82162-y* [18.07.2022]

Swiss Confederation, 2012: Swiss Biodiversity Strategy. Bern. *www.bafu.admin.ch/ud-1060-e* [18.07.2022]

Swiss Confederation, 2012a: Adaptation to climate change in Switzerland. Goals, challenges and fields of action. First part of the Swiss Federal Council's strategy adopted on 2 March 2012. *www.bafu.admin.ch/ud-1055-e* [18.07.2022]

Swiss Confederation, 2014: Anpassung an den Klimawandel in der Schweiz. Aktionsplan 2014–2019. Zweiter Teil der Strategie des Bundesrates vom 9. April 2014. *www.bafu.admin.ch/ud-1081-d* [18.07.2022]

Swiss Confederation, 2020a: Anpassung an den Klimawandel in der Schweiz: Aktionsplan 2020–2025. Swiss Federal Office for the Environment, Bern (also available in French). *http://www.bafu.admin.ch/ui-2022-d* [18.07.2022]

Swiss Confederation, 2020b: Verordnung über die Sicherstellung der Trinkwasserversorgung in schweren Mangellagen (VTM) vom 19.08.2020 (Stand am 01.10.2020). *https://www.fedlex.admin.ch/eli/cc/2020/666/de* [18.07.2022]

Swiss Confederation, 2020c: First Adaptation Communication of Switzerland under the UNFCCC. Submitted on 9 December 2020. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/Switzerland%20First%20Adaptation%20Communication.pdf* [18.07.2022]

Swiss Confederation, 2021: Federal Act on the Protection of Waters (Waters Protection Act, WPA) of 24 January 1991 (Status as of 1 January 2021) *http://www.admin.ch/ch/e/rs/8/814.20.en.pdf* [18.07.2022]

Swiss Confederation, 2021a: Federal Act on Controlling Communicable Human Diseases (Epidemics Act, EpidA) of 28 September 2012 (Status as of 18 December 2021) *https://www.fedlex.admin.ch/eli/cc/2015/297/en* [18.07.2022]

Swiss Federal Council, 2016: Strategie der Schweiz zu invasiven gebietsfremden Arten. Swiss Federal Office for the Environment (Publ.), Bern. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/biodiversitaet/fachinfo-daten/strategie_der_schweizzuinvasivengebietsfremdenarten.pdf* [18.07.2022]

Swiss Federal Council, 2017a: Action Plan for the Swiss Biodiversity Strategy. *https://www.bafu.admin.ch/dam/bafu/en/dokumente/biodiversitaet/fachinfo-daten/aktionsplan-strategie-biodiversitaet-schweiz.pdf* [18.07.2022]

Swiss Federal Council, 2017b: Aktionsplan zur Risikoreduktion und nachhaltigen Anwendung von Pflanzenschutzmitteln (also available in French). *https://www.blw.admin.ch/dam/blw/de/dokumente/Nachhaltige%20Produktion/Pflanzenschutz/AktionsplanPflanzenschutzmittel/Aktionsplan_Pflanzenschutzmittel_de.pdf* [18.07.2022]

Swiss Federal Council, 2021: Federal Government Tourism Strategy. *https://www.seco.admin.ch/dam/seco/en/dokumente/Standortfoerderung/Tourismus/EN%20Tourismusstrategie%20des%20Bundes.pdf* [18.07.2022]

SwissEnergy, 2019: Wärmeschutz und Kühlung von Büro- und Gewerberäumen. Technischer Bericht. *https://storage.topten.ch/source/files/Cool%20Bleiben/Technischer-Bericht-Kuehlung_B%C3%BCro%26Gewerbe_M%C3%A4rz2019.pdf* [18.07.2022]

Vaghefi, S. et al., 2022: Future trends in compound heat extremes in Swiss cities – an assessment considering deep uncertainty and climate adaptation options. *https://dx.doi.org/10.2139/ssrn.4100358* [18.07.2022]

Van Asch, M. et al., 2013: Evolutionary response of the egg hatching date of a herbivorous insect under climate change. Nature Climate Change, 3(3): 244–248. *https://www.nature.com/articles/nclimate1717* [18.07.2022]

Vitasse, Y. et al., 2012: Tree recruitment of European tree species at their current upper elevational limits in the Swiss Alps. Journal of Biogeography 39: 1439–1449. *http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2699.2012.02697.x/full* [18.07.2022]

Vitasse, Y. et al., 2014: Earlier leaf-out rather than difference in freezing resistance puts juvenile trees at greater risk of freeze damage than adult trees. J. Ecol. 102: 981–988. *https://doi.org/10.1111/1365-2745.12251* [18.01.2022]

Vitasse, Y. et al., 2018: Increase in the risk of exposure of forest and fruit trees to spring frosts at higher elevations in Switzerland over the last four decades. Agricultural and Forest Meteorology 248: 60-69. *https://doi.org/10.1016/j.agrformet.2017.09.005* [18.07.2022]

Vitasse, Y. et al., 2021: Phenological and elevational shifts of plants, animals and fungi under climate change in the European Alps. Biological Reviews, 96(5), 1816-1835. *http://dx.doi.org/10.1111/brv.12727* [18.07.2022]

Vittoz, P. et al., 2008: Effects of climate and land-use change on the establishment and growth of cembran pine (Pinus cembra L.) over the altitudinal treeline ecotone in the Central Swiss Alps. Arctic Antarctic and Alpine Research, 40, 225–232. *https://doi.org/10.1657/1523-0430%2806-010%29%5BVITTOZ%5D2.0.CO%3B2* [18.07.2022]

Vöhringer, F. et al., 2019: Cost and benefits of climate change in Switzerland. Climate Change Economics, 10(2), 1950005, pp.1–34. *https://doi.org/10.1142/S2010007819500052* [18.07.2022]

Warren, R. et al., 2018: The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C. Science, 360 (6390), 791-795. *https://ueaeprints.uea.ac.uk/id/eprint/67473/2/RWarren_etal_2018_Science_AAM.pdf* [18.07.2022]

Water Agenda 21, 2011: Watershed Management. Guiding Principles for Integrated Management of Water in Switzerland, Bern. *https://wa21.ch/wp-content/uploads/2017/09/e_Leitbild_IEM_101124.pdf* [18.07.2022]

Webber, H. et al., 2018: Diverging importance of drought stress for maize and winter wheat in Europe. Nature Communications, 9:4249, DOI:10.1038/s41467-018-06525-2. *https://www.nature.com/articles/s41467-018-06525-2* [18.07.2022]

Wehse, H. et al., 2017: Erarbeitung von Massnahmen zur langfristigen Sicherstellung der Wasserressourcen. Mandated by the Swiss Federal Office for the Environment, Bern. *https://tinyurl.com/Wehse17* [18.07.2022]

Wipf, N.C. et al., 2019: Evaluation of honey-baited FTA cards in combination with different mosquito traps in an area of low arbovirus prevalence. Parasites & Vectors 2019, 12(1): 554. *https://doi.org/10.1186/s13071-019-3798-8* [18.07.2022]

WSL, 2021: Climate change could spell trouble for Swiss stone pine. News release of 18.01.2021. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf. *https://www.wsl.ch/en/news/2021/01/climate-change-could-spell-trouble-for-swiss-stone-pine.html* [18.07.2022]

Zekollari, H., Huss, M., Farinotti, D., 2019: Modelling the future evolution of glaciers in the European Alps under the EURO-CORDEX RCM ensemble. The Cryosphere, 13(4), 1125–1146. *https://doi.org/10.5194/tc-13-1125-2019* [18.07.2022]

Zimmermann, N.E. et al., 2016: Baumartenverbreitung und Standorteignung. In: Plüss, A.R., Augustin, S., Brang, P. (Red.): Wald im Klimawandel. Grundlagen für Adaptationsstrategien. Haupt (Bern, Stuttgart, Wien). pp.199-221. [hardcopy]

Zischg, A. P. et al., 2021: Participatory modelling of upward shifts of altitudinal vegetation belts for assessing site type transformation in Swiss forests due to climate change. Appl. Veg. Sci. 24: *https://doi.org/10.1111/avsc.12621* [18.07.2022]

Ziska, L. et al., 2019: Temperature-related changes in airborne allergenic pollen abundance, seasonality across the northern hemisphere: a retrospective data analysis. Lancet Planet Health 2019, Volume 3, e124–e131 *https://www.sciencedirect.com/science/article/pii/S2542519619300154* [18.07.2022]

7 Financial, technological and capacity-building support

7.1 Finance

7.1.1 Introduction

The Federal Constitution of the Swiss Confederation stipulates that Switzerland is committed to the long term preservation of natural resources and to a just and peaceful international order. It further states that Switzerland shall assist in the alleviation of need and poverty in the world and promote respect for human rights and democracy, the peaceful co-existence of peoples as well as the conservation of natural resources. Support for international climate action – through a variety of channels and instruments, such as dedicated multilateral climate funds, specific multilateral and bilateral climate programmes and projects, as well as integrating low-carbon development and climate resilience into Switzerland's development assistance – has thus been a cornerstone of Switzerland's international engagement since the early 1990s. Regarding international climate financing, three government entities – the Swiss Agency for Development and Cooperation, the Swiss State Secretariat for Economic Affairs, and the Swiss Federal Office for the Environment – have specific roles and dedicated budgets. They cooperate closely to ensure the overall effectiveness and coherence of Swiss support for climate change adaptation and mitigation activities in developing countries and countries in transition.

Building on decades of climate-relevant work in developing countries in different areas such as energy efficiency, renewable energy, agriculture and forestry, land-use planning, disaster risk management and technology transfer, Switzerland has played an active role since the early days of international climate policy. In the international climate change arena, Switzerland underscores the relevance of a fair and equitable burden sharing among Parties, while stressing the importance of a sound regulatory framework and an attractive investment environment to achieve a low-carbon and climate-resilient development. Through its multilateral and bilateral cooperation and its membership in the governing bodies of various multilateral institutions (inter alia multilateral development banks, the Green Climate Fund, the Global Environment Facility, the Adaptation Fund, United Nations agencies) Switzerland attaches great importance to increased effectiveness and coherence in their mandates. Furthermore, the establishment of strategic partnerships at all policy levels and the strengthening of dialogue among all stakeholders, including the private sector and civil society, are key principles guiding Switzerland's international climate change engagement.

Switzerland's public climate finance has seen a steady increase over the past years. Standing at 175 million US dollars in 2012 the respective amount grew to 299 million US dollars in 2014, 330 million US dollars in 2016, and 340 million US dollars in 2018 in 411 million US dollars in 2020. The increase between 2012 and 2014 was partly fuelled by the decision of the Swiss Parliament in 2011 to raise the level of official development assistance to 0.5 per cent of gross national income by 2015. In addition, Switzerland's development assistance has gradually shifted to place an enhanced focus on climate change, thus pushing the envelope of climate-relevant and climate-proofed programmes and projects in developing countries. In addition, the strategy for international development cooperation 2021–2024 provides for an increase in funding for climate change mitigation and adaptation to 400 million Swiss francs (approximately 426 million US dollars) per year by 2024. This accounts for around 15 per cent of Switzerland's international development cooperation financial resources. These strategic decisions lead to a remarkable progression compared to previous efforts. The current effort is made in the context of ongoing budget constraints due to the consequences of the corona virus pandemic. Switzerland considers its effort and climate finance therefore to be new and additional and adequate pursuant to Article 4, paragraph 3, of the Convention. Through its multi-annual contributions to multilateral funds, such as the Green Climate Fund and the Global Environment Facility, Switzerland is committed to providing predictable climate finance. In addition, Switzerland's bilateral support for climate action is based on a cooperative, bilateral dialogue with the various partner countries. Every four years the Swiss cooperation offices engage in a demand driven planning dialogue, where, based on the available resources, the needs and priorities of the partner country are assessed with stakeholders. This programmatic procedure ensures country ownership and provides increased predictability for the partner countries, pursuant to Article 4, paragraph 3 of the Convention.

The decision adopted by the Conference of the Parties to the UNFCCC in 2010 in Cancun refers to a variety of sources including the private sector. The financial resources reported in this section relate to financing from public sources attributable to official development assistance only. Furthermore, Tab. 45 provides information about the private climate finance mobilised through bilateral Swiss public interventions, in particular co-financing. Details about current Swiss public investments for climate change adaptation and mitigation measures in developing countries can be found in section 7.1.6. All public funding was provided in the form of grants (no loans).

This biennial report does include bilateral, but not multilateral mobilised private climate finance. It also does not include the outflow data of public climate finance provided and mobilised by multilateral institutions. The rationale for omitting this data is informed by Switzerland's view that bilateral reporting of mobilised private finance through multilateral channels as well as bilateral reporting of the outflow data from multilateral institutions would not do justice to the complexity and the joint effort of all partners involved in multilateral institutions. In addition, Switzerland does not have the necessary information to track, measure and report these climate finance flows. However, Switzerland considers multilateral mobilised private climate finance as well as the full face value of the climate finance outflow of multilateral institutions as climate finance accountable towards the 100 billion US dollars goal. Switzerland remains very much committed to increasing its share of mobilised private finance as part of its climate finance spending. It is also keen to advance efforts at the international level to collectively capture and report on private climate finance mobilised through multilateral channels and to fully capture the outflow of public climate finance by multilateral institutions.

Switzerland has added its data on mobilised private climate finance outside of this report and the UNFCCC reporting namely to the report of the OECD Climate Finance Provided and Mobilised by Developed Countries in 2013–2019 (*OECD*, 2021). Switzerland was part of the donor group, which provided significant methodological input to the report to measure and report mobilised private climate finance in a transparent, comparable and aggregate manner. Switzerland, together with the other donors, followed a robust methodology for the assessment of the mobilised private sector investments (*TWG*, 2015). In developing the methodology, the donor group was guided by the following principles: (i) to ensure that only finance mobilised by developed country governments is counted towards the 100 billion US dollars goal, (ii) that, where multiple actors are involved, the resulting finance is only counted once in tracking the progress, and (iii) to ensure that the reporting framework encourages and incentivises the most effective use of climate finance. The report published in 2021 came to the conclusion that in 2019 all developed countries jointly provided 65.5 billion US dollar from public sources. In addition they mobilised 14.0 billion US dollars in 2019 from private sources through public interventions, in particular co-financing. While improvements in data and methodology relating to private finance (*OECD*, 2021) make comparisons to numbers prior to 2016 difficult, mobilised private finance overall was increasing steadily until 2018, but decreased slightly in 2019.

7.1.2 Multilateral activities

Switzerland has made financial contributions to the UNFCCC secretariat, to the operating entities of the financial mechanism of the Convention, to other multilateral institutions and to international financial institutions such as the World Bank and other multilateral development banks that fund climate change adaptation, mitigation, capacity building and technology cooperation programmes in developing countries. Among the international financial institutions, the largest contributions goes to the International Development Association, a substantial share of which is allocated to finance climate change action. Switzerland's pledge to the 19th replenishment of the International Development Association was a total of 683 million Swiss francs. Moreover, many international organisations, such as the United Nations Development Programme and the Consultative Group on International Agricultural Research, whose operations are co-funded by Swiss core contributions, are increasingly generating important climate benefits.

Where possible, Switzerland calculated the climate relevant part of the Swiss multilateral official development assistance contributions using the climate relevant share of the portfolio for the respective organisation according to the OECD Development Assistance Committee methodology for imputed shares. Switzerland also cooperates with a number of multilateral institutions as implementing agencies of bilateral and regional programmes and projects. The funds invested in those specific programmes are included in Tab. 45 Switzerland's financial support through bilateral, regional and other channels.

Green Climate Fund

As an operating entity of the financial mechanism of the Convention the purpose of the Green Climate Fund is to make a significant and ambitious contribution to the global efforts towards attaining the goal agreed by the international community to keep global warming well below two degrees Celsius pursuing efforts to limit it to 1.5 degrees Celsius. In the context of sustainable development, the Fund promotes a paradigm shift towards low-emission technologies and climate-resilient development with a focus on the most vulnerable countries. From 2015 to 2018 Switzerland contributed in total

100 million US dollars to the Green Climate Fund. Switzerland has committed 150 million US dollars to the first formal replenishment period, increasing its contribution by 50 per cent compared to the Initial Resource Mobilisation Period (2019–2022).

Global Environment Facility

The Global Environment Facility addresses global environmental issues while supporting national sustainable development initiatives. The Global Environment Facility provides support for projects related to climate change, biodiversity, land degradation, forests, the ozone layer, persistent organic pollutants and international waters. Switzerland has supported the Global Environment Facility since its inception in 1991. To the Sixth Replenishment of the Global Environment Facility (2014–2018) Switzerland contributed roughly 135 million US dollars, whereas for the 7th Replenishment Switzerland has contributed roughly 119 million US dollars. The Swiss contribution to GEF-7 is being paid over a period of ten years.

Least Developed Country Fund and Special Climate Change Fund

The Global Environment Facility also features two dedicated climate change funds under the UNFCCC, i.e. the Least Developed Country Fund and the Special Climate Change Fund.

The Least Developed Country Fund was established to address the special needs of the least developed countries with regard to the negative impacts of climate change. The least developed countries identified adaptation as their top priority, which is why the Least Developed Country Fund is thus far the only fund under the Climate Convention tasked specifically with financing the preparation and implementation of National Adaptation Programmes of Action (NAPAs). Unlike the Least Developed Country Fund, the Special Climate Change Fund is open to all developing country Parties to the UNFCCC, supporting adaptation measures and technology transfer. For 2019 and 2020 Switzerland’s contribution to both funds amounted to roughly 7.6 million US dollars.

Adaptation Fund

The Adaptation Fund was established to finance concrete adaptation projects and programmes in developing countries that are Parties to the Kyoto Protocol and are particularly vulnerable to the adverse effects of climate change. It further serves the Paris Agreement since January 1st 2019. Financing for the Adaptation Fund comes mainly from voluntary contributions from governments, the private sector and individuals and a two per cent levy on CERs and other units from the market-based mechanisms under the Convention. In the near future, a five per cent share of proceeds, agreed at CMA3 in Glasgow, from the new multilateral market mechanism (Art. 6.4 of the Paris Agreement) will be an important source of income for the AF. In 2013, Switzerland provided a supplemental contribution of 10.79 million US dollars to the Adaptation Fund in line with Article 12 of the Kyoto Protocol. Switzerland has made further voluntary contributions to the Adaptation Fund of 15 million Swiss francs (2019–2021) and 10 million Swiss francs (2022–2024).

Global Facility for Disaster Reduction and Recovery

The Global Facility for Disaster Reduction and Recovery is a growing global partnership among contributing and recipient countries and several international organisations hosted by the World Bank since 2006. Its mission is to mainstream disaster risk management and climate adaptation into development strategies. The facility carries out a range of activities to support countries to build resilience, structured around five pillars of action: (i) risk identification, (ii) risk reduction, (iii) preparedness, (iv) financial protection, and (v) resilient recovery. Working as a grant-making facility, the Global Facility for Disaster Reduction and Recovery supports countries to develop capacity, generate new knowledge, and apply it to policy reforms and investments for disaster risk management. Switzerland’s different undertaken and planned contributions to the Global Facility for Disaster Reduction and Recovery, both core and program-specific, amount at this stage to 66.6 million Swiss francs from 2006 to 2025 with a particular focus on resilience to climate change.

Addressing the needs of developing country Parties

Relating to multilateral programming – likewise the bilateral programming – Swiss delegates always advocate for country ownership (implying inclusive country-led need-based programming and implementation) and impact oriented programming in the various multilateral funding institutions and governing bodies of multilateral climate finance funding schemes, in which Switzerland participates as a contributor.

All multilateral activities are endorsed by the partner countries to ensure the projects fit within their priorities and advance interventions that are sustainable.

In addition, most multilateral institutions, which are active in the area of climate finance, have started initiatives for a better integration and alignment of their portfolio with the communicated nationally determined contributions of developing countries. The more detailed and precise the nationally determined contributions are formulated, the easier it will be for agencies to align their investments and initiatives with the national priorities of developing countries. In the past, this has been very challenging since the biennial update reports, which could be used to communicate the needs and priorities of developing countries, have not been submitted on time by multiple Parties or have not been submitted at all.

7.1.3 Bilateral activities

Next to the important multilateral engagement, the bilateral programmes and projects constitute a key element of Switzerland’s climate change cooperation. Switzerland works closely with bilateral partners to deliver effective global responses to climate change and tangible results on the ground. Most activities are implemented by one of the two Swiss development agencies – the Swiss Agency for Development and Cooperation or the Swiss State Secretariat for Economic Affairs – in close cooperation with government institutions, non-governmental organisations, private sector entities and research institutions. Switzerland’s bilateral and regional climate-relevant activities are (i) the generation of new and relevant knowledge on climate policy, (ii) the support for technology development and implementation, (iii) the harnessing and replicating successful practices, (iv) the development of skills and capacities of partner countries for their engagement in the international debate on climate change issues, and (v) the implementation of climate action.

In order to effectively tackle the double challenge of addressing climate change mitigation and climate change adaptation in a complementary manner, the climate change activities of the Swiss Agency for Development and Cooperation consist of four main areas: (i) international climate and environment governance and finance, (ii) low-carbon development, (iii) climate-resilient development, and (iv) sustainable management of natural resources. In total the Swiss Agency for Development and Cooperation spent roughly 271 million US dollars between 2019 and 2020 for bilateral climate change programmes.

With the aim to foster climate-friendly growth in developing countries, the climate change portfolio of the Swiss State Secretariat for Economic Affairs is structured mainly along three areas of intervention: (i) sustainable urban management and infrastructure services (e.g. energy, mobility and disaster risk reduction), (ii) resource efficiency in industrial production and sustainable management of natural resources, (iii) access to climate finance (through framework conditions for green financing mechanisms; support to impact investment and ESG standards), and (iv) climate smart public financial management. The Swiss State Secretariat for Economic Affairs provided approximately 169 million US dollars between 2019 and 2020 for its global, regional and bilateral programmes and projects in climate change as well as through the Swiss Investment Fund for Emerging Markets.

Switzerland mobilised 105.7 million US dollars in 2020 up from 71 million US dollars in 2019 from the private sector predominantly through the Swiss Export Risk Insurance (SERV) but also through the Swiss Investment Fund for Emerging Markets, the Private Infrastructure Development Group and the Climate Investment Funds.

Addressing the needs of developing country Parties

Switzerland’s approach to offering bilateral support is oriented towards the needs and priorities of the partner countries. Country-ownership is thus a key requirement. Assistance for climate action is designed jointly and based on a clear demonstration of demand and need by the partner country. As a general rule, all bilateral projects have to be endorsed by the partner country.

Switzerland’s bilateral climate mitigation and adaptation activities are based on national strategies and priorities and are ideally reflected in the partner countries’ national climate change and/or sustainable development policies. Over the next years, Switzerland endeavours to work closely with its partner countries to support the implementation of the Paris Agreement and align the partner countries’ national policies, activities and needs with the Paris Agreement.

Adaptation

Switzerland has undertaken a broad range of activities to support developing countries in reducing their vulnerability to the increasing consequences of climate change, while also minimizing the social and economic costs, notably by:

- Maintaining or increasing productive capital of land (forest, agriculture) and maintaining or increasing water availability at a local level;
- Reducing vulnerability to natural hazards in highly endangered areas at the local/regional level;
- Supporting countries in defining their national and sub-national adaptation strategies and plans;
- Increasing capacity-building, technology transfer and innovation in the field of adaptation in developing and middle-income countries;
- Increasing understanding and awareness about adaptation at different levels and promoting south-south learning processes.

Besides supporting developing countries in adapting to the impacts of climate change, Switzerland has, as part of its adaptation activities, been active for many years in the prevention and reduction of disaster risks. For instance, it developed methods and tools to better integrate disaster risk reduction into project planning and project management.[109]

Switzerland increased its specific support for bilateral adaptation activities from 122 million US dollars in 2019 to 129 million US dollars in 2020.

Through its bilateral and multi-bilateral development cooperation, Switzerland supported several climate change adaptation related projects, such as the Indian Himalayas Climate Adaptation Programme (which is described in more detail for illustrative purposes in Tab. 42) as well as the following projects:

- **Cryospheric Climate Services for Improved Adaptation (CICADA):** The mountain cryosphere in Central Asia is a core determinant for water management and disaster risk management: the mountain glaciers and snow packs serve as water towers in the arid region and glacier retreat can trigger disastrous events such as glacier lake outburst floods or debris flows. Co-financed by the Swiss Agency for Development and Cooperation, the CICADA project has contributed from 2017 to 2021 to improving cryospheric climate services in Central Asia in order to support the region in better adapting to climate change. It has established a modern glacier monitoring system in Central Asia, created high quality data which are now continuously fed in openly accessible databases managed by the World Glacier Monitoring Service. The project was increasing the capacities of national hydrometeorological services and universities in cryosphere monitoring through field campaigns and summer schools. In two pilot regions, the project assessed the impact of glacier retreat on the regional water balance and the formation of additional glacier lakes. A follow up project is currently under development, which will entail monitoring of the entire cryosphere, also including snow and permafrost. This will allow to develop user-oriented climate information services and help to conceptualise targeted adaptation measures;
- **Can Tho Urban Development and Resilience Project:** Co-financed by the Swiss State Secretariat for Economic Affairs together with the World Bank, the project aims to increase the resilience of Can Tho City, Vietnam, to adverse climate change-related events by proactively addressing the two biggest threats to its socioeconomic development: flooding and uncontrolled urbanisation. Situated in the middle of the Mekong Delta, Can Tho is susceptible to flooding caused by Mekong overflow, high tides, and extreme rainfall events. The objective of the Can Tho Urban Development and Resilience Project is to reduce flood risk in the city of Can Tho, guide urban development in a risk informed way, improve connectivity between the city centre and the new low risk urban development areas, and enhance the capacity of city authorities to manage disaster risk sustainably;
- **Green Gold Project in Mongolia:** Regional climate models predict an increase in the annual air temperature of 3.5 to 4 degrees Celsius in Mongolia over the next 100 years and declining precipitation in all parts of the country, accompanied by decreasing soil moisture due to increased temperatures and dryness. Livestock herders repeatedly expressed their concerns about lakes, streams and rivers drying up and declining pasture productivity.

[109] https://www.eda.admin.ch/deza/en/home/themes-sdc/disaster-reduction-relief-reconstruction/disaster-risk-reduction.html

This, in turn, affects pastoral land use patterns, increasing conflicts over scarce water and pasture resources. The past two decades also witnessed two severe winters when millions of livestock perished with devastating effects on the livelihoods of thousands of herder households. In response to these challenges, the Green Gold Project supported community-based rangeland management initiatives of herders aiming at reducing pasture conflicts and prevent rangeland from degradation, as well as to increase resilience and climate change adaption capacity of herders by strengthening the self-regulating feedback of socio-economic and environmental systems of pastoral livestock. The project helped to strengthen the capacities of Mongolian herders who are discussing via novel associations joint rules for pasture management with the local governments. Such recognised autonomous associations are given the permission to manage pastures by local Mongolian authorities, and provided with technical advice and financial support. The project further contributed to the following results: Mongolia's most advanced rangeland monitoring system with over six thousand monitoring spots; over half of Mongolian herder families (90 thousand families) have adopted sustainable rangeland management practices improving their livelihoods; 12 provinces (out of 21) and 46 municipalities (out of 330) have their rangeland management regulations, legalizing the rangeland user agreements signed between Pasture user groups of herder families and local governments, for responsible management of their rangelands; the Animal Health Law and The Livestock Number Taxation law, with special provisions to utilise the tax income locally, making sure herders take part in the decisions regarding sustainable rangeland and herd management; the restoration of 20 million hectares of rangelands in past years;

- **Programme to strengthen the resilience of pastoral and agro-pastoral households to climate crises and insecurity (RESILIA):** In Burkina Faso, insecurity and climate change have led to humanitarian and agro-pastoral crises in the traditional livestock regions of the Sahel and the North. In 2020, more than 3.2 million people, including more than one million internally displaced persons, were in need of humanitarian assistance. The southern border regions, which traditionally are agricultural areas, have become reception, transit, and departure zones for transhumant herds. Pastoralists in these regions face major constraints such as strong agricultural land pressure and degradation of pasture, limiting the mobility of the herds for grazing and livestock trade and often leading to violent conflicts between farmers and pastoralists. In such a context where populations are confronted with multiple crises (climate, food, health, security), the responses also take on multiple dimensions, combining emergency action with measures to create the conditions for the recovery and socio-economic development. The programme supports 700'000 pastoralists and agro-pastoralists to adapt their livestock and herding practices to the climatic and security challenges with a view to improve their livelihoods and resilience to multiple hazards and to promote peace in the country. 20 communes are supported to ensure the management and maintenance of pastoral infrastructures;

- **Ensuring food security for smallholder farmers with micro insurance and microcredits:** The Rural Resilience Initiative combines four climate risk management tools, which are all aimed at preventing or reducing the impact of climate change on the population by rehabilitating irrigation systems, improving soil water retention, promoting sustainable farming practices in the fields, constructing access roads, etc. The Swiss Agency for Development and Cooperation supports project activities in Malawi, Zambia and Zimbabwe. The project provides smallholders who are most at risk from drought or floods with agricultural micro insurance. An innovative measure is that the project allows farmers to pay their insurance premiums by taking part in community work. The project also includes the installation of new weather stations in Zambia and Malawi – an important prerequisite to calculate the price of insurance premiums and better anticipate bad harvests. As a parallel measure, the project trains microcredit agencies in limiting the debt risk. The combination of micro insurance and microcredit is intended to encourage farmers to invest in agricultural activities (inputs, equipment) without fear of losing their farm the following year. Up to end of 2020, the project supported 46,000 households to maintain their livelihood and gave access to weather insurance to 80,000 smallholder farmers (of which 50 per cent are women).

Tab. 42 > Promotion of climate change adaptation in the Indian Himalayas.

Project/programme title:
Indian Himalayas Climate Adaptation Programme.

Goal:
The project aims at strengthening the resilience of vulnerable communities in the Himalayas and to enhance knowledge and capacities of research institutions, communities, and decision-makers.

Recipient country	Sector	Total funding	Years in operation
India	Adaptation	5.6 million Swiss francs	2012–2020

Description:
The project helped to build capacity and enhance knowledge related to three pillars:
- Scientific and technical knowledge cooperation between Indian and Swiss scientific institutions;
- Adaptation measures for vulnerable communities;
- Mainstreaming adaptation policies for improved action in the Indian Himalayan Region.

The Indian Himalayas Climate Change Adaptation Programme was initiated by the Swiss Agency for Development and Cooperation in collaboration with the Department of Science and Technology, Government of India. Implementing partners included a consortium of Swiss (Geneva, Bern, Fribourg, Zurich) and Indian (Jawahrlal Nehru University, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Doon University, Himachal Pradesh Agricultural University Palampur, Birbal Sahni Institute of Palaeobotany, Lucknow) universities.

Key achievements (complementary to the paragraphs below):
- 1200 sector experts and policy makers in Himalayan states sensitised on various issues related to climate change and spring-shed management
- An innovative joint research work (India and Switzerland) on vulnerability, risks and hazard assessment in Kullu district in partnership with the Department of Science & Technology, government of Himachal Pradesh was carried out;
- A common framework for integrated vulnerability, and risk assessment for all Himalayan states was developed; through the project climate vulnerability maps of all 12 Indian Himalayan States have been made available for the first time, using a standardised common framework.
- Results of joint research and common framework help enable planning and implementation of adaptation action at state level;
- Media capacity building workshops were conducted in different Indian Himalayan states with 74 journalists trained;
- Knowledge management and outreach were addressed through policy briefs with an outreach to more than 26 thousand individuals;
- Co-funding support was generated to universities/institutions for promoting a scientific dialogue on climate change impact, vulnerability & adaptation in the Himalayas;
- Technical assistance for the preparation of climate change adaptation projects was provided to Jammu Kashmir and Himachal Pradesh for National Adaptation fund on Climate Change;
- The revival of multi-stakeholder 'Himalayan Sustainable Development Forum' fostered cooperation on sustainable development across the Himalayan region.
- Technical contributions were made to the working group on inventory and revival of springs in the Himalayas for water security.

Technology transferred/capacity building:
The Indian Himalayas Climate Adaptation Programme mainly focused on capacity building of Indian researchers, universities and institutions as well as government representatives in the field of glaciology and related areas. The project helped develop an Indo-Swiss Capacity Building Programme on Himalayan Glaciology through which 52 researchers were trained. The programme was then further developed into a full-fledged 'glaciology course' as part of a Master's curriculum in order to secure the sustainability of the efforts and achievements jointly with the two selected Indian Kashmir and Delhi Universities. Course content was put on an online portal with currently 240 registered users, and is also mainstreamed through the Himalayan University Consortium. The project also conducted an Indo-Swiss Collaborative Research in Kullu district. As a result of this collaborative research a synthesis report was produced (*IHCAP*, 2016).

Impact on government targets:
Through the Indian Himalayas Climate Adaptation Programme the Swiss Agency for Development and Cooperation collaborated with the Department of Science & Technology, Government of India. Indian Himalayas Climate Adaptation Programme was designed to work with existing country systems at national and state levels and directly contributed to the implementation of India's National Mission on Sustaining the Himalayan Environment. It also contributed to the implementation of the State Action Plans and to gaining access to climate finance by supporting the preparation of climate change adaptation projects for the National Adaptation Fund on Climate Change.

Swiss Agency for Development and Cooperation

Mitigation

Greenhouse gas emissions responsible for warming the planet originate from multiple sources. Therefore Switzerland's support of climate change mitigation activities in developing countries is cross-cutting, building on a variety of sectors and actors. Switzerland focuses its activities on access to modern energy infrastructure, including renewable energies, rural electrification, energy efficiency in the industry and in the building/construction sector, cleaner industrial production, and sustainable use of natural resources, namely forests and grasslands. In addition, Switzerland supports its partner countries in the development and use of innovative financing and market mechanisms in climate protection such as emissions trading schemes or carbon taxes. Switzerland further supports developing countries in the design and implementation of ambitious policies to mitigate climate change such as clean air policies or policies to mitigate black carbon emissions. Switzerland's bilateral support for mitigation activities was 99 million US dollars in 2019 and dipped slightly to 94 million US dollars in 2020.

Through its bilateral development cooperation Switzerland supports multiple climate change mitigation projects, such as the Energy Transition Plan for Municipalities in Tunisia (which is described in more detail for illustrative purposes in Tab. 43) as well as the following projects:

- **The Transformative Carbon Asset Facility** is co-financed by the Swiss State Secretariat for Economic Affairs and supports different types of direct and indirect carbon pricing efforts by paying for verified carbon assets that result from these actions. The results-based payments could be used to support the implementing country government to enhance sectoral planning, strengthen low-carbon policy coordination and implementation, and monitor sector performance on greenhouse gas emissions. All these are necessary conditions to create a conducive environment for increasing private sector investment in low carbon technologies. Transformative Carbon Asset Facility will support the measuring, reporting and verification of nationally determined contributions by developing baselines and monitoring performance of the programmes. This support to move from carbon pricing readiness to implementation builds on the work done by the World Bank's Partnership for Market Readiness and other readiness initiatives. Piloting will also inform the international process to develop standards and agreements for future carbon crediting instruments and the transfer of mitigation assets;

- **The Pilot Auction Facility for Methane and Climate Change Mitigation** is an innovative mechanism co-financed by the Swiss State Secretariat for Economic Affairs that pioneers the use of auctions to allocate public finance for climate action efficiently. The facility demonstrates a new pay-for-performance mechanism that takes advantage of existing tools and experience developed at the multilateral level under the Clean Development Mechanism and related carbon markets to deliver financing, in the form of a price guarantee, to projects that combat climate change;
- **Climate Investment Funds**: The Climate Investment Funds support transformational, scaled-up climate action in developing countries that has the potential to leverage significant co-financing from the private sector as well as multilateral development banks and achieve strong climate and development outcomes. The Climate Investment Funds support mitigation, adaptation, and technology transfer activities and are composed of the Clean Technology Fund and the Strategic Climate Fund with its three targeted programmes: (i) the Forest Investment Programme, (ii) the Pilot Programme for Climate Resilience, and (iii) the Scaling Up Renewable Energy in Low Income Countries Programme. Switzerland contributed 26 million US dollars to the Scaling Up Renewable Energy in Low Income Countries Programme. This programme's mandate is to scale up the deployment of renewable energy solutions in low income countries to increase energy access and economic opportunities. It currently supports 27 pilot countries, including one regional programme.

Tab. 43 > Energy Transition Plan for Municipalities in Tunisia.

Project/programme title:
Energy Transition Plan for Municipalities in Tunisia.

Goal:
Supporting Tunisian municipalities in the energy transition by providing them with technical and financial solutions adapted to the context.

Purpose:
To promote the energy transition in Tunisian municipalities.

Recipient country	Sector	Total funding	Years in operation
Tunisia	Energy Efficiency	3.6 million Swiss francs	2019–2022

Description:
The programme consists of the following components:
- Carry out energy audits in 339 municipalities and set up an energy accounting platform;
- Support the National Energy Management Agency for the introduction of the European Energy Award system for sustainable energy management at municipal level;
- Offer technical support and capacity building for the deployment of the European Energy Award system in seven pilot municipalities;
- Offer technical support and financing to help the pilot municipalities to identify, develop and implement quick-win energy efficiency projects.

Strategic partners at the national level are the National Energy Management Agency and the Local Government Loan and Support Fund of Tunisia.

Expected added value of the programme:
- Demonstration effect and replication in other Tunisian cities;
- Support to the introduction of the European Energy Award at the national and local level in Tunisia;
- Strengthen awareness raising on energy efficiency and sustainable energy management at the municipal level;
- Design of a financing mechanism for municipal energy management.

Technology transferred:
Not applicable.

Impact on greenhouse gas emissions/sinks:
Reduction of greenhouse gas emission in the quick-win energy efficiency projects compared to the baseline.

Swiss State Secretariat for Economic Affairs

7.1.4 Multiple benefits of forestry

Agriculture, forestry and other land use contribute 24 per cent to total global greenhouse gas emissions. 9.5 to 10.0 per cent of total global emissions are due to land use change and forest cover loss (*IPCC*, 2014). By absorbing and storing CO_2 from the atmosphere, tropical forests are therefore of critical importance in mitigating climate change. In addition, stronger ecosystems often provide important climate adaptation benefits for livelihoods and hazard protection. However, Switzerland's activities in the field of sustainable management of forests, grasslands and soil do not only focus on mitigation and adaptation effects, but are also geared towards yielding multiple environmental, economic and social benefits. Natural resources are key for the fight against poverty, especially when forests, grasslands and soils are protected and used as a sustainable source of income for local communities.

Through its bilateral, regional and multilateral development cooperation Switzerland supports multiple sustainable forest management and climate change-related projects, such as:

- **Forest Carbon Partnership Facility:** Through the Forest Carbon Partnership Facility at the World Bank, Switzerland supports the development and piloting of REDD+ and thus preparations for a results-based payment scheme to sustainably manage and protect forests as important carbon stocks and sinks. Apart of the financial contribution, Switzerland supported the development of Carbon Fund activities with relevant expertise;
- **Andean Forests Programme *('Bosques Andinos')*:** Andean forest ecosystems are fragile landscapes and particularly vulnerable to the combined effects of climate change, deforestation and forest degradation. At the same time, forest ecosystems potentially contribute to climate change mitigation, restoration of key ecosystem functions and reduced vulnerability of the people living in forested landscapes. In spite of their paramount importance for both human development and ecosystem stability, the Andean forests do not yet receive the necessary attention and recognition in national and international policy processes. Changing this situation is the declared goal of the Andean Forests Programme, which highlights the role of Andean montane forests for adaptation and mitigation of climate change and promotes knowledge development to address information gaps that prevent a more robust set of policies to ensure sustainable management and conservation of the mountain forests. The programme seeks to spark regional political interest in the conservation of Andean forests and shares the experiences made at the global level;
- **Macedonia Nature Conservation Programme:** Switzerland assists Macedonia in the sustainable management of natural resources through practical application of conservation measures such as regional protected areas and integrated forest management in the Bregalnica region. Furthermore, framework conditions are improved and support is provided in implementing national legislation and the Strategy on Nature. By promoting ecologically and sustainably produced products and services, economic benefits for the local population are generated. The aim of the project is to safeguard the natural values and to promote socio-economic development that is sustainable and inclusive in the Bregalnica region;
- **Support to Forestry and Fisheries Communities in Cambodia:** Switzerland contributes to the Partnership for Forestry and Fisheries implemented by a consortium of four non-governmental organisations, led by WWF Cambodia. The programme supports rural communities to secure their access to forestry and fishery resources, to improve income and food security through enhanced production practices, and to advance public dialogue on sustainable natural resource management in four least-developed provinces in the northeast of Cambodia. The aim of the project is to increase the incomes of rural and indigenous communities and households and to improve their resilience to economic and natural shocks by engaging in sustainable community-based livelihood approaches that protect their ecosystems and reduce pressure on their communal natural resource base. Since 2014, amongst other activities, the project helped to develop the capacities of 370 Community Based Natural Resource Management groups to engage in tenure formalisation and sustainable natural resource management, reaching 50,000 households.

7.1.5 Financial support for any economic and social consequences of response measures

Switzerland supports developing countries in the economic diversification and transformation, the creation of decent work and sustainable alternative livelihoods. For example, projects in the forest and energy sector are designed together with partner countries in order to ensure the diversification of livelihoods of local communities and local industries. Project activities usually include a policy dialogue at the local, national and regional level, striving for a sustainable transition to a low-carbon economy and sustainable development. For example the second phase of the Sustainable Recycling Industries programme of the Swiss State Secretariat for Economic Affairs, with a lifespan from 2019–2023, is developing knowledge partnerships in the area of e-waste in Columbia, Peru, Ghana, Egypt and South Africa. The programme supports these countries in their efforts to improve e-waste management systems. The Sustainable Recycling Industries programme focuses on a sustainable integration and participation of small and medium size enterprises from developing and transition countries in the global recycling of secondary resources. The programme organisation includes experts and builds strong local partnerships with governmental organisations, industry and the civil society. Through these and other strong capacity-building components at all levels – from local communities to government officials – Switzerland directly supports and fosters alternative livelihoods and the necessary capacities for the workforce to be ready for a transition to a low-carbon and climate resilient future. In addition, the Swiss State Secretariat for Economic Affairs' *SECO 17* initiative aims to support impact investment funds through technical assistance grants. Through a competitive process four technical assistance facilities were selected, two of which have a climate focus and help reducing CO_2 emissions. The technical assistance facilities provide funding for climate mitigation activities and feasibility studies for renewable power infrastructure in sub-Saharan Africa and South East Asia. The programme helps to reduce the investment risks by creating a bankable pipeline and enhance the resilience of investments, in turn mobilising additional capital for climate. Activities include promoting renewable energy generation (solar, hydro, wind), grid enhancement, as well as watershed protection and reforestation activities.

7.1.6 Provision of financial resources (including under Article 11 KP)

Switzerland's climate-related development cooperation has steadily increased over the last years. Overall, Switzerland disbursed 410.8 million US dollars in the form of grants through bilateral, multi-bilateral and multilateral channels in 2020. In addition, there was a total of 106 million US dollars bilaterally/multi-bilaterally mobilised private finance in 2020 (up from 8.5 million US dollars in 2016). This substantial increase in mobilised private finance was achieved in part through activities of the Swiss Export Risk Insurance (SERV), amounting in 2020 to 86.4 million US dollars mobilised private finance.

Of the bilateral public climate finance disbursed in 2020 a share of 129 million US dollars or 58 per cent went to adaptation and a share of 94 million US dollars or 42 per cent to mitigation (compared to 122 million US dollars or 55 per cent for adaptation and 99 million US dollars or 45 per cent for mitigation in 2019). More details are provided in the BR CTF tables.

The climate-specific part of the multilateral contributions are calculated based on the climate-specific imputed shares published on a year-by-year basis by the OECD Development Assistance Committee.

All contributions provided in Tab. 44 are grant-based public financial contributions from Switzerland. The contributions provided in Tab. 45 are and grant-based public financial contributions from Switzerland and climate-specific mobilised private financial contributions. The climate-specific share of each activity is assessed based on the Rio-marker methodology and reduction factors are applied. A reduction factor of 50 per cent will be applied for activities with an indirect impact on climate change adaptation or mitigation (significant marker) and a reduction factor of 85 per cent will be applied for activities with a direct impact on climate change adaptation or mitigation (principal marker). Double counting between adaptation and mitigation specific activities is excluded by netting out potential overlaps between the climate change adaptation and mitigation Rio markers. Following such an approach is necessary as the same activity may target multiple objectives and can be marked against several Rio markers, thereby reflecting the intertwined nature of the three Rio Conventions but at the same time avoiding double counting of efforts within one convention.

Tab. 44 > Switzerland's financial contributions to multilateral institutions and programmes, 2019 and 2020.

	2019		2020		2019 / 2020
	Core contribution	Climate-specific contribution	Core contribution	Climate-specific contribution	Imputed share
	US dollars				Per cent
Multilateral climate change funds					
Global Environment Facility	29 592 555	19 531 087	31 325 879	26 095 397	66% / 83%
Least Developed Countries Fund	2 515 091	2 515 091	3 407 881	3 407 881	100%
Special Climate Change Fund	792 254	792 254	838 658	838 658	100%
Adaptation Fund	15 090 543	15 090 543	0	0	100% / NA
GCF	0	0	36 581 470	36 581 470	100%
UNFCCC Trust Fund for the core contribution	373 728	373 728	413 815	413 815	100%
Intergovernmental Panel on Climate Change	1 106 640	1 106 640	170 394	170 394	100%
UNFCCC Voluntary Trust Fund	557 040	557 040	428 488	428 488	100%
Capacity Building Initiative for Transparency	0	0	0	0	NA
Sub-total	*50 027 851*	*39 966 382*	*73 166 584*	*67 936 102*	*NA*
Multilateral financial institutions, including regional development banks					
World Bank (including IDA and IBRD)	216 843 159	54 210 790	229 558 892	70 738 573	25% / 31%
International Finance Corporation	0	0	0	0	NA
African Development Bank (AfDB)	58 358 490	16 340 377	69 615 876	23 126 394	28% / 33%
Asian Development Bank	7 049 514	1 621 388	7 462 423	2 112 985	23% / 28%
European Bank for Reconstruction and Development	0	0	0	0	NA
Inter-American Development Bank	3 719 257	967 007	2 454 069	665 126	26% / 27%
Asian Infrastructure Investment Bank	27 861 972	10 866 169	29 493 930	10 794 778	39% /37%
Sub-total	*313 832 391*	*84 005 731*	*338 585 191*	*107 437 856*	*NA*
Specialised United Nations bodies					
United Nations Development Programme	50 000 000	NA	52 928 647	NA	NAV
United Nations Environment Programme	4 416 593	NA	4 675 293	NA	NAV
Sub-total	*54 416 593*	*0*	*57 603 940*	*0*	*NA*
Other					
United Nations International Children's Emergency Fund	19 416 499	NA	20 553 781	NA	NAV
United Nations Convention to Combat Desertification	97 500	NA	104 206	NA	NAV
United Nations Office for Disaster Risk Reduction	1 307 847	NA	1 437 700	NA	NAV
Consultative Group on International Agricultural Research	16 348 089	NA	17 092 652	NA	NAV
International Fund for Agricultural Development	14 103 777	5 782 548	14 110 756	5 208 703	41% / 37%
Multilateral Fund for the Implementation of the Montreal Protocol	2 880 387	2 880 387	3 049 100	3 049 100	100%
Food and Agricultural Organization of the United Nations	0	0	5 971 260	3 897 262	65%
Sub-total	*54 154 099*	*8 662 936*	*62 319 454*	*12 155 066*	*NA*
Total	**472 430 934**	**132 635 048**	**531 675 169**	**187 529 024**	**NA**

NA, not applicable
NAV, not available
IBRD, International Bank for Reconstruction and Development
IDA, International Development Association
AfDB, African Development Bank

Tab. 45 > Switzerland's financial contributions through bilateral and multi-bilateral channels, 2019 and 2020.

	2019		2020	
	Swiss francs	**US dollars**	**Swiss francs**	**US dollars**
Programmes and projects in Africa				
Adaptation	35 960 810	36 177 877	35 658 656	37 975 140
Mitigation	16 154 425	16 251 937	17 749 223	18 902 261
Sub-total bilateral public Africa	*52 115 235*	*52 429 814*	*53 407 879*	*56 877 401*
Private sector mobilised Africa	2 653 514	2 669 531	81 119 926	86 389 698
Programmes and projects in Asia				
Adaptation	31 505 070	31 695 241	29 671 822	31 599 384
Mitigation	17 073 770	17 176 831	17 456 375	18 590 389
Sub-total bilateral public Asia	*48 578 840*	*48 872 072*	*47 128 197*	*50 189 773*
Private sector mobilised Asia	55 765 657	56 102 271	7 354 952	7 832 750
Programmes and projects in Europe				
Adaptation	8 457 974	8 509 028	*8 758 747*	9 327 739
Mitigation	6 760 315	6 801 122	*7 945 732*	8 461 909
Sub-total bilateral public Europe	*15 218 289*	*15 310 150*	*16 704 479*	*17 789 648*
Programmes and projects in Latin America				
Adaptation	22 768 659	22 906 096	*21 784 402*	23 199 576
Mitigation	16 538 793	16 638 625	*10 839 344*	11 543 497
Sub-total bilateral public Latin America	*39 307 452*	*39 544 721*	*32 623 746*	*34 743 073*
Programmes and projects in Oceania				
Adaptation	**0**	0	4 093	4 359
Mitigation	0	0	50 000	53 248
Sub-total bilateral public Oceania	*0*	*0*	*54 093*	*57 607*
Global programmes and projects*				
Adaptation	22 723 802	22 860 968	25 424 610	27 076 262
Mitigation	41 845 898	42 098 489	34 322 263	36 551 931
Sub-total bilateral public global	*64 569 700*	*64 959 457*	*59 746 873*	*63 628 193*
Private sector mobilised global	12 197 772	12 271 400	10 751 496	11 449 942
Summary				
Sub-total bilateral public adaptation	***121 416 315***	***122 149 210***	***121 302 330***	***129 182 460***
Sub-total bilateral public mitigation	***98 373 201***	***98 967 004***	***88 362 937***	***94 103 235***
Sub-total bilateral public climate finance	***219 789 516***	***221 116 214***	***209 665 267***	***223 285 695***
Sub-total bilateral mobilised private climate finance	***70 616 943***	***71 043 202***	***99 226 374***	***105 672 390***
Total public and mobilised private climate finance	**290 406 459**	**292 159 416**	**308 891 641**	**328 958 085**

Exchange rates according to OECD (*https://doi.org/10.1787/067eb6ec-en*):

- 2019: 0.994 Swiss francs per US dollar;
- 2020: 0.939 Swiss francs per US dollar.

* Global programmes and projects include programmes and projects by the Swiss Agency for Development and Cooperation, the Swiss State Secretariat for Economic Affairs, the Swiss Federal Office for the Environment and other government agencies.

Fig. 102 > Swiss international bilateral public climate finance, including climate specific bilateral contributions from different Government entities by region and type of support, 2019 (million Swiss francs).

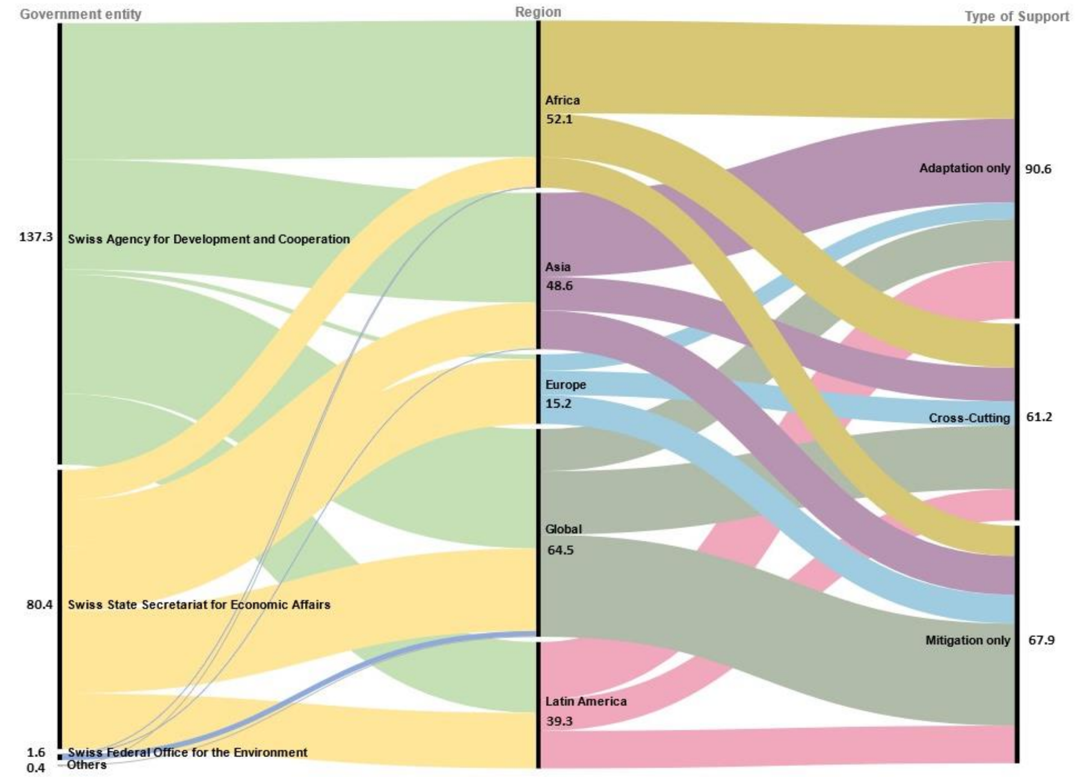
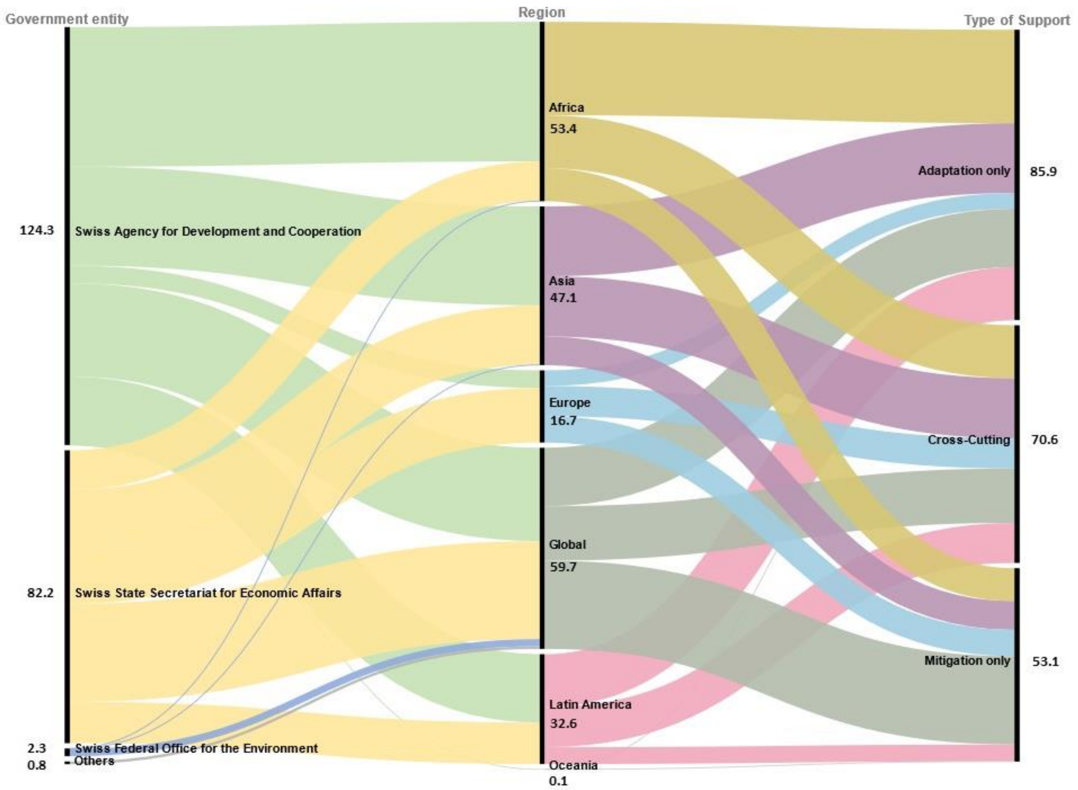


Fig. 103 > Swiss international bilateral public climate finance, including climate specific bilateral contributions from different Government entities by region and type of support, 2020 (million Swiss francs).



Tab. 45 includes aggregated data per region. The BR CTF table 7 (b) contains more disaggregated data on the country level, where possible. Switzerland does not provide activity-level information in the BR CTF table 7 (b). An additional administrative burden would arise and a high risk of errors when entering the data manually. In addition, Switzerland is of the view that activity-level data within the national communication and the BR CTF table 7(b) (with the current technical set-up) is difficult to read and interpret. However, given the relevance of increased transparency and to illustrate the diversity of projects, programmes and regions of Swiss support for climate action in developing countries, a full list of all climate-relevant projects is provided in a supplementary document named 'List of all Swiss projects and programmes to support climate action in developing country Parties (activity level, 2019–2020)'. The table also indicates in detail all sectors, which have benefitted from each of the activities, since it is not possible for Switzerland to give a clear indication of sectors in the BR CTF table 7 (b) due to country-level aggregation. Switzerland is committed to provide disaggregated activity-level information in the future in the context of the enhanced transparency framework agreed under the Paris Agreement. Switzerland will work with other contributors to facilitate an automated data transfer from the OECD DAC CRS into the enhanced transparency framework hosted at the UNFCCC Secretariat to reduce the risk of human errors.

7.2 Technology development and transfer

Numerous Swiss programmes and projects, which support developing countries in their endeavours to mitigate and adapt to climate change, contain a technology development and/or transfer component. Technology development and transfer are critical means of implementation to ensure the sustainability of a project or programme. This is particularly true in the area of infrastructure financing and the development of local markets and products.

Switzerland provides support for technology development and transfer through the below mentioned activities and measures in line with its commitment under Article 10, paragraph c, of the Kyoto Protocol as well as Article 4, paragraphs 3 and 5, of the Convention.

7.2.1 Importance of and measures to promote private sector initiatives for technology transfer

Technology transfer and innovation are crucial for any economic development. Technologies are mostly developed and owned by the private sector. In various areas of environmentally sound technologies, Swiss companies are leading in the development, diffusion and implementation of state-of-the-art solutions. Switzerland is an important hub in terms of R&D, foreign direct investment and technology exports. Some of these climate relevant Swiss private sector activities are supported by the Swiss export promotion agency 'Switzerland Global Enterprise' (*www.s-ge.com*) through its Swiss business hubs in strategic export markets. 'Switzerland Global Enterprise' is mandated by the Swiss Confederation to make information on Swiss Cleantech companies available in a publicly accessible database (*www.s-ge.com/cube*). This database may be used to identify the Swiss partners for environmentally sound solutions. Many companies registered in the database are active in developing countries. 'Switzerland Global Enterprise' is also contributing to some long-term cooperation projects aiming at the same time to add value for developing country Parties and for exporting Swiss companies.

Another important service for private technology suppliers is the Swiss Export Risk Insurance (*www.serv-ch.com*). The Swiss Export Risk Insurance is traditionally very important for Swiss exports, e.g. in the context of railway projects. Through the support of the export of climate friendly technologies by Swiss companies to developing countries, Switzerland contributes to the commitment of Parties under Article 4, paragraph 5, of the Convention. In 2020, the mobilisation of private finance has increased drastically in part due to the finance mobilised by the Swiss Export Risk Insurance (86.4 million US dollars). Moreover, the Swiss Export Risk Insurance adopted in 2021 a new climate strategy, which aims to support climate friendly investments even further.

7.2.2 Role of the public sector in technology transfer

Successful technology transfer uses the know-how, innovation and financing capacity of the private sector. Switzerland is supporting various initiatives in the area of technology development and transfer, targeting developing and transition countries as part of its development cooperation. Switzerland is convinced that the following elements need to be taken into consideration by governments to foster technology transfer and development:

- Creating a sound trade framework: Reduce custom tariffs and non-tariff barriers;

- Creating an enabling investment framework: Protect private property, intellectual property rights (IPR), reduction of administrative hurdles for companies, fight against corruption; legal stability, security, appropriate energy tariff setting, etc.;
- Strengthening financial markets: Improve access to finance particularly for small to medium-sized businesses and strengthen the risk management of financial intermediaries in its partner countries including capacity building in addressing environmental and social risks;
- Capacity-building and sharing of information in order to prepare industry and corporations in developing countries to deal with the challenges of global production chains and new technologies;
- Realising pilot and demonstration projects.

7.2.3 Measures promoting the transfer of, access to and deployment of climate-friendly technologies

In line with the above mentioned elements, Switzerland has implemented several measures to promote, facilitate and finance the transfer of, access to and the deployment of climate-friendly technologies for the benefit of developing country Parties and for the support of the development and enhancement of endogenous capacities and technologies of developing country Parties. Several of these measures are highlighted below.

Renewable energy auction program

2019, the Swiss State Secretariat for Economic Affairs financed a programme that supports the development of a renewable energy auction system in the Western Balkans, the Middle East and North Africa. The programme is implemented in collaboration with the European Bank for Reconstruction and Development (EBRD) and financed with about 5 million Swiss francs (5,030,181 US dollars). It includes improving the regulatory and institutional framework necessary for the successful implementation of renewable energy auctions as well as providing advice and expertise on the design of competitive public procurement. It aims to mobilise more than 170 million Swiss francs (171,026,157 US dollars) in private investment and increase renewable energy capacity by at least 250 megawatts over five years.

Platform for the promotion of renewable energy and energy efficiency in international cooperation (REPIC)

The interdepartmental platform on Renewable Energy, Energy and Resource Efficiency Promotion in International Cooperation (REPIC)[110] is specifically targeting technology transfer and development in renewable energy, energy efficiency and resource efficiency. Beyond enhancing knowledge and coherence, REPIC offers seed money, capacity building and technical advice for promising climate change initiatives during the pre-competitive phases of project development, for technology and market testing. REPIC mobilises currently private funds for climate. In order to increase REPIC mobilisation of private funds for climate activities, a new grant instrument for Corporate Business Development will be implemented in 2022. The purpose is to provide support to business planning and commercialization strategy development, pilot and demonstration projects (proof of concept) and development of new market entry strategies. For climate related projects. A project example is depicted in Tab. 46.

Tab. 46 > Platform for the promotion of renewable energy, energy and resource efficiency in international cooperation (REPIC).

Project/programme title:
Indian SME Rooftops (funded with REPIC seed money)

Purpose:
This project aimed at installing solar energy for small to medium-sized businesses at zero upfront cost for them.

Recipient country	Sector	Total funding	Years in operation
India	Renewable Energy	150 000 Swiss francs	2018–2021

Description:
Schools and small to medium-sized businesses in India face high and rising power prices. They rely on dirty grid power (largely coal-fired) and back-up diesel power whilst lacking access to the financing which would allow them to install solar power on their currently unused rooftops. Within this project Candi solar therefore installed solar energy for several small to medium-sized businesses, for a total power of 700 kilowatts. There were zero upfront costs for small to medium-sized businesses, and they will pay for power over time. Small to medium-sized businesses will thereby own a productive clean energy generating asset in as little as ten years, whilst saving money from day one (given the lower cost of solar power vs. the grid).

Factors that led to project/programme's success:
Candi solar will bring its financing, legal and technical know-how, as well as business concept, to the local partners who in turn provide local expertise, construction and maintenance capabilities. Montavent will provide a unique slide-in solution to mounting, which eliminates the use of screws and thus speeds up installation and de-installation.

110 http://repic.ch/repic-en

Technology transferred:
The project forms an important demonstration project for a new approach: Candi solar signs a uniquely designed power purchase agreement (PPA) and utilises an innovative mounting technology, so that if the clients go bankrupt, the system can be removed at very low cost and redeployed with another small to medium-sized business. This effectively reduces the projects' risk profile and overcomes financing hurdles.

Impact on greenhouse gas emissions/sinks:
Solar power enables to mitigate CO_2 compared to the power from the grid that is still largely coal-fired in India, Candi solar is replicating its model in South Africa and has been able to attract investors thanks to its successful pilot project in India.

Cleaner production and resource efficiency in the construction sector

The building and construction sector has a large potential for climate change mitigation and adaptation measures. Switzerland has been active in this area domestically and is engaged in the transfer of technology and capacity building for multiple years. Tab. 47 shows detailed project information.

Tab. 47 > Low Carbon Cement Project.

Project/programme title:
Low Carbon Cement Project

Purpose:
Limestone Calcined Clay Cement (LC3) is established as reliable, viable and green cement, suitable for general production and construction.

Recipient country	Sector	Total funding	Years in operation
India, Cuba, Global	Building	1.85 million Swiss francs	2020–2022

Description:
The project aims to enable the recognition of a new low carbon cement type (Limestone Calcined Clay Cement – LC3) as suitable for general construction and support its establishment in the market. It has three components:

- Scientifically research to close the remaining critical knowledge gaps of LC3;
- Achieving recognition of LC3 in the Indian cement standard;
- Disseminating information and enabling policy framework to de-risk investment and accelerate commercial deployment.

Implementing partners of the project are: Swiss Federal Institute of Technology, Lausanne; Indian Institute of Technology, Delhi; Indian Institute of Technology, Madras; Technology and Action for Rural Advancement, India; Centro de Investigación y Desarrollo de Estructuras y Materiales, Cuba.

Factors that led to the success of the project/programme:

- Trilateral collaboration between Indian, Cuban and Swiss universities;
- Close collaboration with public and private stakeholders; the project was able to put the topic of Low Carbon Cement on the agenda of governments as well as global cement companies;
- Strong presence at international conferences: The project introduced LC3 prominently at several national and international conferences (e.g. UNFCCC COPs, Global and regional CEMTECH conferences);
- Significant increase of scientific and practical research on LC3;
- Collaboration with different global initiatives and programmes. Cement Sustainability Initiative of the World Business Council on Sustainable Development and the Global Alliance for Buildings and Construction hosted at the United Nations Environmental Programme;
- Contribution to a United Nations Environment Programme Report (2016) on Eco-efficient Cements, available at *http://www.nanocem.org/fileadmin/nanocem_files/documents/misc/2016-UNEP_Report.pdf*.

Technology transferred:
A new low carbon cement type (LC3) was researched and tested jointly between the different involved universities and institutions.

Impact on greenhouse gas emissions/sinks:
Limestone Calcined Clay Cement contains half the clinker content and thus saves up to 40 per cent CO_2 emissions compared to conventional Portland cement.

Climate Technology Centre and Network

The Climate Technology Centre and Network is part of the UNFCCC Technology Mechanism. The Mechanism consists of two complementary bodies: the Technology Executive Committee, whose focus is to develop technology policies and recommendations to support country efforts, and the Climate Technology Centre and Network, which provides technology implementation at the request of developing countries. The Climate Technology Centre and Network ensures its accountability to the UNFCCC Conference of Parties through the oversight of the Climate Technology Centre and Network Advisory Board. Tab. 49 shows additional information for the Climate Technology Centre and Network.

Resource Efficient and Cleaner Production

The Global Eco-Industrial Parks Programme (GEIPP) aims at strengthening the capacity of the management of selected existent industrial parks regarding resource efficient and cleaner production methods and at supporting governments and administrations in their effort to enhance/design the necessary institutional settings. Furthermore the programme works together with enterprises located in the selected industrial parks and enhances their international competitiveness by increasing their (resource-) productivity. Tab. 48 shows detailed project information.

Tab. 48 > Global Eco-Industrial Parks Programme.

Project/programme title:
Global Programme on Resource Efficient and Cleaner Production in developing and transition countries (RECP).

Purpose:
The GEIPP aims at enhancing the resource productivity, competitiveness and environmental performance of selected existing industrial parks in participation countries.

Recipient country	Sector	Total funding	Years in operation
Egypt, Colombia, Indonesia, Peru, South Africa, Ukraine, Vietnam	Multi sector	17.1 million Swiss francs	2019–2023

Description:
The development objective of the Global Eco-Industrial Parks Programme (GEIPP) is to demonstrate the viability and benefits of greening industrial parks by improving resource productivity and economic, environmental and social performances of businesses and thereby contributing to inclusive and sustainable industrial development in the participating countries.
GEIPP focusses on contributing to the following outcomes:

- Eco-Industrial Parks (EIP) incentivised and mainstreamed in relevant policy and regulations leading to an increased role of EIP in environmental, industry and other relevant policies at the national levels in the participating Programme countries;
- EIP opportunities identified and implementation started, with environmental (e.g. resource productivity) economic and social benefits achieved by enterprises confirmed. The implementation of EIP opportunities by enterprises and other organisations will be supported by the EIP services providers, and will lead to reduction of the environmental footprint and operational and compliance costs of businesses, and an increase in their natural resource productivity;
- EIP tools developed, services delivery capacity enhanced and lessons learnt properly capturing and effectively exchanged. EIP tools developed and made applicable beyond the context of the individual parks or countries (via description how to apply tools locally).

Factors that led to project/programme's success:

- In-plant assessments of the different resource streams offer opportunities for improvement and learning;
- Buy-in and ownership of the host country;
- Strengthened implementation capacities of national stakeholders;
- Strengthened awareness of resource efficiency issues.

Technology transferred:
Technology transfer in the context of the RECP global programme encompasses know-how and services as well as organisational and managerial procedures. Furthermore, the programme supports recipient countries to develop an institutional framework that enables the transfer of climate-related technologies. The main focus lies on technical assistance and the build-up of local know-how and expertise.

Impact on greenhouse gas emissions/sinks:
Programme started in 2019; no emissions reductions reported so far.

Multilateral engagement of Switzerland in the area of technology transfer and development

Besides its bilateral projects that oftentimes contain an integrated technology development and transfer component, Switzerland also contributed to specific technology development and transfer funds such as the Climate Technology Centre and Network (about four million Swiss francs), the Special Climate Change Fund (2.8 million Swiss francs between 2015 and 2018) as well as several other funds and multilateral organisations, which are active in the area.

Tab. 49 > Climate Technology Centre and Network.

Project/programme title:
Climate Technology Centre and Network.

Purpose:
The Climate Technology Centre and Network promotes the development and transfer of climate technologies at the request of developing countries for energy efficient, low carbon and climate-resilient development.

Recipient country	Sector	Total funding	Years in operation
Global	Multi sector	Four million US dollars	2016–2020

Description:
The Climate Technology Centre and Network fosters technology development and transfer across numerous adaptation and mitigation sectors by providing three key services:

- Technical Assistance: The Climate Technology Centre and Network provides technical assistance and capacity building in response to requests submitted by developing countries via their National Designated Entities. Upon receipt of such requests, the Centre mobilises its global Network of climate technology experts to design and deliver a customised solution tailored to local circumstances;
- Knowledge Sharing: Through regional forums, publications, an online portal, and its Incubator Programme, the Climate Technology Centre and Network creates environments for capacity building and knowledge sharing on climate technology solutions. The Centre engages its Network and NDEs in highlighting technology best practices, south-south transfer examples, and learning from existing technical assistance experiences;
- Collaboration and Networking: The Climate Technology Centre and Network brings together a diverse global community of climate technology users and providers, decision makers, and funders to identify barriers, share best practices, and identify matchmaking opportunities. Under the umbrella of the UNFCCC Technology Mechanism, Network members gain the opportunity to showcase relevant technologies, policies and practices, and to facilitate their deployment in developing countries.

Factors that led to project/programme's success:
Key factors for programme success are the well-established and still growing network of climate technology experts which will help developing countries to design and develop mitigation and adaptation activities with a strong focus of technology implications. Furthermore the demand driven, bottom-up approach strengthens ownership on the side of the beneficiaries.

Technology transferred:
The main purpose of the Climate Technology Centre and Network is the provision of technical assistance, capacity building and knowledge sharing within the sphere of climate technologies. For more information see the description of the project.

Impact on greenhouse gas emissions/sinks:
The impact on greenhouse gas emissions cannot be calculated. Climate Technology Centre and Network is a mechanism that helps to design and develop projects and does not finance the concrete project implementation.

7.2.4 Quantification of all activities related to technology transfer

Due to the integrated character of the bilateral technology development and transfer support measures of Switzerland, it is not possible to single out and quantify the respective components. In addition, it would not do justice to the integrated approach underpinning Switzerland's climate change interventions. Therefore, the technology development and transfer components of Swiss-funded projects are not systematically identified in this report.

There is internationally no clear understanding and no consensus on how Parties should quantify their technology transfer components within climate-relevant projects. The lack of consensus prevents a comparison of quantifiable data. Switzerland is of the opinion that qualitative information therefore provides much more content to exchange on lessons learnt and improve the technology transfer and overall development support.

If Switzerland were to isolate the technology transfer components of its climate-related activities, it would need to fundamentally redesign its entire national reporting system. An important corollary would be that all project managers both at the headquarters and in the field offices would have to estimate the technology transfer components in the planning phase of their projects. This would considerably increase the administrative burden and reduce the resources available for project implementation, ultimately diminishing the climate impact on the ground.

Switzerland will therefore continue to report on its technology transfer activities in qualitative terms by emphasising their integrative character based on concrete project examples (see section 7.2.3). In addition, Switzerland is submitting BR CTF table 8 with exemplary technology development and transfer support measures as part of the eighth national communication for the first time.

7.3 Capacity building

Capacity building is an essential component of almost all Swiss programmes and projects, which support developing countries in their endeavours to mitigate and adapt to climate change. Capacity building is critical for the successful and effective implementation of climate measures and helps to ensure the sustainability of any project or programme. However, in order to scale up, appropriate set-ups and corresponding tools are needed. Switzerland therefore strives to promote a cooperative model among different actors and has invested considerable efforts in developing a user-friendly tool that helps in mainstreaming climate change both at the strategic as well as at the operational level.

Due to the highly integrated character, it is not possible for Switzerland to single out the capacity-building components of all its development cooperation projects and programmes. Moreover, it would not do justice to the integrated approach underpinning Switzerland's climate change interventions. Therefore, capacity-building components of Swiss-funded projects are not systematically identified in this report. Nevertheless – and for illustrative purposes – various project examples given below showcase how the integrated approach plays out.

Environment and Social Risk Management in Sub-Saharan Africa

In most countries, businesses and individuals do not pay for the negative environmental and social effects they cause. Hence, social and environmental risks do usually not inform the development of business plans as well as daily operations. The Environmental and Social Risk Management Programme (Tab. 50) of the International Finance Cooperation aims to address this problem. The programme is based on the assumption that financial institutions can play a key role when it comes to pushing change in the market because financial institutions are in a position to influence business behaviour through their ability to allocate capital by lending money to companies.

Tab. 50 > Environment and Social Risk Management in Sub-Saharan Africa.

Project/programme title:
Environmental and Social Risk Management for financial institutions in Sub-Saharan Africa

Purpose:
The overall objective of the programme is to increase the uptake of environmental and social standards by financial institutions in the Sub-Saharan Africa region. This is expected to lead to an improvement in environmental and social performance of local businesses in the long term.

Recipient country/region	Targeted area
Sub-Saharan Africa (Ghana, Nigeria, South Africa)	Adaptation

Description:
The programme has just started, hence an overview of the planned capacity building support is provided:
- Training and advisory services make the regulator (mainly the central bank) more effective in dealing with environmental and social issues. In particular, the regulator will be supported in revising existing and designing new environmental and social risk management policies and procedures;
- Development of material and manuals which can be used for environmental and social risk management training;
- Development of sector specific guidelines that fit the relevant country context;
- Provision of country specific environmental and social information to the public, mainly through the development of country specific portals of the FIRST for Sustainability website (*www.firstforsustainability.org*).

It is expected that those activities will lead to:
- The development of effective regulatory policies, procedures and standards in order to create an environment which is conducive to the uptake of ESRM systems;
- The build-up of relevant environmental and social expertise of local consultants in the markets of the programme countries. This expertise can be used/ purchased by financial institutions in order to implement their own Environmental and Social Risk Management Programme systems;
- Increased awareness on environmental and social risks, increased level of publicly available information on environmental and social issues as well as improved information dissemination among financial institutions and other stakeholders.

Swiss Impact Finance Initiative (SIFI)

The Swiss Impact Finance Initiative supports innovative finance approaches that mobilise private funding and contribute to measurable results under the sustainable development goals (SDGs) in developing countries. The goal is to support the piloting, seeding, and scaling of innovative impact investment funds and of products and services with a public good character relevant to the overall impact investing ecosystem (see Tab. 10). End beneficiaries are individuals in developing countries that will benefit from concrete result achievements under their countries' SDGs. The thematic scope and targeted SDGs will be defined ex ante for each call for proposals. Typically, SIFI will track indicators such as (i) amounts mobilised from the private sector, (ii) greenhouse gas emissions saved or avoided, (iii) number of companies or producers with access to capital, and (iv) number of jobs created or retained or improved.

Tab. 51 > Swiss Impact Finance Initiative (SIFI).

Project/programme title:
Swiss Impact Finance Initiative (SIFI)

Purpose:
The purpose of the initiative is to support innovative finance approaches that mobilise private funding and contribute to measureable results under the sustainable development goals in developing countries.

Recipient country/region	Targeted area
Global	Multiple areas

Description:
The objective of SIFI is to support the piloting, seeding, and scaling of innovative impact investment funds and of products and services with a public good character relevant to the overall impact investing ecosystem. Through competitive call for proposals, applicants have the possibility to apply for project grants. The thematic scope and targeted SDGs will be defined ex ante for each call for proposals. Typically, SIFI will track indicators such as (i) amounts mobilised from the private sector, (ii) greenhouse gas emissions saved or avoided, iii) number of companies or producers with access to capital, and (iv) number of jobs created or retained or improved. Individuals in developing countries will benefit from concrete result achievements under their countries' SDGs, including from a low-emission and climate resilient economy.

Key targeted outcomes:
- More private capital allocated to the SDGs;
- More and better innovative products are launched that increase transparency, credibility, and availability of investable products and solutions;
- More and better results are delivered by impact investment funds.

Key targeted outputs:
- Provide grant funding for innovation, seed funding for operating expenses and incentivise collaboration;
- Provide grant funding to impact investment funds for technical assistance.

Climate, Environment and Disaster Risk Reduction Integration Guidance (CEDRIG)

While global aspirations to effectively tackle climate change both via mitigation and adaptation measures are high, the related concrete expectations appear more difficult to be met. This situation is also due to a lack of 'do-how' by many actors. This is why Switzerland has further stepped up its efforts to apply a user friendly tool that helps to mainstream climate change in strategies, programmes and projects among all concerned sectors. Moreover, acknowledging the close interlinkages between climate change, disaster risk reduction and the environment (natural resources) and to ensure that all its investments are climate-proof, the Swiss Agency for Development and Cooperation has enhanced its comprehensive tool for programmatic and operational planning that integrates all three aspects.

Tab. 52 > Climate, Environment and Disaster Risk Reduction Integration Guidance (CEDRIG).

Project/programme title:
Climate, Environment and Disaster Risk Reduction Integration Guidance (CEDRIG)

Purpose:
To help integrate aspects of climate change, environmental degradation and disaster risk reduction into development cooperation at strategic, programmatic and operational levels.

Recipient country/region	Targeted area
Global	Multiple areas

Description:
CEDRIG is a practical and user friendly tool developed by the Swiss Agency for Development and Cooperation. It is meant to systematically integrate climate, environment and disaster risk reduction into development cooperation and humanitarian aid in order to enhance the overall resilience of systems and communities.
CEDRIG helps to understand whether existing and planned strategies, programmes and projects are at risk from climate change, environmental degradation and natural hazards, as well as whether these interventions could further exacerbate greenhouse gas emissions, environmental degradation or risks of natural hazards. The tool is open source, multilingual and offers three independent modules.
CEDRIG follows an integrated approach to assess the risks for and the unintended potential negative impacts of a new strategy, programme or project. By its application, existing or planned interventions will become more climate, environment and risk smart. CEDRIG is divided into three parts: (i) *CEDRIG Light* helps to decide whether a detailed risk and impact assessment must be conducted or not, (ii) in case of a ‘yes’, *CEDRIG Strategic* is used to analyse strategies and programmatic approaches, and (iii) *CEDRIG Operational* is applied for operational projects.
CEDRIG workshops have been carried out in different countries and regions. Fostering a systematic application of a CEDRIG-type process in all projects in the future, regional CEDRIG champions from different parts of the world were trained to become facilitators that will support the application in their respective region. As a result, people and institutions were trained and respective strategies, programmes and projects revised by including or substantiating aspects related to address climate change, disaster risk reduction and the environment.

One UN Climate Change Learning Partnership (UN CC:Learn)

UN CC:Learn is the partnership of key multilateral organizations assisting member states in designing and implementing learning to address climate change. It supports countries in developing national strategies and designs and promotes learning materials to strengthen human resources and skills for climate resilient-development and global climate literacy. Switzerland’s focus therein is on further advancing the youth component and strengthening the sustainability aspects of the initiative.

Tab. 53 > UN CC:Learn.

Project/programme title:
One United Nations Climate Change Learning Partnership (UN CC:Learn)

Purpose:
At the global level, the partnership supports knowledge sharing, promotes the development of common climate change learning materials (free of charge e-learning modules), and coordinates learning interventions through collaboration of United Nations agencies and other partners. At the national level, UN CC:Learn supports countries in developing and implementing national climate change learning strategies.

Recipient country/region	Targeted area
Global with selected partner countries	Multiple areas

Description:
The UN CC:Learn is a collaborative initiative involving 36 multilateral organisations. The secretariat for UN CC:Learn is hosted by UNITAR. It supports countries in designing and implementing country-driven, results-oriented and sustainable learning to address climate change. The initiative was launched at the 2009 Copenhagen Climate Change Summit and has since received substantial funding from the Swiss Agency for Development and Cooperation. UN CC:Learn is included in the ‘One United Nations Climate Change Action Framework’ of the United Nations System Chief Executives Board for Coordination. The Chief Executives Board for Coordination framework aims at maximizing existing synergies, eliminating duplication and optimizing the impact of the collective effort of UN organisations in combatting climate change. As such, UN CC:Learn directly contributes to the implementation of Article 6 of the UNFCCC on education, training and public awareness, Article 12 of the Paris Agreement, the Action for Climate Empowerment (ACE) as well as the Doha Work Programme.
Since its launch in 2009, UN CC:Learn has been supporting 13 countries in developing and implementing their national climate change learning strategies, as well as two regional hubs: in Central America – which led to the launch of a Regional Action Plan on Climate Change Education, Training and Awareness Raising – and in West Africa. As a result, over 70 climate change learning actions have been implemented by countries – ranging from trainings for government officials, teachers and other professionals to the design of new learning materials, the development of guidelines for the integration of climate change into school curricula and youth engagement – leveraging funding from both national and international sources. The capacity of national and regional learning institutions has been strengthened (e.g. coaching for e-learning development) and South-South sharing of learning has increased.

Disaster Risk Finance and Insurance Program

The programme supports selected countries in improving their financial resilience to natural disasters and their financial response capacity post disaster through policy, budgetary and market-based solutions.

Tab. 54 > Disaster Risk Financing and Insurance (DRFI) Program

Project/programme title:
Disaster Risk Financing and Insurance (DRFI) Program

Purpose:
The programme supports selected Middle-Income Countries in improving their financial resilience to natural disasters and their financial response capacity post disaster through policy, budgetary and market-based solutions.

Recipient country/region	Targeted area
Colombia, Peru, Vietnam, Serbia, Morocco, Indonesia, Tunisia, South Africa, Nepal, Georgia, Albania	Multiple areas

Description:
The Swiss State Secretariat for Economic Affairs is partnering with the World Bank since 2011 to implement the Disaster Risk Financing and Insurance (DRFI) Program. Middle-income countries have been the most adversely affected by natural disasters in economic terms over the last two decades as measured in direct losses as a percentage of GDP. They are particularly impacted because risk management measures such as building codes and land-use zoning cannot keep pace with the rapid growth in infrastructure and economic activities.
In this context, middle-income countries have a growing interest in sovereign disaster risk financing and insurance to help them be better financially prepared when disasters strike. Most middle-income countries still rely heavily on post-disaster financing through budget reallocation, post disaster borrowing, or tax increases. The development objective of the programme is to increase the financial resilience of middle-income countries to natural disasters. This includes the strengthening of domestic catastrophe insurance markets. The final beneficiaries are the countries' citizens, particularly the poorest living in disaster-affected areas. Since its inception, the programme built significant human and institutional DRFI capacity. The programme supported its beneficiary countries in assessing and quantifying their financial exposure to natural disasters, develop national (and in some countries sub-national) DRFI strategies, and implement these strategies through the establishment budget reserves, resilience funds, Contingent Credit Lines, or risk-transfers to international markets. Thanks to these interventions, the programme countries' fiscal resilience is significantly strengthened.

7.3.1 Reporting of activities related to capacity building

As mentioned above, due to the integrated character of the bilateral capacity-building support measures of Switzerland, the necessary data to single out and quantify the respective capacity-building components is not available. In addition, a reporting of these components in isolation would not do justice to the integrated approach underpinning Switzerland's climate change interventions. Therefore, the capacity-building components of all Swiss-funded projects are not in isolation systematically identified and quantified in Switzerland's national communication or biennial report.

If Switzerland were to isolate the capacity-building components of all its climate-related activities, it would need to fundamentally redesign its entire national reporting system.

Switzerland will therefore continue to report on its capacity building activities in qualitative terms, by emphasising the integrative character based on concrete project examples. In addition, Switzerland is submitting BR CTF table 9 with exemplary capacity building support projects as part of the eighth national communication for the first time.

References

IHCAP, 2016: Climate Vulnerability, Hazards and Risk: An Integrated Pilot Study in Kullu District, Himachal Pradesh (Synthesis Report). Indian Himalayas Climate Adaptation Programme. *https://bit.ly/37IPghH* [18.07.2022]

IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change. *http://www.ipcc.ch/report/ar5/wg3* [18.07.2022]

OECD, 2015: Climate finance in 2013–2014 and the USD 100 billion goal. OECD in collaboration with Climate Policy Initiative. *http://www.oecd.org/environment/cc/OECD-CPI-Climate-Finance-Report.htm* [18.07.2022]

OECD, 2021: Climate Finance Provided and Mobilised by Developed Countries: Aggregate Trends Updated with 2019 Data, Climate Finance and the USD 100 Billion Goal. OECD Publishing, Paris. *https://doi.org/10.1787/03590fb7-en* [18.07.2022]

TWG, 2015: Accounting for mobilised private climate finance: input to the OECD-CPI Report. Technical Working Group, September 2015, Bern. *http://www.news.admin.ch/NSBSubscriber/message/attachments/41225.pdf* [18.07.2022]

8 Research and systematic observation

8.1 General policy on and funding of research and systematic observation

8.1.1 Research: General policy and funding

According to the Federal Act on the Promotion of Research and Innovation (*Swiss Confederation*, 2012), it is the responsibility of the federal government to support and promote scientific research. The general Swiss policy on research and funding aims to support freely chosen research topics and questions as well as high-quality research. Thus, the major part of research in Switzerland is organised in individual research projects where research groups or institutions have to apply for the corresponding funding. Scientific quality is the main criterion for financial support. For the organization of quality control and funding of research, the federal government mandates the Swiss National Science Foundation SNSF (mainly for basic research) and the Swiss Innovation Agency Innosuisse (for applied research). However, from time to time there are calls for National Research Programmes (NRPs) or National Competence Centres of Research (NCCRs) where topics are proposed to the Swiss Federal Council from a number of clustered high-quality proposals of interested parties.

In addition, the federal departments can commission research in areas of public interest, and parts of the federal administration host fully fledged research institutions. Research that is directly funded by government institutions is divided in eleven thematic federal research programmes.[111] These programmes provide the conceptual framework and set research priorities for each of these eleven policy areas. They are used to coordinate research activities and promote collaboration between research institutions. Furthermore, they can initiate research on questions that are particularly relevant for governmental agencies.

In recent decades, Switzerland has also participated in the European Framework Programmes for Research and Innovation. For many years, Switzerland was fully associated to these programmes and many Swiss scientists have taken leading roles in European research projects and programmes. However, for political reasons, Switzerland has lost full association for some periods, including the current phase (see next section).

All of the above-mentioned research frameworks contain an important part of climate relevant activities.

Funding

Swiss climate research is mainly funded by the Swiss National Science Foundation (SNSF), the European Cooperation in Science and Technology COST and, until the year 2020, by the European Union Framework Programme for Research EU-FPR (in the order of magnitude of about 20 million Swiss francs per year in each case) as well as by direct funding from federal agencies, mainly from environment, agriculture, energy as well as international development and cooperation programmes (funding volume in the same order of magnitude). The federal research programme SWEET (SWiss Energy research for the Energy Transition), which follows the Swiss Competence Centres in Energy Research (SCCER) programme, has been allocated a budget of 148 million Swiss francs for the period 2021–2032. However, this amount does not only cover climate-focused projects.

From 2017 to 2020 Switzerland has been a fully associated member of the EU-FPR ‘Horizon 2020’, i.e. Switzerland payed a fixed contribution to the programme and Swiss researchers could apply for funding in the programme. However, in the 9th Framework Programme ‘Horizon Europe’ (2021–2027), Switzerland participates – for the time being – as a non-associated third country. Therefore, Swiss researchers can apply for project funding, but if successful, the funding is taken over by the Swiss government, which in turn makes no financial contribution to the EU programme.

Research structures

Climate-relevant research in Switzerland can be divided into several categories:

- Individual research projects funded by SNSF or federal research programmes;
- National research programmes (NRPs or specific federal programmes like SWEET);

[111] https://www.ressortforschung.admin.ch/rsf/de/home/themen.html (German), https://www.ressortforschung.admin.ch/rsf/fr/home/themen.html (French)

- National research centres (Oeschger Centre for Climate Change Research, Centre for Climate Systems Modelling, Centre for Development and Environment);
- Projects of the National Centre for Climate Services NCCS;
- Research projects in the framework of the Global Atmosphere Watch Switzerland Programme (GAW-CH) and the Global Climate Observing System Switzerland Programme (GCOS Switzerland);
- Participation in international research programmes (European Union, European Cooperation in Science and Technology, World Climate Research Programme, Future Earth) by researchers at various universities, the Swiss Federal Institutes of Technology in Zurich and Lausanne, universities of applied sciences, and private and public research organisations;
- Collaborations with international research centres and organisations (European Centre for Medium-Range Weather Forecasts, European Organisation for the Exploitation of Meteorological Satellites, World Meteorological Organisation, Intergovernmental Panel on Climate Change).

National research centres

Three research centres have a special focus on climate change and its impacts:

- **Oeschger Centre for Climate Change Research (OCCR) at the University of Bern:**[112] Its main scientific interests are on the climate system and its interactions with society and the economy. The OCCR aims to contribute to the 'Sustainability Focus' of the University of Bern. Research is comprised of four closely linked core areas, namely global climate dynamics, regional climate dynamics, consequences and risks of climate change, as well as the impacts of climate change on the economy and society and the adaptation and legal strategies derived from them;
- **Centre for Climate Systems Modelling (C2SM) at the Swiss Federal Institute of Technology in Zurich (ETH Zurich):**[113] Key research activities are organised around (i) development of next-generation modelling systems for weather and climate, (ii) earth system modelling, (iii) development of user-tailored future climate scenarios, and (iv) integration of applied environmental and impact science into earth system modelling;
- **Centre for Development and Environment (CDE) at the University of Bern:**[114] Its research focusses on the complex structure of global change processes and their consequences, specifically the interplay of natural resources, land use systems, and ecosystems, their political regulation, and the living conditions and lifestyles of population groups.

Sectoral research

Energy research

Switzerland's energy research and development policy aims to contribute to a secure and sustainable energy supply, continue the strong position of Switzerland as a market place for energy technology, and ensure the high quality of its energy research. International cooperation and efficient implementation of research findings are a matter of priority. Dedicated energy research centres are the Energy Science Centre (ESC) at the Swiss Federal Institute of Technology in Zurich (ETH Zurich)[115] and Energy System Integration Platform (ESI) at the Paul Scherrer Institute.[116]

Within the federal administration, the support of energy research is organised by the Swiss State Secretariat for Education, Research and Innovation, the Swiss Federal Office of Energy and the Swiss Commission for Technology and Innovation.

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112 https://www.oeschger.unibe.ch/research/index_eng.html

113 https://c2sm.ethz.ch/research.html

114 https://www.cde.unibe.ch/research/index_eng.html

115 https://esc.ethz.ch/research.html

116 https://www.psi.ch/en/media/overview-esi-platform

Energy research and development policy is laid down in the Federal Energy Research Masterplan (*CORE*, 2020) developed every four years by the Federal Energy Research Commission (CORE), a high-level advisory body to the Swiss government.

CORE's focus for energy research until 2024 is on a holistic view of the energy system, with particular attention to the social sciences and humanities. The focus areas are 'Economy, Society and Policy Measures', 'Living and Working', 'Mobility', 'Energy Systems' and 'Industrial Processes'. The energy research concept is a planning instrument for all federal funding bodies. The cantonal and communal authorities, which have their own funding instruments for energy research, can use it as a guide.

The products and results of the Swiss Competence Centres in Energy Research (SCCER)[117], which were active from 2014 to 2020, can be found on the respective websites.[118] In 2021, the new national energy research programme SWEET (SWiss Energy research for the Energy Transition)[119] was launched. Its main objective is to accelerate innovations that are crucial for the implementation of Switzerland's Energy Strategy 2050 and the achievement of the country's climate goals. SWEET focuses on applied research. Thus, pilot and demonstration projects are key, which requires the involvement of a broad range of stakeholders outside the research community. The first calls for proposals were for the following research tasks:

- Integration of renewables into a sustainable and resilient Swiss energy system;
- Evolving future energy consumption due to new ways of living and working;
- Critical infrastructures, climate change, and resilience of the Swiss energy system;
- Coordinated simulations of the Swiss energy system.

In parallel with SWEET, the additional, complementary programme SOUR (Sweet OUtside-the-box Rethinking) took up operations. SOUR focuses on promoting unconventional, original, alternative and high-risk research projects that are potential game-changers for the Swiss energy system. SOUR projects last for a maximum of 18 months and are conducted by individual researchers or small teams, unlike SWEET projects, which are run by consortia. The SOUR project topics are based on the theme of the SWEET calls.[120]

Transport research

Swiss transport research is mainly carried out by the federal administration, the Swiss Federal Institutes of Technology (ETH) in Zurich and Lausanne, and regionally by the cantonal universities. Outside the public domain, private research institutions such as consultancies and engineering companies also conduct extensive research. Much of this research is coordinated by the association of Swiss road and traffic engineers (VSS). The federal offices conduct, support, coordinate, monitor and fund strategic research.

Agricultural research

Research in the agriculture sector is coordinated by the Swiss Federal Office for Agriculture and to a large extent funded through the government, supplemented by funding from the Swiss National Science Foundation and (until 2020) European Union Framework Programmes. Strategic guidance is provided by the Research Master Plan for the Agri-Food Sector 2021–2024 (*FOAG*, 2020). The Agroscope Federal Research Stations, which are affiliated to the Swiss Federal Office for Agriculture, are organised into several competence divisions or strategic research divisions. Research projects

[117] For a brief description see Switzerland's sixth national communication.

[118] SCCER Future Energy Efficient Buildings & Districts (FEEB&D): *https://www.sccer-feebd.ch/*
SCCER Efficiency of Industrial Processes (EIP): *http://www.sccer-eip.ch/*
SCCER Future Swiss Electrical Infrastructure (FURIES): *https://www.epfl.ch/research/domains/sccer-furies/*
SCCER Heat & Electricity Storage (HaE): *http://www.sccer-hae.ch/*
SCCER Supply of Electricity (SoE): *http://www.sccer-soe.ch/en/home/*
SCCER Competence Centre for Research in Energy, Society and Transition (CREST): *https://www.sccer-crest.ch/*
SCCER Mobility (Mobility): *https://www.sccer-mobility.ch/*
SCCER Biomass for Swiss Energy Future (BIOSWEET): *https://www.sccer-biosweet.ch/*

[119] *https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/funding-program-sweet.html*

[120] *https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/funding-program-sweet/calls-for-proposals-overview.html*

on various aspects of climate protection and adaptation to climate change are carried out under the heading 'Climate and Air'.[121]

Forest research

Forest research in Switzerland is mainly carried out by the Swiss Federal Institute for Forest, Snow and Landscape Research[122] and at the Institute of Terrestrial Ecosystems of the Swiss Federal Institute of Technology in Zurich.[123] Applied forest research activities are carried out by several Universities of Applied Sciences as well as by a few private institutions mainly mandated by federal or cantonal administrations. Climate impact research has started in the early 1990s, and is increasingly emphasizing adaptation measures.

In 2017, the Swiss Federal Institute for Forest, Snow and Landscape Research initiated the SwissForestLab[124], an infrastructure network and research platform with a strong focus on outreach and applied research. With the aim of using synergies from the expertise in forest research in Switzerland, it promotes cooperative research for a deeper understanding of the functioning, resistance and resilience of forest ecosystems.

Research collaboration at the international level

Switzerland has a long tradition of cooperation in research and innovation with the European Union. Researchers in Switzerland have been participating in the EU Research Framework Programmes since 1988, either as associated or third country partners. From 2017 to 2020, Switzerland was fully associated to the Horizon 2020 programme. For the time being, Switzerland is participating as a non-associated third country in the current EU-FPR (Horizon Europe 2021–2027).

Switzerland participates in various international research programmes (e.g. World Climate Research Programme, Future Earth) through individual research projects, research conducted at federal institutes and within coordinated programmes (Climate Research Centres). Switzerland also participates in the operation of climate monitoring stations and networks (in the framework of the Global Climate Observing System, GCOS) and contributes to international projects by maintaining calibration and data centres.

Switzerland contributes significantly to a number of 'Global Research Projects' of Future Earth. The international project offices for the Past Global Changes (PAGES) project, the Global Mountain Biodiversity Assessment, the international research programme on biodiversity science (bioDISCOVERY) as well as the Global Land Project are all hosted by Swiss research institutions and at least partly funded by Switzerland. Swiss scientists are involved in many other Global Research Projects within Future Earth. Switzerland also contributes substantially to capacity building in transdisciplinary research methods within Future Earth through its 'Network of Transdisciplinarity' (td-net).

Furthermore, Switzerland also hosts and funds the Mountain Research Initiative (MRI), a multidisciplinary scientific organisation that addresses global change issues in mountain regions around the world, including developing countries. The MRI strives to support the design of integrated research strategies and programmes that further the understanding of the impacts of global change in mountain areas and that lead to tangible results for stakeholders and policy-makers.

A number of Swiss researchers (many of them in leading positions) were involved in the preparation of the sixth assessment report of the Intergovernmental Panel on Climate Change, including the Summary for Policymakers. Andreas Fischlin, professor emeritus at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), serves as vice chair of Working Group II of the Intergovernmental Panel on Climate Change.

[121] https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/climate-air-quality.html

[122] https://www.wsl.ch/en/index.html

[123] https://ites.ethz.ch/

[124] https://swissforestlab.wsl.ch/en/index.html

As a centre of excellence for sustainable development research, the Centre for Development and Environment (CDE) of the University of Bern[125] has a strong international focus. For examples of collaboration activities with institutions abroad see section 8.2.5.

8.1.2 Systematic observation: General policy and funding

The Global Climate Observing System (GCOS) is designed to ensure that observations and information needed to address climate-related issues are obtained systematically and made available to all potential users, in accordance with the requirements of the UNFCCC. GCOS is co-sponsored by the World Meteorological Organisation, the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO), the United Nations Environment Programme (UNEP), and the International Science Council (ISC). Switzerland's contribution to GCOS has last been reported to the UNFCCC in the seventh national communication.[126]

National GCOS coordination

Switzerland has a long-standing tradition of climate observation. Temperature and precipitation records extending over more than 150 years, the world's longest total ozone series, glacier measurements dating back to the end of the 19th century and the 20-year anniversary of the Swiss Permafrost Monitoring Network form some of the highlights of the Swiss contribution to global climate monitoring. The Swiss GCOS Office at MeteoSwiss[127] is responsible for coordinating all climate-relevant measurements conducted by federal offices, research institutes, universities, and private companies. The Office also serves as the national focal point for the GCOS programme. It was formally established at MeteoSwiss in 2006, following the Swiss Federal Council's dispatch concerning the ratification of the Kyoto Protocol. Since April 2022, the coordination of both national Global Atmosphere Watch and Global Climate Observing System programmes has been brought closer together in a joint Swiss GAW/GCOS Office at the Federal Office of Meteorology and Climatology MeteoSwiss.

Since its establishment over a decade ago, the Swiss GCOS Office (now the Swiss GAW/GCOS Office), together with its partner institutions, has undertaken a number of activities to coordinate climate observation in Switzerland and to ensure that high-quality Swiss contributions to GCOS will continue to be made in the future. Activities included, for example, the elaboration of an inventory report of climate observations and international data centres in Switzerland (*Seiz and Foppa*, 2007) as a basis for a request to the Swiss Federal Council for funding of the most important climate observations in Switzerland. In 2008, the Swiss Federal Council agreed to the request, hence putting selected Essential Climate Variables and data centres on a sound financial basis.

The inventory was updated in 2018 and currently includes 33 Essential Climate Variables (ECVs), two ancillary datasets and six international centres operated by Swiss institutions. For each variable, the type of observations carried out in Switzerland, the legal basis, the importance and international significance of a long time series are described. In addition, the report identifies time series and international centres that are at risk of being discontinued due to inadequate financial resources (*MeteoSwiss*, 2018). Furthermore, the report on Swiss GCOS Data in International Data Centres presents an overview on the availability of Swiss data submitted to respective International Data Centres recognised by GCOS (*MeteoSwiss*, 2015). Both reports will be updated in the future.

National coordination also includes the organisation of an annual national roundtable and outreach activities, such as maintaining a website (*http://www.gcos.ch*) and contributing to popular science articles. In 2021, the Swiss GCOS Office, together with the GAW-CH Office (now the Swiss GAW/GCOS Office) at MeteoSwiss, organised a joint Swiss National GAW/GCOS Symposium to promote the role of consistent observations for understanding the Earth system across the water, energy and carbon cycles. The aim of the event was to (i) showcase achievements of the national GAW and GCOS programmes and their associated communities, (ii) promote the understanding of the water, carbon and energy cycles and assess related observational gaps, and (iii) spark ideas for innovative and collaborative approaches across the broader

[125] *https://www.cde.unibe.ch/*

[126] Available for download at the website *www.climatereporting.ch*

[127] *https://www.meteoswiss.admin.ch/home/research-and-cooperation/international-cooperation/gcos/swiss-gcos-office.html*

Swiss GAW and GCOS communities. A white paper was published outlining the main findings of the Symposium (*MeteoSwiss*, 2022). Following this, a joint GAW-CH/GCOS-CH call for proposals was issued and the Swiss GAW/GCOS Scientific Steering Committee established.

The national climate observing system (GCOS Switzerland) also serves as the 'observation and monitoring' pillar for the national implementation of the Global Framework for Climate Services. The national implementation of the Global Framework for Climate Services is coordinated by the National Centre for Climate Services at MeteoSwiss (section 6.4.2).

Aligned with the schedule of the international GCOS programme and its Implementation Plan 2016 (IP-16) (*WMO*, 2016) and in close collaboration with its national partner institutions, the Swiss GCOS Office (now the Swiss GAW/GCOS Office) at MeteoSwiss elaborated a strategy for the GCOS Switzerland programme for the period 2017–2026 (*MeteoSwiss*, 2017). While maintaining a priority on securing the most important long measurement series, particular emphasis is put on promoting, e.g., the integration of new measurement techniques, an integrative monitoring approach across earth system cycles, and enhanced communication with stakeholders. The strategy is continuously implemented through actions by the entirety of the Swiss GCOS community, under the guidance of the GCOS Switzerland Steering Committee (now the Swiss GAW/GCOS Scientific Steering Committee).

GCOS Switzerland legal mandate

Based on the Swiss Meteorology and Climatology Ordinance (*Swiss Confederation*, 2000), Switzerland makes a financial contribution to the Global Climate Observing System GCOS on an annual basis. This contribution from the Swiss government can support measurement series of climatic variables in Switzerland, data centres operated by Swiss institutions and projects serving the international GCOS implementation plan. According to the Swiss Federal Council's decision in 2008, the total financial envelope available for activities in the framework of GCOS Switzerland amounts to 1.6 million Swiss francs per year. It is subject to the approval of the annual federal budget by the Swiss Parliament. MeteoSwiss, where the Swiss GAW/GCOS Office is located, may conclude performance agreements with third parties.

8.1.3 Opportunities for and barriers to free and open international exchange of data

Switzerland has developed an Open Research Data (ORD) Strategy that was adopted in April 2021 by the main Swiss academic associations (academies of arts and sciences, swissuniversities) as well as by the Swiss National Science Foundation SNSF and the federal institutes of technology (ETH domain) (*swissuniversities*, 2021).

The strategy has defined guiding principles ('FAIR principles': improve findability, accessibility, interoperability, and reuse of digital assets; openness as a prerequisite and a means of supporting high-quality research; as open as possible and as protected as necessary, e.g. regarding commercially sensitive data; recognition of the value of data; respecting disciplinary diversity; connection to existing and emerging national and international infrastructures and organisations; a sustainable data management approach) that help to support the open exchange of research data. It describes a set of goals that should be aimed at in order to implement these principles:

- Support researchers and research communities in imagining and adopting ORD practices;
- Develop, promote, and maintain financially sustainable basic infrastructures and services for all researchers;
- Equip researchers for ORD (skills development and exchange of best practices);
- Build up systemic und supportive conditions for institutions and research communities.

The implementation of the ORD strategy still faces a number of challenges. For example, it is crucial that the future ORD landscape be set up and developed in adherence with the political framework conditions and taking into account the needs of researchers. Efficient and effective governance is needed to ensure that good decisions are made at the right time and at the right level, involving the stakeholders affected by the Swiss ORD strategy. To this end, an ORD Strategy Council is charged with ensuring both coherence and interoperability of all infrastructures and services while also underpinning the interfaces with other research areas. It is also responsible for initiating and promoting the development and communication of positions and policies across Switzerland in international debates.

The Swiss National Science Foundation SNSF, the most important funding body in Switzerland, has already issued strict rules for open access and open data. Thus, applicants for project funding have to declare and ensure how they provide access to all important data after finishing a project. This is a first and necessary step, but by itself does not guarantee that the goal will be achieved. The effectiveness of rules depends on (i) effective control mechanisms to ensure that the rules are respected and (ii) sanctions for non-compliance that are important enough to encourage researchers to comply. Ways to address this include linking the payment of part of a grant to the completion of data submission to open repositories, strengthening the importance of making research data available for scientific careers, and facilitating data submission to repositories. However, experience with these approaches is still quite limited. In the area of data transfer, the SNSF actively supports the establishment and operation of open data repositories, particularly in the social sciences and humanities.

Contributions to international data exchange by means of international data and calibration centres and specialised databases are documented in section 8.3.5. In addition, section 8.3.7 addresses contributions and challenges regarding the availability of Swiss GCOS data in international data centres.

8.2 Research

This section has been brought more closely in line with the structure as suggested by the revised UNFCCC reporting guidelines for preparation of national communications. Its contents were rearranged to best reflect circumstances and activities linked to the topic of research. In the following, some highlights, innovations and significant efforts in different fields are summarised.

8.2.1 Climate process and climate system studies, including paleoclimatic studies

In recent years, the detection, attribution, projection and the understanding of changes in weather and climate extremes (in particular heat waves over land and oceans, heavy precipitation events and droughts) have been substantially advanced by new observational data and improved process understanding in combination with novel climate model experiments (*Fischer et al.*, 2021; *Zscheischler and Fischer*, 2020; *Vogel et al.*, 2020; *Zeder and Fischer*, 2020; *Padrón et al.*, 2020). Observational constraints and model weighting procedures have been used to narrow the projected changes at global to regional scale (e.g. *Tokarska et al.*, 2020; *Brunner et al.*, 2020). By combining multi-model experiments with Big Data methods, it was shown that on the basis of a single day of globally observed temperature and moisture, the fingerprint of climate change can be detected (*Sippel et al.*, 2020).

In the framework of the European Research Council funded ‘Palaeo-Reanalysis’ project, the climatology group of the University of Bern reconstructed the global monthly climate over the past 600 years by combining climate proxies, historical information and early instrumental measurements with climate model simulations (*Valler et al.*, 2021). Based on these reconstructions, the group investigated mechanisms behind past climatic events such as droughts, monsoon variations, or the climate system recovery from volcanic eruptions (*Brönnimann et al.*, 2019a).

For Europe and Switzerland, the day-to-day weather over the past 250 to 350 years was reconstructed within the SNSF Project ‘Weather Reconstructions’ (*Pfister et al.*, 2020) with the aim to better understand daily weather variations underlying climate extremes. This relies on extensive data rescue activities (*Brönnimann et al.*, 2019b; *Pappert et al.*, 2021). The same research group also operates an urban climate monitoring network in Bern and develops geostatistical techniques to produce heat maps from these data (*Burger et al.*, 2021).

8.2.2 Modelling and prediction, including global and regional climate models

New Swiss Climate Change Scenarios have been developed based on a large set of bias adjusted regional climate model experiments under different emission scenarios. These climate scenarios provide a new basis for mitigation and adaptation decisions at the national to local levels (*NCCS*, 2018; see section 6.1.1). Modelling activities are ongoing at a number of Swiss Research institutions. Two important examples are described below.

Modelling activities at C2SM: Since more than a decade, the Centre for Climate Systems Modelling (C2SM) has been strongly involved in preparing weather forecast and climate codes for high-performance computers. In the last years, it has contributed to several projects of the Swiss Platform for Advanced Scientific Computing (PASC), e. g. the ENIAC (Enabling the ICON model on heterogeneous architectures) and the PASCHA (Portability And Scalability of COSMO on Heterogeneous Architectures) projects. A recent major success is the approval, in 2020, of the project EXCLAIM funded by the Swiss Federal Institute of Technology in Zurich (ETH Zurich) which targets to develop an extreme scale computing and data platform for cloud-resolving weather and climate modelling over the next six years. The result will be an ICON model-based infrastructure that is capable of running kilometre-scale climate simulations at both regional and global scales. This platform will become a basis for weather and climate modelling for the decades to come.[128]

Modelling activities at MeteoSwiss: The assessment of future climate change in Switzerland heavily relies on information extracted from comprehensive global and regional climate model ensembles. Together with its partners at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and C2SM, MeteoSwiss is engaged in improving and evaluating the quality of the underlying climate models and in establishing a distillation interface that translates climate model output into actionable and user-tailored scenario products. Besides several active contributions to WCRP's CORDEX initiative[129], current foci relate to the integration of the CMIP6 global climate model ensemble into national Swiss climate scenarios and to the identification and exploitation of the added value of recently established convection-permitting climate model ensembles at the kilometre scale. Furthermore, and in order to secure and sustain high-level climate modelling expertise, MeteoSwiss is actively working towards the establishment of a national-scale strategy on regional climate modelling.

8.2.3 Research on the impacts of climate change

Updated information on research activities and findings on the impacts of climate change on the sectors most affected in Switzerland is presented in section 6.3 of this report. Below, a project of a more general nature is presented.

In May 2019, representatives from business, science and administration met to discuss the biggest challenges related to climate change. The aim was to identify the problems and needs of different stakeholders in relation to knowledge about the impacts of climate change. The discussion was based on the four 'storylines' of the CH2018 climate scenarios: dry summers, heavy precipitation, more hot days and snow-scarce winters (*NCCS*, 2018). In addition, the creeping increase in temperature was considered as a further topic for discussion.

An important finding was that in addition to the acquisition and co-production of knowledge, the availability and communication of research results is essential. The results must be accessible to a broad audience and be prepared in a way that is suitable for the target group. Inter- and transdisciplinary cooperation across the different sectors is equally important. Good and fair solutions require the comprehensive linking of interests, involving a broad spectrum of stakeholders and decision-makers. The results of the discussions were recorded in a report that provides a guideline for the preparation of future research on climate change impacts in Switzerland (*CH-Impacts*, 2019).

8.2.4 Socio-economic analysis, including analysis of the impacts of climate change and response options

The ongoing National Research Programme 'Sustainable Economy: resource-friendly, future-oriented, innovative' (NRP 73) aims to generate scientific knowledge about a sustainable economy that uses natural resources sparingly, creates welfare and increases the competitiveness of the Swiss economy (*SNSF*, 2020).

- A material flow analysis (MFA) of the 'Post-fossil Cities' project shows that current measures for the housing sector are not sufficient to achieve the Swiss Federal Council's goal of carbon neutrality by 2050. A novel simulation game developed as part of this project allows policy makers to better understand and manage the impact of specific measures, timelines and delays;
- The project 'Decarbonisation of the transport sector' suggests that technological improvements, e.g. a change in fuel mix or lower energy consumption per vehicle, will not be sufficient to achieve carbon neutrality. Instead, a shift to other modes of transport is needed, including regulatory measures and behavioural changes towards alternative transport modes;
- As part of the project 'Towards a sustainable circular economy', environmental indicators for circular value chains in Switzerland were developed. Life cycle analyses (LCA) were used to determine the environmental value achieved through reuse, remanufacturing, repair or recycling. A dynamic material flow analysis for these

128 https://c2sm.ethz.ch/research/exclaim.html

129 https://cordex.org

materials predicts a recycling rate of ten per cent in 2055 in a business-as-usual scenario, while improved deconstruction practices and removal of contaminants would lead to a recycling rate of 62 per cent and a reduction in climate impact of 30 per cent;

- The project ‘Digital innovations for sustainable agriculture’ combines experimental and economic analysis to explore how agriculture’s environmental footprint could be reduced.

Whereas most of the ongoing research still focusses on effects of financial and non-financial instruments, research done within the sustainability research group at the university of Basel looks at broader governance arrangements facilitating sustainability-oriented transformations. Using the classical differentiation of policy, politics and polity, this research group established a nuanced and differentiated picture of governance arrangements, also critically positioning the nudging debate in it (*Bornemann et al.*, 2018; *Bornemann and Christen*, 2018; *Bornemann and Burger*, 2019; *Lange et al.*, 2019; *Schmid and Bornemann*, 2019).

A Swiss Mercator Foundation funded project studied various facets of lifestyle change among households towards a more dematerialised way of life. By using approaches informed by sociology and psychology, results indicate that such changes are fostered by the interplay of structural (e. g. provision of parking slots for cargo-bikes) and individual (e. g. feeling comfortable when using cargo-bikes) factors. Moreover, research results highlight the importance of target group-specific approaches (*Burger et al.*, 2019a; *Burger et al.*, 2019b; *Hess et al.*, 2018; *Hess and Schubert*, 2019; *Schubert et al.*, 2020).

Focussing on the food sector, the Centre for Development and Environment (CDE) of the University of Bern, in cooperation with partners from Finland, has conducted the research programme ‘Tackling inequalities on the way to sustainable food systems (JUST-FOOD)’. The programme investigated how food systems can be transformed to achieve climate goals while meeting equity criteria.[130]

8.2.5 Research and development of mitigation and adaptation approaches, including technologies

Significant contributions to the development of mitigation and adaptation approaches stem from the Centre for Development and Environment at the University of Bern. The Centre has a leading role in the World Overview of Conservation Approaches and Technologies (WOCAT)[131] network. The newly created linkage of the WOCAT global Sustainable Land Management (SLM) Database with the Carbon Benefit Project (CBP) tools[132] allows individual users and projects to document SLM good practice, including an estimate of its impact on climate change mitigation (carbon stock changes and greenhouse gas emissions).

Also through the global WOCAT network, the Centre for Development and Environment is collaborating with the International Fund for Agriculture Development (IFAD) to support the scaling up of climate resilient land management practices with smallholder farmers in the global south. Under a partnership agreement with UNCCD, WOCAT is supporting the evaluation, sharing and promotion of good land management practices to mitigate sand and dust storms as well as droughts.

In 2012, the Swiss Federal Council launched the National Research Programmes ‘Energy Turnaround’ (NRP 70) and ‘Managing Energy Consumption’ (NRP 71). Whereas NRP 70 primarily dealt with technological issues, taking economic aspects into account, NRP 71 specifically addressed the socioeconomic and regulatory aspects of transforming the energy system.[133]

Several studies conducted or supported by SCCER CREST researchers investigated distributional effects of policy measures such as taxes on greenhouse gas emissions. A uniform effective price of carbon (taking into account other existing taxes and levies as well as environmental damages apart from climate change) appeared to be the most efficient economic instrument to achieve the emission reduction targets in the long run. However, many studies of SCCER CREST highlighted that there might be reasons to diverge from this policy in the short run (*SCCER CREST*, 2021).

130 www.cde.unibe.ch/research/projects/tackling_inequalities_on_the_way_to_sustainable_food_systems__just_food/index_eng.html

131 www.wocat.org

132 Available at https://cbp.nrel.colostate.edu/

133 https://nfp-energie.ch/en/program/resumee/

8.3 Systematic observation

Based on the Swiss Federal Council's decision of 2008, several GCOS Switzerland agreements were signed between MeteoSwiss and partner institutions concerning the observation of atmospheric and terrestrial climate variables and the operation of international data centres. Establishing these agreements was a crucial step forward in securing long-term systematic climate observation in Switzerland. Since 2018, based on the Swiss Meteorology and Climatology Ordinance (*Swiss Confederation*, 2000), MeteoSwiss provides temporary funding to projects playing a significant role in the rollout of the GCOS Implementation Plan (*WMO*, 2016) and the GCOS Switzerland Strategy (*MeteoSwiss*, 2017). Since 2018, around 30 project agreements have been signed with Swiss institutions, covering a variety of Essential Climate Variables (ECVs). A list of all current and completed projects can be found on the Swiss GCOS website.[134]

8.3.1 Atmospheric climate observing systems

Atmospheric observations are classified into three domains, namely surface, upper air and atmospheric composition (Tab. 55). Pollen is not listed as an Essential Climate Variable in the GCOS Implementation Plan (*WMO*, 2016), however, since its measurement has a long tradition in Switzerland, it forms an important part of GCOS Switzerland data.

MeteoSwiss is responsible for the operation and maintenance of the meteorological and climatological network in Switzerland, guaranteeing regular measurements over the entire country. Within the project SwissMetNet (completed in 2015), MeteoSwiss renewed its ground-based standardised stations to about 160 state of the art automatic weather stations. SwissMetNet replaces previously existing networks. The geographical distribution of the stations represents the complex topography of the entire country.

The Swiss National Basic Climatological Network is the core of the climatological observation network and consists of 29 stations of greatest climatological importance for surface-based atmospheric observations. Eight stations of the Regional Basic Climatological Network (*Begert et al.*, 2007) including the two GCOS Surface Network stations Säntis and Grand St. Bernard belong to the Swiss National Basic Climatological Network. To adequately represent the climatology of precipitation in Switzerland, 46 additional stations for precipitation (Swiss National Basic Climatological Network for Precipitation) complement the network (*Begert*, 2008). The operation of all stations of the Swiss National Basic Climatological Network follows the GCOS Climate Monitoring Principles (*WMO*, 2016).

Tab. 55 > Switzerland's atmospheric observation networks. Some stations may be part of several networks.

Domain	Variable	Number of stations and observation networks
Surface	Air temperature, wind speed and direction, humidity, air pressure, precipitation	2 GCOS Surface Network 8 Regional Basic Climatological Network 29 Swiss National Basic Climatological Network 46 Swiss National Basic Climatological Network for Precipitation
	Radiation	1 Baseline Surface Radiation Network 4 Swiss Alpine Climate Radiation Monitoring Network
Upper air	Air temperature, wind speed and direction, water vapour	1 GCOS Reference Upper Air Network 2 NDACC (Payerne, Bern-Zimmerwald)
	Cloud properties	26 MeteoSwiss Manual Observation Network 1 ACTRIS national facility for cloud remote sensing (Payerne)
Composition	CO_2, other greenhouse gases, ozone, aerosols, air pollutants Anthropogenic greenhouse gas fluxes	5 stations of the Global Atmosphere Watch programme 3 CO_2, 2 other greenhouse gases (in-situ) 1 CO_2, 1 other greenhouse gases (total column) 1 ICOS class 1 atmosphere station 2 ozone (total column, profile) 4 Swiss Alpine Climate Radiation Monitoring Network, 2 AERONET, 1 ACTRIS national facility for aerosol remote sensing, (aerosols: optical depth, properties, concentrations) 16 Swiss National Air Pollution Monitoring Network (air pollutants) 6 Swiss FluxNet, 2 Urban Flux Network
	Pollen	18 SwissPollen sites

GCOS Switzerland

Since 1992, an extensive set of surface-based radiation parameters has been measured at the Payerne aerological station of MeteoSwiss as part of the Baseline Surface Radiation Network. The Baseline Surface Radiation Network consists of around 55 stations worldwide and represents the surface radiation observation section of GCOS. In addition, high quality

[134] https://www.meteoswiss.admin.ch/home/research-and-cooperation/international-cooperation/gcos/gcos-switzerland-projects.html

radiation measurements as part of the Swiss Alpine Climate Radiation Monitoring Network are conducted in Payerne, Locarno-Monti, Davos and on the Jungfraujoch.

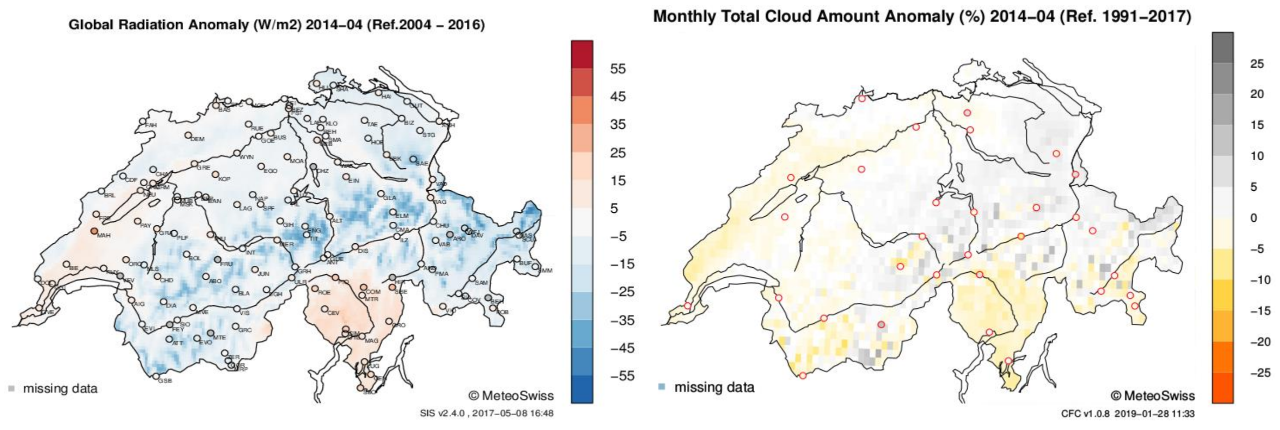
At the MeteoSwiss Payerne station, measurements of the atmospheric profile of temperature, air pressure, and wind have been performed for more than 50 years using radiosondes. Since 2008, upper air observations carried out at Payerne belong to the GCOS Upper Air Network (GUAN). Upon invitation from the World Meteorological Organisation, Payerne became part of the GCOS Reference Upper Air Network in 2010 (Fig. 104). The GCOS Reference Upper Air Network forms a set of selected stations worldwide that provide long-term, high-quality upper-air observing data.

Fig. 104 > MeteoSwiss station Payerne. Payerne is an important atmospheric observation site in Switzerland belonging to the GCOS Reference Upper Air Network.

Photo: MeteoSwiss

Observations of cloud variables (e.g. level of cloud cover, type of cloud) are made by human observers at regular intervals at 26 stations of the MeteoSwiss Manual Observation Network. In addition, measurements of microphysical properties and aerosol-cloud interactions are done at the Jungfraujoch research station. Since 2016, in addition to human observers, present weather sensors (PWSs) measure a number of cloud variables at international airports in Switzerland. As part of its engagement in the Satellite Application Facility on Climate Monitoring (CM SAF), MeteoSwiss has developed its own solar irradiance and fractional cloud cover climate data record from long-term Meteosat observations (Fig. 105). MeteoSwiss is further developing a satellite-based surface radiation balance data record covering Europe and Africa.

Fig. 105 > Global radiation anomaly (left) and fractional cloud cover anomaly (right) over Switzerland for April 2014 developed in the framework of the Satellite Application Facility on Climate Monitoring (CM SAF) and operationalised within the MeteoSwiss climate service.



MeteoSwiss

With regard to atmospheric composition, several measurement stations in Switzerland continue to contribute to the Global Atmosphere Watch (GAW) programme of the World Meteorological Organisation. The Global Atmosphere Watch programme coordinates activities and data from 30 particularly distinguished (global) stations, more than 400 regional stations, and around 100 contributing stations operated by contributing networks. The high-altitude research station Jungfraujoch belongs to the global network of the Global Atmosphere Watch programme. The scope of activities of the Swiss Global Atmosphere Watch programme is defined in Article 5 of the Swiss Meteorology and Climatology Ordinance (*Swiss Confederation*, 2000). The national implementation of the programme is coordinated by the Swiss GAW/GCOS Office since April 2022 and by the GAW-CH Office before that (see section 8.1.2), located at MeteoSwiss.

Today, atmospheric measurements of greenhouse gases are being performed at Bern (CO_2), Beromünster (CO_2, CH_4, N_2O), Dübendorf (halogenated greenhouse gases), and Jungfraujoch (CO_2, CH_4, N_2O and halogenated greenhouse gases). Except at Dübendorf, these measurements are combined with molecular O_2. The funding of CO_2 measurements at Jungfraujoch is assured through the National Air Pollution Monitoring Network (NABEL) supported by the Swiss Federal Office for the Environment, the Swiss contribution to the European Integrated Carbon Observation System (ICOS) infrastructure, and the Swiss Federal Laboratories for Materials Science and Technology (Empa). In-situ measurements of atmospheric concentrations of other greenhouse gases (halogenated greenhouse gases, CH_4, N_2O) at Jungfraujoch are supported by the Swiss Federal Office for the Environment and partly through the Swiss contribution to ICOS. Carbon dioxide measurements at Bern and Beromünster and the total column measurements on the Jungfraujoch are currently carried out as part of projects at the University of Bern and at the University of Liège, respectively. Observations are also used for the independent verification of the Swiss greenhouse gas inventory (see section 3.3.6). Since 2017, annually updated results are also documented in Annex 5 of Switzerland's national inventory reports (*FOEN*, 2022a).

Adding to the 'conventional' CO_2 measurement network, CO_2 fluxes are measured at six ecosystem and two urban sites. The six ecosystem sites are part of the Swiss FluxNet network, maintained by the Swiss Federal Institute of Technology in Zurich, and cover forest, grassland and cropland sites. All Swiss FluxNet stations are part of the global FluxNet. Based on third-party projects, ecosystem CH_4 and N_2O fluxes are measured as well. In addition, the University of Basel maintains two stations for urban CO_2 fluxes, both contributing to the Urban Flux Network. Anthropogenic greenhouse gas fluxes have been included in the GCOS Implementation Plan (*WMO*, 2016, *WMO*, 2021).

Long-term observations of total ozone and estimates of the ozone profile at the Light Climatic Observatory (LKO) in Arosa since the beginning of the last century until 2021 and at the PMOD/WRC in Davos since 2016, together with measurements of ozone profiles at Payerne up to an altitude of more than 30 kilometres by radiosondes since 1968, are also part of the Swiss contribution to the Global Atmosphere Watch programme. Continuous aerosol measurements (concentrations and properties) are carried out by the Paul Scherrer Institute at Jungfraujoch station on behalf of MeteoSwiss. Measurements of aerosol optical depth are carried out at the four stations of the Swiss Alpine Climate Radiation Monitoring Network. In addition, two Swiss ground-based aerosol remote sensing stations are operated, which belong to the Aerosol Robotic Network (AERONET) programme. The Payerne Ralmo Lidar is part of the ACTRIS national facility for aerosol remote sensing.

Continuous in-situ measurements of air pollutants such as nitrogen oxides, ozone, carbon monoxide, sulphur dioxide and particulate matter are conducted at 16 stations of the National Air Pollution Monitoring Network (NABEL). It is operated by the Swiss Federal Laboratories for Materials Science and Technology and the Swiss Federal Office for the Environment.

MeteoSwiss is responsible for operating the national pollen monitoring network (NAPOL). It comprises 14 stations equipped with manual volumetric pollen traps, and is operated during the vegetation period (January to September). MeteoSwiss is currently rolling out 18 stations of the Swiss automatic pollen monitoring network (SwissPollen) with Swisens Poleno, an instrument providing real time data at high temporal resolution. Both networks cover Switzerland's main climate and vegetation regions. SwissPollen replaces the previous manual network NAPOL and will be completed in 2022. The geographical distribution of the stations represents the entire country. In return, the NAPOL network will be reduced to five stations from 2024.

8.3.2 Ocean climate observing systems

As a landlocked country, Switzerland does not maintain measurements in the oceanic domain.

8.3.3 Terrestrial climate observing systems

Climate observations in the terrestrial domain are subdivided into the hydrosphere (river discharge and temperature, groundwater, isotopes, lakes, and soil moisture), the biosphere (albedo, land use, forest ecosystem, soil carbon, forest fires, land surface temperature and phenology; Tab. 56), and the cryosphere (see separate section 8.3.4). River temperature, isotopes and phenology are not listed as Essential Climate Variables in the GCOS Implementation Plan (*WMO*, 2016). However, since their measurement has a long tradition in Switzerland, they are an important part of the national climate observing system (GCOS Switzerland).

Tab. 56 > Switzerland's hydrosphere and biosphere observation networks.

Domain	Variable	Number of stations and observation networks
Hydrosphere	River discharge	207 federal stations (78 contributing to GTN-R)
	River temperature	79 federal stations, > 400 cantonal stations
	Groundwater	> 600 NAQUA sites
	Isotopes	22 ISOT sites (13 precipitation, 9 surface water)
	Lakes	33 sites (all contributing to GTN-L)
	Soil moisture	17 sites (SwissSMEX) 6 sites (SOMOMOUNT)
	Land evaporation	7 sites
Biosphere	Albedo	6 SwissMetNet station
	Land use and land cover	4.1 million observation points (1 point/hectare)
	Biomass, growth rate, ecosystem and microclimatological variables	50 study sites 19 monitoring sites (LWF) 1 ICOS class 1 ecosystem station
	Soil carbon	114 NABO sites
	Land surface temperature	1 Baseline Surface Radiation Network 3 SwissMetNet 2 former ASRB network 2 Urban Flux Network 6 Swiss FluxNet sites
	Biodiversity	520 sampling areas 1600 terrestrial sample points 570 aquatic sampling transects
	Phenology	12 (most important observation sites of the Swiss Phenology Network) 2 (longest historical series)

GCOS Switzerland, Biodiversity Monitoring Switzerland

The Swiss Federal Office for the Environment operates various hydrological monitoring networks and provides monitoring information on discharge, temperature, water levels and water flows. Water quality for rivers, lakes and groundwater bodies are monitored by the Swiss Federal Office for the Environment in cooperation with the cantons, the Swiss Federal Institute of Aquatic Science and Technology (Eawag) and the Swiss Federal Institute for Forest, Snow and Landscape Research. Daily river discharge data from 78 stations are submitted to the Global Runoff Data Centre (GRDC), in support of the Global Terrestrial Network for River Discharge (GTN-R).

The national groundwater monitoring (NAQUA) is based on more than 600 stations including modules for long-term assessments of groundwater quality and quantity. The module for isotopes in the water cycle (ISOT) currently comprises 22 sites distributed throughout Switzerland and is operated by the Swiss Federal Office for the Environment. Lake level, groundwater data, and isotope analyses are partly submitted to the designated international data centres as a contribution to the Global Terrestrial Network for Hydrology (GTN-H).

Swiss lake water levels are monitored at 33 stations as part of the basic hydrological monitoring network operated by the Swiss Federal Office for the Environment. Monthly data from 33 lakes contribute to the Global Terrestrial Network for Lakes (GTN-L). Measurements of lake water temperatures and lake ice are carried out as part of comprehensive water quality studies by cantonal water protection agencies, international commissions and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). Ice thickness monitoring is partly carried out by municipalities or private institutions, e.g. for Lake St. Moritz, whose time series since 1832 is unique for Central Europe.

Soil moisture as an important parameter influencing land-atmosphere interactions was included in the inventory of the most important climate observations in Switzerland in 2015. In a collaboration between the Swiss Federal Institute of Technology in Zurich, Agroscope, the Swiss Federal Institute for Forest, Snow and Landscape Research, and MeteoSwiss, soil moisture has been monitored in Switzerland in the framework of the Swiss Soil Moisture Experiment (SwissSMEX) project starting in 2008. The SwissSMEX monitoring network has continued to collect data since the project ended in 2011 and consists of 19 soil moisture profiles at 17 sites (16 operational profiles to date) across Switzerland. Since 2017, seven SwissSMEX sites are equipped with lysimeters for the observation of land evaporation. The project SMiLE-ECV-CH as well as a one-off support, both within the framework of GCOS Switzerland, currently aim to assess the monitoring capabilities of the soil moisture network and ensure its continuity. In addition, six stations are operated by the University of Fribourg within the SOMOMOUNT research monitoring network at medium and high altitudes. Depending on the Swiss FluxNet sites, soil moisture as well as temperature and profiles within the canopy have been measured since 1997 (one site) or since 2003 (five sites), run by the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and within ICOS RI.

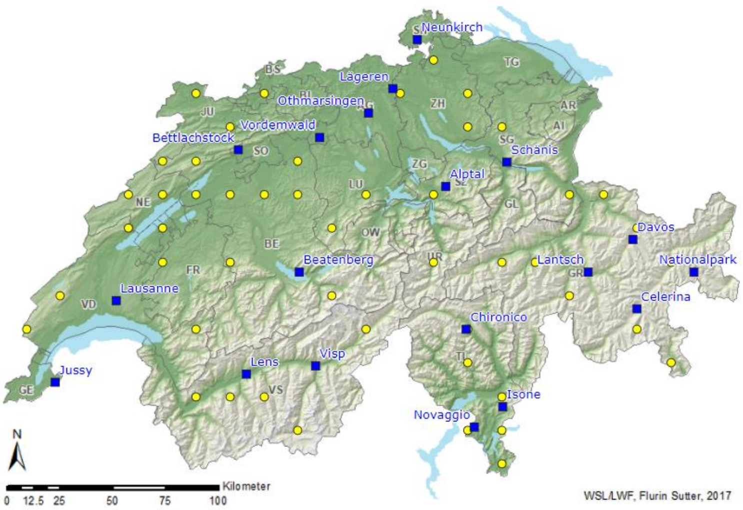
Albedo controls the amount of radiation absorbed by the surface. The downward and reflected shortwave radiation components are recorded simultaneously at six SwissMetNet sites (section 8.3.1). While ground measurements are precise and quality controlled, they are only representative for a small area. Satellite sensors can monitor the spatial heterogeneity of ‘Land Surface Albedo’ on a regional scale. MeteoSwiss will generate this Essential Climate Variable in a joint Meteosat retrieval in the framework of the Satellite Application Facility on Climate Monitoring (CM SAF) in 2022.

The land-use statistics of the Swiss Federal Statistical Office determines the land cover and land use of a sample point at every hectare of Switzerland, based on the interpretation of aerial photographs. Currently the long time series consists of 4 surveys, including the land use change over 33 years between 1985 and 2018. The ongoing fifth survey reduces the interval to 6 years by using artificial intelligence for aerial image analysis.

Monitoring activities of the forest ecosystem are conducted in the national forest inventory surveys that register the current state and changes of the Swiss forests. After completion of the continuous 4th survey period (2009–2017), the continuous survey of the 5th national forest inventory (NFI5/2018–2026) in a collaboration between the Swiss Federal Institute for Forest, Snow and Landscape Research and the Swiss Federal Office for the Environment is now in progress.

Documentation of long-term tree health (since 1985) is guaranteed at approximately 50 sites through the Sanasilva inventory. Under the Federal Long-term Forest Ecosystem Research Programme (LWF), more in-depth and wide-ranging studies at 19 sites are being pursued as part of an integrated approach to forest monitoring (Fig. 106). A database containing information and statistics on forest fires, for some areas dating back to the 19th century, is centrally managed at the Swiss Federal Institute for Forest, Snow and Landscape Research. Two of the LWF sites are also Swiss FluxNet sites and one of the LWF sites is an ICOS-CH class 1 ecosystem station.

Fig. 106 > Overview of the 50 Sanasilva (yellow) and 19 LWF (blue) sites in Switzerland.

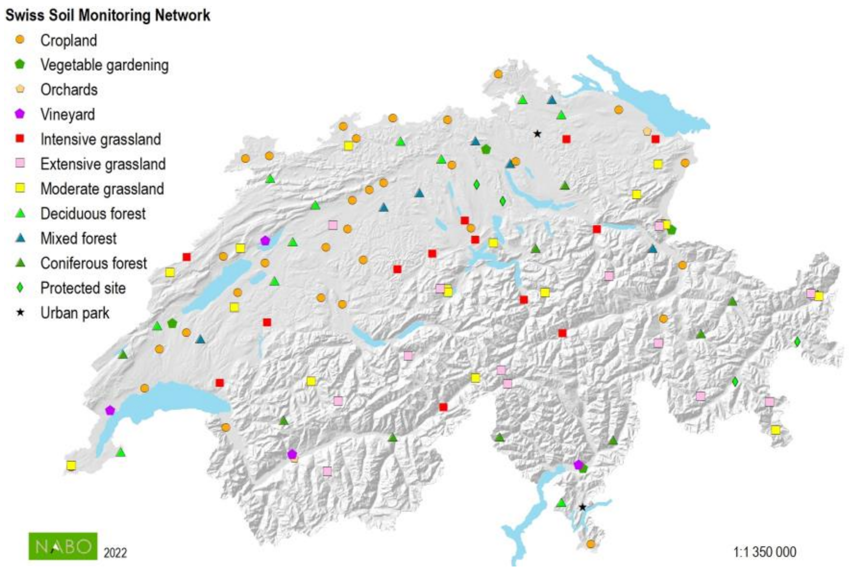


Swiss Federal Institute for Forest, Snow and Landscape Research

Soil Carbon is monitored jointly by the Swiss Federal Office for the Environment and the Swiss Federal Office for Agriculture as part of the national reference network for observing infringements of the soil (NABO).[135] NABO currently operates 114 long-term monitoring sites throughout Switzerland covering all relevant land uses (Fig. 107). The national soil carbon data are periodically sent to the Joint Research Centre JRC of the European Commission via the European Environment Information and Observation Network EIONET. The NABO measurements since 1985 are one of the longest time series of soil carbon observations in Europe.

Land Surface Temperature (LST) is retrieved from outgoing longwave radiation measurements at Payerne aerological station of MeteoSwiss as part of the Baseline Surface Radiation Network. Further measurements are done at three SwissMetNet sites, at the six Swiss FluxNet sites as well as at the Urban Flux Network sites of the University of Basel. In addition, LST can be determined from satellite data in the infrared part of the spectrum. A long-term LST climate data record for Switzerland was released in 2017 as part of the MeteoSwiss contribution for the Satellite Application Facility on Climate Monitoring (CM SAF). In 2022, an updated long-term LST climate data record, covering the entire WMO climatological norm period 1991–2020, will be available.

Fig. 107 > Swiss Soil Monitoring Network (NABO) – Distribution of NABO sites according to land use category.



Agroscope

Biodiversity Monitoring Switzerland (BDM)[136] surveys the long-term development of species diversity in selected plant and animal species (Fig. 108). By keeping an eye on common and widespread species, BDM focuses on trends and developments in Switzerland's normal landscape.

Observations of annual vegetation phenology are obtained through the Swiss Phenology Network (SPN). The network has been operational since 1951, is managed by MeteoSwiss and now comprises approximately 160 stations. A subset of twelve sites covering a variety of regions and elevations represents the most important phenological observations in Switzerland.

The bud burst date for horse chestnut has been recorded in Geneva since 1808. This is Switzerland's longest phenological time series. Of equal importance is a second historical series – cherry tree flowering dates at the rural Liestal-Weideli station – which goes back to 1894. The Geneva and Liestal-Weideli sites are not part of the phenological monitoring network. All Swiss observers operate on a voluntary basis.

135 https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/soil-bodies-water-nutrients/nabo.html

136 www.biodiversitymonitoring.ch

Fig. 108 > Overview of the 520 biodiversity monitoring sampling areas in Switzerland.

Biodiversity Monitoring Switzerland

8.3.4 Cryosphere climate observing systems

Apart from the hydrosphere and biosphere, terrestrial climate observations also include the cryosphere (snow cover, glaciers and permafrost) (Tab. 57).

Tab. 57 > Switzerland's cryosphere observation networks.

Domain	Variable	Number of stations and observation networks
Cryosphere	Snow cover	71 Swiss National Basic Climatological Network for Snow (including 22 GCOS Switzerland snow stations)
	Glacier mass balance and length	Seasonal/annual mass balance at 22 glaciers, pentadal ice-volume change at >50 glaciers, length change at about 100 glaciers
	Permafrost	15 borehole sites with 28 boreholes, 6 weather stations and 5 geoelectrical measurements; 15 rock glaciers with 18 measured lobes and 8 permanent GNSS devices; 250 ground surface temperature measurements at borehole and rock glacier sites

GCOS Switzerland

Records of snow cover (snow depth, new snow height, snow water equivalent), with some series dating back more than 100 years, are available from measurement networks operated by MeteoSwiss, the Institute for Snow and Avalanche Research and other cantonal and private institutions. Based on the National Basic Climatological Network for Snow (*Marty and Schweizer*, 2015; *Wüthrich et al.*, 2010), a subset of 22 stations was defined as Swiss GCOS snow stations. Two GCOS Switzerland agreements are in place securing the continuation of long-term snow water equivalent measurements: Since 2010 the measurements in Wägital by Meteodat GmbH and since 2015 measurements at eleven selected Swiss GCOS snow stations by WSL-SLF.

Glacier monitoring in Switzerland goes back to the late 19th century. Today, more than 100 glaciers are surveyed annually. Since 2015, data acquisition, analysis and publication are coordinated by the Glacier Monitoring Switzerland (GLAMOS) programme, which is co-funded by the Swiss Federal Office for the Environment, MeteoSwiss (in the framework of GCOS Switzerland) and the Swiss Academy of Sciences. The Swiss Federal Institute of Technology in Zurich (ETH Zurich), along with the Universities of Zurich and Fribourg, is responsible for the operational implementation. Also, since 2015 GCOS Switzerland agreements between MeteoSwiss and the implementing institutions ensure a continued monitoring of the most important glaciers. GLAMOS makes an important contribution to the Global Terrestrial Network for Glaciers (GTN-G).

The Swiss Permafrost Monitoring Network (PERMOS) provides a systematic long-term documentation of state and changes of mountain permafrost in the Swiss Alps, contributing to the Global Terrestrial Network for Permafrost (GTN-P). The PERMOS office is jointly run by the University of Fribourg and the Institute for Snow and Avalanche Research. PERMOS is supported by six university partner institutes and co-financed by MeteoSwiss, the Swiss Federal Office for the Environment and the Swiss Academy of Sciences on the basis of four-year contracts.

8.3.5 International activities, including support for developing countries

International data centres

Switzerland is host to a number of important international data and calibration centres that make a vital contribution to data quality and the global standardisation of observations, both in the atmospheric and terrestrial domains.

The World Radiation Centre (WRC) at the Physical Meteorological Observatory (PMOD) in Davos serves as an international centre for the calibration of radiation and includes the WRC Solar Radiometry (WRC-SRS), the WRC Infrared Radiometry (WRC-IRS), the WCC for World Optical depth Research and Calibration Centre (WORCC), and the WCC for UV (WCC-UV). Further World Calibration Centres (WCCs) of the Global Atmosphere Watch programme of the World Meteorological Organisation include the institution for the Global Atmosphere Watch programme Quality Assurance/Scientific Activity Centre (QA/SAC Switzerland) for surface ozone, carbon monoxide, CH_4, and CO_2, and the World Calibration Centre (WCC) for surface ozone, carbon monoxide and CH_4 (WCC-Empa), which are both hosted by the Swiss Federal Laboratories for Materials Science and Technology.

The Global Energy Balance Archive (GEBA) database[137] was implemented at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) in 1988. It incorporates worldwide observations of various surface energy balance components, with a total of 19 different variables (e.g. global radiation, short- and long-wave radiation or turbulent heat fluxes). The GEBA energy balance components are of fundamental importance for the understanding of various processes in the climate system (including the cryosphere).

The World Glacier Monitoring Service[138] at the University of Zurich collects standardised observations on glacier changes in mass, volume, area and length as well as statistical information on the spatial distribution of glaciers. Through a GCOS Switzerland agreement between MeteoSwiss and the University of Zurich, sustained operation of the World Glacier Monitoring Service has been secured since 2010. In collaboration with other international institutions, the World Glacier Monitoring Service jointly runs the Global Terrestrial Network for Glaciers (GTN-G).[139]

Historical documentary data provide important information for studies on climate change and are a vital component of long-term systematic climate observation in Switzerland. Euro-Climhist is a database developed and operated by the University of Bern, currently containing more than 330,000 historical documentary and instrumental records for the period 1264–2020. For the coming years, the continuous extension of the database with records on weather and climate in Europe from the Middle Ages onwards will be implemented based on a network of international cooperation partners. In 2015, a user-friendly data query platform was released.[140] Sustained operation of Euro-Climhist is secured through a GCOS Switzerland agreement between MeteoSwiss and the University of Bern (since 2010).

In 2015, the Swiss GCOS Office (now the Swiss GAW/GCOS Office) published an update of its report on Swiss GCOS Data in International Data Centres (*MeteoSwiss*, 2015). For each Essential Climate Variable listed in the national GCOS inventory report (*MeteoSwiss*, 2018), the document reports on the flow of data and the respective responsibilities. It further identifies areas of action and therefore provides the basis for future improvements regarding the availability of Swiss GCOS data at designated international data centres.

Capacity building

Switzerland actively supports capacity building in emerging and developing countries by participating in the GCOS Cooperation Mechanism. Through technical and/or financial support, Swiss institutions enable high-quality climate observations, as illustrated by the following examples:

- Climate resilience, mitigation and adaptation strategies must be based on sound baseline information such as climate observations, and in particular, the ECVs defined by GCOS (*Bojinski et al*., 2014). As stated by the

137 https://www.geba.ethz.ch

138 https://www.wgms.ch

139 https://www.gtn-g.org

140 http://www.euroclimhist.unibe.ch

World Meteorological Organization, large gaps currently exist in the global climate observing system, particularly in high mountain environments (*WMO*, 2019). Openly accessible observational data enable the production of reliable regional climate scenarios and services for water runoff and natural hazards. Therefore, baseline data must be made available for essential cryospheric variables such as snow, glaciers and permafrost as these are major controlling factors of the hydrological cycle and the natural hazard situation in mountain regions;

- In recent years, major efforts have been made by Switzerland to establish or re-establish an in-situ glacier monitoring network in Central Asia. This network is now close to being completed thanks to strong financial support from the Swiss Agency for Development and Cooperation (SDC) and the University of Fribourg (UniFR) (e.g., CATCOS I & II and CICADA projects, documented in *Hoelzle et al.*, 2017). The new, re-established glacier network now encompasses three additional countries, with glacier observations in Kyrgyzstan, Kazakhstan, Tajikistan, Uzbekistan and China. The project is planned to develop into a network of complete cryospheric sites, including monitoring of snow and permafrost variables;
- The World Glacier Monitoring Service at the University of Zurich offers technical support for glacier observations, e.g. in South America and Central Asia (Fig. 109). This includes assurance of compliance with international methods and standards, data quality control and training for glaciologists in the field;
- In the framework of the Global Atmosphere Watch programme, MeteoSwiss supports weekly ozone soundings in Nairobi, Kenya. Also, regular on-site training is provided to assure the quality of the various operational ozone measurement systems on site;
- Switzerland – through the operation of a Quality Assurance / Science Activity Centre (QA/SAC-CH) and a World Calibration Centre (WCC-Empa) – is a key contributor to the quality management framework of the Global Atmosphere Watch programme. To support and improve the spatial coverage of atmospheric composition measurements globally, long-term twinning partnerships between the Swiss Federal Laboratories for Materials Science and Technology (Empa) and station operators in developing and emerging countries (e.g. Indonesia) are maintained. The focus is on training, quality assurance, technical support, and the promotion of scientific exploitation of data gained by the Global Atmosphere Watch programme.

Fig. 109 > WGMS international summer school on mass balance measurements and analysis in Bishkek, Kyrgyzstan 2015.

Photo: Andi Hasler

8.3.6 Space-based observing programmes

Switzerland, through its membership in the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), contributes to a global infrastructure for monitoring climate from space. Through various projects and initiatives, EUMETSAT also provides comprehensive support to developing countries, particularly in Africa.

8.3.7 Long-term continuity, quality control and availability, and exchange and archiving of data

At the national level, Swiss GCOS data are obtained, quality-controlled, and then archived by the responsible institutions in a variety of data holding systems to ensure their long-term availability. Swiss GCOS data are also submitted to the designated international data centres, as highlighted in *MeteoSwiss* (2015). This report also showed that in some cases there is still room for improvement, in particular for data in the terrestrial domain of GCOS. A priority of the Swiss GCOS Office (now the Swiss GAW/GCOS Office) as the national focal point for GCOS is to constantly improve the availability of Swiss data internationally. Building on the 2015 report on the availability of Swiss GCOS data in international data centres, the Office is currently evaluating a new way of providing this information online. These efforts are based on the GCOS Switzerland Strategy 2017–2026, in particular strategic priority 1.5, i.e. to ensure that standardised observations of all Essential Climate Variables are archived and made freely available to all interested users.

References

Begert, M. et al., 2007: Die Überführung der klimatologischen Referenzstationen der Schweiz in das Swiss National Basic Climatological Network. Arbeitsberichte der MeteoSchweiz Nr. 215. *http://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/Ungebundene-Seiten/Publikationen/Fachberichte/doc/arbeitsbericht215.pdf* [18.07.2022]

Begert, M., 2008: Die Repräsentativität der Stationen im Swiss National Basic Climatological Network. Arbeitsberichte der MeteoSchweiz Nr. 217. *http://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/Ungebundene-Seiten/Publikationen/Fachberichte/doc/arbeitsbericht217.pdf* [18.07.2022]

Bojinski, S. et al., 2014: The Concept of Essential Climate Variables in Support of Climate Research, Applications, and Policy: Bulletin of the American Meteorological Society, Vol 95, No 9. *https://journals.ametsoc.org/downloadpdf/journals/bams/95/9/bams-d-13-00047.1.xml* [18.07.2022]

Bornemann, B. and Burger, P., 2019: Nudging to sustainability? Critical reflections on nudging from a theoretically informed sustainability perspective, pp.209–226. In: Strassheim, H., and Beck, S. (eds.): Handbook of Behavioural Change and Public Policy. Cheltenham: Edward Elgar Publishing. [hardcopy]

Bornemann, B. and Christen, M., 2018: Sustainability Governance in Public Administration – Interpreting Practical Governance Arrangements in Swiss Cantons. Environmental Policy and Governance, 1–11. *https://doi.org/10.1002/eet.1840* [18.07.2022]

Bornemann, B. et al., 2018: Future governance of individual energy consumption behavior change – A framework for reflexive designs. Energy Research & Social Science, 35, 140-151. *https://doi.org/10.1016/j.erss.2017.10.040* [18.07.2022]

Brönnimann, S. et al., 2019a: Last phase of the Little Ice Age forced by volcanic eruptions. Nature Geoscience, 12, 650–656 *https://www.nature.com/articles/s41561-019-0402-y* [18.07.2022]

Brönnimann, S. et al., 2019b: Unlocking pre-1850 instrumental meteorological records: A global inventory. Bull. Amer. Meteorol. Soc. 100, ES389–ES413 *https://doi.org/10.1175/BAMS-D-19-0040.1* [18.07.2022]

Brunner, L. et al., 2020: Reduced global warming from CMIP6 projections when weighting models by performance and independence. Earth System Dynamics, 11(4), 995-1012. *https://doi.org/10.5194/esd-11-995-2020* [18.07.2022]

Burger, M. et al., 2021: Modelling the spatial pattern of the urban heat island of Bern during heatwaves in 2018 and 2019 using a land use regression approach. Urban Climate 38. *https://doi.org/10.1016/j.uclim.2021.100885* [18.07.2022]

Burger, P. et al., 2019a: Sufficiency in everyday life – Promising steps towards achieving a low-carbon society. University of Basel / Swiss Mercator Foundation. *https://nachhaltigkeit.philhist.unibas.ch/fileadmin/user_upload/nachhaltigkeit/Aktuelles/News/Sufficiency_in_Everyday_Life.pdf* [18.07.2022]

Burger, P. et al., 2019b: Governance for Sufficiency: A new approach to a contested field, pp.157–177. In: Hamman, P. (ed.): Sustainability Governance and Hierarchy. London/New York: Routledge [hardcopy]

CH-Impacts, 2019: Klimaszenarien CH2018 und daraus abgeleitete Folgen für die Schweiz – wie weiter? Grundlagenbericht des Vorprojekts. ProClim, Bern / Swiss Federal Office for the Environment, Bern / Swiss Federal Institute of Technology in Zurich, Zurich / MeteoSwiss, Zurich / National Centre for Climate Services, Zurich / University of Bern, Bern / University of Zurich, Zurich / Institute for Snow and Avalanche Research, Davos. *https://doi.org/10.3929/ethz-b-000364227* [18.07.2022]

CORE, 2020: Energy research Masterplan of the Federal Government 2021–2024. Developed by the Federal Energy Research Commission CORE, Bern. *https://www.newsd.admin.ch/newsd/message/attachments/64144.pdf* [18.07.2022]

Fischer, E.M. et al., 2021: Increasing probability of record-shattering climate extremes. Nature Climate Change 11.8 (2021): 689–695. *https://www.nature.com/articles/s41558-021-01092-9* [18.07.2022]

FOAG, 2020: Research Master Plan for the Agri-Food Sector 2021–2024. Summary (full versions available in German and French). Swiss Federal Office for Agriculture, Bern. *https://tinyurl.com/FOAG20* [18.07.2022]

FOEN, 2022a: Switzerland's greenhouse gas inventory 1990–2020: National inventory report, reporting tables (CRF), supplementary information for LULUCF activities under the Kyoto Protocol and SEF tables of the national registry. Submission of April 2022 under the UNFCCC and under the Kyoto Protocol. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

Hess, A.-K. and Schubert, I., 2019: Functional perceptions, barriers, and demographics concerning e-cargo bike sharing in Switzerland, Transportation research: an international journal. Part D, Transport and environment, 71, pp. 153–168. *https://doi.org/10.1016/j.trd.2018.12.013* [18.07.2022]

Hess, A.-K. et al., 2018: Informing a social practice theory framework with social-psychological factors for analyzing routinized energy consumption: A multivariate analysis of three practices. Energy Research and Social Science, 46, 183–193. *https://doi.org/10.1016/j.erss.2018.06.012* [18.07.2022]

Hoelzle, M. et al., 2017: Re-establishing glacier monitoring in Kyrgyzstan and Uzbekistan, Central Asia: Geoscientific Instrumentation, Methods and Data Systems, v. 6, no. 2, p. 397–418. *https://gi.copernicus.org/articles/6/397/2017/gi-6-397-2017.pdf* [18.07.2022]

Lange, Ph. et al., 2019: Sustainability impacts of governance modes: insights from Swiss energy policy. Journal of environmental policy & planning 21.2, 174–187. *https://doi.org/10.1080/1523908X.2019.1566062* [18.07.2022]

Marty, C. and Schweizer, J., 2015: Konzept langjährige Schneewasseräquivalent (SWE)-Messungen Schweiz. Institute for Snow and Avalanche Research, Davos. [confidential/internal]

MeteoSwiss, 2015: Swiss GCOS Data in International Data Centres (GCOS Switzerland). Swiss GCOS Office, 2011 (Update 2015). *http://www.meteoswiss.admin.ch/content/dam/meteoswiss/en/Forschung-und-Zusammenarbeit/Internationale-Zusammenarbeit/GCOS/doc/20150612_Swiss_GCOS_Data_in_intl_Datacentres_draft_report_final.pdf* [18.07.2022]

MeteoSwiss, 2017: GCOS Switzerland Strategy 2017–2026. Swiss GCOS Office, Zurich *https://www.meteoswiss.admin.ch/content/dam/meteoswiss/en/Forschung-und-Zusammenarbeit/Internationale-Zusammenarbeit/GCOS/doc/GCOS-Switzerland-Strategy-2017-2026.pdf* [18.07.2022]

MeteoSwiss, 2018: National Climate Observing System (GCOS Switzerland). Update 2018. Swiss GCOS Office, Zurich *https://www.meteoswiss.admin.ch/content/dam/meteoswiss/en/Forschung-und-Zusammenarbeit/Internationale-Zusammenarbeit/GCOS/doc/NationalClimateObservingSystem_GCOSSwitzerland-Small.pdf* [18.07.2022]

MeteoSwiss, 2022: 1st Swiss National GAW/GCOS Symposium 2021: White Paper. Technical Report MeteoSwiss No. 280. MeteoSwiss, Zurich. *https://doi.org/10.18751/pmch/tr/280.gawgcos/1.0* [18.07.2022]

NCCS, 2018: CH2018 – Climate Scenarios for Switzerland. National Centre for Climate Services, Zurich. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/klima/CH2018_broschure.pdf* [18.07.2022]

Padrón, R.S. et al., 2020: Observed changes in dry-season water availability attributed to human-induced climate change. Nature geoscience 13, no. 7 (2020): 477–481. *https://doi.org/10.1038/s41561-020-0594-1* [18.07.2022]

Pappert, D. et al., 2021: Unlocking weather observations from the Societas Meteorologica Palatina (1781–1792). Clim. Past, *https://doi.org/10.5194/cp-2021-57* [18.07.2022]

Pfister, L. et al., 2020: Statistical Reconstruction of Daily Precipitation and Temperature Fields in Switzerland back to 1864. Climate of the Past, 16, 663–678. *https://cp.copernicus.org/articles/16/663/2020/cp-16-663-2020.pdf* [18.07.2022]

SCCER CREST, 2021: SCCER CREST 2014–2020 (selected results and insights). *www.sccer-crest.ch/fileadmin/FILES/Datenbank_Personen_Projekte_Publikationen/Publications/White_Papers/SCCER_CREST_End_Communication_final_webversion.pdf* [18.07.2022]

Schmid, B. and Bornemann, B., 2019: What Political Settings Promote Renewable Energy Investments by Energy Utilities? A Qualitative Comparative Analysis in Swiss Cantons, European Policy Analysis, 5.2, 232–265. *https://onlinelibrary.wiley.com/doi/epdf/10.1002/epa2.1055* [18.07.2022]

Schubert, I. et al., 2020: The role of lifestyle, quality of life preferences and geographical context in personal air travel, Journal of sustainable tourism. Routledge, 28(10), pp. 1519–1550. *https://doi.org/10.1080/09669582.2020.1745214* [18.07.2022]

Seiz, G. and Foppa, N., 2007: National Climate Observing System (GCOS Switzerland). MeteoSwiss, Zurich / ProClim (Forum for Climate and Global Change of the Swiss Academy of Sciences), Bern. *http://www.meteoswiss.admin.ch/content/dam/meteoswiss/en/Ungebundene-Seiten/Publikationen/Berichte-GCOS-Schweiz/doc/2007seizfoppa.pdf* [18.07.2022]

Sippel, S. et al., 2020: Climate change now detectable from any single day of weather at global scale. Nature Climate Change, 10. *https://www.nature.com/articles/s41558-019-0666-7* [18.07.2022]

SNSF, 2020: Overview of the State of Research in NRP 73. A well-designed political framework and consumption and production patterns for a sustainable economy. Swiss National Science Foundation, Bern. *http://www.nrp73.ch/SiteCollectionDocuments/NFP73_Zwischenbericht_EN.pdf* [18.07.2022]

Swiss Confederation, 2000: Verordnung über die Meteorologie und Klimatologie (MetV) vom 21. November 2018 (Status as o 1 January 2019, also available in French). *https://www.fedlex.admin.ch/eli/cc/2018/772/de* [18.07.2022]

Swiss Confederation, 2012: Federal Act on the Promotion of Research and Innovation (RIPA) of 14 December 2012 (Status as of 15.04.2022). *https://www.admin.ch/opc/en/classified-compilation/20091419/index.html* [18.07.2022]

swissuniversities, 2021: Swiss National Open Research Data Strategy. Adopted by the Delegation Open Science on 23 April 2021 (commissioned by the State Secretariat for Education Research and Innovation). *https://api.swiss-academies.ch/site/assets/files/34541/swiss_national_ord_strategy_en.pdf* [18.07.2022]

Tokarska, K.B. et al., 2020: Past warming trend constrains future warming in CMIP6 models. Science Advances, 18 Mar 2020, Vol 6, Issue 12. *https://www.science.org/doi/10.1126/sciadv.aaz9549* [18.07.2022]

Valler, V. et al., 2021: An updated global atmospheric paleo-reanalysis covering the last 400 years. Geosc. Data J., *https://doi.org/10.1002/gdj3.121* [18.07.2022]

Vogel, M.M. et al., 2020: Development of future heatwaves for different hazard thresholds. Journal of Geophysical Research: Atmospheres, 125(9). *https://doi.org/10.1029/2019JD032070* [18.07.2022]

WMO, 2016: The Global Observing System for Climate: Implementation Needs. GCOS-200. *https://library.wmo.int/opac/doc_num.php?explnum_id=3417* [18.07.2022]

WMO, 2019: Call to action: Avoiding the impending crisis in mountain weather, climate, snow, ice and water: Pathways to a Sustainable Global Future: World Meteorological Organization. *https://ane4bf-datap1.s3.eu-west-1.amazonaws.com/wmod8_hms/s3fs-public/2019-misc-obs-hms-call-for-action-25828-191549_en_0.pdf?S2_aK_JVeTkXUSrIuxMzVOT6F76g_J1M=* [18.07.2022]

WMO, 2021: The Status of the Global Climate Observing System 2021: The GCOS Status Report (GCOS-240), pub WMO, Geneva. *https://ane4bf-datap1.s3.eu-west-1.amazonaws.com/wmod8_gcos/s3fs-public/gcos-status_report_full_text-240_lr_compressed.pdf* [18.07.2022]

Wüthrich, C. et al., 2010: Die langen Schneemessreihen der Schweiz – Eine basisklimatologische Netzanalyse und Bestimmung besonders wertvoller Stationen mit Messbeginn vor 1961. Arbeitsberichte der MeteoSchweiz Nr. 233. *http://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/Ungebundene-Seiten/Publikationen/Fachberichte/doc/ab233.pdf* [18.07.2022]

Zeder, J. and Fischer, E.M., 2020: Observed extreme precipitation trends and scaling in Central Europe. Weather and Climate Extremes, 29. *https://doi.org/10.1016/j.wace.2020.100266* [18.07.2022]

Zscheischler, J. and Fischer, E.M., 2020: The record-breaking compound hot and dry 2018 growing season in Germany. Weather and Climate Extremes 29 (2020). *https://doi.org/10.1016/j.wace.2020.100270* [18.07.2022]

9 Education, training and public awareness[141]

In Switzerland, environmental issues have a long-standing tradition as an element of public debate. To some extent, this may be related to the alpine landscapes and their natural hazards which coined the notion that precautionary measures and risk management represent the only viable strategies to maintain a high standard of living in terms of safety.

The 'classical' natural hazards (such as, e.g., landslides or flooding) still exist, however, some have been, or are projected to be, exacerbated by climate change. Furthermore, relatively rare hazards (such as heat waves and droughts) are expected to occur more often according to regional climate model projections. Over the past decade, recurrent severe weather events that may be related to a changing climate have reinforced the public perception of climate change. Impacts of exceptional weather conditions on agriculture and winter tourism are increasingly seen as potential harbingers of a shifting climate regime.

At the same time, in the political debate about more sustainable modes of energy provision as well as about drivers, trends and patterns of energy consumption, greenhouse gas emissions and climate change have become a prominent element. Next to conventional criteria such as price and security of supply, the carbon content of energy systems is now a broadly accepted criterion in the evaluation of options for shaping the future provision with, and use of, energy.

According to the latest available results of an annual representative survey (*Credit Suisse*, 2021), in summer 2021 the corona virus pandemic and its consequences, environmental protection and climate change, and old-age provision were seen as the greatest challenges facing the country. Notwithstanding the strong influence of the corona virus pandemic on citizens' concerns, the survey shows that climate change remains a key issue in the eyes of voters. There seems to be a broad consensus among the population that environmental protection and climate change are among the biggest problems of our time – regardless of the immediate topicality of the day.

However, the challenges this poses to current modes of production and consumption may not yet be fully understood. On the one hand, as a survey (*gfs.bern*, 2021) after the vote on the third CO_2 Act in June 2021 has shown, a majority of voters believe that more decisive action must be taken against climate change because it causes great damage and high costs. Thus, the 'no' to the measures proposed in the third CO_2 Act should not be interpreted as a 'no' to climate protection. On the other hand, the acceptance for the introduction of new or the increase of existing CO_2 levies is limited. The new version of the third CO_2 Act therefore relies more on financial incentives and promotional measures (see *FOEN*, 2021, and section 4.2). Further efforts in the areas of education, training and public awareness are essential to build the necessary support for the adoption and implementation of effective measures and to facilitate the fulfilment of the commitments contained in Switzerland's latest update of its nationally determined contribution.[142]

9.1 General policy on education, training and public awareness

At the national level, the Swiss State Secretariat for Education, Research and Innovation is the Swiss government's specialised agency for matters concerning education. Cantonal and communal authorities are responsible for preschool, primary and lower-secondary school (compulsory education). Upper-secondary level (post-compulsory education) is divided into vocational education and training and general education (baccalaureate schools and specialised schools).

The federal government acts in a full regulatory capacity within the vocational education and training system. The cantons are responsible for implementation while professional organisations establish training content and create apprenticeship positions for vocational education and training programmes. The cantons are primarily responsible for general education.

With regard to continuing education and training, the allocation of responsibilities for implementation, sponsorship and funding is extremely complex. The federal government is responsible for specifying and promoting the basic principles of continuing education and training.

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[141] In this chapter, the sections correspond to the letters (a) to (h) in paragraph 69 of the 'Revision of the Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part II: UNFCCC reporting guidelines on national communications' (FCCC/SBI/2016/L.22). Regarding the order of the sections, letter (e) is discussed in section 9.2 to ease cross references.

[142] *https://www4.unfccc.int/sites/ndcstaging/Pages/Party.aspx?party=CHE&prototype=1*

In its 2030 sustainable development strategy (*Swiss Federal Council*, 2021b), the Swiss Federal Council outlines its priorities in implementing the 2030 agenda for sustainable development of the United Nations over the next ten years (see also section 4.1.1). The strategy and the associated 2021–2023 action plan were adopted by the Swiss Federal Council in June 2021. The Swiss Federal Office for Spatial Development coordinates the activities related to Education for Sustainable Development.

9.1.1 Compulsory education

Switzerland has a federal education system, in which the education ministries of the 26 cantons have far-reaching competencies to decide about the school system on all levels, including curricula and learning methods. In recent years, efforts to harmonise curricula for compulsory education have been undertaken.

By 2021, a large majority of German speaking and bilingual cantons have aligned their educational frameworks with the national model curriculum called ‘Lehrplan 21’. This curriculum defines goals at all levels of compulsory education in conformity with the related requirements as set out in the Federal Constitution of the Swiss Confederation. It serves as a planning tool for schools.

Within the ‘Lehrplan 21’ curriculum, education for sustainable development is acknowledged as a cross-disciplinary theme relevant to a wide range of subjects. However, there is no systemic approach to the integration of the notion of sustainable development in the formal education system nor are there binding national guidelines concerning its integration into educators’ initial training.

As regards topics directly related to the core issues of the UNFCCC, in the national model curriculum for the lower-secondary level, weather, climate and climate change are explicitly addressed, including the study of climate change causes, impacts and mitigation options.

The French speaking cantons have elaborated their own model curriculum called ‘Plan d’étude romand’ where, again, at the lower-secondary level climate phenomena and climate change are listed among the topics to be treated in class.

Building on the results of a nationwide assessment of climate education at primary and secondary school level (*John et al.*, 2016), the CCESO (Climate Change and Education Science Outreach) research project was conducted between 2016 and 2019 in order to develop a teaching conception on climate topics directed at all levels of compulsory education. This project led to the production of a comprehensive set of teaching materials on climate change, climate protection and climate policy made available via the platform éducation21 (see also section 9.3.2 below).

9.1.2 Vocational education and training

The Federal Act on Vocational and Professional Education and Training (*Swiss Confederation*, 2002, Article 15) and the Ordinance on Minimum General Education Requirements in Vocational Education and Training Programmes (*Swiss Confederation*, 2006) have an explicit reference to sustainable development as a learning objective. This includes acquirement of ecological knowledge and competencies. Thus, education for sustainable development is part of the general studies curriculum for all apprentices in Switzerland. Additionally, in many of the decrees for each profession there is a reference to education for sustainable development.

The SwissEnergy programme contains measures directed at professionals from various trades. One of its ambitions is to include new developments in energy technologies in vocational education, offering up-to-date training materials and accelerating knowledge transfer. In addition, the ‘Climate Programme Training and Communication’ (*FOEN*, 2017a) has a special focus on professions with high relevance for Switzerland’s greenhouse gas emissions (see section 9.2.3).

9.1.3 Public awareness

In recent years, no public awareness-raising campaigns focussing specifically on climate change and directed at the general public have been conducted by the federal authorities. Climate change is widely recognised as one of the major long-term challenges for Switzerland. This is partly due to a committed scientific community, but also to an active scene of environmental non-governmental organisations, complemented by ecologically oriented business associations, both of which work to raise awareness and stimulate public debate about climate policy (see section 9.6). Nevertheless, as emission reduction targets need strengthening and the field of adaptation gains in importance, maintaining public support for related policies and measures remains a challenge.

At the federal level, SwissEnergy is the major programme for conveying information related to energy efficiency and renewable energies to the general public. In 2020, the SwissEnergy programme launched ‘erneuerbar heizen’ (‘heating with renewables’), a nationwide awareness-raising and advisory campaign promoting the conversion from fossil to renewable energy sources in heating systems (see section 9.4.1).

9.2 Resource or information centres

9.2.1 Competence centres at the national level

Switzerland founded its National Centre for Climate Services (NCCS) in late 2015. The main purpose of the NCCS is to coordinate the development and implementation of climate services within the Swiss government and to provide consolidated information in support of policy-makers from national to local level as well as the private sector and society at large (*http://www.nccs.ch*; see also section 6.4.2). Climate services offered comprise scientific information and data on the climate of the past, present and future, as well as its impacts. The parties involved in the NCCS include several Swiss Federal Offices (MeteoSwiss, Environment, Agriculture, Civil Protection, Public Health, Food Safety and Veterinary, Energy) and three research institutions.

The Swiss Federal Office for the Environment and the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss) also respond to climate-related enquiries from the general public. In addition, the Swiss Federal Office for the Environment provides – on its website – access to the official documents submitted by Switzerland under the UNFCCC as well as under the Kyoto Protocol (*http://www.climatereporting.ch*) and to trend assessments covering a wide range of indicators related to climate change (*https://www.bafu.admin.ch/bafu/en/home/topics/climate/state/indicators.html*). Extensive information on adaptation policy and action is available at *www.bafu.admin.ch/klimaanpassung* (see also section 6.4.2).

MeteoSwiss provides climatological services and information including regular updates on the current state of the Swiss climate and climate change as well as climate predictions on seasonal to multi-decadal time scales (*http://www.meteoswiss.admin.ch/home/climate.html*). MeteoSwiss also co-founded and supports the Centre for Climate Systems Modelling (C2SM), a network of Zurich-based institutions active in climate system research (see section 8.1.1).

The Forum for Climate and Global Change of the Swiss Academy of Sciences (ProClim) is an institution active at the interface between science, policy and the public. More information on scientific and other expert bodies that contribute to the dissemination of climate-related information may be found in section 9.2.5.

The National Centre for Climate Services, the Swiss Federal Office for the Environment, the Swiss Federal Office of Meteorology and Climatology and ProClim maintain comprehensive websites that cover aspects of climate change and climate politics. These information channels are supplemented with a wide spectrum of magazines and reports (e.g. *FOEN*, 2017a; *FOEN*, 2017b; *FOEN*, 2018; *FOEN*, 2019a; *FOEN*, 2020a; *FOEN*, 2020b; *FOEN et al.*, 2020; *MeteoSwiss*, 2018; *MeteoSwiss*, 2021; *NCCS*, 2017; *NCCS*, 2018; *NCCS and FOEN*, 2021), media releases, as well as blogs[143], talks and public appearances at exhibitions and meetings by representatives of the federal administration.

9.2.2 SwissEnergy programme

Under the auspices of the Swiss Federal Office of Energy, the SwissEnergy programme (see also section 4.3.2) aims at enhancing energy efficiency and increasing the share of renewable energies in the Swiss energy mix. Its main instruments are information and awareness raising activities, consulting, as well as targeted support for education and training projects. The information presented in this and the following sections focusses on the most climate-relevant aspects and elements of the SwissEnergy programme.

143 See, e.g., ‘MeteoSwiss Climate Blog’ at *https://www.meteoschweiz.admin.ch/home/aktuell/meteoschweiz-blog/meteoschweiz-blog.html?topic=/content/meteoswiss/tags/topics/klima* (with contributions in German, French and Italian)

The SwissEnergy programme sponsors projects that are implemented by partner organisations in the public and private sectors. As opposed to the earlier ‘agency model’, where tasks were delegated on a long-term basis to private sector organisations in charge of thematic clusters of projects, the ‘project model’ used since 2016 relies on fixed-term contracts with individual project partners. This has rendered the programme more flexible and responsive to changing conditions and allows to implement measures more efficiently.

The information portal of SwissEnergy (*https://www.suisseenergie.ch/*, available in French, German and Italian) was launched in autumn 2011 and completely redesigned, restructured and updated in 2021 following a strict user experience design approach. In addition to extensive information on energy efficiency and renewable energy, the newly developed website offers individual queries, practical calls to action, FAQs, tools and calculators and a new, inspiring format called ‘EnergieStories’.

One of the major and largest projects supported by SwissEnergy is ‘SwissEnergy for Communities’ (*https://www.local-energy.swiss/fr/#/*). Under the umbrella of SwissEnergy for Communities, the programmes ‘Energy Region’ (*www.energie-region.ch*) along with the programmes ‘2000 Watt Society’ (*http://www.2000watt.ch*), ‘Smart Cities’ (*http://www.smartcity-schweiz.ch*) and ‘SwissEnergy for Communities – Mobility’ build a broad basis for pioneering projects towards sustainable development in a local to regional context. SwissEnergy for Communities closely cooperates with other partner organisations, as listed further below.

In order to ensure that innovations contributing to a more sustainable use of energy are well understood and related cost reduction potentials are better known, SwissEnergy offers advice to citizens, investors, buyers and operators of facilities, appliances and buildings. Manufacturers and sellers of appliances and facilities are included in SwissEnergy’s communication efforts, too.

Below, organisations presently partnering with the SwissEnergy programme are listed according to their focus of activity. All partner organisations have their own information channels including targeted campaigns focussing on the services offered. Further campaigns and specific awareness raising activities implemented with support from the SwissEnergy programme are documented in section 9.4.1.

Partner organisations in the field of renewable energies and efficient energy use

- AEE Suisse (agency for renewable energies and energy efficiency), representing 22 branch organisations including 15,000 enterprises and energy providers (*http://www.aeesuisse.ch*);
- Wood Energy Switzerland, promoting wood as an energy source (*http://www.holzenergie.ch*);
- Infrawatt, supporting operators of waste incineration plants, wastewater treatment plants and water supply systems in the assessment and exploitation of the potential for energy production (*http://www.infrawatt.ch*);
- Swiss Eole, promoting the use of wind energy (*http://www.suisse-eole.ch*);
- Swissolar, promoting the use of solar energy (*http://www.swissolar.ch*, *http://www.solarprofis.ch*);
- ‘Fördergemeinschaft Wärmepumpen Schweiz’ (FWS), promoting and offering support for labelled, quality-controlled heat pump systems (*http://wp-systemmodul.ch*).

Partner organisations in the buildings sector

- Minergie, an association pioneering in the establishment of standards and labels for low- to zero-energy buildings (*www.minergie.ch*);
- GEAK, an association under the auspices of the Conference of Cantonal Energy Directors, offering building checks that establish comparable figures on the energy use for room and water heating as well as electricity consumption and assist in identifying improvement potentials (*http://geak.ch*);
- NNBS (Sustainable Construction Network Switzerland), a network of public and private entities, who have established a comprehensive concept for the development of the built environment in line with the principles of sustainability (*www.nnbs.ch*);
- Energo, a competence centre for energy efficient buildings and building services (*http://www.energo.ch*).

Partner organisations in the industry and services sectors

- Energy Agency of the Swiss Private Sector (*http://enaw.ch*) and Cleantech Agency Switzerland (*https://act-schweiz.ch*), two organisations assisting enterprises wishing to undergo a negotiated reduction commitment for exemption from the CO_2 levy (see section 4.2.7) or in need of support for the implementation of other measures and obligations in line with national or cantonal energy laws;
- PEIK, a platform promoting energy and cost efficiency by offering targeted advice to small and medium-sized enterprises (*https://kmu.peik.ch*).

Partner organisations in the transport sector

- QAED (Quality Alliance Eco-Drive), an alliance of public and private organisations collaborating in offering training sessions for economical, low emissions driving in the private and business sectors (*http://www.eco-drive.ch*);
- AutoEnergieCheck, a service offered by the Swiss association of garage owners aiming at saving energy and money in operating cars (*http://www.autoenergiecheck.ch*);
- Mobility Car Sharing, a pioneering organisation for car sharing in Switzerland (*www.mobility.ch*);
- ProVelo Schweiz, the national umbrella organisation representing the interests of cyclists and organising activities in promotion of the use of bicycles (*www.pro-velo.ch*).

9.2.3 Climate Programme Training and Communication

The second CO_2 Act (Article 41) and the corresponding CO_2 Ordinance (Articles 128 and 129) provide a number of 'soft' measures that support the achievement of Switzerland's climate policy goals. The Climate Programme Training and Communication was developed by the Swiss Federal Office for the Environment in close cooperation with the Swiss Federal Office of Energy. It supports and complements other related activities, e.g. within the framework of the SwissEnergy programme (see above), and is implemented in partnership with stakeholders, the cantons, cities and municipalities and other interested parties.

In its second phase of implementation, starting in 2021, the programme aims to support professionals and municipalities on their way to achieving the net-zero target of Switzerland for 2050 (*FOEN*, 2020c). It also contributes to the other goals of the Paris Agreement, namely adaptation to climate change and the climate-friendly orientation of financial flows. In the field of education, the programme strengthens climate-relevant competences in the training and further education of specialists and managers in professions with high climate relevance. To this end, it provides basic principles and tools, supports the transfer of knowledge into education and practice, and promotes educational programmes. In the area of communication, the programme advises and supports municipalities so that they can better realise their scope for action in climate policy and their role model function.

The Swiss Federal Office for the Environment, as the implementing agency of the Climate Programme Training and Communication, supports organisations that offer appropriate education and training. Information on the measures of the Climate Programme Training and Communication is presented in sections 9.3.1, 9.4.2 and 9.5.2.

9.2.4 éducation21

The foundation éducation21 promotes and facilitates implementing education for sustainable development in Switzerland. It acts as a national competence centre for primary and secondary education. The foundation is active on national, language region and cantonal levels. Its main target groups are teachers and school boards (and subsequently children and youth); indirectly éducation21 also addresses teacher education institutions, non-governmental organisations and public authorities. A broad offering of services related to education for sustainable development – ranging from teaching materials and media to systemic development support and expertise – is available (see sections 9.3.2 and 9.5.3).

éducation21 is an independent foundation which is mandated and financed by the Swiss Conference of Cantonal Ministers of Education and seven Swiss federal offices responsible for vocational/professional education, development and cooperation, public health, environment, energy, combating discrimination and racism, food safety, and spatial development (contractual framework for the period 2021–2024). Additional funds are generated, e.g., through service agreements with public and private institutions, e.g. currently by the tobacco prevention foundation for a programme addressing children and youth.

9.2.5 Scientific and other expert bodies contributing to the dissemination of information

The main competence centres at the interface between science, policy and the public are ProClim (Forum for Climate and Global Change of the Swiss Academy of Sciences) and, until 2021, the OcCC (Advisory Body on Climate Change).

Initiated in 1988, ProClim (*https://proclim.scnat.ch/en/about-proclim*) is an independent organisation of the Swiss Academy of Sciences. Its mission includes the promotion of interdisciplinary scientific collaboration and the distribution and exchange of information on global change science within Switzerland. It aims at providing a holistic view on climate change, including the physical climate system, biogeochemical processes and the human dimensions of global change. In recent years, the focus has been extended to climate communication and psychological aspects of communication and policies.

ProClim supports nationwide networking amongst people and institutions involved, particularly between science on the one hand and policy, economy and the media on the other hand. This is mainly done by assessments of current knowledge on any issues related to climate change (thus down-scaling the work of IPCC to the national level) and by a wide range of dissemination activities (factsheets, workshops, meetings with stakeholders, social media etc.). ProClim organises the annual ‘Swiss Global Change Day’, where the Swiss climate change community meets and discusses latest results in climate change research.

ProClim maintains a website where a wealth of information, contact details of experts as well as links to related institutions in Switzerland and abroad can be found.[144] It is involved in translating and distributing the summaries of reports of the Intergovernmental Panel on Climate Change and manages the process of adapting the respective latest findings to the Swiss context (*SCNAT*, 2016).

The Advisory Body on Climate Change (OcCC; *http://occc.ch/*, *http://occc.ch/index_f.html*) was appointed in 1996 by the Swiss Federal Department of Home Affairs and the Swiss Federal Department of the Environment, Transport, Energy and Communications. Its task was to formulate recommendations on climate and global change issues for politicians and the federal administration. By the end of 2021, the OcCC was dissolved. ProClim will continue to publish consolidated statements by the research community aimed at policy makers (e.g. *SCNAT*, 2021a, *SCNAT*, 2021b).

9.3 Primary, secondary and higher education

9.3.1 Measures within the ‘Climate Programme Training and Communication’

In the domain of compulsory education, in the context of the CCESO research project, the programme contributed to the elaboration of an educational concept focussing on the definition and illustration of good practice with regard to methods and contents of climate education at all levels. On the basis of this concept, a comprehensive set of ready-to-use materials on climate change, climate protection and climate policy was produced and made available to schools via the éducation21 web platform (*https://www.education21.ch/fr/dossiers-thematiques/climat*, available in French, German and Italian).

In addition, in order to enhance the effectiveness of educational offerings aimed at the improvement of climate-related competencies, institutions active in the domain of environmental education at all levels of compulsory and general education are offered targeted support. As an example, the ‘Klimaworkshop’ project (*https://www.klimaworkshop.ch/*) was realised with such support. Teachers can book a half day workshop where secondary level pupils deal with climate protection issues and the possibilities of becoming active themselves in everyday life. Another project called ‘Jobs for Future’ aims at enabling students to take a new perspective on their career choice by learning about the relationship between various professions and sustainability (*www.myclimate.org/jobsforfuture*).

[144] *https://sciencesnaturelles.ch/climate*; *http://4dweb.proclim.ch/4dcgi/proclim/en/index.html*

9.3.2 Services offered by éducation21

éducation21 provides teachers, school boards and other involved parties with pedagogically tested and certified teaching materials, information, advice and expertise related to education for sustainable development.

The éducation21 web platform *(https://www.education21.ch)* features a permanently updated data base, giving access to a wide range of recommended teaching media (including VOD, games, online media, etc.) in German, French and partially in Italian. The platform allows for targeted searching, e.g. by use of keywords explicitly addressing topics related to the SDGs (i.e. ecological, social and economic issues). In recent years, éducation21 has expanded its services to include tools and the strengthening of specific networks to bring education for sustainable development into schools. Various topics related to education for sustainable development are presented with the relevant teaching resources in thematic units. The platform offers units covering the full range of topics addressed by the SDG goals of Agenda 2030, including climate change. This service provides teachers with information and ready-to-use teaching materials for primary and secondary schools that they can incorporate into their daily lessons.

Additionally three times per year, éducation21 publishes the magazine 'ventuno'. Each issue is focussing on one of the topics of the thematic units, offers further theoretical insight and highlights selected materials and examples of teaching. One of the 2020 issues of the magazine was dedicated to climate change.[145]

Another key service consists of coordinating the "Schools Network21", which focusses on health and sustainable development education. A recently established data base facilitates the network and exchange of experience. Furthermore, schools can benefit from financial support for specific projects in class or for the school as a whole (Whole School Approach). Since 2020 grants are offered to teacher training colleges for research projects relevant to implementing education for sustainable development in schools.

9.4 Public information campaigns

9.4.1 Campaigns and activities supported by the SwissEnergy programme

SwissEnergy uses a wide range of channels and instruments to reach its various target audiences, many of which in the three official languages (German, French, Italian):

- Nationwide campaigns (e.g., road shows, accompanied by print and online media coverage);
- TV commercials, advertisements, video clips, apps (including educational games);
- Appearances at trade fairs and exhibitions;
- Advertorials (articles in industry publications, responding to the specific needs of the particular professional audiences);
- Annual newspaper ('Energiejournal') on topical issues and trends in renovation of buildings, mobility and renewable energy use; newsletters directed at homeowners;
- Website, social media, brochures, leaflets.

The Swiss building stock causes around one third of Switzerland's total CO_2 emissions. In order to bring building emissions in line with climate policy targets, the programme 'erneuerbar heizen' of SwissEnergy ('heating with renewables'; *https://erneuerbarheizen.ch; https://opendata.swiss/en/dataset/impulsberatung-erneuerbar-heizen*), a major national awareness and advisory campaign, was launched in 2020. Its goals are to demonstrate that (i) the switch from fossil heating systems to domestic, renewable energy sources is reducing emissions very efficiently, (ii) renewable heating systems are cost-effective in the long term, and (iii) there is a suitable solution for every type of house.

The programme comprises, inter alia, a road show visiting exhibits, a comprehensive website with success stories, hints on how to best finance a new heating system, and a heating cost calculator. Additionally, the campaign website offers interested homeowners the possibility to search for a regional energy advisor for an initial impulse consultation. As switching to renewable heating systems is also a challenge for the construction industry, the programme also supports

[145] https://www.education21.ch/de/ventuno/klima

installers and consultants in their daily work. The programme adopts a partnership approach, involving the expertise and financial support of all cantons and many industry associations, thus facilitating wide-spread implementation at the cantonal and municipalities level.

Other important awareness raising and consumer information activities funded by SwissEnergy include:

- 'Make Heat Simple' (*https://makeheatsimple.ch/fr/*), a programme by SwissEnergy and its numerous partners to reduce the energy costs of secondary homes. With the installation of remote control systems, more than 2,000 gigawatt-hours per year could be saved in the approximately 700,000 secondary homes in Switzerland;
- 'Cyclomania', a campaign to promote cycling in urban areas. For one month, municipalities, cities and regions carry out a cycling promotion campaign for the population (*https://www.cyclomania.ch/fr*);
- the 'Energy Reporter' (*https://www.suisseenergie.ch/tools/reporterenergie/*), an online tool showing to what extent a municipality is on track towards an ecologically sound energy future. It displays the shares of electric mobility, solar energy and heating systems with renewable energies at municipality level.

9.4.2 Measures within the 'Climate Programme Training and Communication'

Together with the 'SwissEnergy for Communities' project, synergies between energy and climate policy are exploited and additional topics such as climate adaptation are integrated. For example, various resources have been developed for the priority topic of adaptation to climate change with a focus on preserving or enhancing green spaces while mitigating the urban heat island effect in densely populated areas. A planning aid for municipalities and cities, municipal implementation examples and a video with the municipality of Suhr as an example were made available, and a series of events on green and open spaces was held. Furthermore, training workshops on the topics of adaptation to climate change and climate activities in municipalities were offered to energy city advisors and interested parties.[146]

In order to support the numerous medium-sized and smaller municipalities on their way to a climate-neutral Switzerland, the climate programme provides for low-threshold offers and targeted advice for local authorities. The 'Online-Tool Adaptation to Climate Change for Municipalities in Switzerland' assists municipalities in analysing how they are affected by climate change and shows which measures can be taken at the municipal level (see section 6.4.2). Furthermore, the Climate Programme, together with the 2000-Watt Society / SwissEnergy programme, supports medium-sized and smaller municipalities in the development of a climate strategy. The 'Climate Strategy Guide for Communities' (*FOEN and SFOE*, 2022) shows step by step how the net-zero target can be achieved at the municipal level. In addition, practical climate tips on sticky notes may be used by municipalities and cities to raise awareness of climate-friendly lifestyles among the population.

9.4.3 Other awareness raising activities at the national level

In the following, a few events related to awareness raising at the national level in the course of the year 2021 are highlighted:

- On 16 March 2021, the NCCS together with ProClim and the OcCC organised an online event on the new hydrological scenarios for Switzerland (Hydro-CH2018). The event took place under the title 'Swiss Water Bodies in Climate Change' (in German: Schweizer Gewässer im Klimawandel) and presented results and products of Hydro-CH2018 to the public. It was addressed to all interested parties and, in particular, to representatives from authorities, economy, politics as well as private actors working in the field of hydrology and water management and/or dealing with climate change. Hydro-CH2018 is a core topic of the NCCS focussing on water resources and their future development. Its main objective is to supply the necessary fundamental hydrological information for adaptation (see also section 6.3.1);
- On 9 August 2021, the sixth assessment report of the Intergovernmental Panel on Climate Change on the physical science basis of climate change was published. MeteoSwiss accompanied the publication with various blog posts and Tweets, in which both background information and the main statements of the report were presented to a broad audience;

[146] *https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/verminderungsmassnahmen/klimaprogramm/klimaprogramm-kommunikation.html*

- On 26 October 2021, the Centre for Climate Systems Modelling (C2SM) and the Energy Science Centre (ESC) of the Swiss Federal Institute of Technology in Zurich (ETH Zurich) organised the ETH Climate Roundtable (in German 'ETH Klimarunde'). With well over 400 participants from industry, science, business and politics, the event on the topic of 'Net Zero: How do we achieve climate neutrality?' met with great interest. The ETH Climate Roundtable takes place once a year. Its goal is to discuss and inform a broad audience on current climate-relevant topics and raise the awareness about climate change;

- From 1 to 12 November 2021, the Swiss Federal Department for Foreign Affairs together with MeteoSwiss organised a Cryosphere Pavilion with the International Cryosphere Climate Initiative (ICCI) at the 26th Conference of the Parties to the UNFCCC (COP26) in Glasgow. At the same time, a Cryosphere Hub in Geneva virtually linked the pavilion in Glasgow with Switzerland and was open to the public. Scientists from Swiss universities and research institutions presented their work carried out in several fields related to the cryosphere and facilitated the dialogue between science, society and policy;

- On 16 November 2021, MeteoSwiss, under the aegis of the NCCS, published climate scenarios for the cantonal level. The new cantonal climate scenarios contain data on past climate change and the climate future of each individual canton. They provide an important basis for the Swiss cantons to develop effective adaptation and mitigation strategies. Canton-specific information is provided in fact sheets; corresponding data sets are available through the Web Atlas *https://www.nccs.admin.ch/nccs/en/home/data-and-media-library/data/ch2018-web-atlas.html* (see also section 6.4.2);

- The Climate Communication Congress (in German: Kongress zu Klimakommunikation, K3) is another example of awareness raising activities at the national level. It was initiated in 2017 by five organizations from Germany, Austria and Switzerland. Target groups of this event are scientists from natural sciences, social sciences and humanities, practitioners of climate protection and climate communication from the fields of politics, administration and economy, interest groups, NGOs as well as media and PR. The aim of the K3 Congress is to provide an overview of the state of research on climate communication and to make use of new research findings in order to transfer communication into action. Key questions are: How can communication support decision-making in political, social or corporate processes and motivate actions that protect the climate? Due to the corona virus pandemic, the 2021 congress was postponed and will be held 14 to 15 September 2022 in Zurich, Switzerland (*https://k3-klimakongress.org/*);

- Within the pilot programme 'Adaptation to climate change', implemented under the leadership of the Swiss Federal Office for the Environment (see section 6.4.2), several projects are dedicated to the target of raising awareness for climate change adaptation in cantons, regions and municipalities. Early projects and their products are documented in *FOEN* (2017b). Information on projects implemented during the second programme phase may be found in *FOEN* (2019a) as well as at *https://www.nccs.admin.ch/nccs/en/home/measures/pak/projekte-phase2.html*.

9.5 Training programmes

As mentioned in section 9.1, education for sustainable development is part of the general studies curriculum for basic vocational education and training in Switzerland, with specific guidelines contained in the Federal Act on Vocational and Professional Education and Training. The Swiss State Secretariat for Education, Research and Innovation oversees the development or the mandatory quinquennial evaluation, and possible revision, of occupation-specific regulations (ordinances, curricula). The Swiss Federal Office for the Environment and the Swiss Federal Office of Energy may, at an early stage, give their opinion about topics that should be taken into account. Recent examples concern the expertise required from refrigeration system planners and installers regarding the climatic effect of refrigerants.

Important new instruments for identifying relevant climate competences in occupations are the tools published by the State Secretariat for Education, Research and Innovation (*SERI*, 2020) and the Swiss Federal Office for the Environment together with the Swiss Federal Office of Energy (*FOEN and SFOE*, 2020), respectively.

At the level of advanced professional education and training, regular evaluations of regulations are not mandatory and it is up to the professional organisations if they wish to invite advice or recommendations from the competent government authorities. Thus, close collaboration is limited to those professional organisations that expect economical or image benefits from strengthening environmental matters in their training curricula and examination requirements.

An example for an initiative of a professional organisation is the project 'Stärkung der Klima-, Energie- und Umweltkompetenzen' ('Strengthening competences in the fields of climate, energy and environment') by Hotel & Gastro formation, the Swiss institution in charge of training and further education offers in the hotel and catering industry. Digital learning tools are being developed to help persons in leadership positions to acquire competencies in climate change, climate-friendly menu design, food waste reduction and energy efficiency in kitchens and hotels as they prepare for federal examinations.

9.5.1 Training-related activities supported by the SwissEnergy programme

In January 2022, SwissEnergy launched a multi-year education and training initiative focussing on the buildings sector (*Ecoplan*, 2021). The Swiss building stock is responsible for around half of Switzerland's energy consumption and is therefore of central importance for achieving the national energy and climate targets. Numerous fossil-fuelled heating systems must be replaced in the coming years, the existing building stock must be energy-efficiently renovated and renewable energies must be massively expanded. To achieve this goal, experienced, well-trained and sufficiently skilled workers are needed.

SwissEnergy, together with the industry and education professionals, conducted a broad stakeholder dialogue to develop the education and training initiative. Consequently, it serves the following objectives:

- Recruitment of new professionals;
- Retaining existing professionals;
- Strengthening the skills of professionals.

Several focal areas have been defined and related measures addressing trainees and professionals dealing with energy have been implemented with a view to:

- Accelerating transfer of knowledge and improvement of offers at all levels of vocational education and training, inter alia, by systematically including up-to-date energy and climate issues in training materials;
- Consolidating programmes for newcomers with a different educational background – in particular for vocational fields with a lack of trainees (e.g. technical building equipment; see also *https://suissetec-freiburg.ch/de/passerelle-ausbildung.html*);
- Ensuring coordination and topicality of educational offers while minimising duplication of efforts through the establishment of annual round tables, facilitation of stakeholder dialogues and assessment of educational needs, in particular in the area of solar energy applications;
- Ensuring expertise regarding new regulations and their implementation in the energy sector;
- Coordinating solar education in Switzerland; implementation of the Swiss Solar Education Strategy (*Koordination Solarbildung Schweiz*, 2017) through provision of market-oriented, needs-based, high quality education and training services in the field solar heat and solar power.

Independently of the ongoing education and training initiative, SwissEnergy supports the development and implementation of several specialised vocational education and training offers (e.g. *http://www.enbau.ch*, *http://www.mas-eddbat.ch*, *www.solarteure.ch*, *https://www.suissetec.ch/de/projektleiter-in-solarmontage.html*, *www.supsi.ch/isaac/formazione.html*, *https://www.werz.hsr.ch/index.php?id=12433*, *www.fe3.ch*). In addition, under the address *https://www.energieschweiz.ch/bildung/weiterbildungsangebote/*, SwissEnergy presents a comprehensive list of continuing education offers relevant to students or professionals in the energy sector.

At the level of basic vocational education and training, SwissEnergy supports the 'Energie- und Klimawerkstatt' ('Energy and Climate Laboratory'), where vocational schools and companies with trainees can participate in a project competition for students and trainees (*http://www.myclimate.org/education/climate-laboratory*).

In recent years, the total budget of SwissEnergy dedicated to basic and continuing vocational education and training has been settled around 4 to 5 million Swiss francs per year. Annually, about 100 projects receive funds from this budget.

9.5.2 Measures within the ‘Climate Programme Training and Communication’

Complementing the offers under the umbrella of SwissEnergy, within this programme occupation-specific teaching and examination materials are developed and tested for use in the various training environments of basic and advanced professional education and training (companies, branch courses, specialised schools and colleges). In the area of vocational training, the focus of the programme is on climate-relevant professions such as transport, logistics and trade. Teachers and examiners are supported in exam questions and further training on the topic of climate protection.

In line with existing procedures, occupation-specific regulations (vocational education and training ordinances) undergoing a reform or regulations established for newly defined occupations are assessed for the need of integrating climate-relevant skills and competencies in the respective education, training and examination requirements.

A further focus lies on the promotion and strengthening of information exchange between professional organisations, education and training institutions, and companies. The aim is to enhance the transfer of climate-relevant knowledge, experiences and good practice examples amongst the specialists responsible for or involved in training programmes. Networking events are held to support this transfer process (for an example, see *FOEN*, 2019b).

9.5.3 Services offered by éducation21

As far as training and continuing education for teaching staff is concerned, éducation21 closely cooperates with teacher education institutions, providing them with advice, networking support, events and training units on education for sustainable development.

éducation21 is working with various stakeholders with the aim to anchor education for sustainable development in the field of vocational education and training. The focus is on fostering and anchoring education for sustainable development by means of tools, expertise and whole system support. Two new projects aim at developing such tools, one with the Swiss Federal University for Vocational Education and Training[147] and another with the Lucerne University of Teacher Education. Furthermore, éducation21 is collaborating with employer’s associations, e.g. Swissbanking, in order to introduce education for sustainable development into their operational vocational training.

9.6 Involvement of the public and non-governmental organisations

After many years of public debate about climate change, its implications for society and economy, and appropriate ways of responding to the challenges linked to this, it is impossible to overlook all the civil and private sector initiatives related to climate change in Switzerland. Thus, every attempt to summarise relevant activities is bound to be fragmentary and distorted. As a more recent element, the Fridays for Future movement in Switzerland started in late 2018 and impacted the public discourse on climate, the media coverage, the positioning of political parties and also the national elections in 2019.

In the following paragraphs, some of the more visible actors and activities, as perceived from a national perspective, are listed. Inevitably, this approach fails to document the numerous initiatives at regional and local level contributing to public awareness, fostering discussions about necessary action and motivating individuals to change their behaviour as consumers, employees or citizens.

Organisations offering climate-relevant services in the area of education and training

(in alphabetical order, non-exhaustive list; German sites frequently are available in French and Italian, too)

- éducation21 (*https://www.education21.ch/de/themendossier/klima*);
- Globe (*https://www.globe-swiss.ch*);
- myblueplanet (*https://www.myblueplanet.ch*);
- myclimate (*http://www.myclimate.org/de/bildung*);

[147] *https://www.sfuvet.swiss/*

- Ökozentrum Langenbruck (*https://oekozentrum.ch/de/angebot; https://oekozentrum.ch/de/projekte/klima-energie*);
- PUSCH (*http://www.pusch.ch/fuer-gemeinden; http://www.pusch.ch/fuer-schulen/umweltunterricht/energie-und-klima*);
- WWF (*https://www.wwf.ch/de/aktiv-werden/lehrerinnen-und-lehrer*; *https://www.wwf.ch/de/unsere-ziele/bildung-begeisterung-fuer-die-natur-wecken*).

Environmental non-governmental organisations and grassroots organisations

The main Swiss non-governmental organisation in the field of climate policy, combining more than 120 environmental, faith, union, climate solutions and development organisation interests and coordinating overarching campaigns, is Klima-Allianz (Climate Alliance Switzerland). An overview of its activities with links to its member organisations can be found at *https://www.klima-allianz.ch*.

Businesses committed to science based targets

Swiss companies and financial institutions that have joined the Science Based Targets initiative (SBTi) to reduce their emissions in line with climate science can be found at *https://sciencebasedtargets.org/companies-taking-action#table* by setting the filter to the location 'Switzerland'. The SBTi is a partnership between CDP (formerly known as the Carbon Disclosure Project), the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF).

9.7 Participation in international activities

International activities supported by Switzerland with a strong bearing for training and capacity building are documented in sections 7.2 and 7.3. In the following, some additional activities relevant to education, training and awareness raising at the international level are listed.

éducation21

The éducation21 web portal provides information and resources on Switzerland's contribution to the international education for sustainable development community (e.g. the European network of schools for health – SHE, see *https://www.education21.ch/fr/approche-institutionnelle-globale*). The portal also documents projects and programmes led or supported by the universities of applied sciences in teacher education in the period 2004–2018 (*https://www.education21.ch/de/partnerschaften-nord-sued*). éducation21 also participates in UNESCO activities, e.g., in 2021 éducation21 took an active part in the preparation of, and made contributions to, the UNESCO world conference.

One UN Climate Change Learning Partnership (UN CC:Learn)

The One UN Climate Change Learning Partnership, also referred to as UN CC:Learn, is a collaborative initiative of 36 multilateral organizations working together to support countries in building the knowledge and skills they need to take action on climate change. The programme aims at designing and implementing continued, results-oriented climate change learning programmes to support people, governments and businesses to understand, adapt and build resilience to climate change.

Launched at the 2009 Climate Change Summit held in Copenhagen – and supported by the Swiss Agency for Development and Cooperation since that moment – the initiative has constantly expanded the number of partner countries. It now engages with 30 countries either bilaterally or through regional programmes. The level of Swiss funding of around half a million Swiss francs per year has remained constant over the years, but has decreased in terms of percentage as other bilateral and multilateral contributors have joined. A new phase of Swiss support to UN CC:Learn for the period up to the end of 2025 was formalised in fall 2021. Free of charge e-learning courses that draw on the expertise of the many partners from the UN family and beyond are the backbone of the initiative. But UN CC:Learn is much more than that, and its knowledge sharing platform has actually developed into a 'one-stop-shop' for access to learning materials, activities and services offered by UN organizations.

An important flagship activity under the initiative are the Youth Climate Dialogues (YCD), which provide a space for young people in different countries to exchange via video conferencing and offer the opportunity to voice their own views, perspectives and experiences on climate change. Starting as a small pilot initiated jointly by UNITAR and the Swiss Agency for Development and Cooperation in 2015, more than 30 such dialogues have been successfully organised in the period 2017–2020, involving hundreds of students from all over the world. Thanks to the YCDs, Swiss high schools have forged partnerships with education institutions in the South, which continue now on their own.

Switzerland's commitment within the framework of the UN CC:Learn initiative is part of a broader approach to better engage youth in addressing global challenges such as climate change. Young people are the ones who will feel the consequences of climate change most directly. Preparing them for their role as future decision-makers and leaders is therefore a meaningful endeavour in itself.

Swiss Climate Summer School

Since many years, the Centre for Climate Systems Modelling at the Swiss Federal Institute of Technology in Zurich, together with the Oeschger Centre for Climate Change Research, sponsors and organises the Swiss Climate Summer School. The Summer School invites young researchers from all fields of climate research. For a limited number of students from developing countries and economies in transition, grants covering the expenses for the registration fee (1300 Swiss francs) are available. The courses cover a broad spectrum of cutting-edge climate research and promote interdisciplinary connections. For an overview of Summer Schools conducted this far, see *https://c2sm.ethz.ch/education/summer-school.html*.

Partnership on Transparency in the Paris Agreement[148]

Since 2016, in the context of the Cluster Francophone of the Partnership on Transparency in the Paris Agreement, Switzerland is contributing to the organisation and implementation of regional workshops. The workshops offer the opportunity for experts from French speaking developing countries to benefit from the knowledge base of the Partnership on Transparency in the Paris Agreement. Participants share experiences and receive expert inputs related to the establishment of reports under the UNFCCC and the development of approaches for MRV of mitigation actions in line with the evolving transparency framework under the UNFCCC (*https://www.transparency-partnership.net/*; *https://www.transparency-partnership.net/activity/partnership-francophone*).

9.8 Monitoring, review and evaluation of the implementation of Article 6 of the Convention

In Switzerland, there is no formal monitoring, review and evaluation process in place for assessing the implementation of Article 6 of the UNFCCC. However, as documented in this report, implementation of Article 6 is taken into account as part of other commitments related to mitigation, adaptation and international cooperation.

Preparation and review of the national communication

The Swiss political system offers far-reaching possibilities to interested stakeholders for participation in policy-making and policy review processes (see section 2.1). In Switzerland, the preparation of national communications under the UNFCCC is not considered an element of policy-making or policy review. Rather, national communications serve as a means to give account of policy implementation towards an international audience.

In practice, national communications under the UNFCCC are prepared involving a wide range of government and scientific community experts knowledgeable in the topics covered (see the imprint of the present report and earlier Swiss national communications). The content of national communications is subject to review by IDA-Klima, an interdepartmental committee on climate of the federal authorities (see section 4.1.1). The national inventory system supervisory board (NISSB) is responsible for the official consideration of Switzerland's national communications as well as for the recommendation for official approval by the directorate of the Swiss Federal Office for the Environment.

In view of this and of earlier experiences with the involvement of stakeholders in the process, public participation in the preparation or domestic review of national communications under the UNFCCC are considered neither particularly useful nor necessary. The original report itself is publicly available for download via the website of the Swiss Federal Office for the Environment (e.g. at *http://www.climatereporting.ch*). An overview brochure with the most important statements on Switzerland's commitments under the UNFCCC and their implementation is periodically made available to the media,

[148] Formerly known as the International Partnership on Mitigation and MRV.

schools and the general public in electronic and printed form (see *FOEN*, 2018 for the version published after submission of Switzerland’s seventh national communication).

References

Credit Suisse, 2021: Sorgenbarometer 2021. Die Pandemie in der zweiten Phase. Resilienz und Rückzug in individuelle Lebenswelten. gfs.bern, November 2021 *https://www.credit-suisse.com/media/assets/corporate/docs/about-us/responsibility/worry-barometer/schlussbericht-credit-suisse-sorgenbarometer-2021.pdf* [18.07.2022]

Ecoplan, 2021: Bildungsoffensive Gebäude. Roadmap mit Massnahmenkatalog. Bern (mandate by the Swiss Federal Office of Energy/SwissEnergy). *https://pubdb.bfe.admin.ch/de/publication/download/10780* [18.07.2022]

FOEN, 2017a: Anpassung an den Klimawandel. Magazin Umwelt 3/2017. Swiss Federal Office for the Environment, Bern (available in German and French). *www.bafu.admin.ch/magazin2017-3* [18.07.2022]

FOEN, 2017b: Impulse für eine klimaangepasste Schweiz – Erkenntnisse aus 31 Pilotprojekten zur Anpassung an den Klimawandel. Swiss Federal Office for the Environment, Bern (als available in French). *http://www.bafu.admin.ch/ui-1703-d* [18.07.2022]

FOEN, 2018: Switzerland's climate policy. Implementation of the Paris Agreement. Swiss Federal Office for the Environment, Bern. Environmental Info no. 1803 (available in French, German, Italian and English). *www.bafu.admin.ch/ui-1803-e* [18.07.2022]

FOEN, 2019a: Adaptation to climate change – Pilot programme phase II. Swiss Federal Office for the Environment, Bern. Environmental Info no. 1911. *http://www.bafu.admin.ch/ui-1911-e* [18.07.2022]

FOEN, 2019b: Klimakompetenzen in Bildung und Praxis. Netzwerkveranstaltung. Mittwoch, 15. Mai 2019, Mobilcity, Bern. *https://www.bafu.admin.ch/dam/bafu/de/dokumente/bildung/fachinfo-daten/Klimakompetenzen%20in%20Bildung%20und%20Praxis.pdf* [18.07.2022]

FOEN, 2020a: Effects of climate change abroad – risks and opportunities for Switzerland. Swiss Federal Office for the Environment, Bern. *http://www.bafu.admin.ch/ui-2002-e* [18.07.2022]

FOEN, 2020b: Wird in der Schweiz das Wasser knapp? Magazin «die umwelt» 4/2020. Swiss Federal Office for the Environment, Bern (available in German and French). *https://www.bafu.admin.ch/bafu/de/home/themen/wasser/dossiers/magazin2020-4-dossier.html* [18.07.2022]

FOEN, 2020c: Klimaprogramm Bildung und Kommunikation 2021 bis 2030. Konzept. Swiss Federal Office for the Environment, Bern (available in German and French). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/fachinfo-daten/konzept-klimaprogramm2021-2030-bildung-und-kommunikation.pdf* [18.07.2022]

FOEN et al., 2020: Management summary: Climate change in Switzerland. Indicators of driving forces, impact and response. State of the environment no. 2013. Swiss Federal Office for the Environment,Bern (full-length versions available in German, French and Italian). *www.bafu.admin.ch/uz-2013-e* [18.07.2022]

FOEN, 2021: Revision des CO_2-Gesetzes. Erläuternder Bericht zur Vernehmlassungsvorlage. Swiss Federal Office for the Environment, Bern, 17. December 2021 (available in German and French). *https://www.newsd.admin.ch/newsd/message/attachments/69699.pdf* [18.07.2022]

FOEN and SFOE, 2020: Jeder Beruf zählt! Umwelt-, Klima- und Energiekompetenzen für eine nachhaltige Entwicklung. Eine Arbeitshilfe für den Berufsentwicklungsprozess. Swiss Federal Office for the Environment and Swiss Federal Office of Energy, Bern (available in German only). *https://www.bafu.admin.ch/dam/bafu/de/dokumente/bildung/fachinfo-daten/arbeitshilfe-jeder-beruf-zaehlt.pdf* [18.07.2022]

FOEN and SFOE, 2022: Wegweiser Klimastrategie für Gemeinden. Swiss Federal Office for the Environment and Swiss Federal Office of Energy, Bern (available in German, French and Italian). *www.bafu.admin.ch/ui-2209-d* [18.07.2022]

gfs.bern, 2021: VOX-Analyse zur Abstimmung vom 13. Juni 2021. Nachbefragung und Analyse zur eidgenössischen Volksabstimmung vom 13. Juni 2021. gfs.bern, Juli 2021. *https://vox.gfsbern.ch/wp-content/uploads/2021/10/d_vox_schlussbericht_def_v5.pdf* [18.07.2022]

John, M. et al., 2016: Klimabildung und Klimawissen in der obligatorischen Schule und auf Sekundarstufe II. Ist-Analyse, Bedarfsabklärung und Vorschläge. Schlussbericht. Markus John Bildung und internationale Zusammenarbeit, Zurich/Bern (mandated by the Swiss Federal Office for the Environment, Bern). 44 pp. [confidential/internal]

Koordination Solarbildung Schweiz, 2017: Strategie Solarbildung Schweiz. Kurzfassung. e4plus AG, Kriens (mandated by the Swiss Federal Office of Energy/SwissEnergy). *https://pubdb.bfe.admin.ch/de/publication/download/8785* [18.07.2022]

MeteoSwiss, 2018: Hitze und Trockenheit im Sommerhalbjahr 2018 – eine klimatologische Übersicht. Fachbericht MeteoSchweiz, 272. *https://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/Fachbericht_TrockenheitHitze_2018_final_d.pdf* [18.07.2022]

MeteoSwiss, 2021: Klimareport 2020. MeteoSwiss, Zurich (available in German and French). *https://www.meteoschweiz.admin.ch/content/dam/meteoswiss/de/service-und-publikationen/Publikationen/doc/klimareport_2020_de.pdf* [18.07.2022]

NCCS, 2017: National Centre for Climate Services NCCS. Short presentation leaflet. November 2017. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/allgemeines/Leaflet_NCCS.pdf* [18.07.2022]

NCCS, 2018: CH2018 – Climate Scenarios for Switzerland. National Centre for Climate Services, Zurich. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/klima/CH2018_broschure.pdf* [18.07.2022]

NCCS and FOEN, 2021: Swiss Water Bodies in a Changing Climate. National Centre for Climate Services, Zurich, and Swiss Federal Office for the Environment, Bern. *https://www.nccs.admin.ch/dam/nccs/en/dokumente/website/hydro-ch2018/Broschuere/broschuere.pdf* [18.07.2022]

SCNAT, 2016: Brennpunkt Klima Schweiz. Grundlagen, Folgen und Perspektiven. Swiss Academies Reports 11 (5). *https://proclim.scnat.ch/en/activities/brennpunkt* [18.07.2022]

SCNAT, 2021a: Tackling climate change and biodiversity loss jointly. Swiss Academies Factsheet 16 (3). *https://scnat.ch/en/uuid/i/4bb62ca1-4819-570d-beb1-ee58eabea746-Tackling_climate_change_and_biodiversity_loss_jointly* [18.07.2022]

SCNAT, 2021b: The impact of emissions from aviation on the climate. Swiss Academies Communications 16 (3). *https://scnat.ch/en/id/cSx4y* [18.07.2022]

SERI, 2020: Guide sur le développement durable dans la formation professionnelle. State Secretariat for Education, Research and Innovation SERI, Bern (available in French and German). *https://www.sbfi.admin.ch/sbfi/fr/home/formation/fps/developpement-durable.html* [18.07.2022]

Swiss Confederation, 2002: Federal Act on Vocational and Professional Education and Training (Vocational and Professional Education and Training Act, VPETA) of 13 December 2002 (Status as of 01.04.2022). *https://www.admin.ch/opc/en/classified-compilation/20001860/index.html* [18.07.2022]

Swiss Confederation, 2006: Verordnung des SBFI über Mindestvorschriften für die Allgemeinbildung in der beruflichen Grundbildung vom 27. April 2006 (Status as of 04.03.2014). *https://www.admin.ch/opc/de/classified-compilation/20061526/index.html* [18.07.2022]

Swiss Federal Council, 2021b: 2030 Sustainable Development Strategy. Swiss Federal Council, Bern. 23.06.2021. *https://www.are.admin.ch/dam/are/en/dokumente/nachhaltige_entwicklung/publikationen/sne2030.pdf.download.pdf/sne2030.pdf* [18.07.2021]

Annex A Supplementary information under Article 7, paragraph 2, of the Kyoto Protocol

Supplementary information under Article 7, paragraph 2, of the Kyoto Protocol is contained in different chapters and sections of Switzerland's eighth national communication, as detailed in Tab. 58.

Tab. 58 > Reference to chapters and sections of Switzerland's eighth national communication containing the supplementary information under Article 7, paragraph 2, of the Kyoto Protocol.

National systems in accordance with Article 5, paragraph 1	Section 3.3
National registry	Section 3.4
Supplementarity relating to the mechanisms pursuant to Articles 6, 12 and 17	Annex B.3.6
Policies and measures in accordance with Article 2	Chapter 4
International Civil Aviation Organisation	Section 4.4.1, 4.4.9 to 4.4.12
International Maritime Organisation	Section 4.4.13
Minimising adverse effects	Section 4.13
Domestic and regional programmes and/or legislative arrangements and enforcement and administrative procedures…	Tab. 15
…to meet the commitments under the Kyoto Protocol (legal authorities, cases of non-compliance, public availability of information)	Section 4.1.1, Tab. 15
…to coordinate activities relating to participation in the mechanisms under Articles 6, 12 and 17	Section 4.1.1
…to ensure the conservation of biodiversity and sustainable use of natural resources when implementing Articles 3.3 and 3.4	Section 4.7.1
Information under Article 10	
Article 10a: Programmes to improve the quality of local emission factors, activity data and/or models	Section 3.3
Article 10b: Programmes containing measures to mitigate climate change and measures to facilitate adaptation to climate change	Chapter 4, chapter 6
Article 10c: Transfer of technologies	Section 7.2
Article 10d: Scientific and technical research, systematic observation systems	Chapter 8
Article 10e: Education and training programmes	Chapter 9
Financial resources	Chapter 7

Annex B Fifth biennial report of Switzerland

B.1 Introduction

Switzerland’s fifth biennial report is presented as an annex to Switzerland’s eighth national communication. It consists of the BR CTF tables (see separate submission) and the textual part (Annex B.2 to B.7), addressing the reporting requirements according to the ‘UNFCCC biennial reporting guidelines for developed country Parties’. To report the same information once only, reference to the respective chapters and sections of Switzerland’s eighth national communication is provided where appropriate.

B.2 Information on greenhouse gas emissions and trends

Summary information from the national greenhouse gas inventory on emissions and emission trends prepared according to the UNFCCC Annex I inventory reporting guidelines are presented in BR CTF tables 1(a) to 1(d), as well as in Switzerland’s eighth national communication (chapter 3, sections 3.1 and 3.2). The presented data cover the period from 1990 to 2020 and are fully consistent with that provided in the most recent annual inventory submission of April 2022.

Summary information on Switzerland’s national inventory arrangements, including changes since the fourth biennial report, are also presented in Switzerland’s eighth national communication (chapter 3, section 3.3). As required by the ‘Guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol’, information on the national registry is further reported in Switzerland’s eighth national communication (chapter 3, section 3.4).

B.3 Quantified economy-wide emission reduction target

While all information regarding Switzerland’s emission reduction commitment is summarised in BR CTF table 2, this section provides further background information in textual form. The focus lies on Switzerland’s emission reduction commitment for the period up to 2020.

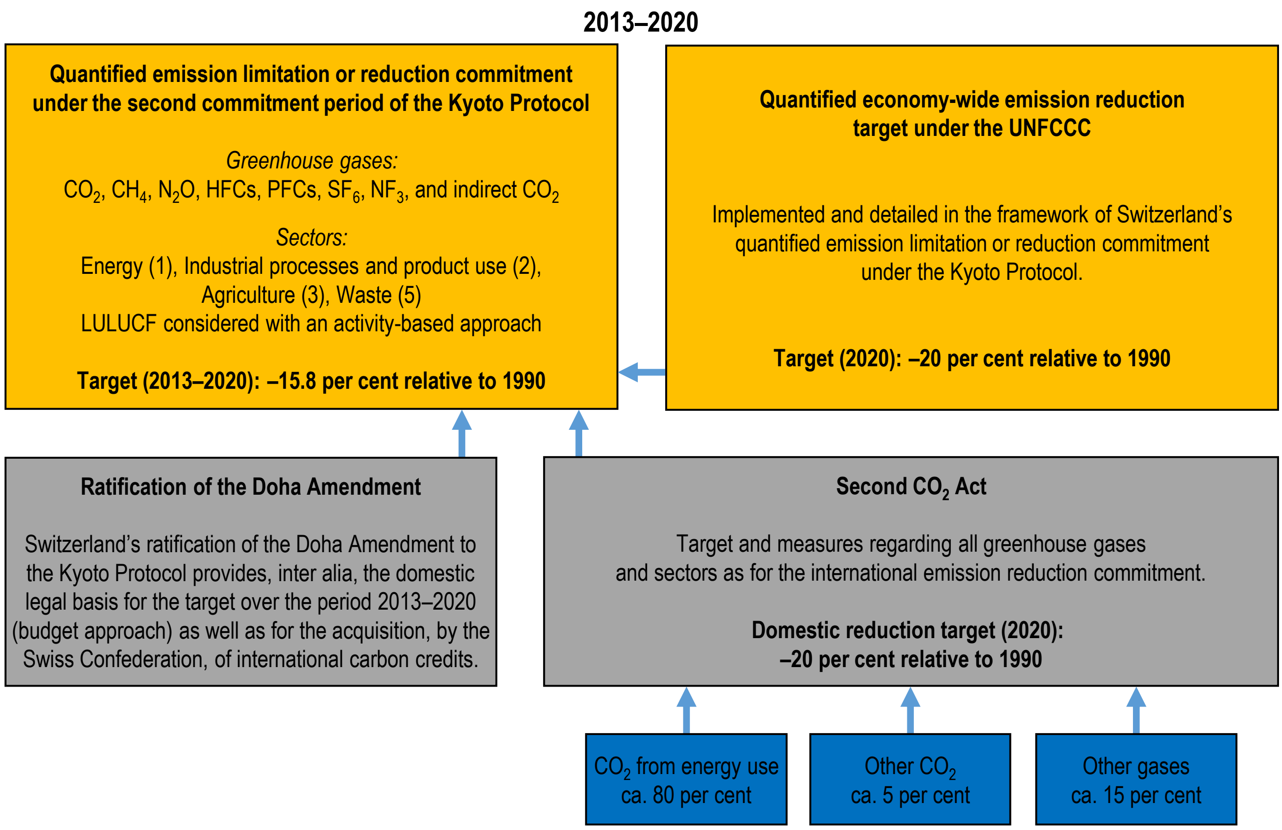
B.3.1 General information

By ratifying the UNFCCC in 1993, Switzerland committed to contribute to the stabilisation of greenhouse gas emissions at a level that prevents dangerous anthropogenic interference with the climate system. Switzerland’s quantified economy-wide emission reduction target under the UNFCCC is – in a consistent manner – implemented under the Kyoto Protocol, making Switzerland’s emission reduction commitment internationally binding. Accordingly, Switzerland, in 2003, ratified the Kyoto Protocol, which entered into force in 2005. In this context, Switzerland made a quantified emission limitation or reduction commitment of 92 per cent of the base year (1990) level for the first commitment period of the Kyoto Protocol (2008–2012). For the second commitment period of the Kyoto Protocol (2013–2020), Switzerland has continued its emission reduction efforts and submitted its instrument of acceptance of the Doha Amendment to the Kyoto Protocol on 28 August 2015. Therewith, Switzerland has entered into a quantified emission limitation or reduction commitment of 84.2 per cent of the base year (1990) level for the second commitment period of the Kyoto Protocol (2013–2020). This quantified emission limitation or reduction commitment implements and details in a consistent manner Switzerland’s quantified economy-wide emission reduction target of 20 per cent below the emissions of the year 1990, to be reached by 2020. Consistently implementing the quantified economy-wide emission reduction target under the UNFCCC under the quantified emission limitation or reduction commitment under the Kyoto Protocol means that Switzerland assesses the fulfilment of the quantified economy-wide emission reduction target under the UNFCCC by accounting against its quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol. By reaching its quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol, Switzerland also considers the quantified economy-wide emission reduction target under the UNFCCC as fulfilled. Switzerland’s targets are unconditional under both the UNFCCC and the Kyoto Protocol.[149] The international emission reduction commitment has been implemented nationally by means of the second CO_2 Act and the corresponding policies and measures (for details see chapter 4 of Switzerland’s eighth national communication). Based on the second CO_2 Act

[149] However, as part of a global and comprehensive agreement for the period beyond 2012, Switzerland reiterated its conditional offer to move from its target of a 20 per cent emission reduction by 2020 compared with 1990 levels to a 30 per cent emission reduction, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities (see FCCC/SB/2011/INF.1/Rev.1).

and in consistency with the international emission reduction commitment, Switzerland's national target for 2020 corresponds to a reduction of domestic greenhouse gas emissions by at least 20 per cent relative to 1990 levels (in contrast, Switzerland's international emission reduction commitment allows for the supplemental use of international carbon credits). An overview of Switzerland's national and international emission reduction commitment up to 2020 is provided in Fig. 110.

Fig. 110 > Switzerland's national and international emission reduction commitment up to 2020. The national target under the second CO_2 Act, Switzerland's quantified economy-wide emission reduction target under the UNFCCC, as well as Switzerland's quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol were aligned and, thus, consistent. LULUCF: Land use, land-use change and forestry.



In the framework of the Paris Agreement[150], Switzerland submitted an updated version of its first nationally determined contribution (NDC)[151] to the UNFCCC secretariat on 9 December 2020:

- Switzerland is committed to follow recommendations of science in order to limit warming to 1.5 degrees Celsius. In view of its climate neutrality target by 2050, Switzerland's nationally determined contribution is to reduce its greenhouse gas emissions by at least 50 per cent by 2030 compared with 1990 levels, corresponding to an average reduction of greenhouse gas emissions by at least 35 per cent over the period 2021–2030. By 2025, a reduction of greenhouse gases by at least 35 per cent compared with 1990 levels is anticipated. Internationally transferred mitigation outcomes from cooperation under Article 6 of the Paris Agreement will partly be used.

In the long term, Switzerland aims to reduce its greenhouse gas emissions to net zero by 2050. This target lays the foundations for Switzerland's long-term climate strategy to 2050, which was submitted to the UNFCCC secretariat on 28 January 2021.[152]

150 Switzerland deposited its instruments of ratification on 6 October 2017 with the Depositary, leading to the entry into force of the Paris Agreement for Switzerland on 5 November 2017.

151 https://www4.unfccc.int/sites/ndcstaging/Pages/Party.aspx?party=CHE&prototype=1

152 https://unfccc.int/sites/default/files/resource/LTS1_Switzerland.pdf

B.3.2 Base year

As mentioned above, the base year is 1990 for all sectors and gases covered. For the second commitment period of the Kyoto Protocol, Switzerland's base year emissions are defined in Switzerland's second initial report under the Kyoto Protocol (in particular in the update following the in-country review by an expert review team coordinated by the UNFCCC secretariat, see also FCCC/IRR/2016/CHE). Accordingly, the relevant base year emissions are 53,706,729 tonnes of CO_2 equivalents and the assigned amount for the second commitment period of the Kyoto Protocol is 361,768,524 tonnes of CO_2 equivalents. These base year emissions are relevant for Switzerland's quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol, Switzerland's quantified economy-wide emission reduction target under the UNFCCC as well as for Switzerland's national target under the second CO_2 Act.

B.3.3 Gases and sectors covered

In the international context, Switzerland's quantified economy-wide emission reduction target under the UNFCCC as well as Switzerland's quantified emission limitation or reduction commitment under the Kyoto Protocol cover the full set of reported greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3). All targets also include indirect CO_2 emissions, as long as the indirect CO_2 emissions are of fossil origin and not already considered under the direct CO_2 emissions (e.g. when an oxidation factor of 100 per cent is applied, see also section 3.2.4). All targets include the emissions from the sectors energy (1), industrial processes and product use (2), agriculture (3), and waste (5). Land use, land-use change, and forestry is considered with an activity-based approach (Articles 3.3 and 3.4). From sector 'Other' (6), all emissions (in particular also indirect CO_2 emissions) are not included. The second CO_2 Act covers the same gases and sectors as relevant for the international reduction commitments.

B.3.4 Global warming potential values

Switzerland consistently uses the global warming potential values listed in the column entitled 'Global warming potential for given time horizon' in Table 2.14 of the errata to the contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change (*IPCC*, 2007), based on the effect of greenhouse gases over a 100-year time horizon. These global warming potential values are also reflected in Annex I of the Ordinance on the Reduction of CO_2 Emissions (CO_2 Ordinance; *Swiss Confederation*, 2012) for the period 2013–2020.

B.3.5 Approach to counting emissions and removals from the land use, land-use change and forestry sector

According to Article 3.7 of the Kyoto Protocol, the land use, land-use change and forestry sector is only included in the calculation of the assigned amount in case this sector constituted a net source of greenhouse gases in 1990. In Switzerland, the land use, land-use change and forestry sector was a net sink in 1990 and is therefore excluded from the base year level and target.

With regard to Switzerland's emission reduction commitment, the land use, land-use change and forestry sector is accounted for with an activity-based approach. Under Article 3.3 of the Kyoto Protocol, Switzerland accounts for afforestation, reforestation as well as deforestation, and under Article 3.4 of the Kyoto Protocol for forest management (*FOEN*, 2016c; *FOEN*, 2016d). Importantly, the sum of emissions/removals of forest management under Article 3.4 needs to be offset against Switzerland's forest management reference level and the technical corrections to the forest management reference level. Accordingly, Switzerland consistently applies the rules to accounting emissions and removals from the land use, land-use change and forestry sector as established under the Kyoto Protocol. According to Switzerland's most recent annual inventory submission of April 2022, Switzerland's forest management reference level including the technical corrections amounts to –1,801,440 tonnes of CO_2 equivalents per year. For the entire second commitment period of the Kyoto Protocol, the difference between the removals from forest management under Article 3.4 and Switzerland's forest management reference level including the technical corrections is –5,894,857 tonnes of CO_2 equivalents. This value is below the forest management cap[153], i.e. the cap does not reduce Switzerland's accounting quantity for forest management under Article 3.4. Taking into account – in addition to forest management under Article 3.4 – afforestation, reforestation and deforestation under Article 3.3, Switzerland's accounting quantity amounts to a total of –4,508,318 tonnes of CO_2 equivalents over the entire second commitment period of the Kyoto Protocol (corresponding to roughly 0.56

[153] In accordance with Annex I to Decision 2/CMP.7 (paragraph 13), the forest management cap corresponds to 3.5 per cent of base year emissions excluding land use, land-use change and forestry times eight. For Switzerland the cap thus amounts to 15,037,884 tonnes of CO_2 equivalents for the entire commitment period 2013–2020.

million tonnes of CO_2 equivalents per year). These values are provisional estimates; final values will become available after the conclusion of the individual review of Switzerland's greenhouse gas inventory submitted in 2022.

B.3.6 Use of international market-based mechanisms

Switzerland's climate policy generally aims at domestic reductions of greenhouse gas emissions. However, Switzerland plans to use international carbon credits generated from the flexible mechanisms under the Kyoto Protocol to compensate for some of its emissions over the period 2013–2020. While Switzerland will decide on the final modalities pertaining to the supplemental use of international carbon credits in the course of the true-up period, the following information can be provided at this stage:

- Switzerland is applying quality requirements to determine the eligibility of international carbon credits. These quality requirements are stipulated in Annex II of the CO_2 Ordinance[154] and detailed in a fact sheet[155] published by the Swiss Federal Office for the Environment;
- In Annex II of decision 2/CMP.8 Switzerland made a clear political declaration relating to AAUs carried over from the first commitment period of the Kyoto Protocol. Accordingly, under the Swiss domestic legislation applicable during the second commitment period, Switzerland will not use carry-over AAUs transferred from other Parties for compliance under Article 3 of the Kyoto Protocol for the second commitment period. Switzerland will adhere to arrangements in other countries relating to the transfer of AAUs under any arrangement that may link Switzerland's emissions trading scheme with the emissions trading schemes of other countries. Switzerland intends to use its own carry-over AAUs;
- The second CO_2 Act defines Switzerland's 20 per cent reduction target (by 2020, relative to 1990) as domestic. However, international carbon credits play a minor role in the sanction mechanisms (see Tab. 15) and the implementation of some individual policies and measures: (i) the emissions trading scheme (section 4.2.6), (ii) the negotiated reduction commitments (for exemption from the CO_2 levy, section 4.2.7), and (iii) the partial compensation of CO_2 emissions from motor fuel use (section 4.4.5). However, Switzerland intends to transfer the respective international carbon credits (CERs) on its voluntary cancellation account and will not account them towards the achievement of its emission reduction targets for the second commitment period;
- Switzerland intends to use additional international carbon credits recognised under the Kyoto Protocol to meet the differences between the approaches used under national legislation (i.e. emission reduction target defined for the year 2020) and under the Kyoto Protocol (i.e. 'carbon budget' approach used to calculate the quantified emission limitation or reduction commitment for the period 2013–2020). International carbon credits to be used for this purpose are available from the Climate Cent Foundation (section 4.4.4), which is obligated to use excess revenues from the period 2005–2012 for the acquisition of international carbon credits and to hand these over to the Swiss government (in the course of 2022).

The possible scale of contributions of international carbon credits needed by Switzerland in order to reach its emission reduction targets for the second commitment period can be provisionally estimated based on Switzerland's greenhouse gas inventory submitted in 2022. Accordingly, Switzerland's total greenhouse gas emissions amount to about 382.8 million tonnes of CO_2 equivalents over the entire second commitment period of the Kyoto Protocol. As reported in BR CTF Table 2(e)I, the following contributions are expected:

- **CERs:** Switzerland plans to use CERs handed over to the Swiss government by the Climate Cent Foundation. According to the latest available information, these CERs may amount to approximately 18 million tonnes of CO_2 equivalents;
- **ERUs:** Switzerland does currently not plan to use ERUs;
- **AAUs:** Switzerland plans to use AAUs corresponding to its assigned amount of 361.8 million tonnes of CO_2 equivalents. As described above, adherence to arrangements in other countries relating to the transfer of AAUs may play a minor role;

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154 http://www.admin.ch/opc/en/classified-compilation/20120090/index.html#app2

155 https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/formular/qualitaet_von_imauslanderzieltenemissionsverminderungen.pdf

- **Carry-over units:** Switzerland plans to use its own carry-over units. On Switzerland's previous period surplus reserve account, AAUs of about 5.8 million tonnes of CO_2 equivalents are available;
- **RMUs:** Switzerland plans to use RMUs of about 4.5 million tonnes of CO_2 equivalents based on the provisional accounting quantity for activities under Articles 3.3 and 3.4 of the Kyoto Protocol as described in Annex B.3.5.

Therewith, Switzerland's is confident to overachieve its quantified emission limitation or reduction commitment under the second commitment period of the Kyoto Protocol. Given the provisional nature, the values provided are rounded to one decimal digit in millions; final values will become available after the conclusion of the individual review of Switzerland's greenhouse gas inventory submitted in 2022 and the following true-up period.

B.3.7 Any other information

As Switzerland's quantified economy-wide emission reduction target under the UNFCCC is – in a consistent manner – implemented under the Kyoto Protocol, Switzerland follows the accounting rules implemented and detailed in the framework of its quantified emission limitation or reduction commitment under the Kyoto Protocol.

B.4 Progress in achievement of quantified economy-wide emission reduction targets and relevant information

B.4.1 Mitigation actions and their effects

Information on Switzerland's mitigation actions, including on the policies and measures implemented or planned to be implemented since the last national communication or biennial report to achieve the emission reduction commitment, is summarised in BR CTF table 3. Chapter 4 of Switzerland's eighth national communication provides details for each policy and measure, in particular also regarding the estimated mitigation impacts and, if applicable, a further strengthening of the policy and measure in the future.

Information on Switzerland's domestic institutional arrangements, including institutional, legal, administrative and procedural arrangements used for domestic compliance, monitoring, reporting, archiving of information and evaluation of the progress towards the economy-wide emission reduction target is provided in section 4.1.2 and 4.1.3 of Switzerland's eighth national communication.

Detailed information on the assessment of the economic and social consequences of response measures (adverse effects) is presented in section 4.13 of Switzerland's eighth national communication.

B.4.2 Estimates of emission reductions and removals and the use of units from the market-based mechanisms and land use, land-use change and forestry activities

Detailed information on progress in the achievement of the quantified economy-wide emission reduction targets is provided in BR CTF table 4. The following points are noteworthy:

- Base year emissions (without land use, land-use change and forestry) are indicated in BR CTF table 4 according to the report on the review of the report to facilitate the calculation of the assigned amount for the second commitment period of the Kyoto Protocol of Switzerland (FCCC/IRR/2016/CHE, see also Annex B.3.2). Due to recalculations, the relevant base year emissions slightly differ from the respective values provided in Switzerland's most recent greenhouse gas inventory (as presented e.g. in BR CTF table 1);
- Base year emissions include emissions of all greenhouse gases (including indirect emissions of CO_2) from the sectors energy (1), industrial processes and product use (2), agriculture (3), and waste (5). See section B.3 for more details;
- The contribution from LULUCF (i.e. KP-LULUCF for Switzerland) corresponds to the sum of emissions/removals for activities under Articles 3.3 and 3.4, offset against Switzerland's forest management reference level and the technical corrections to the forest management reference level. The forest management cap is considered for the final accounting at the end of the commitment period, but does not reduce Switzerland's the accounting quantity for forest management under Article 3.4 (see also Annex B.3.5);

- Switzerland will account for contributions from market-based mechanisms (including carry-over units as detailed below) during the true-up period (i.e. after the conclusion of the individual review of Switzerland's greenhouse gas inventory submitted in 2022), therefore no annual numbers can be provided. However, as recommended by the UNFCCC expert review team during a previous review, Switzerland reports the amount of units from market-based mechanisms on the party holding accounts in the national registry at the end of the preceding year as a provisional estimate. Contrary to the indication in BR CTF Table 4(b), the figures are not shown for 2020, but for 2021 (end of year). The contributions from market-based mechanisms for the preceding years are included in the provisional estimate for 2021 and, thus, reported as 'IE' (included elsewhere). For 2021, the total number of 369,524,689 units is composed as follows: (i) number of units on the party holding accounts at the end of 2021 (361,768,524 AAUs reflecting the assigned amount and 1,961,642 CERs[156], see Tab. 14 of Switzerland's eighth national communication or Table 4 of RREG1_CH_2021_2_3), (ii) number of carry-over units from the first to the second commitment period of the Kyoto Protocol available on the previous period surplus reserve account (5,794,523 AAUs, see Tab. 14 of Switzerland's eighth national communication or Table 4 in RREG1_CH_2021_2_3), and (iii) there are currently no units on the retirement account for the second commitment period. Please refer to BR CTF Table 2(e)I for the possible scale of contributions from market-based mechanisms.

B.5 Projections

Information – including supporting documentation – on updated projections for the years 2025, 2030 and 2035 are presented in BR CTF tables 5 and 6(a) to 6(c), as well as in chapter 5 of Switzerland's eighth national communication. Changes in the model or methodologies used for the preparation of projections are detailed in section 5.3.8 of Switzerland's eighth national communication.

B.6 Provision of financial, technological and capacity-building support to developing country Parties

Information regarding the provision of financial, technological and capacity-building support to developing country Parties is provided in BR CTF tables 7, 8, and 9, as well as in chapter 7 of Switzerland's eighth national communication.

B.6.1 Finance

How Switzerland ensures that the resources it provides effectively address the needs of developing countries with regard to climate adaptation and mitigation is reported sections 7.1.2 and 7.1.3 of Switzerland's eighth national communication.

The information on the financial support provided for the purpose of assisting developing countries to mitigate greenhouse gas emissions and adapt to adverse climate change is reported in section 7.1 of Switzerland's eighth national communication. The quantitative information on the financial support for developing countries for climate change adaptation, mitigation, technology transfer and capacity building through bilateral and multilateral channels is reported in section 7.1.6 of Switzerland's eighth national communication as well as in BR CTF tables 7(a) and 7(b).

Section 7.1.5 of Switzerland's eighth national communication reports on information on financial support of Switzerland for developing countries in the area of economic and social consequences of response measures.

How Switzerland determined how the resources it provided are new and additional is highlighted in section 7.1.1 of Switzerland's eighth national communication as well as in the documentation boxes of BR CTF tables 7(a) and 7(b).

Switzerland also reported on private financial flows which were leveraged by its bilateral climate finance towards mitigation and adaptation activities in developing countries. The respective information is reported in section 7.1.1 of Switzerland's eighth national communication. The quantitative information is included in BR CTF table 7(b).

[156] The CERs available on Switzerland's party holding accounts in the national registry at the end of 2021 stem from the implementation of some individual policies and measures. Switzerland intends to transfer these CERs on its voluntary cancellation account and will not account them towards the achievement of its emission reduction targets for the second commitment period. Instead, Switzerland will use international carbon credits which the Climate Cent Foundation is obligated to hand over to the Swiss government (in the course of 2022). For more details see Annex B.3.6.

The types of instruments used in the provision of the Swiss assistance to developing countries is included in BR CTF tables 7(a) and 7(b) and their documentation boxes.

B.6.2 Technology development and transfer

The information on measures taken by Switzerland to promote, facilitate and finance the transfer of, access to and deployment of climate-friendly technologies for the benefit of developing countries, and for the support of the development and enhancement of endogenous capacities and technologies of developing countries is included in section 7.2 of Switzerland's eighth national communication.

Switzerland provides information in textual format in section 7.2.3 of its eighth national communication on some selected projects/programmes that promote the transfer of, access to and deployment of climate-friendly technologies in tabular format as well. In addition, Switzerland is submitting BR CTF table 8 with exemplary technology development and transfer support measures as part of the eighth national communication for the first time.

B.6.3 Capacity building

How Switzerland has provided capacity-building support that responds to existing and emerging capacity-building needs identified by developing countries in the areas of mitigation, adaptation, technology development and transfer can be found in section 7.3 of Switzerland's eighth national communication. In addition, Switzerland is submitting BR CTF table 9 with exemplary capacity building support projects as part of the eighth national communication for the first time.

B.7 Other reporting matters

Switzerland's domestic arrangements established for the process of the self-assessment of compliance with emission reductions in comparison with emission reduction commitments are addressed in section 4.1 of Switzerland's eighth national communication. This section also presents the establishment of national rules for taking local action against domestic non-compliance with emission reduction targets (sector-specific interim targets, proposition of additional policies and measures, automatic increase of the CO_2 levy on heating and process fuels, sanction mechanisms for various policies and measures, etc.). Switzerland considers that its eighth national communication and fifth biennial report includes all information relevant to the achievement of the objective of the Convention.

References

FOEN, 2016c: Switzerland's second initial report under the Kyoto Protocol. Report to facilitate the calculation of the assigned amount pursuant to Article 3, paragraphs 7bis, 8 and 8bis, of the Kyoto Protocol for the second commitment period 2013–2020. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

FOEN, 2016d: Switzerland's second initial report under the Kyoto Protocol. Update following the in-country review by an expert review team coordinated by the UNFCCC secretariat. Swiss Federal Office for the Environment, Bern. *http://www.climatereporting.ch* [18.07.2022]

IPCC, 2007: Fourth assessment report. Intergovernmental Panel on Climate Change. *https://www.ipcc.ch/report/ar4/wg1* [18.07.2022]

Swiss Confederation, 2012: Ordinance on the Reduction of CO_2 Emissions (CO_2 Ordinance) of 30.11.2012 (Status as of 04.03.2022). *https://www.admin.ch/opc/en/classified-compilation/20120090/index.html* [18.07.2022]

Annex C Responses to recommendations and encouragements

Tab. 59 and Tab. 60 list the recommendations and encouragements from the ‘report of the technical review of the seventh national communication of Switzerland’ (FCCC/IDR.7/CHE) and the ‘report of the technical review of the fourth biennial report of Switzerland’ (FCCC/TRR.4/CHE). To each of the recommendations and encouragements a brief response is provided, with reference to the respective section in Switzerland’s eighth national communication and fifth biennial report where appropriate.

Tab. 59 > Responses to recommendations of previous reviews.

Recommendation	Response	Reference to chapter/section of Switzerland’s eighth national communication
‘Report of the technical review of the **seventh national communication** of Switzerland’ (FCCC/IDR.7/CHE)		
No recommendations were made in the ‘report of the technical review of the seventh national communication of Switzerland’.		
‘Report of the technical review of the **fourth biennial report** of Switzerland’ (FCCC/TRR.4/CHE)		
Table 9, No. 1: The Party reported the bilateral climate finance disbursed in 2017 and 2018 for both mitigation and adaptation to climate change in its BR4. However, the ERT noted that the values provided as bilateral climate finance for mitigation and adaptation included mobilised private finance, and this was not transparently reported in the BR4. The ERT noted that this is not in accordance with paragraph 17 of the UNFCCC reporting guidelines on BRs, which require the reporting of support provided, committed and/or pledged, and not support mobilised. During the review Switzerland confirmed that the values provided in the BR4 and CTF table 7 for bilateral climate finance for adaptation and mitigation included mobilised private finance, but that the values for climate finance for adaptation and mitigation can be derived from tables 40 and 41 provided in the BR4. However, the ERT considers that the information is not transparently reported in the BR4. The ERT recommends that Switzerland enhance the transparency of the reporting of the public bilateral climate finance for mitigation and adaptation by providing the total values provided for mitigation and adaptation without including mobilised private finance, which should be reported separately.	As part of Switzerland’s eighth national communication and fifth biennial report and to enhance transparency Switzerland reports public bilateral climate finance per country separately for adaptation, mitigation and mobilised private finance.	BR CTF table 7(b) and Tab. 45
Table 9, No. 2: The Party reported in CTF table 7(b) the projects and programmes for which it has provided financial support. The ERT noted that some of the contributions listed in these tables include Ukraine as a recipient country. It noted that this is not in line with requirements of paragraph 18 of the UNFCCC reporting guidelines on BRs, which requires reporting on the assistance provided to non-Annex I Parties. During the review Switzerland explained that the financial support provided to Ukraine was unintentionally included in the totals, given that Ukraine is considered to be an eligible ODA recipient country under the OECD Development Assistance Committee methodology. The ERT recommends that Switzerland include only non-Annex I Parties as recipient countries in CTF table 7(b) or exclude the support provided to Annex I Parties from the totals in CTF table 7(b).	Switzerland recognises this error and has not included any support provided to Ukraine in the current BR CTF table 7(b).	BR CTF table 7(b)
Table 9, No. 3: The Party did not provide any information in CTF table 8 on the provision of support for technology development and transfer, which is not in line with paragraph 22 of the UNFCCC reporting guidelines on BRs. However, the ERT noted that relevant information to be included in CTF table 8 was provided in the BR4 for a number of projects and programmes that contribute to technology development and transfer. This information includes the recipient country, the sector involved, the target area (mitigation/adaptation) and the total funding. During the review Switzerland explained that it is not possible to determine the financial resources within the overall budget of a project or programme that correspond to technology transfer activities given that there is no international consensus and commonly accepted methodology on how to quantify technology transfer components of projects, and that, in order to quantify technology transfer components of projects, it would have to fundamentally redesign its entire national reporting system. The ERT reiterates the recommendation made in the previous three review reports for the Party to enhance the completeness of its reporting by providing information on the provision of technology development and transfer support in CTF table 8. The ERT considers that at a minimum, providing qualitative information on activities and measures for technology transfer support in the CTF table, consistently with that reported in the BR4, could improve the completeness of reporting by the Party.	To partially address this concern, Switzerland is submitting BR CTF table 8: Provision of technology development and transfer support with ten examples of activities and measures for technology transfer support as part of Switzerland’s eighth national communication and fifth biennial report.	BR CTF table 8

Tab. 60 > Responses to encouragements of previous reviews.

Encouragement	Response	Reference to chapter/section of Switzerland's eighth national communication
'Report of the technical review of the **seventh national communication** of Switzerland' (FCCC/IDR.7/CHE)		
Table 9, No. 1: Switzerland reported limited information on the results of its sensitivity analyses in its NC7, although it did conduct a sensitivity analysis on the projections for various assumptions such as GDP and international oil and gas prices. During the review, Switzerland provided an amendment to the NC7, in which the Party explained that the sensitivity analyses conducted were for comparing sensitivity scenarios. The ERT commends Switzerland for this supplementary information. However, as the details have to be obtained from a technical report (EPFL and INFRAS, 2016), it remains difficult to circumscribe the underlying assumptions and it is not always straightforward to analyse the linkages between the underlying assumptions and the reported projections. For example, the non-price bottom-up PaMs are listed in table 1 in the executive summary of EPFL and INFRAS (2016), whereas the sensitivity analysis is to be found in chapter 5 of that publication, which made it difficult for the ERT to assess the underlying assumptions on bottom-up estimates of the impact of non-price PaMs. The ERT encourages Switzerland to enhance the transparency of the reporting in its next NC by reconsidering ways of presenting the information, notably to better explain the implication of underlying assumptions on the projections.	This encouragement is identical to the encouragement 'Table 8, No. 1' made in the 'report of the technical review of the third biennial report of Switzerland'. Switzerland addressed the issue in its fourth biennial report and the expert review team considered the encouragement as resolved. Switzerland's eighth national communication and fifth biennial report contains the respective improvements as well.	5.3.9
'Report of the technical review of the **fourth biennial report** of Switzerland' (FCCC/TRR.4/CHE)		
Table 9, No. 4: The Party did not provide information in CTF table 9 on the provision of capacity-building support. This is not in line with paragraph 23 of the UNFCCC reporting guidelines on BRs. However, relevant information, including the recipient country, the sector involved, the target area (mitigation/adaptation) and the total funding provided, to be included in CTF table 9 is provided in the BR4 for a number of projects and programmes which contribute to capacity-building. During the review Switzerland explained that capacity-building is integrated within various climate actions that it undertakes in its cooperation activities, and that if it were to isolate the capacity-building component of the climate-related activities, it would need to fundamentally redesign its entire national reporting system. The ERT reiterates the encouragement made in the previous three review reports on the technical reviews of the BR1, BR2 and BR3 for the Party to provide information on the provision of capacity-building support, to the extent possible, in CTF table 9 in its next BR. The ERT considers that the provision in CTF table 9 of at least qualitative information on activities and measures for capacity-building support in CTF table 9 could improve the completeness of the reporting by the Party.	To partially address this concern, Switzerland is submitting BR CTF table 9: Provision of capacity building support with ten examples of activities and measures for capacity building support as part of Switzerland's eighth national communication and fifth biennial report.	BR CTF table 9