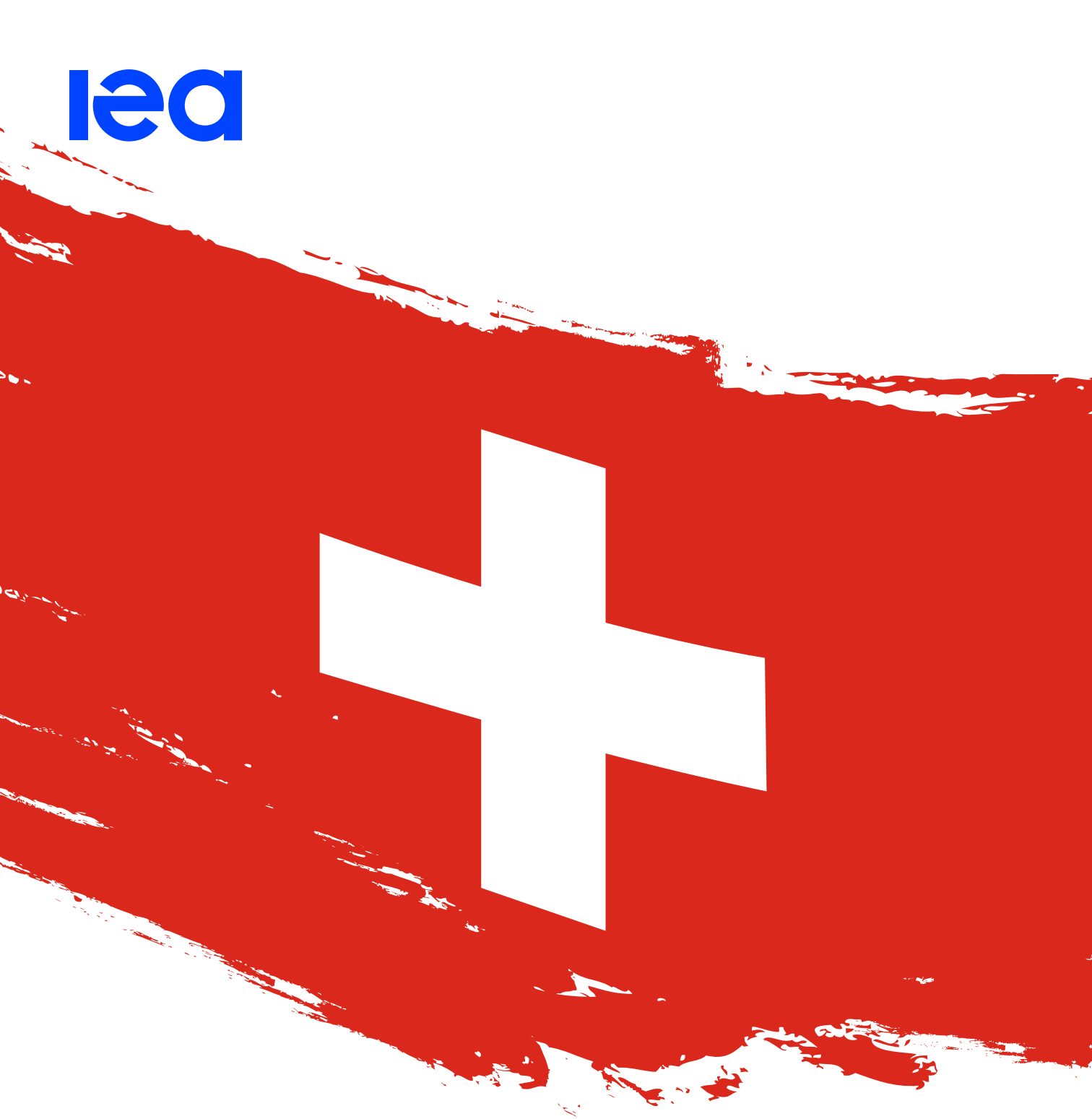

Switzerland 2023

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Executive summary

Switzerland is committed to reach net zero emissions by 2050 and reduce greenhouse gas (GHG) emissions by at least 50% by 2030 compared to 1990. To support this, the government has prepared several pieces of legislation. The long-term Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security foresees substantial subsidies for replacing fossil heating and processes. A revision to the CO_2 Act for the period beyond 2025 with instruments to reach the country's 2030 target under the Paris Agreement was being debated in parliament at the time of writing. The third piece of legislation is a revision of the 2018 Energy Act to replace the indicative targets for the expansion of renewables and per capita energy and electricity consumption with binding targets complemented with concrete measures to speed up deployment.

Reaching the climate target for 2030 will require substantial efforts, especially in the building and transport sectors, which both failed to meet their 2020 sectoral emissions targets. One challenge for the government is that the domestic climate legislation is currently in a flux. A revision of the CO_2 Act for the period to 2030 was rejected in referendum in 2021 and the new proposed CO_2 Act is still in the legislative process. Voters have, in particular, rejected the planned substantial increase in the CO_2 levy on stationary fuels. The new proposed CO_2 Act shifts the focus from regulations and tax increases to incentives and foresees a notable increase in funding for measures targeting the transport and building sectors. The new proposed CO_2 Act to 2030 also increases the share of emissions reductions that can happen abroad to a maximum of 40%.

Energy efficiency is a key pillar of Switzerland's strategy towards reaching its energy and climate targets for 2030 and the net zero target for 2050. Switzerland shows notable decoupling between energy consumption and economic growth. Its total final consumption per capita is substantially below the IEA average and decreased by 13% between 2011 and 2021. However, the government's five-year monitoring report published in late 2022 concluded that the current policy measures are insufficient to reach the 2030 targets. It is, therefore, important that energy efficiency as the first fuel principle is anchored as a pillar of new energy and climate legislation.

Switzerland recognises that by 2050 it will still emit around one-quarter of its current GHG emissions from hard-to-abate sectors, around 60% of which would be balanced via net emissions technologies (NETs) in Switzerland and abroad. The country also has plans to develop carbon capture and storage (CCS) technologies and infrastructure to avoid the remaining approximate 7 million tonnes (Mt) of carbon dioxide (CO_2) from waste incineration and concrete production – a notable shift in positions compared to the IEA's last in-depth review in 2018, when CCS and NETs were not part of the proposed policy and technology mix. However, the federal government is legally limited in the development

of CO_2 transport and storage infrastructure within Switzerland because surface and subsurface territorial planning is under the competence of cantons.

Ensuring security of electricity supply in winter

While advancing its energy transition, Switzerland must also ensure security of supply, especially during the winter months. There are several challenges ahead and tackling them in a co-ordinated way will require a whole-of-government, whole-economy approach.

The greatest challenges lay in the electricity sector, which will undergo major changes with the gradual phase-out of nuclear, the accelerated electrification of the heating and transport sectors, and the need to ramp-up generation from renewable electricity to ensure the net zero emissions trajectory to 2050. Primarily, solar PV and hydro are expected to fill the gap from the phase-out of nuclear power.

The Swiss electricity system has a very high degree of flexibility thanks to its large installed capacity of pumped hydro storage. But Switzerland is dependent on imports to cover its electricity demand in winter when water reserves run low, and demand is high. With the expected changes to the energy mix in neighbouring countries, the winter import dependency might become critical, although Switzerland is importing electricity mainly at times when electricity prices are low in Europe. There is hence a need to accelerate the expansion of renewable energy and, in particular, technologies that offer more generation during winter, such as wind and hydro.

The 2022 energy crisis and the tense situation in the nuclear sector in France (a major exporter to Switzerland in winter), compelled the government to implement urgent but time-limited measures to ensure short-term security of electricity and gas supply. It advanced several policy initiatives that had been languishing in the complex Swiss legal approval system. Under the so-called “winter reserve ordinance”, Switzerland is implementing measures to address the specific Swiss electricity shortage during winter; they include the creation of and regulation for the use of a hydropower reserve of 500 gigawatt hours (GWh) and the construction of a 250 megawatt (MW) reserve power plant that can run on several fuels (gas, oil and hydrogen), with provisions for contracting pooled emergency generators and other existing gas turbines. Both would have permission to operate until the end of April 2026. By then, the ordinance would have been absorbed in the Act on the Secure Electricity Supply with Renewables that is currently in the legislative process.

In the gas sector, the government obliged the gas industry to secure additional storage capacities outside of Switzerland equivalent to 15% of annual consumption (there is no gas storage within the country) and to buy gas purchase options for about 20% of winter consumption. The energy crisis has revealed how necessary basic gas sector regulation is; the creation of an independent transmission system operator and a gas regulator should be pursued with urgency.

Facilitating permitting processes and enhancing policy co-ordination

A key obstacle to Switzerland’s energy transition is the permitting processes for energy projects which mirror complex, time-intensive governance and legal structures. Projects often face long legal proceedings, which can delay projects for decades. Although the

Energy Act of 2018 requires cantons to designate areas for renewables, the practical impact so far is limited, as the overall approval process remains complex. The same legislation designates large hydro and wind projects as being in the national interest. The government should now provide legal clarification that this designation applies to all renewable power plants and their connection to the grid, as well as the building and operation of electricity grids in general. The energy security benefits of such projects should also be reflected when weighing the legal interests in individual cases.

Under Switzerland's distinct federal structure, the cantons have extensive legal prerogatives with respect to energy and, in particular, for energy use in buildings, spatial planning and water resources. Close co-operation between the federal and the cantonal level is hence a must to advance the energy transition. Moreover, cantons have their own laws, programmes and financing schemes, which are, however, co-ordinated at the national level. As such, the model regulations of the cantons in the energy sector, developed by the Conference of Cantonal Energy Directors, have contributed to achieving some harmonisation in cantonal energy regulations for buildings. They set a best practice example. A similar approach could also be applied to further enhance harmonisation between cantons in other fields, such as permitting processes and spatial planning.

Another challenge for the energy transition is the lack of qualified labour, which is also an issue for the Swiss economy more broadly, causing delays in project development and construction. The Swiss Federal Office for Energy (SFOE), jointly with concerned stakeholders, launched a "training offensive" in late 2021 specifically targeting professions related to the building sector. This is a commendable initiative, and the government should closely monitor its implementation and reinforcement if it fails to deliver the expected results.

Relationship with the European Union

Switzerland is not part of the European Union (EU) but its energy, and in particular its electricity, market is closely intertwined with that of its neighbouring EU countries. However, since the IEA's last in-depth review in 2018, negotiations on an electricity agreement between Switzerland and the European Union have suffered a major setback, as they were suspended in 2018. Switzerland is increasingly excluded from the advancing EU market integration, including certain market mechanisms which are crucial for grid security.

Market integration with the European Union would improve the efficiency and co-ordination of transmission flows; contribute to security of supply in Switzerland and in EU member countries, especially in view of the export of highly flexible Swiss hydropower; and offer benefits for Swiss consumers.

Switzerland's electricity and gas markets are not yet fully liberalised and there has never been public support for this despite the government's efforts. Moreover, skyrocketing energy prices due to the energy crisis have reduced support for further opening the market. The government has aimed to cushion the opening by ensuring that no consumer is forced into the open market and that the supplier of last resort would remain an option for each consumer. Open markets are a pre-condition for any eventual signing of an electricity agreement with the European Union.

Key recommendations

The government of Switzerland should:

- Work together with cantons to speed up permitting of energy projects of national interest.
- Encourage the cantons to harmonise and accelerate permitting processes, improve spatial planning for renewables, and remove legal barriers.
- Ensure timely preparation for the period after 2030 by starting to conceptualise the measures that need to be included in a new draft CO_2 Act for the post-2030 period.
- Introduce basic gas market regulation.
- Establish an energy efficiency first principle in the energy and climate legislation to ensure it is considered and implemented in all relevant policies and plans.
- Align its electricity market regulations with those in the European Union, including on full market opening, while preserving the system of electricity supplies of last resort, and prepare for the legal integration of Switzerland into the EU internal market.

1. General energy policy

Key data (2021)

Total energy supply (TES): 954 PJ, -9% since 2011

TES by source: oil 34.3%, nuclear 22.3%, hydro 14.0%, natural gas 13.6%, bioenergy and waste 13.1%, solar and wind 1.4%, electricity net imports 0.9%, coal 0.4%

Energy intensity per capita (TES/capita): 109.5 GJ/capita (IEA average: 166.7 GJ/capita); -18% since 2011

Energy intensity per GDP* (TES/GDP): 1.61 MJ per USD (IEA average at 3.7 MJ per USD); -23% change since 2011

Total final consumption (TFC): 759 PJ; -5% since 2011

TFC by sector: Buildings 47.4%, transport 29.3%, industry 23.3%

*GDP data are in USD 2015 prices and purchasing power parity (PPP).

Source: IEA (2022), IEA World Energy Balances.

Country overview

Switzerland is a small, landlocked country located in the centre of Western Europe. Bordered by Austria, France, Germany, Italy and Liechtenstein, the country's territory expands over 41 285 km² and is composed of 3 distinct geographical regions: the Alps (58% of the country), the Central Plateau (31%) and the Jura (11%). Switzerland has 6% of the European freshwater reserves, including the Rhone, Rhine, Ticino and Inn Rivers in the Swiss Alps. There are about 1 500 lakes, which together with other bodies of water cover 4% of the country's surface.

Switzerland's population was 8.7 million in 2021, 20% higher than in 2000. Population growth is notably higher than the average rate of IEA member countries, which experienced a population growth of 13% in the same time frame. With 218.6 people per square kilometre and 85% of the population living in urban areas, Switzerland has a relatively high population density. The capital of Switzerland is Bern, with around 135 000 residents; other major cities include Zurich, Geneva, Basel and Lausanne. Switzerland has four official languages, with German being the mother tongue for 63% of the population, French for 22%, Italian for 9% and Romansch for just under 1%. A notable amount of the population has a mother tongue other than the national languages.

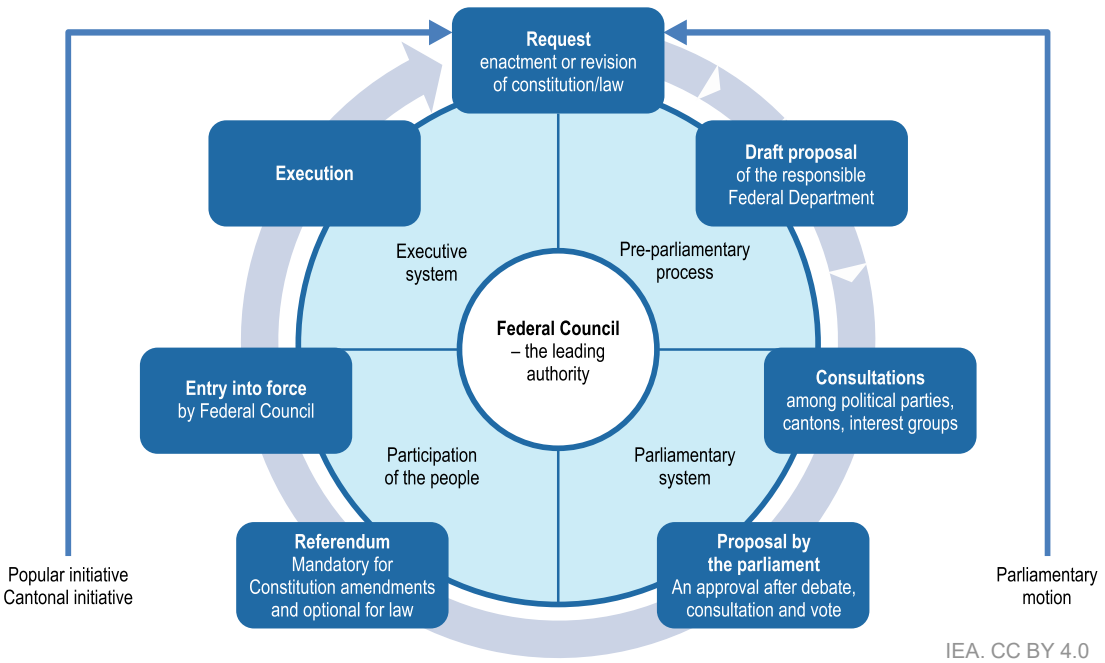
Switzerland's climate is temperate but varies across regions, ranging from glacial freeze on the mountain tops to an almost Mediterranean climate at the southern tip. Precipitation is spread evenly throughout the seasons, with little variation.

Switzerland is a federal state comprising 26 cantons, with a high degree of autonomy and each with a constitution and an assembly. Powers are devolved to the lowest possible state level, following the subsidiarity principle, and the cantons and communes implement most of the federal policies. Vertical co-operation is maintained through close consultation between the Federal Council (government) and the cantons for policy- and law-making processes. All policies not explicitly assigned to the federal level are the responsibility of the cantons.

The federal legislative power is vested in the bicameral parliament, the Federal Assembly, which is elected every four years. It consists of the National Council, representing the people, and the Council of States, representing the cantons. The executive power is held by the Federal Council, which consists of seven councillors who each serve as the head of a government department. Switzerland does not have a full-time president. Following an established order, the Federal Assembly elects one of the seven councillors every year to take up presidential duties, which are mainly representational.

Swiss people have a unique direct say on political affairs and laws under the country's direct democracy. A referendum is mandatory for any change to the Constitution and international treaties and optional for new legislation passed by parliament. A collection of 50 000 signatures within 100 days after parliament adopts a law triggers a referendum, which, if successful, invalidates the law.

Figure 1.1 Policy-making cycle in Switzerland



Source: IEA (2018), Energy Policies of IEA Countries Switzerland 2018 Review.

Two referendums are mentioned in this review: The first, on 13 June 2021, which rejected the CO_2 Act for 2021-30, which had been adopted by parliament in the second half of 2020. The second, on 18 June 2023, which aimed (unsuccessfully) to overturn the Climate

Protection Act[1] adopted by parliament in September 2022 (see Chapter 2). In Switzerland, 100 000 signatures are required to launch a popular initiative for a constitutional amendment. This review mentions one initiative, the so-called "Glaciers Initiative", launched in 2019, which called for a constitutional ban on the use of fossil fuels by 2050. The government and parliament considered this to be excessive and passed the Climate Protection Act in September 2022 as a counterproposal. The promoters of the "Glaciers Initiative" withdrew their proposal but reserved the right to table it again in case the Climate Protection Act was defeated in the June 2023 referendum (see Chapter 2 and Figure 2.5).

While the Swiss political system can result in a considerable increase in the lead time of legislation, once approved, policies prove to be stable and effective. The federal government's forward-looking policy making and effective public engagement are essential for any policy initiative.

Switzerland's energy policy is guided by Article 89 of the Constitution, which calls for a sufficient, reliable, diversified, cost-effective and environmentally sound energy supply and emphasises the importance of energy efficiency. Energy policy is a shared responsibility between the federal government and the 26 cantons. Federal energy policy making has been strengthened in recent times, chiefly by means of amendments to the 1998 Energy Act. Beyond setting targets, the federal level, for example, also provides incentives for renewables and decides on the allocation of the receipts from the CO_2 tax. In other domains, such as spatial planning and buildings, cantons have retained their prerogatives. Cantons also have their own energy laws, programmes and financing schemes, which complement federal laws and programmes.

The Department of the Environment, Transport, Energy and Communications (DETEC) is the lead ministry in charge of energy policy, in both its formulation and implementation. Combining the energy and environmental portfolios under a single ministry is intended to strengthen sustainability concerns in energy policy making. Within DETEC, the Swiss Federal Office of Energy (SFOE) is responsible for the administration of energy policy.

Economy

In 2021, Switzerland's nominal gross domestic product (GDP) per capita was USD 75 951, the fourth-highest among IEA member countries after Luxembourg, Ireland and Norway, and well above the average of the Organisation for Economic Co-operation and Development (OECD) of USD 48 957. The service sector accounted for 73.8% of Switzerland's GDP, industry 25.5% and the primary sector 0.6%. The unemployment rate in the third quarter of 2022 was 4.2%, lower than the OECD average (4.9%). The Covid-19 pandemic caused GDP to fall by 2.4% in 2020, but it rebounded in 2021 by 4.2%, higher than in 2019.

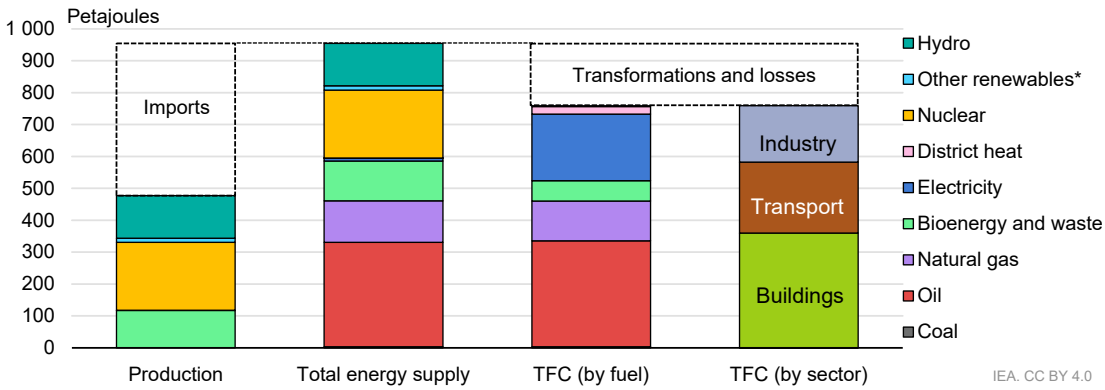
Although Switzerland is not an EU member country, it maintains close engagements with the European Union, which is the country's largest trading partner. In 2021, 61% of Switzerland's imports originated from the European Union, and 47% of its exports were to the European Union. Switzerland participates in the European Free Trade Association and the Schengen Agreement.

[1] Full name: Federal Law on Climate Protection Goals, Innovation and Strengthening Energy Security.

Energy supply and demand

Switzerland does not produce hydrocarbons. In 2021, the country's energy production consisted of nuclear power (45%), hydro (28%), bioenergy and waste (25%), and only a small share of variable renewable energies (2.8%) (Figure 1.2). Domestic production covers 50% of TES and the remainder consists of imported fossil fuels. Fossil fuels account for 48% of TES, with oil accounting for 34%, nuclear for 22%, natural gas for 14% and coal 0.4%. Oil is the largest fuel in total final consumption (TFC) followed by electricity, natural gas and bioenergy. The buildings sector dominates TFC, followed by transport and industry.

Figure 1.2 Overview of energy production, supply and demand in Switzerland, 2021



**Other renewables* include wind, solar and geothermal.

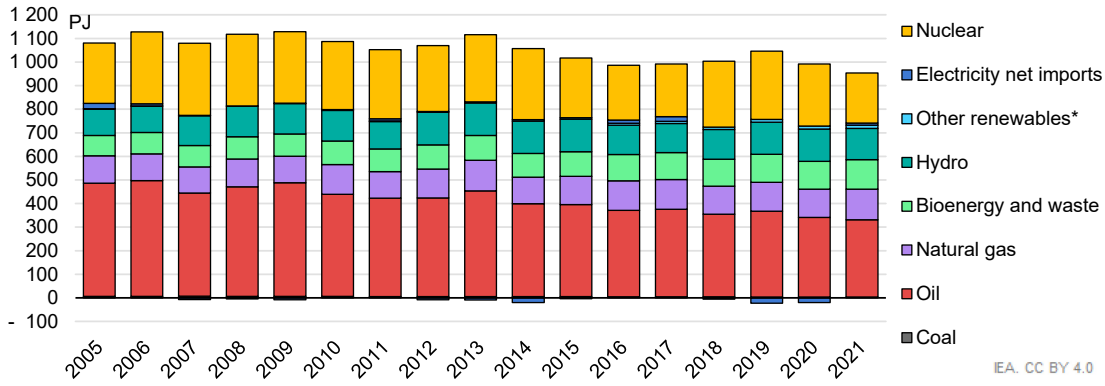
Source: IEA (2022), World Energy Balances.

Total energy supply

From 2005 to 2021, Switzerland's TES fluctuated in a downwards trend (Figure 1.3). The fluctuations were driven by changes in energy demand, mainly linked to heating, and fluctuating supply from hydro and nuclear. TES decreased in 2020 because of the pandemic, and in 2021 because of lower energy supply from nuclear (-19%), bioenergy (-4%) and hydro (-2%), partially offset by increased electricity imports. The share of fossil fuels in TES decreased from 56% in 2005 to 48% in 2021. Oil remains the single largest fuel in TES, accounting for 35%, but its share has decreased since 2005, when it was 44%. The second energy source in TES is nuclear (22% in 2021), which fluctuated depending on the availability of nuclear reactors. In 2021, hydro had the third-largest share of TES (14%), slightly higher than natural gas (14%) and bioenergy and waste (13%). Hydro shows considerable annual change, depending on the annual variation of precipitations. Solar, wind and geothermal still represent small shares of TES (1.4% in total in 2021), despite having grown fivefold since 2011.

Coal use is insignificant and is consumed only by the cement industry to produce clinker. The cement industry is partly replacing coal with other fuels, such as combustible renewables and old tyres.

Figure 1.3 Total energy supply by source in Switzerland, 2005-2021



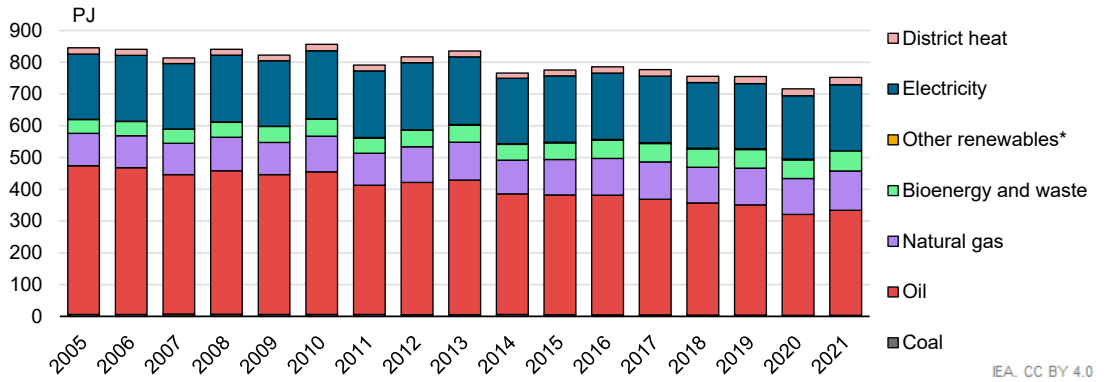
**Other renewables* include solar, wind and geothermal; it is barely visible at this scale and increased from 1.9 PJ in 2010 to 13.5 PJ in 2021.

Source: IEA (2022), World Energy Balances.

Energy demand

From 2005 to 2021, TFC decreased from 846 petajoule (PJ) to 755 PJ (-11%) (Figure 1.4). From 2019 to 2020, TFC dropped by 5.1%, mainly due to the Covid-19 pandemic, but rebounded in 2021 to a level very similar to 2019. In 2021, oil accounted for the largest share of TFC, at 44%, followed by electricity at 28%. The share of electricity is the fourth-highest among International Energy Agency (IEA) member countries, showing a high level of electrification of Switzerland's energy demand. The share of natural gas in TFC increased from 12% in 2005 to 16% in 2021.

Figure 1.4 Total final consumption by source in Switzerland, 2005-2021



**Other renewables* include solar and geothermal; it is barely visible at this scale and increased from 1.6 PJ in 2011 to 2.7 PJ in 2021.

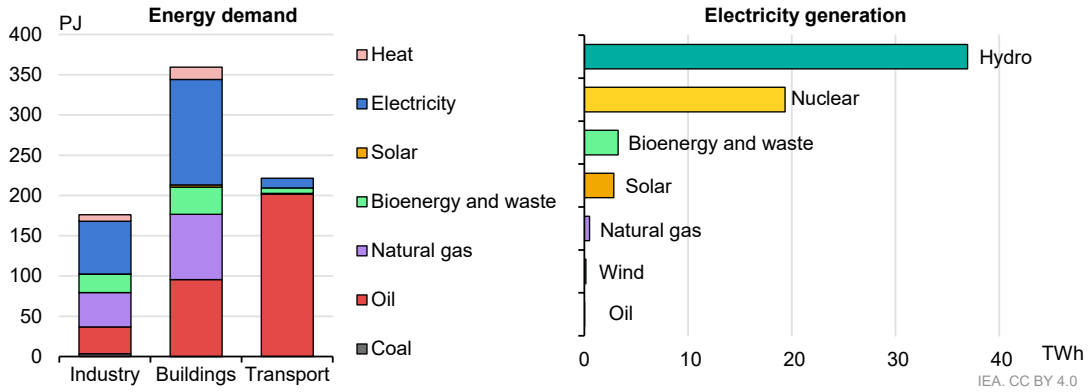
Source: IEA (2022), World Energy Balances.

The buildings sector accounted for 47% of TFC in 2021, followed by transport (29%) then industry (23%) (Figure 1.5). Electricity is the first source of energy in both buildings (37% of the sector's demand) and industry (36%). The share of electricity in industry is much higher than the IEA average (23%). All other energy demand in industry is covered by natural gas (24%), oil (19%), bioenergy (13%), district heat (4.4%) and coal (2%). After electricity, energy demand in buildings is covered by oil (27%, the fifth-highest share among IEA member countries), natural gas (23%), bioenergy (9%) and district heat (4%).

As for most IEA member countries, Switzerland's transport sector largely relies on oil (91% in 2021). Electricity, mainly used in rail, represents the second source of energy in transport (5%), followed by biofuels (3.5%) and natural gas (0.5%).

In 2021, Switzerland's main source of electricity generation was hydro, which covered 59% of total generation, followed by nuclear (31%). Smaller shares come from bioenergy and waste (5.2%), solar (4.5%), and natural gas (0.8%), as well as 0.2% from wind and 0.1% from oil.

Figure 1.5 Energy demand per sector and per fuel and electricity generation by fuel in Switzerland, 2021



Note: TWh = terawatt hour.

Source: IEA (2022), World Energy Balances.

Key policies

Energy Strategy 2050

The Energy Strategy 2050 (ES2050) is a strategic policy package to advance Switzerland's energy transition towards a low-carbon economy. It consists of a comprehensive set of new and revised laws and ordinances as well as policy measures that are implemented in phases. At its centre is the complete revision of the Energy Act of 1998 that entered into force on 1 January 2018 jointly with related new and revised laws and ordinances.

The ES2050 has four pillars: 1) phase out nuclear energy; 2) reduce energy consumption and emissions per capita; 3) promote renewable energy sources and energy efficiency; and 4) improved energy security. The ES2050 contains a number of indicative targets for energy efficiency and the expansion of renewables for 2020, 2035 and 2050 (see Tables 2.1 and 2.2). It also addresses the impacts of Switzerland's decision for a progressive withdrawal from nuclear energy production in the electricity sector. The first nuclear plant (Mühleberg) shut down in 2019 for commercial reasons upon the decision of its operator.

Implementation of the ES2050 is monitored through annual reports. The reports have been prepared annually since 2018. In addition, a five-yearly report was prepared for the first time in 2022, with an assessment of energy policies, existing and planned measures towards reaching the objectives of the ES2050, and conclusions and recommendations on how to move forward.

The key findings of the five-year report note that the policy measures in place are insufficient to reach the energy efficiency and renewable deployment targets for 2030 and beyond. The report also noted the problems caused by lengthy approval and judicial processes for any kind of investments in the energy sector. The government is already addressing these concerns through, among other measures, the new Act on the Secure Electricity Supply with Renewables (see below). Continuous monitoring based on relevant data and statistics to allow for early corrective actions, if needed, will be crucial to stay on track towards achieving the energy and climate targets.

Switzerland has an excellent overall data collection system to monitor its policies and continuously strives for further improvement. For sectoral demand data, the SFOE carries out an annual national survey on energy consumption in industry and services, covering 19 sub-sectors through a stratified sample. For all other sectors, data are based on information from energy suppliers, such as electricity utilities.

Energy end-use and efficiency data are produced as model analyses, with four sectoral bottom-up models (households, services, industry and transport). This work is carried out on an annual basis by external partners under the authority of the SFOE. Although input data for the model analyses are limited, there are no plans to develop any surveys to get more detailed sectoral and end-use information. The resources allocated for energy statistics are sufficient to address current data requirements, though they may be limited to ensure significant expansion of future data needs for the energy transition.

However, the energy crisis revealed severe gaps in closer-to-real-time data. Electricity and gas demand (or savings) data during the past winter were difficult to obtain for various reasons, such as fragmented, decentralised and reluctant sectors and industries and the lack of a legal basis to compel energy users to disclose data. The SFOE had to use various tools and specifically advanced data science modelling to compile plausible figures for its dashboard. The SFOE is currently preparing legislation to lay the base to enable it to access data.

Long-Term Climate Strategy to 2050 and carbon pricing

In 2019, Switzerland committed to net zero emissions by 2050. In 2021, the government adopted the country's Long-term Climate Strategy to 2050 in line with the Paris Agreement. The strategy sets out emissions pathways for various sectors of the Swiss economy, including buildings, industry, transport, synthetic gases, aviation, and the waste industry, to reach the net zero target by 2050. Those pathways are based on the Energy Perspectives 2050+ (EP2050+), a set of scenarios developed in 2020 (see next section).

Under the Paris Agreement, in December 2020 Switzerland committed to cut GHG emissions by at least 50% by 2030 compared to 1990 levels. Emissions reductions in Switzerland are supported by the CO_2 Act that first entered into force in 2000. Since 2008, Switzerland has levied a carbon price, the CO_2 levy, on stationary uses of fossil fuels. Motor fuels are not subject to a CO_2 levy. In total, about one-third of Switzerland's GHG emissions are covered by the CO_2 levy and another 10% are covered by the Emissions Trading System (see Chapter 2).

The carbon content determines the amount of the CO_2 levy for each energy source. The levy started at CHF 12[2] per tonne of CO_2 (t CO_2) in 2008 and was automatically increased if intermediate emissions targets were not achieved. This happened until the current level of 120 CHF/t CO_2 was reached at the beginning of 2022. The current and proposed legislation does not provide for any further increases. In December 2017, the government proposed a new CO_2 Act with additional instruments for the period to 2030 to ensure Switzerland can meet its Paris Agreement commitment. After having been adopted by parliament in autumn 2020, the law was rejected in a referendum in June 2021. As some of the instruments in the existing law were due to expire, parliament extended the CO_2 Act until the end of 2024 in the hope of passing a revised law before then (see Chapter 2).

In September 2022, the government submitted a revised proposed CO_2 Act to parliament that no longer includes the proposal to increase the CO_2 levy to 240 CHF/t CO_2 if intermediate emissions targets are not met, as was proposed in the rejected CO_2 Act. A study undertaken in 2018 found that the CO_2 levy has a higher emissions reduction impact than that of other measures.

A special feature of the Swiss CO_2 levy is the distribution of its revenues. Currently about two-thirds are redistributed to the population and economy; the remaining third is used to support energy efficiency upgrades and the installation of renewable heating systems in buildings; a small amount is allocated to a Technology Fund. Swiss residents benefit on a per capita basis through a refund on their mandatory health insurance. The redistribution to the economy is provided to all employers as a subsidy on their share of pension fund contributions.

There is an ongoing discussion in Switzerland if and how to address the country's embedded emissions into its climate policy. Switzerland imports a large part of the goods it consumes, as the economy is dominated by the service sector and has a relatively low share of energy-intensive industry. McKinsey estimated that embedded emissions in imported goods are estimated to account for 1.5 times of domestic emissions. The OECD and the World Bank undertake similar calculations at a global level, albeit using different methodologies; however, they also point towards substantially greater total emissions for Switzerland if imports are taken into consideration.

Energy Perspectives 2050+

The SFOE commissioned a comprehensive study, the EP2050+, to set out different pathways to reach a net zero GHG emissions by 2050 while also ensuring security of supply (no net electricity imports on a yearly basis by 2050). The study examined a base scenario (Zero Base) and three variants (ZERO A, ZERO B and ZERO C). The scenarios differ in the assumed technology mix while the business-as-usual scenario shows how the Swiss energy mix and emissions profile would look in 2050 with the continuation of existing policies and measures.

Scenario Zero Base is based on a mix of technologies that has high social acceptance and provides high cost efficiency today. In comparison, Zero A has a higher degree of electrification. Zero B assumes a higher availability of synthetic gases. Zero C gives more importance to electricity-based liquid energy sources and heating networks. In addition, several scenarios were modelled specifically for the electricity sector to account for

[2] CHF: Swiss franc. CHF 1 = EUR 1.04 = USD 1.15 (1 August 2023).

different pathways in the expansion of renewables while maintaining an annual electricity import-export balance in 2050.

To allow Switzerland to reach net zero in 2050 with existing technologies and address residual emissions through NETs, the EP2050+ noted the need to, among others:

(i) Fully explore the potential of energy efficiency and domestic renewables.
(ii) Use electricity as the main energy carrier for building heat and mobility.
(iii) Only use electricity-based agents[3] in areas where there are no, or limited alternatives, given their current high costs. Those areas include aviation and heavy goods traffic.
(iv) Exclude scenarios Zero B and C that imply higher energy imports and hence increasing import dependency, which counteracts the expected reduction of import dependency through lower consumption of imported fossil fuels.

Regarding the reduction of fossil fuels consumption, the EP2050+ includes a target to replace natural gas almost entirely with biogas in 2050 with overall gas consumption at half the level of 2020 (66 PJ). Mostly, imported electricity-based fuels such as green hydrogen will replace fossil fuels in the heavy transport sector. To accelerate the shift towards electrification of the transport sector, the government has been implementing an e-mobility roadmap since 2018, which was revised in 2022 to reflect more ambitious goals by 2025 (see Chapter 3).

The EP2050+ analysis found that, compared to the business-as-usual case, the Zero Base scenario would result in additional net costs of CHF 73 billion; this is lower than for the other three scenarios and needs to be compared with annual end consumer expenditures for energy of more than CHF 20 billion. The government already has several support schemes in place, for example for the accelerated deployment of renewable electricity sources and replacing fossil with renewable and non-direct electricity heating systems. It does not believe that shortage of funding will constrain the energy transition. Instead, the critical barriers identified are high labour costs and a shortage of skilled labour; lack of social acceptance of some of the proposed measures, such as wind power; complex administrative and legal planning and permitting processes that can delay projects considerably, sometimes for decades.

The government is taking steps to address the non-financial barriers. In early 2022, the SFOE, after two years of preparation with stakeholders, launched a roadmap "training offensive for buildings". The roadmap includes 32 measures to increase the skilled workforce for building refurbishment, rooftop photovoltaics (PV), heat pumps, etc. The training offensive consists of a network of industry associations from the building sector, educational institutions and institutional partners such as federal agencies. It also includes the Conference of Cantonal Energy Services that is aligned with the Conference of Cantonal Energy Directors (EnDK), as responsibility for buildings lays with the cantons under the Swiss Constitution.

The EnDK focuses on the use of energy in buildings and has developed the "model regulations of the cantons in the energy sector" (MuKEn). With the MuKEn, the cantons aim to achieve a high degree of harmonisation in cantonal energy regulations for buildings, to simplify construction planning and the certification for professionals who work in several

[3] Electricity-based agents include synthetic fuels in liquid or gaseous form as well as hydrogen.

cantons. The MuKEn are not a law, but recommendations for the cantonal legislation and regularly updated (see Chapter 3).

The government is also operating a single-window clearance for project permits at the federal level. The Energy Act of 2018 declares large hydro and wind projects to be of national interest, but still excludes smaller generation projects and the necessary grid infrastructure. Moreover, it does not address the additional permits necessary from the cantonal and municipal authorities. While since 2018, cantons must designate go-to areas for renewables, data do not show a significant increase in the number of new projects going ahead, as the overall permitting procedure remains complex. With the new Act on the Secure Electricity Supply with Renewables presently in parliamentary debate (see below), this issue is addressed carefully, also in view of the urgency due to the 2022 European energy crisis.

Therefore, at the beginning of 2022, the government proposed additional legal measures to accelerate the planning and licensing procedures for hydropower plants considered of high system relevance, and for wind power and solar PV. The objective is to create a single planning approval process at the cantonal level that combines all required legal approvals into one process instead of going through different stages with each of those stages being open to a court challenge before the federal supreme court. The government is currently preparing this so-called acceleration bill and the parliament has already taken up some elements (see above). While the approval of the energy amendment package is pending (see below), temporary legal adjustments were proposed in parliament to accelerate the construction of wind and solar power plants.

The Act on a Secure Electricity Supply from Renewables

The indicative targets in the ES2050 are no longer adequate to meet Switzerland's strengthened energy and climate commitments for 2030 and 2050. The government therefore prepared the Federal Act on a Secure Electricity Supply from Renewable Energy Sources. This act is a combination of amendments to the Energy Act and the Electricity Supply Act; hence called the energy amendment package and is based on the Zero Base scenario of the ES2050+.

The main purpose of the energy amendment package is to strengthen the security of electricity supply and reach the net zero target for 2050 through a rapid expansion of renewable electricity generation and to strengthen longer term security of supply, including through an adequate grid infrastructure. To achieve this, the amendment includes provisions for the creation of a strategic energy reserve. It also introduces a legal basis to allow end consumers and storage operators to use their flexibility in a way that is beneficial to the electricity system.

The revision of the Energy Act (Pa. Iv. Girod) provides long-term planning certainty for investors by postponing the end of support measures for renewable electricity from 2030 to 2035; and by introducing new support measures for technologies that as of 2023 are no longer supported through feed-in remunerations. It entered into force in 2023. The ongoing energy amendment package will further replace the indicative targets for renewables and energy consumption with binding targets and further strengthen the roll-out of renewable electricity production (Tables 1.1 and 1.2).

Table 1.1 Energy efficiency targets in the ES2050, EP2050+ and parliament decision

Change with respect to 2000	ES2050		ES2050+		Parliament decision	
	2035	2050	2035	2050	2035	2050
Per capita energy consumption	-43%	-54%	-41%	-53%	-43%	-53%
Per capita electricity consumption	-13%	-18%	-12%	-5%	-13%	-5%

Source: Country submission and information provided by Switzerland.

Table 1.2 Renewables targets in the ES2050, EP2050+ and parliament decision

Yearly electricity production in terawatt hours (TWh)	ES2050		ES2050+		Parliament decision	
	2035	2050	2035	2050	2035	2050
Renewables excluding large hydro	11.4	24.2	17.3	39.1	35	45
Hydro	37.4	38.6	37.4	38.6	37.4	38.6

Source: Country submission and information provided by Switzerland.

The revised Energy Act and Electricity Supply Act include binding parameters for security of supply and climate and will enhance planning security for investors. This has become necessary in light of the shift towards the electrification of the energy sector. Switzerland is principally a net electricity exporter but with strong intra-annual variations. It relies on electricity imports in the winter season when hydro reserves run low. With a shift to more electricity-based heating systems and the phase-out of nuclear electricity, the need for imports would increase and potentially undermine Switzerland's long-term security of supply. The EP2050+ sees a 38% increase of electricity demand due to e-mobility, heat pumps and electrolyses in 2050. Ensuring security of electricity supply in the winter is hence of urgency for policy makers.

The revised Electricity Supply Act therefore includes provisions for an increase in hydro storage capacity to strengthen Switzerland's self-sufficiency in winter. The aim is to add 2 TWh of supply in winter by 2040. The revised Electricity Supply Act also includes a set of provisions to facilitate the integration of variable renewable sources into the electricity market by enabling local electricity communities, enhanced data management and the establishment of a data hub. The energy amendment package is not expected to enter into force before 2025, as it is potentially subject to a referendum. In addition, the Climate Protection Act anchors the net zero target at the legislative level and defines a reduction path from 2030 to 2050 with sectoral emissions reduction targets for the buildings, transport, and industry sectors (see Chapter 2).

The European Union's clean energy package includes a provision that at least 70% of cross-border electricity grid capacities must be kept free for trading within the European Union from 2025 onwards but has not specified how such capacities in non-EU countries would be taken into account. Potentially, Switzerland's import capacity could be strongly curtailed as a result, and the consequent loop flows resulting from intra-EU electricity trading could further increase and undermine Switzerland's, and ultimately also other EU countries', grid stability.

At the same time, electricity exports from Switzerland, mainly from hydro pump and storage plants, are important to maintain security of supply in neighbouring countries. Excluding Switzerland from the European electricity trading could potentially also have

negative consequences for European countries, either by resulting in temporary outages and/or requiring additional investments in generation capacity and electricity systems' expansion projects.

Switzerland had aimed to sign a bilateral electricity agreement with the European Union, but negotiations were suspended in 2018 and no progress has been made since, while electricity trade has continued. Beyond the political dimension of the bilateral electricity agreement, as a key condition for concluding the electricity agreement, the European Union demanded the full opening of the Swiss electricity market.

The Swiss government had proposed the full market opening for all end consumers in 2017 and reiterated this position in 2021. However, strong political forces threatened to launch a referendum against legislation calling for full market opening. Consequently, the upper chamber of parliament voted to remove full opening from the draft energy amendment package even though the government made it clear that even if the electricity market was fully opened, no consumer would be forced to leave the current system of regulated prices but could stay with the supplier of last resort, as is the case in several EU member countries such as Germany.

Measures to ensure short-term energy security during the winters of 2022/23 and 2023/24

With the single amending act, Switzerland aims to ensure the long-term energy security of supply. However, like most other European countries, Switzerland is also concerned with addressing short-term security of electricity and gas supply, especially for the winter seasons 2022/23 and 2023/24.

In the gas sector, Switzerland aligned with the EU goal of saving 15% of gas consumption between October 2022 and March 2023 and launched a public campaign to alert the population about the situation, despite the absence of a gas supply act or a gas regulator. Moreover, the government implemented several measures to strengthen gas supply for the winter of 2022/23; these could also help address any possible security of supply concerns in the winter of 2023/24 (see Chapter 7).

Among those measures are an obligation for the gas industry to secure additional storage capacities outside of Switzerland equivalent to 15% of annual consumption and to explore options for additional supplies of non-Russian gas by buying gas purchase options for about 20% of winter consumption. The government has also strived for so-called solidarity agreements with some neighbouring countries, notably Germany and Italy.

As of 1 October 2022, and until end of March 2023, all dual-fuel installations that can run on oil and gas have been encouraged to shift to oil, potentially increasing Switzerland's heating oil demand by 30 PJ in the winter of 2022/23. The government released domestic oil stocks and granted temporary exemptions from certain air pollution and emission laws to prevent penalties on operators of dual-fuel installations. If the voluntary fuel switching and public savings campaign did not generate sufficient gas savings, the government planned to implement gas consumption quotas. The government noted that the delivery of the additional heating oil could have caused logistical challenges due to a lack of trucks and truck drivers. One possible solution considered was temporary permission for trucks to operate on Sundays. Temporarily, installations switching to oil are exempted from strict emissions and local air pollution norms to avoid having to pay fines.

The 2022 gas situation has underlined the need for a gas act in Switzerland that would assign clear responsibilities to the various actors at government and industry level and establish clear regulatory accountability for ensuring gas supply security under the supervision of a gas regulator. A draft Gas Supply Act has been debated for several years and the government is expected to present it in the first three months of 2024. The act should consider the lessons learnt from the gas supply situation in the winter of 2022/23 and propose elements of basic market regulation, such as a regulator and an independent transmission system operator.

Switzerland is also implementing measures to address the specific Swiss electricity shortage during winter which became even more urgent in 2022 due to the tense situation in the nuclear sector in France, the main exporter of electricity to Switzerland in the winter. The key measures are subsumed in the so-called winter reserve ordinance and aim to provide additional generation of 1 000 megawatts (MW). It includes the creation of and regulation for the use of a hydropower reserve of 500 gigawatt hours (GWh) and the construction of a 250 MW reserve power plant that can run on several fuels (gas, oil and hydrogen) and provisions for pooling emergency power units based on tenders. The reserve power plant would have permission to operate until the end of April 2026.

An innovative feature in the winter reserve ordinance is the creation of emergency power groups and pooling of co-generation installations. The reserve plants and emergency power groups would not produce for the market, only when called upon during times of expected shortages.

Beyond these, the government also gave temporary permission from 1 October 2022 until the end of April 2023 for two additional measures. One was to allow certain hydropower plants that met lowered ecological requirements to use more water for electricity production than usually permitted; this would provide an additional 150 GWh of electricity. The second was to increase the capacities of two transmission lines to alleviate transmission bottlenecks and increase import capacities by up to 850 MW.

Hydrogen

The Swiss government is preparing a (green) hydrogen roadmap that will be presented in 2023. The roadmap will flag those sectors for which the use of renewable-based hydrogen is most suitable and highlight the required regulatory framework to allow the development of a domestic hydrogen economy. Another of the roadmap's important analyses is the assessment of if and at what cost the conversion of green hydrogen into electricity can contribute to ensuring Switzerland's security of supply in the winter period and the necessary extent of storage potential.

The roadmap will also look at the overall grid infrastructure development needs and assess if the existing gas distribution network can be absorbed into the future hydrogen network, and at what costs. Finally, the roadmap will evaluate possible production sites for future hydrogen and power-to-X, sites for extraction of CO_2 and CO_2 transport possibilities.

Switzerland has not set any specific targets for the hydrogen economy, pending the completion of the roadmap. However, the EP2050+ anticipates a "power-to-x" demand of around 56 PJ by 2050 and a hydrogen production goal of around 7 PJ in 2050. The long-term aim is to use and produce green hydrogen by means of electrolysers.

Assessment

Switzerland must simultaneously advance its energy transition and ensure security of supply in the context of an ongoing global energy crisis, especially during the winter months. There are several challenges ahead and tackling them in a co-ordinated way will require a whole-of-government, whole-economy approach.

In the immediate term, Switzerland, like many other countries, has been concerned with addressing security of supply due to the global energy crises. Domestic production of nuclear, hydro and renewable energy covered 50% of Switzerland's TES in 2021. However, the situation is very different for fossil fuels: oil is the single largest fuel in Switzerland's TES (34% in 2021) and the country is completely reliant on imports to meet all its fossil fuel needs. The government has implemented several short-term measures to help ensure security of supply, especially through the winter season. The quick measures seem to be appropriate to address the challenges of the winter of 2022/23 and the next, if needed.

Binding and long-term energy and climate targets are necessary for forward-looking planning by all stakeholders. The government prepared a new Act on the Secure Electricity Supply with Renewables, which is a combination of amendments to the Electricity Supply and the Energy Act (the so-called energy amendment package) to replace the indicative targets of the ES2050 with binding targets to 2050, further strengthen the roll-out of renewable electricity production and ensure long-term energy security. The energy amendment package is currently being debated in parliament and is not expected to enter into force before 2025.

The government has recognised the urgency and enacted some measures contained in the energy amendment package by way of ordinance. These include a hydropower reserve and gas turbines to enhance security of supply especially in the winter, when Switzerland relies on electricity imports. A timely entry into force of the full single amending act is crucial. As well as setting targets, it is key to implement measures to reach the energy and climate targets.

Switzerland has a balanced electricity trade on an annual basis, with substantial electricity imports in the winter season when hydro reserves run low and exports in the summer. The phase-out of nuclear electricity and a shift towards electrification of the energy system due to the roll-out of heat pumps and electric mobility will further increase winter import dependency and underlines the need for the expansion of renewable energies for the country's longer term security of supply. In particular, technologies with winter generation capacity, such as wind, would help. However, wind energy currently does not account for a significant share of the expected capacity additions to 2030.

Switzerland has a unique system of direct democracy and a distinct federal structure in which the cantons have extensive legal prerogatives with respect to energy (especially energy in buildings, spatial planning and water resources). An advantage of this system is that the people are more closely involved in decisions. On the other hand, this can result in delayed decision making. Furthermore, the regulations may differ from canton to canton.

A key obstacle to Switzerland's energy transition is the permitting processes for energy projects (generation and grid), which reflect complex, time-intensive governance and legal structures. Projects are often subject to long legal proceedings all the way up to the

Federal Court, which can delay them by decades. Although the Energy Act of 2018 requires cantons to designate areas for renewables, the practical impact so far is limited, as the overall approval process remains complex. The same legislation designates large hydro and wind projects as being in the national interest, and the government should now provide legal clarification that this designation applies to all renewable power plants and their connection to the grid, as well as the building and operation of electricity grids in general. The energy security benefits of such projects should also be reflected when weighing the legal interests in individual cases.

The MuKEn aim to achieve a high degree of harmonisation in cantonal energy regulations for buildings and construction planning. The MuKEn are not a law, but recommendations for the cantonal legislation and are largely followed in all cantons. The process applied to develop the MuKEn could serve as a blueprint to enhance harmonisation between cantons in fields beyond buildings, such as permitting processes or spatial planning.

Another challenge for the energy transition is the lack of qualified labour, which is also an issue for the Swiss economy more broadly. The lack of qualified labour causes delays in energy project development and construction. The SFOE, jointly with concerned stakeholders, launched a “training offensive” in late 2021 specifically targeting professions related to the building sector. This is a commendable initiative, and the government should closely monitor its implementation and reinforcement if it fails to deliver the expected results.

Fully liberalised electricity and gas markets would strengthen consumer rights, create competition, enable the supply of electricity flexibility to the market, realise the full potential of digitalisation and further align the Swiss energy markets with neighbouring countries for mutual benefits. In addition, the global energy crisis has revealed how necessary basic gas regulation is, and the creation of an independent gas transmission system operator and a gas regulator should be pursued with urgency.

The lack of an electricity agreement with the European Union leads to difficulties for Switzerland and its market players. Market integration with the European Union would improve the efficiency and co-ordination of transmission flows, with benefits for Swiss consumers (via lower redispatch costs and security of electricity supply in winter) and contribute to security of supply in EU member countries (especially with exports of highly flexible Swiss hydropower).

Recommendations

The government of Switzerland should:

- ☐ Work together with cantons to speed up permitting of energy projects of national interest.
- ☐ Encourage the cantons to harmonise and accelerate permitting processes, improve spatial planning for renewables, and remove legal barriers.
- ☐ Focus on the implementation of effective measures to reach energy and climate targets.
- ☐ Fully open the electricity market while preserving the system of electricity supplies of last resort to legally integrate Switzerland into the EU internal market.
- ☐ Introduce basic gas market regulation.
- ☐ Closely monitor measures to address the shortage of qualified labour in the energy sector and reinforce them if necessary.
- ☐ Consider cost-effective options to improve the granularity of sectoral and end-use data that are used as a basis for modelling, given the importance of tracking energy demand for energy transitions.

2. Energy and climate change

Key data (2021)

GHG emissions with LULUCF:* 43.3 Mt CO_2-eq; -19% since 2005, -19% since 1990

GHG emissions without LULUCF:* 45.1 Mt CO_2-eq; -20% since 2005, -18% since 1990

Energy-related GHG emissions from fuel combustion: 35.7 Mt CO_2-eq; -20% since 2005, -14% since 1990

Energy-related GHG emissions by sector: transport 42%, buildings 34%, industry 16%, electricity and heat generation 7.8%

Energy-related GHG emissions per GDP: 0.06 kg CO_2-eq/USD (IEA average in 2020: 0.19 kgCO_2-eq /USD)

Energy-related GHG emissions per capita: 4.10 t CO_2-eq/capita (IEA average in 2020: 7.97 tCO_2-eq /capita)

*Source: Switzerland, Federal Office for the Environment, (2023).

Overview

In August 2019, Switzerland announced its target to achieve net zero GHG emissions by 2050. In January 2021, the government further elaborated on the strategy to reach this goal within its Long-Term Climate Strategy submitted to the United Nations Framework Convention on Climate Change (UNFCCC). According to this strategy, in 2050 Switzerland would still emit around 12 million tonnes of carbon dioxide equivalent (Mt CO_2-eq) per year from hard-to-abate sources. The government estimates that around 5 Mt CO_2-eq of these residual emissions can be avoided through CCS. The remainder must be balanced via NETs in Switzerland (2 Mt CO_2-eq) and abroad (around 5 Mt CO_2-eq).

In the shorter term, Switzerland has set an economy-wide target to reduce its GHG emissions by *at least* 50% by 2030 compared to 1990 levels through its updated first Nationally Determined Contribution (NDC). Additionally, emissions in the period 2021-30 must be reduced by at least 35% at a continuous rate.

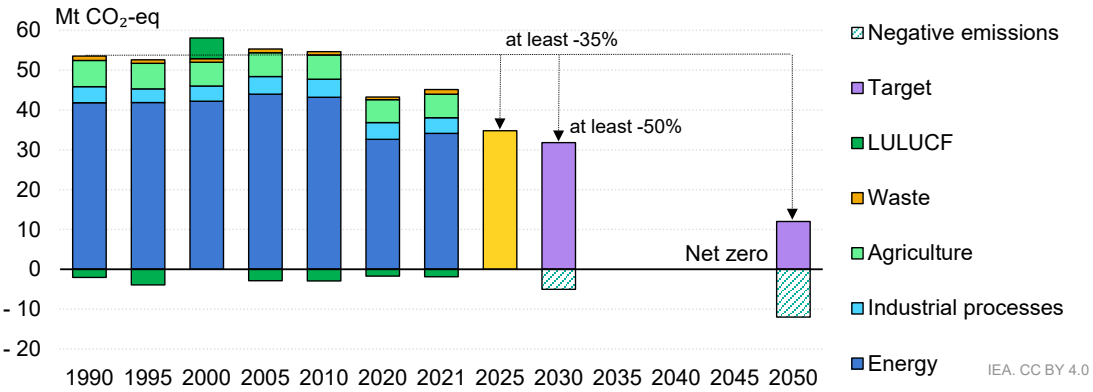
GHG emissions in the base year (1990) were 54.9 Mt CO_2-eq, excluding land use, land-use change and forestry (LULUCF). In 2021, Switzerland's total GHG emissions stood at 45.1 Mt CO_2-eq, an 18% decline since 1990 (Figure 2.1). In 2020, the net effect of the LULUCF sector in Switzerland was a 1.9 Mt CO_2-eq reduction.

Over the period 2013-20, the CO_2 Act – the main climate policy instrument – mandated Switzerland to reduce GHG emissions by 20% by 2020 compared to 1990 levels,

exclusively with domestic measures. Switzerland narrowly missed this target, as it reduced GHG emissions by 19%. During the same time frame, Switzerland fulfilled its international commitment under the Kyoto Protocol thanks to the purchase of emissions reductions abroad.

In 2021, energy sector emissions were 34 Mt CO_2-eq and accounted for 76% of total GHG emissions. Emissions from agriculture were 5.9 Mt CO_2-eq, or 13% of total GHG emissions. Industrial processes accounted for 8.7% of total emissions, followed by waste with 2.5%.

Figure 2.1 Total greenhouse gas emissions by sector in Switzerland, 1990-2021, and 2030 and 2050 targets



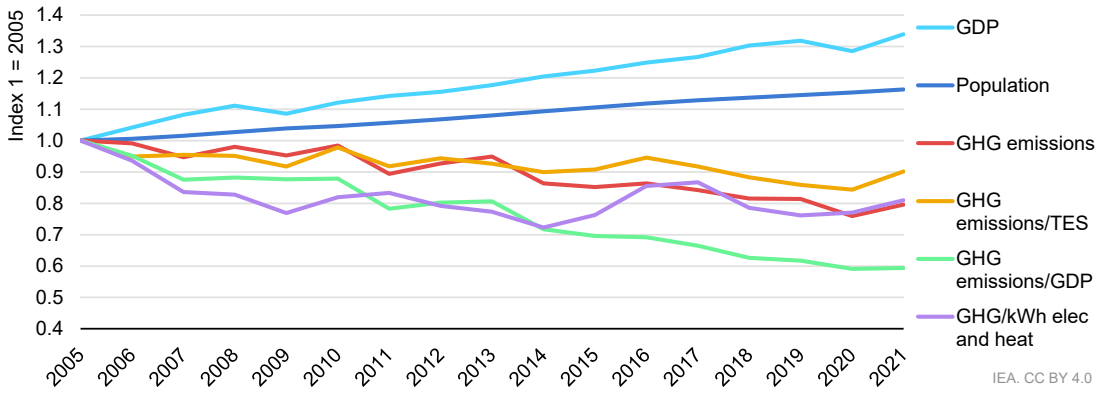
Notes: ITMOs = internationally transferred mitigation outcomes. The level of ITMOs used in 2030 is only illustrative.
Source: IEA based on data from UNFCCC (2022) and Switzerland, Federal Council, (2021).

Energy-related GHG emissions drivers and GHG intensity

Switzerland shows a notable decoupling between domestic energy-related GHG emissions and economic and population growth. Between 2005 and 2021, Switzerland's GDP increased by 34% while energy-related GHG emissions decreased by 20%. This level of decoupling is even starker than the decoupling between economic and population growth and energy consumption (see Chapter 3). Switzerland's economy is dominated by the service sector, accounting for 74% of its GDP. The domestic industry, wherein the energy-intensive process industries only play a small role, constitutes 26% of GDP. Including embedded emissions, Switzerland's total GHG emissions are estimated to be 1.5 times higher according to World Bank estimates (see Chapter 1). However, there is no globally accepted methodology on how to account for embedded emissions in a country's overall emissions.

Switzerland's strong decoupling is also evident from other indicators. From 2005 to 2021, the energy-related GHG emissions intensity of Switzerland's GDP (GHG/GDP) decreased by 41%; GHG emissions over TES decreased by 10% and GHG emissions per electricity production fell by 41% (Figure 2.2).

Figure 2.2 Energy-related greenhouse gas emissions and main drivers in Switzerland, 2005-2021



Note: kWh = kilowatt hour.

Source: IEA (2022), Greenhouse Gas Emissions from Energy (database).

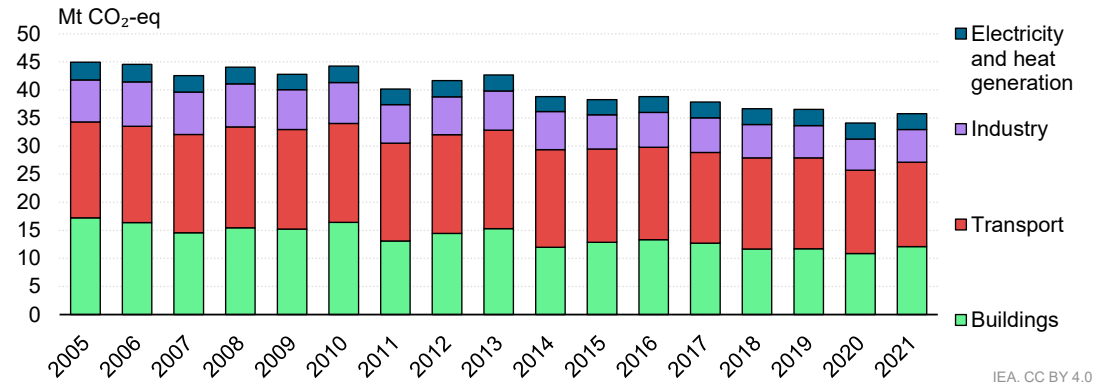
In 2021, energy-related GHG emissions per unit of GDP in Switzerland were 0.06 kilogrammes of CO_2-eq per USD (kg CO_2-eq/USD), which is the lowest among IEA member countries, well below the IEA average of 0.19 kg CO_2-eq/USD.

Energy-related GHG emissions

The transport sector is the largest energy-related GHG emitting sector. It accounted for 42% of the total energy-related GHG emissions in 2021. The other emitting sectors are buildings (34%), industry (16%), and electricity and heat generation (7.8%) (Figure 2.3). After peaking in 2005, energy-related GHG emissions have decreased unevenly depending on the year, with an overall decrease of 20% from 2005 to 2021. From 2011 to 2021, energy-related GHG emissions fell by 15% for industry, 14% for transport, 8% for buildings, and 1% for electricity and heat generation.

The Covid-19 pandemic had also a noticeable effect on emissions. In 2019, energy-related emissions were 36.5 Mt CO_2-eq. In 2020, energy-related GHG emissions decreased by 7% year-on-year to 34.1 Mt CO_2-eq, mainly driven by lower emissions in transport due to the Covid-19 pandemic. As the pandemic restrictions were relaxed in 2021, energy-related GHG emissions rebounded by 5% year-on-year to 35.7 Mt CO_2-eq, but were still lower than the pre-pandemic level.

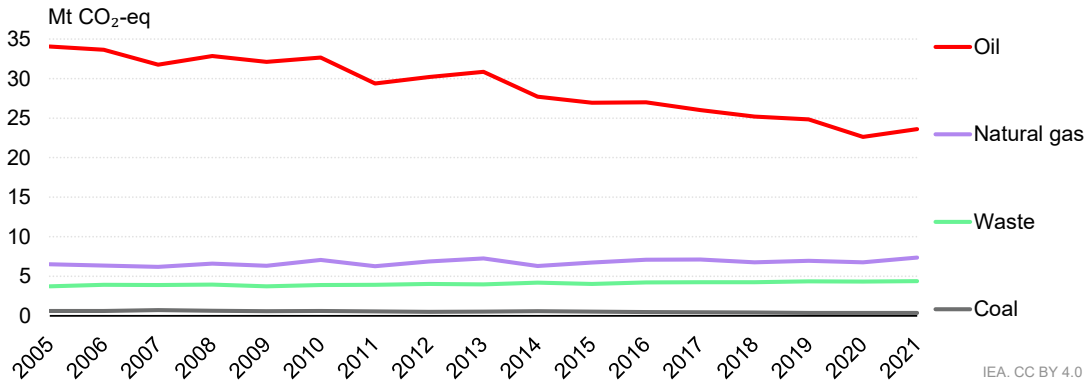
Figure 2.3 Energy-related GHG emissions by sector in Switzerland, 2005-2021



Source: IEA(202), Greenhouse Gas Emissions from Energy (database).

Oil accounts for the largest part of energy-related GHG emissions, reaching two-thirds of the total in 2021, followed by natural gas at 21%, waste at 12% and coal at 1% (Figure 2.4). From 2005 to 2021, energy-related GHG emissions from oil decreased by 31% while natural gas emissions increased by 13%.

Figure 2.4 Energy-related GHG emissions by energy source in Switzerland, 2005-2021



Source: IEA(2022), Greenhouse Gas Emissions from Energy (database).

Climate targets

For the period 2013-20, Switzerland had one national emissions reduction target and one international target. The national target, defined in the 2013-2020 CO_2 Act, provided that Switzerland had to reduce its GHG emissions by 20% by 2020 compared to 1990 levels. This target was narrowly missed, despite lower-than-usual emissions from the buildings sector in 2020 because of a mild winter and the Covid-19 pandemic. Switzerland had 43.1 Mt CO_2-eq of net emissions in 2020, which was 0.1 Mt CO_2-eq above the set target. However, while the industry sector met its domestic emissions reduction goal, emissions in the building, transport and other sectors were above the objectives in 2020 (Table 2.1).

The international target, committed under the second period of the Kyoto Protocol, was to reach an average reduction by 15.8% over the period 2013-20. Domestically, Switzerland managed to reduce its GHG emissions by around 11% over the same period. Switzerland reduced the remaining 4.8% by purchasing emissions reductions through projects abroad, to comply with the international target.

Table 2.1 Switzerland's GHG emissions trends under main sectors and CO_2 Act goals

Sector	1990 GHG emissions (Mt CO_2-eq)	2020 GHG emissions (Mt CO_2-eq)	Variation 1990-2020	CO_2 Act objective for 2020
Buildings	17.1	10.4	-39%	-40%
Transport	14.9	13.7	-8%	-10%
Industry	13.0	10.7	-17%	-15%
Others (including agriculture)	8.7	8.6	-2%	-10%
Total	**53.7**	**43.4**	**-19%**	**-20%**

Source: Switzerland, Federal Office for the Environment, (2022).

Switzerland enshrined its climate targets for the period 2021-30 in its updated first NDC, committing the country to reduce its GHG emissions by at least 50% by 2030 compared with 1990 levels, and by an average of at least 35% over the 2021-30 period. To reach this target, Switzerland plans to implement measures domestically and abroad, co-operating internationally with other countries. International co-operation means Switzerland will purchase emissions reductions and removals occurred abroad in the form of carbon credits (internationally transferred mitigation outcomes [ITMOs], under Article 6 of the Paris Agreement) that the country will claim against its NDC target.

In the longer term, Switzerland aims to achieve net zero GHG emissions by 2050. It plans to reduce its GHG emissions to around 90% from 1990 levels by 2050, as was elaborated in its Long-Term Climate Strategy submitted to the UNFCCC. The remaining emissions (11.8 Mt CO_2-eq) are associated with industry, waste and agriculture. The Swiss government estimates that around 5 Mt CO_2-eq of these residual emissions can be avoided through CCS. The rest must be balanced via NETs in Switzerland (2 Mt CO_2-eq) and abroad (4.8 Mt CO_2-eq).

Table 2.2 Summary of Switzerland's climate targets

	2020	2030	2050
Emissions reduction target compared to 1990 levels	-20%*	At least -50%	-90%
Average reduction over the relevant period	-15.8%**	-35%	N/A
Estimated residual emissions in Mt CO_2-eq (excluding CCS contributions)	42.4	36.1	11.8

*Domestic target.

**International target under the second commitment period of the Kyoto Protocol.

Sources: UNFCCC and Switzerland, Federal Council (2021).

Climate policies

Switzerland's domestic climate policy legislation is currently in a state of flux, making the climate policy landscape quite complex. This section provides an overview to illustrate the two main pieces of legislation that guide Swiss climate policy, namely the current "CO_2 Act" and the "Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security" (Climate Protection Act).

The evolution of the CO_2 Act

The Federal Act on the Reduction of CO_2 Emissions, the so-called CO_2 Act, is at the core of Switzerland's climate legislation. It was first enacted on 1 May 2000 and has been updated, amended and extended several times since (Table 2.3). The CO_2 Act covers the main emitting sectors, building, transport and industry sectors, and other sectors (including agriculture).

Table 2.3 Terminology to describe the evolution of the CO_2 Act

Period covered	Terminology used
2013-20	2013-2020 CO_2 Act
2021-30	Rejected 2021-2030 CO_2 Act
2021-24	Extended 2013-2020 CO_2 Act
2025-30	Proposed 2025-2030 CO_2 Act

Source: IEA based on information provided by Switzerland.

On 1 January 2013, a revised CO_2 Act (2013-2020 CO_2 Act) entered into force to cover the period from 2013 to 2020, equivalent to the second commitment period of the Kyoto Protocol. The scope of the 2013-2020 CO_2 Act was broadened to include all GHG emissions and carbon sinks from forestry and harvested wood products and introduced new measures for reducing emissions from heating and transport fuels.

In the third quarter of 2020, parliament adopted a revised CO_2 Act to cover the period from 2021 to 2030, including new instruments to help Switzerland meet its 2030 target under the Paris Agreement. However, in June 2021, a referendum rejected the 2021-2030 CO_2 Act. To avoid a legislative gap, in December 2021, parliament voted to extend the 2013-2020 CO_2 Act until the end of 2024, in anticipation that a new revision could enter into force from 2025. This new proposed CO_2 Act, as proposed by the government in September 2022, would cover the period 2025-30. At the time of writing, it was still in the legislative process and potentially subject to another referendum.

Figure 2.5 Selected measures of Switzerland's CO_2 Act over time

	Measures		
CO_2 Act version	**CO_2 levy (CHF/t CO_2) if interim target not met**	**Transport fuel compensation obligation**	**Swiss Emissions Trading System (ETS)**
2008-2012 CO_2 Act Applies to CO_2 only	CO_2 levy Initially set at **12 CHF/t CO_2** (2008)	Voluntary initiative (Fuel Importers Association)	
		The Climate Cent Foundation (2005-2012)	Voluntary programme (2008)
2013-2020 CO_2 Act	Increased to **36 CHF/t CO_2** (2013) **60 CHF/t CO_2** (2014)	KliK Foundation established, with initial compensation rate at 2%*	Mandatory for energy-intensive entities (2013 –)
Partial revision of **2013-2020 CO_2 Act**	Increased to **84 CHF/t CO_2** (2016) **96 CHF/t CO_2** (2018) **120 CHF/t CO_2** (2020)	Increased to 5% for 2016-17 Increased to 8% on January 2018	Swiss ETS Linked with EU ETS (2020)
2022-2025 extension of CO_2 Act	Stays at **120 CHF/t CO_2**	17% (2022) 20% (2023) 23% (2024)	
Parliamentary legislative procedure for **2025-2030 CO_2 Act****	Stays at maximum cap of **120 CHF/t CO_2** **	Maximum increased from 40% to 90%**	Tighten ETS in line with Fit-for-55 Allow inclusion of CCS**

*Referring to the share of transport sector emissions only.

**This is the current proposal as of March 2023, subject to changes.

Note: A draft 2021-2030 CO_2 Act was introduced by parliament in 2020 but rejected by referendum in June 2021. The draft included a CO_2 levy of 210 CHF/t CO_2, a transport fuel levy of up to 12 cents/litre and an aviation carbon tax of up to CHF 120, with revenues redistributed to the population.

Extended 2013-2020 CO_2 Act until the end of 2024

The extended 2013-2020 CO_2 Act contains several policy measures and instruments that will be valid until the end of 2024. Some of the key measures are discussed below.

CO_2 levy

The CO_2 levy applies to stationary fuel uses of fossil fuels, such as heating oil and natural gas. The level of the CO_2 levy was automatically increased if intermediate emissions targets were not achieved (see Chapter 1). The level was 12 CHF/t CO_2 in 2008 and reached 120 CHF/t CO_2 in 2022 after a number of automatic increases. Two-thirds of the proceeds from the CO_2 levy are refunded to the Swiss population through a health insurance premium and to companies proportionally to payments into the pension scheme. The remaining third is used to support a building refurbishment programme, and a smaller portion is used to replenish a Technology Fund. Operators of emission-intensive installations, who do not qualify to participate under the Swiss ETS can be exempted from the CO_2 levy if they commit to reducing their emissions. However, there is a high fine for non-compliance, equivalent to CHF 125 per over-emitted t CO_2. According to the proposed revision of the CO_2 Act for 2025-30, the exemption from the CO_2 levy shall end in 2040 to also incentivise small and medium-sized enterprises to switch to non-fossil fuels.

Swiss ETS

The Swiss ETS caps the emissions produced by industrial installations by defining the total amount of emissions allowances in advance. This sets a maximum limit for the GHG emissions of all participants in the ETS. From 2021, a yearly linear reduction factor is applied to the emission cap equivalent to 2.2%. As of 2022, there were nearly 100 stationary installations covered by the Swiss ETS. The Swiss ETS linked with the EU ETS in 2020, expanding to cover domestic aviation and flights to the European Economic Area and fossil-thermal power plants. Industrial entities, including those in the cement, chemicals, pharmaceuticals, paper, refining and steel sectors, are subject to ETS compliance, which covered about 10% of the country's total GHG emissions in 2019. Participants in the ETS are exempt from the CO_2 levy, and some emissions allowances are allocated for free while others are auctioned off. The ETS allows opt-in for smaller installations and opt-out for those with emissions below 25 kilotonnes of CO_2 per year.

Compensation obligation for fuel importers

Because transport fuels are not covered by the CO_2 levy, Switzerland requires fossil fuel importers to offset a portion of the transport sector emissions through the purchase and retirement of carbon credits. Since 2013, the KliK Foundation has been mandated to secure carbon credits from mitigation projects in Switzerland and abroad. The mandated share of transport sector emissions to be compensated increases gradually over time (see Figure 2.5). At least 15% of this share must be compensated for through domestic projects until 2024.

Under the extended 2013-2020 CO_2 Act, the Fuel Importers Association may levy a maximum of CHF 5 cents/litre on transportation fuels but effectively charged less than CHF 1.5 cents/litre in the period 2013-20. Between 2013 and 2021, the proceeds from this levy were CHF 1 067 billion, which the KliK Foundation used to abate 12.07 Mt CO_2 through domestic and international mitigation projects at an average reduction cost of 90.21 CHF/t CO_2. Within Switzerland, this mechanism efficiently supports the clean

energy transition, with the KliK Foundation purchasing credits from projects in the transport sector, industry, buildings and agriculture.

The scope of eligible compensation projects is limited by the CO_2 Act and ensuring crediting additionality in an increasingly regulated policy environment risks reducing the possibility to credit from domestic activities. Internationally, the KliK Foundation purchases carbon credits from foreign projects, meeting the requirement of Article 6 of the Paris Agreement and aligned with the CO_2 Act. Switzerland has concluded bilateral agreements with a dozen countries to carry out voluntary co-operation under Article 6.2 of the Paris Agreement that can also be used by the KliK Foundation to source carbon credits to comply with the compensation obligation for fuel importers. However, if the international market for Article 6 credits struggles to develop, there could be a risk of non-compliance for fossil fuel importers.

CO_2 emissions regulations for new cars and light duty vehicles

Since 2012, Switzerland has CO_2 emissions regulations for new passenger cars and light duty vehicles based on EU regulations (see Chapter 3). Since 2020, these limits are 95 g CO_2/km for new passenger cars, and 147 g CO_2/km for vans and light duty vehicles.

Climate Programme Training and Communication

In addition to the key instruments above, the “Climate Programme Training and Communication” supplements and strengthens the measures of the CO_2 Act. It supports skilled workers and communes as they work to achieve Switzerland's net zero target by 2050 and provides training to managers and skilled workers to contribute to the other targets set under the Paris Agreement, specifically adaptation to climate change and climate-aligned financial flows.

Proposed 2025-2030 CO_2 Act

The proposed 2025-2030 CO_2 Act reflects the results of the 2021 referendum that rejected the 2021-2030 CO_2 Act and shifts the focus from regulations and tax increases to incentives, especially in the transport and building sectors. These incentives are supplemented by new targeted subsidies and investments. Further changes to the proposed 2025-2030 CO_2 Act are possible as a result of the parliamentary debate.

If the proposed 2025-2030 CO_2 Act is adopted, the 50% emissions reduction target (compared to 1990 levels) will be anchored in national law. And Switzerland remains committed to an emissions reduction of 35% between 2021 and 2030. The reduction must be continuously achieved over the period. However, one important change in the proposed CO_2 Act is the proportion of emissions reductions that have to be domestic (within Switzerland’s borders). Under the extended 2013-2020 CO_2 Act, a maximum 25% of emissions reductions can be achieved abroad. Under the proposed CO_2 Act, the government will determine the minimum domestic share. It is intended to achieve a ratio of at least 60% domestically and a maximum of 40% abroad. For this, Switzerland has already entered into agreements with several countries to voluntarily co-operate under Article 6.2 of the Paris Agreement. The proposed CO_2 Act is expected to reduce GHG emissions within Switzerland by 34% by 2030, which corresponds to a domestic share of more than two-thirds.

The domestic reductions are achieved mainly in the transport, buildings and industry sectors. The government proposes to mobilise over CHF 650 million per year from various

fiscal instruments to fund the domestic measures under the proposed CO_2 Act. This is a significant increase from the CHF 475 million available under the extended 2013-2020 CO_2 Act, that is solely funded by the CO_2 levy proceeds. The additional funds would be collected through existing measures, such as fines for vehicle importers, diesel tax proceeds, the fuel excise tax on domestic flights and revenues from ETS auctioning in the aviation sector.

CO_2 levy

The rejected 2021-2030 CO_2 Act planned to let the CO_2 levy increase to a maximum of 210 CHF/t CO_2, which is considered one of the main reasons the Act was rejected in the referendum. Consequently, the proposed 2025-2030 CO_2 Act keeps the maximum level at 120 CHF/t CO_2, the current level.

The proposed 2025-2030 CO_2 Act also proposes changes in the use of the receipt from the CO_2 levy. Instead of refunding two-thirds directly to the population, this share will be reduced to 51%. Conversely, the share of revenues that can be used for emissions reduction measures – such as building refurbishment, fossil heating replacement, e-vehicle charging stations, district heating planning and risk guarantees for geothermal energy – is increased to 49%.

The extended 2013-2020 CO_2 Act provides that only specific sectors can be exempted from the CO_2 levy under certain conditions, while the proposed 2025-2030 CO_2 Act opens the possibility of an exemption to all sectors if they are compliant with credible emissions reduction covenants. The proposed CO_2 Act also foresees allowing companies to propose emissions reduction commitments up to 2040, after which no exemption will be possible. Companies will also have to submit a decarbonisation plan within three years of the start of the emissions reduction commitments and update it periodically.

Swiss ETS

The proposed CO_2 Act foresees further developing and tightening the ETS for installations and the aviation sector in line with the revision of the EU ETS. This will involve, for example, a faster reduction path of the cap and a gradual phase-out of free allowances. Furthermore, the ETS shall take into account CCS in the Swiss ETS, in analogy with the EU ETS.

Compensation obligation for fuel importers

While the extended 2013-2020 CO_2 Act provides that fossil fuel importers must compensate up to 23% of transport sector emissions until 2024 (with a maximum possible share of 40% according to the law), the proposed 2025-2030 CO_2 Act foresees increasing the maximum share of emissions that must be compensated from 40% to 90% but reduces the quote of this share that must be compensated through domestic offsets. The proposed CO_2 Act maintains the current levy level of maximum CHF 5 cents.

CO_2 emissions regulations for new cars and light duty vehicles

The proposed 2025-2030 CO_2 Act includes the possibility to further tighten Switzerland's CO_2 emissions regulations for new cars and light duty vehicles to the more stringent EU "Fit-for-55" targets. Moreover, it introduces for the first time CO_2 emissions targets for heavy-duty vehicles (see Chapter 3).

Other proposed measures

The proposed 2025-2030 CO_2 Act also includes new measures that will also contribute to enlarging the available financial envelope. These include:

- **Sustainable aviation fuels (SAF) blending obligation**: The proposed CO_2 Act introduces minimum SAF blending obligations, aligned to the ones adopted in the related EU regulations. It proposes allocating CHF 25-30 million annually to incentivise SAF production and research and development.
- **Fossil-free transport**: The proposed CO_2 Act removes the tax exemption for diesel consumed by public buses and boats to accelerate the market uptake of electric or hydrogen buses and boats. Funds from the general budget will be used to promote the transition to electric buses. Moreover, the proposed CO_2 Act allocates up to CHF 30 million per year to support public transport companies to improve the offer for cross-border rail passengers, including through night trains. The proposed CO_2 Act also includes incentives for installing electric vehicle (EV) charging stations and blending requirements for biofuels (see Chapters 4 and 9).
- **Extending tax exemptions for electric and hydrogen heavy-duty vehicles**: The proposed CO_2 Act extends to 2030 the exemption from the diesel tax and heavy-duty vehicle levy for electric and hydrogen heavy-duty vehicles, making them more economically competitive.
- **Phasing out fossil heating in buildings**: The building refurbishment programme (see Chapter 3) remains a major pillar of Swiss climate and energy policies. The proposed CO_2 Act allocates on average CHF 470 million per year from the CO_2 levy proceeds for building refurbishment. Moreover, improved investment incentives for district heating by replenishing the Technology Fund are planned, which will derisk the associated investments in the district heating networks and heat generation plants.
- **Reporting obligation of climate risks for the financial system**: The proposed CO_2 Act introduces a requirement for the Swiss Financial Market Supervisory Authority to examine and regularly report climate-related financial risks of the financial institutions under its supervision. The proposed CO_2 Act also tasks the Swiss National Bank to monitor potential risks to the stability of the financial system arising from climate change.

Climate Protection Act

In November 2019, a civil society initiative named "The Glaciers Initiative" called for enshrining climate neutrality in the Swiss Constitution and for banning all fossil fuels by 2050. In August 2021, the government tabled a direct counterproposal to "The Glaciers Initiative", because it considered enshrining a fossil fuel ban into the Constitution as too radical. The direct counterproposal allows the use of fossil fuels for the military, police and emergency services beyond 2050.

In September 2022, parliament adopted an indirect counterproposal to "The Glaciers Initiative", the "Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security" , or "Climate Protection Act". The Climate Protection Act includes the main elements of the initiative but would not enshrine the climate targets in the Constitution, but rather in a new law. The Climate Protection Act was approved in a referendum on 18 June 2023.

This new law is a cornerstone of Swiss climate policy, as it embeds the long-term 2050 net zero target in national law. It provides sectoral targets for the main emitting sectors (buildings, transport and industry) and puts forward two further objectives consistent with

the Paris Agreement: 1) climate-compatible financial flows; and 2) strengthening climate adaptation measures. The Swiss Confederation is now a role model, with a net zero target set for its operations and assets by 2040. All Swiss companies also must achieve net zero by 2050. To achieve these goals, the Climate Protection Act proposes two support schemes. The first is the promotion of innovative processes and technologies in industry, with an envelope of CHF 1.2 billion over six years. The second is an incentive programme to replace fossil fuel heating systems and increase the energy efficiency of buildings, with a budget of CHF 2 billion over ten years. Both support schemes are financed through the regular budget and not the receipts from the CO_2 tax. The implementation of the Climate Protection Act will be ensured through future revisions of the CO_2 Act.

Carbon capture and storage and carbon dioxide removal

Switzerland recognises that both CCS and carbon dioxide removal (CDR) technologies, such as direct air capture and storage (DACS), will be necessary to reach the domestic climate goal, but that these technologies must be applied only for mitigation or compensation of "hard-to-abate" emissions. As mentioned above, by 2050, Switzerland estimates it will need 5 Mt CO_2 per year of CCS on fossil or geogenic emissions inland, 2 Mt CO_2 per year of CCS on biogenic emissions inland and 4.8 Mt CO_2 per year of CDR abroad (including DACS).

However, the government is legally limited in the development of CO_2 transport and storage infrastructure within Switzerland, because surface and subsurface territorial planning is the competence of the cantons. Currently, different cantons have different views of the potential that local energy and climate policies have for favouring the development of CCS and CDR projects on their land. More clarity on potential constitutional and regulatory modifications that could unlock this situation is expected in 2024.

In the meantime, for CCS and CDR to be achieved abroad, Switzerland has already signed a joint declaration of intent with Iceland (Agreement on DACS) as part of the international co-operation under Article 6 of the Paris Agreement. Under this joint declaration, the Swiss and Icelandic environmental agencies declared their intention to work together to address climate change through CDR and CCS technologies. The joint declaration aims to form a partnership to exchange information, enhance understanding and consider legal frameworks for co-operation in this field. Switzerland has also signed a memorandum of understanding with the Netherlands to promote the development of CCS and CDR technologies, also under the framework of Article 6 of the Paris Agreement. The co-operation will be facilitated through a joint working group to share technical knowledge, evaluate policy mechanisms, and explore the need for a bilateral agreement or arrangement to enable cross-border transportation and storage of CO_2.

Adaptation and resilience to climate change

Switzerland's average temperature is rising two to three times faster than the global average, with a 2ºC increase between 1864 and 2016. This trend is projected to continue until near the end of the century, with the level of warming ranging from 0.6°C to 5.4°C depending on GHG concentration scenarios. This will lead to more intense, frequent and longer heatwaves, particularly in southern Switzerland, affecting energy demand patterns

by decreasing heating needs and increasing cooling demands. Winter precipitation is expected to increase by 15% by 2070-99, and extreme precipitation events will continue to occur in all seasons and regions, with the largest increases in heavy precipitation likely to occur in winter and northern Switzerland. This intensification and a shift from snowfall to rainfall will likely affect hydropower generation.

In 2012, the government approved a strategy on adapting to climate change. The strategy establishes a framework for federal agencies to take co-ordinated action towards climate change adaptation, identifying fields of action and setting goals. The strategy is supplemented with a corresponding action plan. The first Action Plan 2014-2019 was updated in 2019 with the Action Plan 2020-2025. It builds on analysis of the so-called regional "CH2018" Climate Scenarios and additional assessment of climate change-related opportunities and risks. The Action Plan 2020-2025 contains 75 concrete federal-level adaptation measures to enhance energy sector climate resilience, including building the climate resilience of the energy sector, a concrete time frame, cross-sector challenges, the scope of the intervention anticipated, resource needs and priorities. The plan identifies rising energy demand for cooling in buildings, passenger transport and industrial processes as well as lower hydropower generation due to low water levels and flooding during summer as key challenges.

Environmental impacts of the energy sector

Switzerland's air quality is above the OECD average. The average annual exposure to particulate measures (PM)2.5 stood at of 10 micrograms per cubic metre air ($\mu g/m^3$) in 2019, a reduction of more than 30% since 2000. The main sources of Swiss air pollution are road transport, wood combustion, agriculture and industry. The Ordinance on Air Pollution Control (OAPC, 1985) defines limit values for atmospheric pollutants and the design of preventive measures. Swiss air quality standards are overall in line with the World Health Organization's recommended limits.

Methane emissions accounted for 10.6% of Switzerland's total GHG emissions in 2020 and come nearly exclusively from the agricultural sector and waste landfill sites. Energy-related methane emissions are negligible, only occurring due to, for example, pipeline maintenance work, and voluntary measures for further reductions have been sufficient to almost completely replace problematic (brittle) pipe materials in the past decades. Methane emissions are estimated by the Federal Office for the Environment in the framework of the GHG inventory to the UNFCCC. Accordingly, the methodologies rely on respective IPCC Guidelines and are described in detail in Switzerland's National Inventory Report.

Assessment

Switzerland shows a notable decoupling between domestic energy-related GHG emissions and economic and population growth. After peaking in 2005, energy-related GHG emissions have decreased unevenly depending on the year, as weather conditions affect emissions for heating. Between 2019 and 2020, GHG emissions decreased by 7%, mainly due to the Covid-19 pandemic, and rebounded in 2021 by 5%, to a level still 2% lower than in 2019.

Switzerland has narrowly missed its 2020 domestic climate target, and met its international commitment only thanks to emissions reductions abroad. Importantly, emissions in key sectors, such as building and transport, have decreased more slowly than expected.

The government has set clear emissions reductions targets for 2030 and 2050. However, Switzerland's domestic climate policy legislation detailing how to achieve these targets is currently in a state of flux, making the policy landscape quite complex. The two main pieces of legislation that aim to regulate future Swiss climate policy are the 2025-2030 CO_2 Act and the Climate Protection Act (that was approved in a referendum in June 2023).

Since 2008, the CO_2 Act is an evolving piece of legislation with provisions for domestic emissions reduction measures in key sectors. The CO_2 levy on stationary uses of fossil fuels, the Swiss ETS and a compensation obligation for fossil fuel importers have proven to be effective measures to put Swiss emissions in structural decline.

A proposal to make the CO_2 Act more ambitious for the period 2021-30 was rejected by referendum in June 2021. One of the main reasons for the rejection was the perception that some of the new proposed measures were "punitive". These measures included the introduction of a new aviation carbon tax, an increase of the compensation obligation for fossil fuel importers, an increase of the CO_2 levy on stationary fuels up to 210 CHF/t CO_2 if Switzerland was off its emissions reduction target trajectory (from 120 CHF/t CO_2 in 2022), and an implicit phase-out of fossil heating systems through the gradual introduction of very strict refurbishment requirements.

The rejected 2021-2030 CO_2 Act was supposed to replace the 2013-2020 CO_2 Act as of January 2021. To avoid a legislative gap, in December 2021, parliament approved an extension of certain measures of the 2013-2020 CO_2 Act until the end of 2024. In the meantime, the government hopes to gain approval of the proposed CO_2 Act 2025-2030 that was submitted to parliament in September 2022. The proposed 2025-2030 CO_2 Act shifts the focus from regulations to incentives, especially in the transport and building sectors, supplementing them with new targeted subsidies and investments while reducing Switzerland's dependence on oil and natural gas.

While the proposed 2025-2030 CO_2 Act maintains some important measures, such as the CO_2 levy or the CO_2 emissions regulations for new cars and light duty vehicles, they are complemented by new measures, including blending mandates for sustainable fuels in road transport and aviation; increased support for fossil heating replacement and energy efficiency measures; geothermal risk guarantees; local energy plans; support for sustainable aviation fuel production and cross-border rail; and incentives for district heating/cooling, e-vehicle charging infrastructure and non-fossil public transport. The budget to implement these measures is expected to increase from CHF 450 million to over CHF 650 million, which is a very welcome signal.

Another change in the proposed 2025-2030 CO_2 Act is the increase of the probable share of emissions reductions achieved abroad. The increase of the compensation obligation for transport fuel importers would increase to up to 90% of transport emissions by 2030 (from 23% in 2024) should provide Switzerland with enough financial means to purchase carbon credits to account for 40% of its 2030 target.

However, an increased reliance on reductions abroad should not deflect attention from the need for more domestic emissions reductions. Changes to the proposed CO_2 Act are still possible during the parliamentary debate, which started in the first quarter of 2023.

The second important piece of climate legislation is the “Climate Protection Act” or “indirect counterproposal to the Glaciers Initiative”. In November 2019, the “Glaciers Initiative” was officially tabled, calling for enshrining climate neutrality in the Swiss Constitution and for banning all fossil fuels by 2050. In August 2021, the government tabled a direct counterproposal because it considered that a fossil fuel ban would be too radical. In 2022, parliament adopted an indirect counterproposal, which includes the main elements of the initiative, but would not enshrine the net zero target in the Constitution but rather in a new law. The Climate Protection Act was approved in a referendum on 18 June 2023.

The Climate Protection Act is a framework law enshrining the net zero target by 2050 in national legislation and also outlining the path to this target, with interim targets and final targets for the different sectors. By contrast, the 2030 climate target is to be achieved through measures provided for in the proposed CO_2 Act. The Climate Protection Act therefore is an important cornerstone of the Swiss climate and energy policy for decades to come.

There is currently a misalignment between the extended 2013-2020 CO_2 Act and the pace of emissions reductions needed to achieve the 2030 targets. The proposed 2025-2030 CO_2 Act would put Switzerland on track with the trajectory to the 2030 emissions reduction goal. However, two main concerns arise from the current situation.

The first concern is that there could be implementation bottlenecks for the measures proposed in both the short term (i.e. in the proposed 2025-2030 CO_2 Act) and in the longer term (i.e. in the Climate Protection Act). These bottlenecks relate to a lack of specialised skilled workers needed for installing heat pumps or EV charging stations; the slow renewable energy permitting processes; and to international bottlenecks, such as supply chain disruptions or critical minerals supply. In both cases, such bottlenecks risk delaying the achievement of the climate goals.

The second concern is a potential misalignment in the implementation of the short- and long-term goals. When working on designing and implementing the provisions for the Climate Protection Act, an effective interplay with the CO_2 Act must also be ensured, because the CO_2 Act details the key climate policy instruments that will be used to implement the strategy. Ensuring proper co-ordination between the provisions of the Climate Protection Act and the key climate policy instruments outlined in the CO_2 Act will be crucial for achieving the desired short- and long-term goals of the overall Swiss climate strategy.

Finally, Switzerland has developed and implemented a robust adaptation and resilience strategy for its energy sector, coupled with a comprehensive regulatory framework and monitoring system to address the environmental impact of its energy practices. It is crucial to prioritise the continued enforcement and execution of these measures to sustain these high standards.

Recommendations

The government of Switzerland should:

- Ensure timely preparation for the period after 2030, by starting to conceptualise the measures that need to be included in a new draft CO_2 Act for the post-2030 period.
- Ensure alignment between the short- and long-term climate policy implementation, especially in key sectors such as buildings and transport, by fostering an effective interplay between the Climate Protection Act and the CO_2 Act.
- Strengthen the communication strategy aimed at increasing public awareness of climate change and the government initiatives to address it.
- Elaborate a detailed plan on how to address potential bottlenecks in the implementation of Swiss domestic mitigation efforts towards the short- and long-term climate goals.

3. Energy efficiency

Key data (2021)

TFC: 759 PJ, -5% since 2011

TFC by source: oil 43.7%, electricity 27.6%, natural gas 16.4%, bioenergy and waste 8.4%, district heat 3.0%, coal 0.5%, solar thermal 0.4%

TFC by sector: buildings 47.4%, transport 29.3%, industry 23.3%

TFC per capita: 87.1 GJ/capita (IEA average in 2020: 112.8 GJ/capita), -13% since 2011

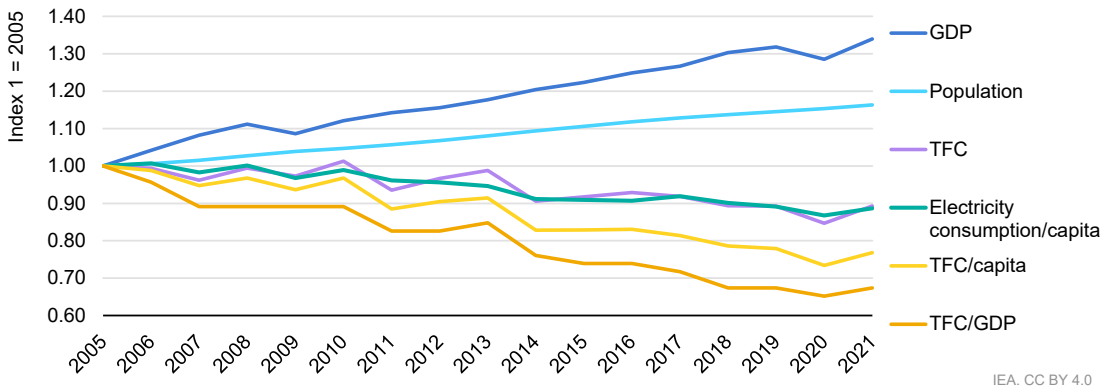
TFC per GDP: 1.28 MJ/USD (IEA average in 2020: 2.66 MJ/USD), -19% since 2011

Source: IEA (2022), World Energy Balances.

Overview

Switzerland shows a clear decoupling between economic and population growth and energy consumption. Between 2011 and 2021, Switzerland's TFC decreased by 5% while GDP increased by 17% and the population grew by 10%. Due to the Covid-19 pandemic, GDP dropped by 3% in 2020 but rebounded by 6% in 2021, above the 2019 level. Energy intensity has decreased, both in terms of TFC per GDP (-18% from 2011 to 2021) and TFC per capita (-13% from 2011 to 2021). Electricity consumption per capita also dropped by 8% between 2011 and 2021.

Figure 3.1 Energy demand and drivers in Switzerland, 2005-2021

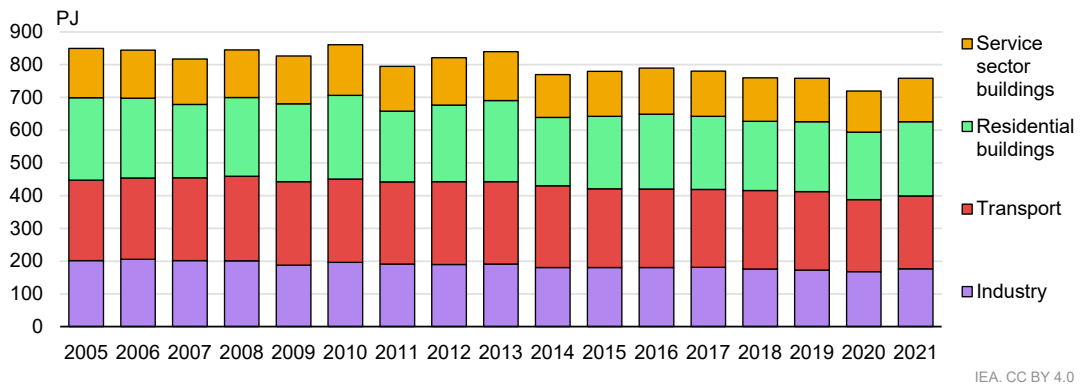


Source: IEA (2022), World Energy Balances.

A 2022 study, commissioned by the SFOE, undertook an in-depth analysis about the major drivers for reducing energy demand by demand sector and fuel. The study's key findings show that energy demand reductions and efficiency gains are primarily due to technology progress and policy interventions; fuel substitution; and, especially in the industry sector, structural factors such as a reduction in the share of energy-intensive industries in the Swiss economy.

TFC in Switzerland was 759 PJ in 2021, and has been following a downward trend since 2010, with fluctuations mainly depending on demand for heating from buildings (Figure 3.2). The buildings sector was the largest energy-consuming sector in 2021, covering 47% of TFC (30% from residential buildings and 17% from service sector buildings), followed by transport (29%) and industry (23%). Transport, industry and service sector buildings have decreased their TFC since 2011, with transport experiencing the largest decrease (by 11%), followed by industry (8%) and service sector buildings (3%). Residential buildings increased their TFC by 5% from 2011 to 2021.

Figure 3.2 Total final consumption by sector in Switzerland, 2005-2021



Note: Industry includes non-energy use.

Source: IEA (2022), World Energy Balances.

Policy targets and measures

Energy efficiency is a key pillar in Switzerland's strategy towards reaching its energy and climate targets for 2030 and the net zero target for 2050. Since the ES2050 entered into force, the energy efficiency measures have consistently been strengthened. The energy amendment package that is currently under discussion in parliament (see Chapter 1) proposes converting the indicative targets for energy consumption and efficiency set under the ES2050 into binding targets and further strengthening them as set out in the EP2050+ (Table 3.1). Switzerland overachieved its 2020 targets for per capita energy and electricity consumption, and is well on its way to reach the interim targets set for 2035 (Table 3.2). However, reaching the 2050 target is challenging and will require close monitoring to take early corrective action if needed.

The Energy Act of 1998 is the main legal foundation for energy efficiency policy. It gives the federal government responsibility for energy labelling and the right to set minimum energy performance standards for vehicles, systems and appliances. The cantons are in charge of building regulations and must create favourable conditions for increasing energy efficiency and the use of renewables in buildings.

Table 3.1 Switzerland's energy efficiency targets according to ES2050 and EP2050+

Change with respect to 2000	ES2050		EP2050+	
	2035	2050	2035	2050
Per capita energy consumption	-43%	-54%	-43%	-53%
Per capita electricity consumption	-13%	-18%	-13%	-5%

Source: Country submission.

Table 3.2 Switzerland's indicative energy efficiency targets and actual achievement in 2020

Change with respect to 2000	Indicative target of ES 2050	Achieved savings
Average energy consumption per capita and year	-16%	-20.8%*
Average electricity consumption per capita and year	-3%	-10.4%*

*Figures for achieved savings in 2020 are in weather-adjusted data. Savings are -23.7% and -11.3%, respectively, before weather-adjustment.

Source: Country submission.

Generally, the SFOE runs broad public information campaigns, whereas the cantons focus on providing advice. The federal government finances research and development and promotes professional training in energy efficiency. The SwissEnergy Programme, which is run by a division of the SFOE, plays a crucial role for information, professional training and advice. In accordance with the subsidiarity principle, private sector agencies are also closely involved in policy implementation, especially in the industry sector. These include the Energy Agency of the Economy, Agence Cleantech and the KliK Foundation. All face the challenge of finding sufficient highly skilled professionals to address the growing demand for projects (see Chapter 1).

In January 2023, the SFOE published its Heat Strategy 2050. The strategy aims to achieve a 30% reduction of total heat demand in 2050, substitute energy carriers towards renewables and synthetic fuels, and use sector coupling and digitalisation to reach Switzerland's 2050 net zero target. The strategy sets out measures for a total of ten areas: building efficiency; heating systems; process heat; thermal storage; and networks; electrification; renewable gases and synthetic fuels; co-ordination of federal, canton and municipal policies; and legal frameworks to reach net zero; training of highly qualified professionals to undertake the work. The Heat Strategy 2050 will inform all related policies, laws and support programmes. The Climate Protection Act and the draft revised CO_2 Act (currently being debated in parliament) (see Chapter 2) already include provisions to significantly increase the allocation of funds to support the shift from fossil fuel and direct electric heating systems.

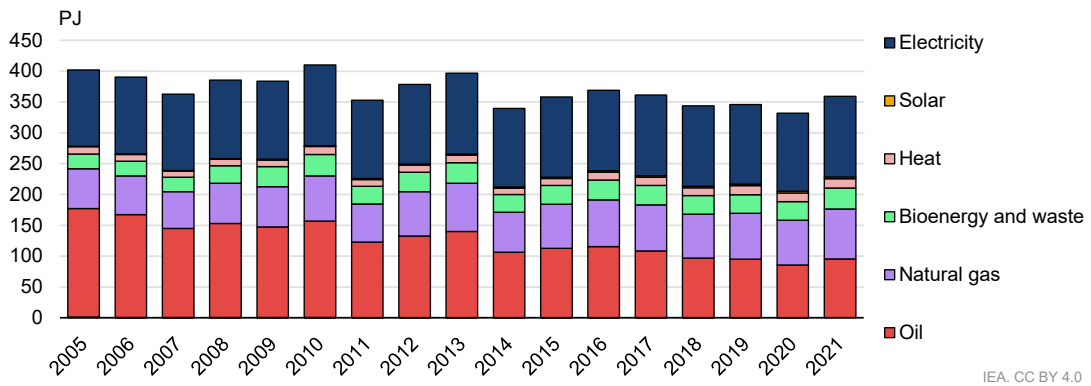
Buildings

In 2021, the buildings sector accounted for the largest share of TFC (47%, or 359 PJ). This sector includes residential buildings (63% of buildings TFC in 2020) and service sector buildings (37%). The largest part of energy consumption in buildings is covered by electricity (36% in 2021; residential 32%, service sector buildings 44%). The second-largest source of energy for buildings is oil (27% in 2021), followed by natural gas (23%).

Oil and gas are used in both the residential sector (29% and 24% respectively in 2021) and the service sector (22% and 20% respectively). The share of oil in buildings is the fifth-highest among IEA member countries. Bioenergy satisfies 9% of residential buildings' and 10% of service buildings' TFC. District heat is also used in both residential and service buildings TFC, covering 4.2% of building sector demand in 2021. The share of solar in buildings TFC was 0.7% in 2021 and is hence not visible in Figure 3.3.

The potential for heat supply via thermal grids using renewable heat and unused waste heat is estimated to be somewhere between 17 TWh and 22 TWh annually. Several cantons have created a legal basis so that the communes can impose a connection obligation, provided that the heat is offered at technically and economically reasonable conditions. This policy is supported by the federal government. However, the investment costs in grid expansion and the increase of renewable heat sources will increase the cost to consumers and make the connection potentially unattractive. The government is considering subsidies. One consideration is for district heat to use the capacity of the gas grids, as Switzerland plans to phase out natural gas by 2050.

Figure 3.3 Total final consumption in the buildings sector in Switzerland by source, 2005-2021



Source: IEA (2022), World Energy Balances.

Policies and measures in the buildings sector

The cantonal energy offices, overseen by the EnDK, play an important role in implementing energy policies in the building sector, which is a cantonal remit under the Swiss Constitution. As a consequence, there is no national building code or regulations, but each of the 26 cantons sets its own requirements. The EnDK has prepared cantonal model prescriptions, the so-called MuKEn, to facilitate the adoption of more unified building regulations. However, they are not legally binding and need to be transposed into cantonal law. The EnDK regularly monitors which cantons have transposed which measures into cantonal law.

The latest version of the MuKEn dates back to 2014 and sets the standard for new buildings in line with EU recommendations for near zero energy buildings; prescribing a maximum consumption of 3.5 litres of oil equivalent per square metre per year for new residential buildings. They also include regulations for the existing building stock, such as prohibiting the use of direct electric heating systems 15 years after the relevant cantonal legal provisions enter into force. Minimum standards are also set for major renovations, also requiring a minimum share of renewables when the heating system is replaced,

resulting in fossil fuels being replaced by renewables. Less than 2% of homes built since 2011 are heated by oil. As of 31 March 2023, 22 cantons had fully adopted the MuKEn 2014 and transposed them into cantonal law.

The EnDK is working on further tightening the prescriptions to align with Switzerland's net zero target for 2050.The revised MuKEn are expected to be issued in 2025. Buildings are seen as an energy hub combining consumption, production and storage of energy and no longer only as passive consumers of energy. The revised regulations will include targets for on-site electricity production, 100% renewable energy for heating (and cooling) in all new buildings and gradually also in the existing building stock, smart-home installations, smart meters, and e-mobility to improve the overall efficiency of operating buildings. All cantons have agreed in principle to the proposal but need to individually transpose it into cantonal law. In the meantime, the EnDK is issuing partial revisions to the 2014 MuKEn to address, for example, heating and electricity production in buildings (expected in the second half of 2023).

The EnDK adopted those principles in 2022 and further agreed that buildings owned by cantons will be operated CO_2-free from 2040 at the latest. For this, the EnDK also agreed, among other measures, to use suitable areas of the cantonal building stock for the installation of solar PV. However, these agreements all need to be transposed into cantonal law by each canton.

Building refurbishment programme

At the end of 2021, the building stock comprised almost 1.8 million residential buildings (compared to 1.65 million in 2011) and 1 million non-residential buildings. A large share of the population rents their home. In 2021, only 36% of households owned their residence and 47% of the owners of the rented houses are private individuals. The most recent census showed that 1.1 million fossil heating systems are in use. Almost three-quarters of rented homes use fossil heating systems, either oil, gas or district heating, while the share is 59% for owner-occupied homes. The share of owner-occupied homes with heat pumps is double the share in rented accommodation (11%). Fossil fuels are also the dominant sources for warm water heating, followed by electricity.

Around 8% of buildings use direct electric heating. This is an additional strain for electricity security in winter (see Chapters 1 and 6). The government, jointly with the cantons, has examined measures to speed up replacement. The main recommendation was that all cantons should implement deadlines to replace existing direct electric heating systems. This regulation is already in force in a few cantons. The Climate Protection Act includes a provision for additional subsidies to facilitate the replacement of direct electric heating systems, as they often require costly constructional measures.

For existing buildings, proceeds from the CO_2 levy have financed a national building refurbishment programme since 2010. The refurbishment programme has seen increasing demand for the decarbonisation of heating systems, while the demand for measures to reduce building energy consumption has remained stable. Although heat pumps are only subsidised up to a capacity of 50 watts per m^2, they can be installed in homes which may not be sufficiently well insulated to fully benefit from the heat pump. This policy could result in more expensive heat pumps, with greater capacity being installed. It is therefore important that after a later building renovation, the heating curve/heating limit is set lower to avoid excess demand for electricity. Alternatively, the government could consider not supporting funding for heat pumps in the most poorly insulated buildings.

To reach the net zero target in 2050, 30 000 fossil and direct electric heating systems need to be replaced annually. The government estimates that in 2020, some 25 000 buildings were upgraded with new heating systems, with approximately 5 000 of these doing so outside of the subsidy schemes.

In addition, other types of building refurbishment, such as insulation, will need to be undertaken to reduce the energy consumption of existent buildings – ideally before heat pumps are installed. Between 10 000 and 12 000 residential buildings were refurbished in 2020; yet, window replacement or roof insulation was more widespread. To reach the 2050 target, an estimated 2% of the existing building stock would need to be upgraded annually. It is important that the government continues to incentivise building owners to upgrade their properties. Beyond the cost savings, the government should also increase awareness of the multiple benefits of energy efficiency at the individual, community and national level. Both the level of anticipated building refurbishment activity and of the replacement of fossil fuel and direct electrical heating systems indicates that additional capacity in the construction sector is needed (see Chapter 1).

Given the high share of people living in rented accommodation, Switzerland faces a split incentive when it comes to retrofitting homes, as the benefits of comfort and energy savings are experienced by the tenant rather than the building owner, who pays for the improvements. The ES2050 introduced new tax incentives to encourage investments. Since 2020, tax deductions for efficiency investments can be spread over a period of up to three years instead of one. In addition, the demolition costs of old buildings that will be replaced with new energy-efficient buildings can benefit from a tax deduction. The aim is to encourage total renovation instead of partial renovation, which until 2017 was more attractive in fiscal terms, but which is less effective from an energy efficiency point of view.

In 2020, Switzerland amended the regulation on residential and commercial rents to partly address the landlord-tenant dilemma. Landlords may, under certain conditions, pass on the cost of a refurbishment carried out by an energy services company to tenants over a maximum of ten years. The impact of this measure has not been evaluated so far.

Since April 2022, free advice is being offered to homeowners for choosing the optimal new heating system if their existing heating system is more than ten years old. This programme is implemented by SwissEnergie and runs from 2022 to 2025. SwissEnergy also conducted an energy savings campaign on behalf of the government especially for the winter of 2022/23. The campaign offered simple and concrete recommendations for private households, companies, municipalities and building managers.

Switzerland does not have quantitative targets under the national building refurbishment programme and there is no systematic evaluation of the quantitative effects of the subsidised measures on CO_2 emissions. Instead, a CO_2 reduction effect was assigned to each subsidised measure *ex ante* and all funded measures added up to reach the mitigation impact of the national building refurbishment programme. The calculations are adapted to exclude measures that would have been realised in the absence of subsidies. Modelling carried out on the CO_2 abatement impact of various energy efficiency measures, taking into account the investments available up to 2025, estimates a mitigation impact of 1.12 Mt CO_2-eq by 2020 and of 1.49 Mt CO_2-eq by 2025 from the building refurbishment programme.

Funding

The major funding source for energy efficiency improvements in the building sector is the allocation of one-third from the revenues of the CO_2 levy (up to a maximum of CHF 450 million annually) for the national building refurbishment programme (see Chapter 2). In 2021, the programme was oversubscribed. The government has made provisions in the draft proposed CO_2 Act to increase the allocation to the programme from one-third to 49% for the period 2025-30.

Most of the allocation is used for replacing fossil fuel heating systems and thermal insulation. Funding allocations for the programme do, however, vary by measure, location and canton, as the cantons have the lead for buildings and also implement the programme and provide additional co-funding. The ratio between funding from earmarked CO_2 levy proceeds and cantonal financing is fixed at 2:1. The SFOE is responsible for the overall supervision. Given Switzerland's subsidiarity principle, private sector agencies are also closely involved in policy implementation.

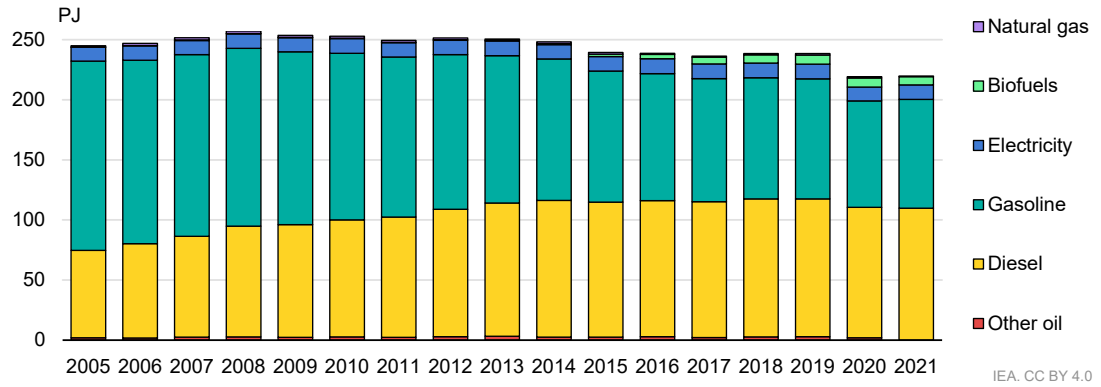
Another major funding source allocation for energy efficiency in buildings is the allocation of 0.1 cent/kilowatt hour (kWh) from proceeds of the electrical grid surcharge. The government created the ProKilowatt scheme, which is an auction programme for electricity efficiency projects aimed at electricity savings in industry, households and the service sector funded by the surcharge. To qualify, projects must have payback periods of more than four years. There is high demand for the scheme. Multiple benefits and other policy objectives are not considered in project adjudication, as only the projects with the most kWh saved per CHF invested are funded. Over the period 2010-21, 800 projects were implemented, resulting in 915 GWh of annual energy savings at a cost of 2.8 CHF/kWh.

In addition, the Climate Protection Act contains provisions for an additional CHF 200 million in subsidies for the shift toward more efficient and fossil-free heating and specifically to facilitate the replacement of direct electrical heating systems, which requires costly constructional measures.

Transport

In 2021, energy demand in the transport sector accounted for 29% of total TFC (222 PJ). Energy consumption in the sector decreased by 6% from 2010 to 2019, and dropped another 8% from 2019 to 2020 due to the Covid-19 pandemic (Figure 3.4). From 2020 to 2021, the rebound of demand was mild, with just 1%, remaining 7% lower than the 2019 level. Oil products cover most transport energy demand, with diesel and gasoline accounting for 50% and 41%, respectively, of transport's TFC in 2021. Diesel's share has been increasing since 2005, slowly replacing gasoline, but this trend slowed after 2013. The share of gasoline slightly increased for the first time in 2021. The share of electricity has been constant at around 5% over the past decade, mainly used in rail. Biofuels accounted for 3% in 2021, a significant increase since 2014, when they accounted for just 0.3%. Natural gas is barely visible on Figure 3.4 as it only represented a steady share of 0.3%, around 1 PJ every year.

Figure 3.4 Total final consumption in transport in Switzerland by energy source, 2005-2021



Notes: Transport sector demand excludes international aviation and navigation. *Natural gas* is barely visible at this scale.

Source: IEA (2022), World Energy Balances.

Policies and measures in the transport sector

Switzerland's total vehicle fleet has been continuously expanding and reached 6.4 million in 2022. The passenger vehicle fleet was just over 4.7 million vehicles and the light duty vehicle fleet just over 420 000 vehicles in 2022. A key characteristic of the Swiss passenger vehicle fleet is the high share of all-wheel drive vehicles that tend to be heavier and hence consume more fuel and emit more emissions. At the same time, the share of EVs is expanding fast and accounted for 2.3% of all passenger cars in 2022.

Vehicle emissions and fuel consumption

CO_2 emissions regulations for new passenger cars and vans are based on EU regulations. At the end of 2020 they were set at 118 g CO_2/km for passenger cars, and 186 g CO_2/km for vans and light duty vehicles; this was the first time a target was set for this vehicle category. The proposed CO_2 Act currently in parliament includes provisions to further tighten the standards in line with those under the European Union's Fit-for-55 package. It also includes provisions to introduce CO_2 emissions targets for heavy-duty vehicles that are currently not included in the regulation.

Vehicle importers that are not in compliance with the CO_2 requirements must pay a penalty. In 2020, importers had to pay a penalty of CHF 132 million for new passenger car imports. The penalty was just CHF 28 million in 2021, with the average CO_2 emissions for new passenger cars at 129.8 g/CO_2. Since the method of calculating emissions was different in 2021 than in 2020, an inter-annual comparison of average fleet emissions is not useful. As passenger vehicles with all-wheel drive accounted for almost 48% of newly registered vehicles in 2021, the average CO_2 emissions of newly registered passenger vehicles would have been higher if the share of new EVs had not increased notably to reach 22.5% of all new registrations. The average fuel consumption of the new passenger vehicle fleet is also showing a declining trend, in line with a reduced share of newly registered SUVs since 2018 and the increase in EVs. Based on the new calculation method, it was 6.12 litres per 100 kilometres (km) (in gasoline equivalent). Emissions and fuel consumption of vans and light duty vehicles are also declining, with the increasing share of EVs in this category that accounted for 5.5% of new registrations in 2021. Transport

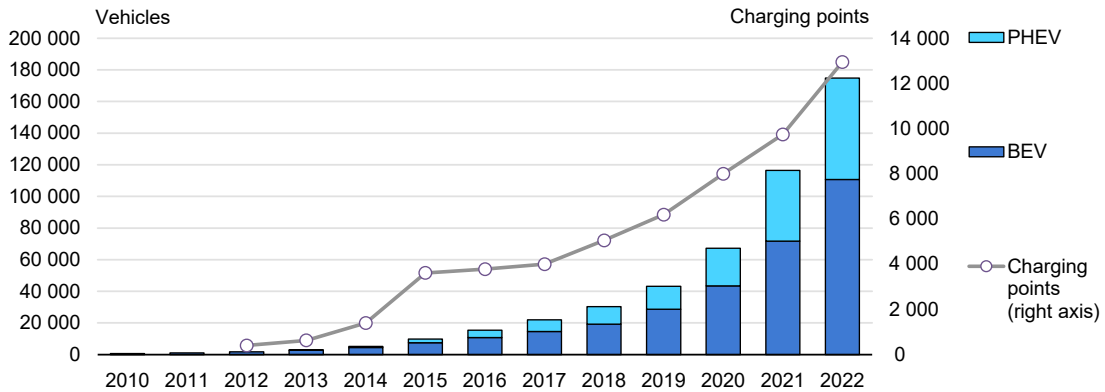
fuels are not included under the CO_2 levy; instead, fuel importers and producers are obliged to partially compensate for the emissions caused by transport (see Chapter 2).

Electric mobility

EVs experienced a rapid increase, from 1 044 vehicles in 2012 to 174 796 in 2022. Despite the Covid-19 pandemic and the subsequent decrease in transport TFC, the number of registered EVs and public charging points continued to increase from 2020 to 2022. In 2022, there were 110 751 battery electric vehicles (BEV) and 64 045 plug-in hybrid (PHEV) electric vehicles, along with 12 949 public charging points (Figure 3.5).

Several cantons have introduced tax exemptions for BEV and fuel cell EVs. Fuel cell EVs are exempted from the mineral oil tax. In addition, heavy-duty fuel cell and battery electric trucks are also exempted from the heavy vehicle fee.

Figure 3.5 Registered electric vehicles and public charging points in Switzerland, 2010-2022



Note: Data for charging points for 2012 to 2019 are from the IEA; data for 2020 to 2022 are from the Swiss Federal Statistical Office.

Sources: IEA (2022), Global EV Data Explorer; Switzerland, Federal Statistical Office, Stock of Passenger Cars by Fuel Type, 2023.

In 2018, the government, jointly with stakeholders, launched the "electromobility roadmap" with the aim of reaching a share of 15% in the registration of new passenger plug-in EVs (pure electric cars and plug-in hybrids) by 2022. This target was achieved much earlier due to efforts made by the car import industry and the changing preferences of the population. In 2022, newly registered plug-in EVs accounted for almost 26%. In consultation with stakeholders, the government prolonged the roadmap to 2025 and set three stronger targets.

First, the share in the registration of plug-in EVs should reach 50% by the end of 2025. Second, by the end of 2025, 20 000 generally accessible charging stations should be available on a voluntary roll-out basis. In January 2023, there were 9 132 stations. To promote the development of a comprehensive network of fast-charging stations along the national roads, the federal Act on National Roads was amended in 2018 to allow the construction and operation of fast-charging stations at rest areas along national roads under the federal remit. However, in line with Switzerland's subsidiarity principal, the federal government will not build and operate the charging stations itself. Instead, this will be done by private investors. By the end of 2023, 67 of the 100 rest areas will be equipped with fast-charging stations. This will offer a fast-charging station every 20 km based on the

national road network of 2 250 km. The Swiss charging station network will thus be three times denser than the European Union's alternative fuels infrastructure regulation requirements.

The third target relates to the expansion of the charging infrastructure in multi-party residential buildings, at companies and roads not under the federal remit. For this, the proposed CO_2 Act includes a provision of CHF 210 million over seven years. Since most of the population lives in rented accommodation or owns a home in a multi-party building, it will be important to also tackle the legal challenges for installing charging infrastructure in residential buildings and to create an enabling regulatory framework. The creation of a comprehensive charging infrastructure in buildings is also part of the building hub concept that is being promoted with the new MuKEN 2025.

Another point for consideration is the reducing penalty payments by vehicle importers with the increasing share of EVs. The penalty payments are paid into the fund created under the CO_2 Act and are used to finance climate and energy efficiency measures (see Chapter 2). The government may need to compensate for diminishing penalty payments to ensure the ongoing financial support for the energy transition.

Modal shift policy

Switzerland is pursuing a modal shift towards the use of public transport, car sharing, and walking and cycling for passenger travel and freight transport. Yet, travel by passenger car remains the dominant form of transport despite an excellent public transport system. However, travel by private passenger vehicles in 2021 was still below the pre-Covid level and about the same level as in 2016.

A car-sharing strategy was developed in 2022 to promote sharing offers through various means, such as open data applications (and will be published soon). This will include a series of measures to promote sharing. To facilitate the dissemination of sharing, SwissEnergy has launched a data service that provides a map of shared vehicles. The map shows the location and availability of each vehicle (station-based and free-floating) in real time. These data could also be used to measure the success of the policies.

Supports and measures are also in place for cycling and walking, with budgets available to subsidise projects. The government is also actively promoting the use of bicycles among distinct target groups. For this, schools and municipalities have rolled out several initiatives. The budget for these types of activities is CHF 1.2 million annually. In 2018, Switzerland voted to include the promotion of cycle paths in its Constitution, providing impetus for further action in this area. In relation to micro mobility, a number of cantons already provide incentives for the purchase of e-bikes.

Despite these measures, the number of journeys by car remains dominant outside of urban areas. The government sees mobility pricing[4] as an opportunity for a more efficient transport system and therefore supports feasibility studies to further specify mobility pricing projects. Together with interested cantons and municipalities as well as the Swiss railway company, DETEC has identified five project ideas. All cover public transport and will analyse the instruments needed for implementation, the actual cost and revenues to be

[4] Mobility pricing aims to reduce peak transport demand hours and more evenly distribute demand for transport (individually and public) over time by pricing transport demand based on time of usage. This helps achieve more equal use of transport infrastructure by pricing transport demand.

expected, and if the proposed measures such as pricing usage during peak hours and promoting flexible working and education hours will indeed result in the expected outcome. The results of the studies are expected in 2023.

Since the beginning of 2001, lorries on all Swiss roads pay a distance-, weight- and emission-related fee. Two-thirds of the revenue from the fee flows into the Rail Infrastructure Fund, which is used to finance the new railway link through the Alps, among other things. The proposed CO_2 Act mentions additional measures, such as a CO_2 emissions target for heavy-duty vehicles. In 2020, a total of 214 electric lorries were registered, with the number of newly registered electric lorries increasing by 160% between 2020 and 2021. The current exemption of electric and hydrogen vehicles from the performance-related heavy vehicle charge is to be legally fixed until 2030 in the proposed CO_2 Act.

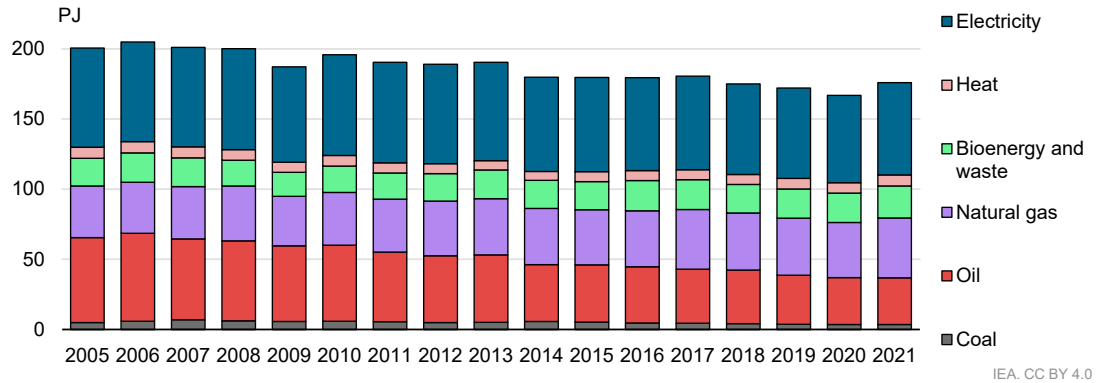
The government has a mandate to shift freight from road to rail, especially for crossing the Alps. For this, the country is heavily investing in improving railway infrastructure and has opened the rail network to third parties, among other measures. As a result, the number of heavy goods vehicles passing through the Swiss Alps has fallen to below 1 million. The government estimates that without these measures, around 800 000 additional lorries and semi-trailers would now be crossing the Alps every year.

Industry

The Swiss industry sector is characterised by the ongoing shift out of energy-intensive industries (such as refining) towards less energy-intensive and mainly electricity-driven industries (such as machinery). Industry is the sector with the lowest TFC; in 2021, its share of energy consumption was 23% (177 PJ), 8% lower than 2011.

Industry demand decreased by 3% from 2019 to 2020 due to the Covid-19 pandemic, but rebounded by 5% from 2020 to 2021, reaching a similar level as in 2018 (Figure 3.6). In 2021, the main energy source in industry was electricity, accounting for 37% of consumption, a high share compared to the IEA average of 23%. Natural gas accounts for 24%, oil for 19% and coal for 2%. Bioenergy satisfies 13% of energy demand and district heat 4%. Since 2010, the industry sector has reduced the use of coal (-35%), oil (-33%) and electricity (-8%), while increasing the use of bioenergy and waste (22%), natural gas (13%), and heat (8%). In the same period, energy from solar increased by one-third but still accounted for just 0.1% of the TFC of industry in 2021.

Figure 3.6 Total final consumption in industry by source in Switzerland, 2005-2021



Note: Industry includes non-energy use (mainly feedstocks for the chemical and petrochemical sector).
Source: IEA (2022), World Energy Balances.

Policies and measures in the industry sector

The EP2050+ Zero Base scenario has estimated the energy efficiency potential in Swiss industry at 15-20%. Large industries participate in the ETS, which was linked with the EU ETS in 2020. The Swiss ETS is small, with just over 95 participants and covering about 10% of national emissions.

Small and medium enterprises (SMEs) can choose between two distinct policy provisions. First, they can choose to either pay the CO_2 levy on their stationary emissions from fossil fuels or they can sign so-called binding target agreements with the government to reduce their CO_2 emissions and benefit from a levy refund. Under the target agreements, SMEs commit to undertake activities selected from a list included in the relevant legal framework. The emissions reductions are monitored and verified. If a company misses their reduction target, a fine is levied.

Second, energy-intensive SMEs that are not covered under the ETS can also be exempted from paying the electricity grid surcharge (levied to promote renewables) if they have signed a binding energy efficiency target agreement. Energy-intensive companies are those which spend more than 10% of their gross value added on electricity. A partial exemption exists for companies paying between 5% and 10% of their gross added value on electricity.

Around 6 000 companies have currently entered target agreements, i.e. a large number of companies are not currently participating. The proposed CO_2 Act currently in parliament foresees that from January 2025, all companies will be able to apply for a refund of the CO_2 levy if they enter into a mandatory efficiency target agreement. However, as only cost-effective measures are mandatory, the overall impact on additional energy efficiency gains is considered limited.

Private sector agencies are closely involved in policy implementation of the target agreements. The Energy Agency of the Economy and Agence Cleantech handle agreements between enterprises and the government, so that these enterprises may benefit from the CO_2 levy exemption, the refund of the grid surcharge and/or comply with the cantonal legislation. The sector is struggling to cope with increasing demand for energy audits, as it cannot find enough skilled professionals to undertake the work. SwissEnergy supports SMEs with training and capacity building. It works closely with other actors to disseminate information and methods for process optimisation and the use of efficient motors and equipment.

Cantons operate their own energy efficiency programmes for industry. For example, in some cantons, large energy consumers can choose to conclude an energy efficiency target agreement with the cantonal authorities instead of the mandatory environmental reporting at the cantonal level.

Public sector

The federal government and the cantons function as a role model for energy efficiency. The same applies for parastatal companies such as the railway and the post. All of the electricity consumed by the federal administration comes from renewable energy sources. However, only a small part of the federal administration's energy consumption is self-produced. The draft Energy Amendment Act states that all of the federal

administration's or parastatal enterprises' buildings' roofs or facades should be used for PV or solar thermal (with some exceptions, such as heritage buildings).

The Resource Management and Environmental Management System of the Federal Administration (RUMBA) was adopted on 1 January 2017. It focuses on buildings (electricity, heating, water, and waste), paper consumption and service travel. RUMBA co-ordinates the federal administration's environmental activities, improves efficiency to save costs, and reduces the environmental burden and GHG emissions while raising employee awareness. Under the Climate Protection Act, the federal administration, the cantonal administrations, and parastatal companies commit to net zero emissions by 2040. Despite the successes since the launch of RUMBA, there is still potential to be exploited.

Since 2014, the government has been working with the Federal Institutes of Technology (ETH), parastatal companies and the cantons as part of the Exemplary Energy Initiative to promote innovative and exemplary energy management.

Assessment

Switzerland shows notable decoupling between energy consumption and economic growth. TFC decreased by 5% from 2011 to 2021 while GDP increased by 17% and the population by 10%. The ES2050 strategy sets indicative targets for per capita energy and electricity consumption for 2020 and Switzerland has overachieved these targets even after accounting for the impact of the Covid-19 pandemic on TFC in the same year. The energy efficiency improvements were mainly driven by technology improvements, such as the introduction of improved lighting and appliances and fuel substitution. Structural changes, such as a shift from industry to services and a reduction in the share of energy-intensive industries, contributed to diminishing TFC.

To reach the ambitious energy efficiency targets set for 2050, it is important that energy efficiency as the first fuel is anchored as a pillar of the new legislation. Equally important is the conversion of indicative into binding targets as proposed in the energy amendment package. The federal government is responsible for minimum energy performance standards for vehicles, systems, and appliances and for energy labelling. The cantons are responsible for energy in buildings.

Switzerland was successful in achieving efficiency through the introduction of minimum energy performance standards for appliances and lighting. It is moving ahead of the European Union on certain appliances, such as household tumble dryers and water and space heaters. Moreover, on 1 January 2023, the requirements of several additional appliances were further tightened compared to the EU requirements. This was also done with a view to the possible electricity shortages during the winter.

Buildings

Residential buildings is the only sector that saw an increase in TFC from 2011 to 2021. The 5% increase in TFC compares to a 7% increase in residential floor space over the same period. About 60% of residential buildings are heated by fossil fuels while 8% use direct electric heating.

Switzerland has no national building codes or regulations, but each canton sets its own requirements. Instead, norms are codified in the MukEN guidelines and cantons must transpose them into cantonal law. The last revision of the MukEN from 2014, in line with

EU recommendations for near zero energy buildings, has been transposed by 22 of the 26 cantons. The MukEN also set minimum standards for major renovation, including requiring a minimum share of renewables when the heating system is changed.

All cantons have also agreed in principle with the revised recommendations for the next MukEN revision that are expected to be adopted into cantonal law starting in 2025. The basic thrust of this revision is the vision of “energy hub buildings”, reflecting the fact that the building is increasingly becoming the central unit for the consumption, production and storage of energy. The roll-out of smart meters, that is also largely dependent on the cantons, will be critical to realise this concept. Enactment of advanced building norms has gained momentum with the current energy crisis. This contrasts with various cantonal referendums in the years prior to the energy crisis, which rejected more stringent rules for example relating to heating system replacement.

For existent buildings, proceeds from the CO_2 levy have financed a national building refurbishment programme since 2010. The CO_2 levy is set to increase under the draft proposed CO_2 Act. It is a best practice example to allocate taxation revenue on polluting fuels for decarbonisation. Another sign of increased momentum is the fact that since 2020, all earmarked CO_2 levy proceeds were solicited for projects. And in 2021, funding demand exceeded available funds. The continuation of the building refurbishment programme beyond 2025 through various legal provisions reflects a recommendation made in the IEA’s last in-depth review of Switzerland in 2018.

The refurbishment programme currently seems to receive more applications for the decarbonisation of heating over reducing energy consumption. Subsidies may go to oversized heat pumps in insufficiently insulated buildings. The government should consider restricting funding for heat pumps to houses that are still only poorly insulated, as they may prove to be oversized after a building is later insulated.

A large majority of the population rents their home. There therefore is a split incentive when it comes to retrofitting rented homes, with the comfort and energy savings benefits for the tenant rather than the owner who pays for the improvements. It is estimated that 30 000 heating systems will need to be replaced annually, along with other building energy upgrade works, to reach the net zero target in 2050. This level of building activity stresses the need for additional capacity in the construction sector. The 2022 roadmap to increase the number of more qualified people in the buildings sector is a commendable initiative.

To entice landlords to refurbish, costs for efficiency measures can be deducted from taxes. Since 2020, owners of large residential buildings are eligible for a larger share of support for refurbishment and replacement measures, which reflects a recommendation made in the IEA’s 2018 review. Tax breaks are also in place for fully demolishing buildings, which could incentivise rebuilding rather than retrofitting. The embodied carbon emissions associated with the demolishing and rebuilding rather than retrofitting should be examined.

Other IEA countries address the split incentive either by allowing the landlord to increase the rent (to reflect the higher value) and/or to directly subsidise the landlord for the investments made. Switzerland could also study the experience with a new legal provision in Germany, which requires landlords to share the CO_2 price of the heating bill with the tenants on a sliding scale set in relation to the energy rating of the building.

In January 2023, the SFOE published its Heat Strategy to achieve a 30% reduction of total heat demand in 2050, a substitution of energy carriers and sector coupling to reach the

net zero target. The strategy sets out measures for ten areas, including building efficiency; thermal storage networks; process heat; synthetic fuels; co-ordination of federal, canton and municipal policies; legal framework; and training of professionals.

Transport

Transport demand did not rebound significantly after the Covid-19 pandemic in 2021 and remained 7% below the 2019 level. Switzerland's total vehicle fleet has been continuously expanding and is characterised by a high share of four-wheel drive vehicles and a rapidly increasing share of EVs. To reduce emissions and energy demand in the transport sector, Switzerland is pursuing a shift to electric mobility and a modal shift towards public and rail transport, car sharing, and walking and cycling.

Switzerland's CO_2 emissions norms for new vehicles are aligned with EU regulations; the latest standards came into effect on 1 January 2020. The draft proposed CO_2 Act includes provisions to further tighten standards in line with the European Union's Fit-for-55 regulations. Vehicle importers are obliged to pay a penalty if the average emissions of the imported vehicles do not comply with the requirements. Transport fuels are not included under the CO_2 levy; instead, fuel importers are obliged to partially compensate for the emissions caused by transport by funding eligible energy savings and carbon abatement projects.

A combination of fiscal advantages, commitment by the car importers and shifting preferences of the population allowed Switzerland's electric mobility roadmap to achieve its targets for 2022 (share of EVs, number of charging stations) well ahead of schedule. The roadmap was extended to 2025 and the targets tightened. As the share of EVs in newly registered vehicles grew strongly across all vehicle types, the government's focus in now shifting towards creating more enabling conditions for the roll-out of the charging infrastructure.

For this, the government has proposed in the draft proposed CO_2 Act to provide CHF 210 million over seven years to accelerate the expansion of the charging infrastructure in multi-unit buildings, at companies and on roads. However, creating enabling legal and regulatory conditions to facilitate the roll-out is equally important. Further, the government modified the legal framework to allow the construction of charging stations at rest areas along national roads in the federal remit. By the end of 2023, there will be a fast-charging station every 20 km, which will make the Swiss charging network three times denser than the requirements set by the European Union.

The Swiss modal shift policy for freight transport, a combination of levying a distance-, weight- and emissions-related fee on heavy goods vehicles and a substantial investment in rail infrastructure, has successfully reduced the volume of freight traffic through the Alpine region. According to government estimates, without these measures, around 800 000 additional lorries and semi-trailers would now be crossing the Alps every year. The government is also considering the introduction of CO_2 emissions norms for new heavy good vehicles to further encourage the modal shift.

Switzerland already has an excellent public transport system, which is continuously improved. Planned measures include optimisation of the network and easier to use services, which is welcomed. As part of a new car-sharing strategy, SwissEnergy launched a data service that provides a map of shared vehicles. The map shows the location and availability of each vehicle (station-based and free-floating) in real-time. The government

should consider how to use the data to measure the success of the policies. In 2018, Switzerland voted to include the promotion of cycle paths in its Constitution, providing impetus for further action in this area.

Despite the comprehensive measures to support the modal shift, private passenger vehicles remain the dominant form of transport, although the number of journeys by car has not yet recovered from the Covid-related restriction in 2020. There are opportunities to consider a larger implementation of mobility pricing. The launch of several feasibility studies on this issue is welcomed.

Industry

Switzerland has relatively little heavy industry and a lot of electricity-driven manufacturing. Therefore, industry is the sector with the lowest share in TFC. The energy efficiency potential in Swiss industry is estimated at 15-20%.

Switzerland has successfully aligned its ETS with the EU ETS since 2020. Only about 95 large industries participate in the ETS and account for about 10% of Swiss emissions. SMEs have the option to conclude an emissions reduction target agreement with the government to benefit from a refund of the CO_2 levy. Energy-intensive SMEs can also opt to conclude an energy efficiency target agreement to benefit from a refund of the grid surcharge. Target agreements only allow projects for energy savings in the SMEs that signed the contract. While it is important to find a balance only around 6 000 companies are currently covered by target agreements and the proposed CO_2 Act under discussion proposes that all companies be able to enter mandatory energy efficiency agreements from 2025 onwards. However, the impact on additional energy efficiency gains from this provision is unclear. The government could consider allowing the companies to deliver energy savings projects outside their own business, but within Switzerland, to incentivise further savings that would not otherwise happen.

The CO_2 tax and the grid surcharge are important revenue streams to fund measures for promoting energy efficiency and renewable energy (see Chapter 4). It will be important to ensure that broadening the eligibility for target agreements to smaller companies does not result in allowing weaker conditions to be met over time, as this would ultimately hamper the efficacity of the target agreements. The goal should be to maximise the efficiency gains and CO_2 reductions overall.

In accordance with the Swiss subsidiarity principle, private sector agencies are closely involved in delivering energy savings under the target agreements. They have seen demand for their services rise rapidly but are struggling to find enough skilled professionals to undertake the work.

Public sector

To cement its role as an example for energy efficiency and emissions reductions, as provided for in the ES2050, the public administration has committed to net zero emissions by 2040 under the Climate Protection Act. The central cantonal administration and the federal parastatal enterprises committed to aim to reach the 2040 net zero target.

To reach that commitment, the government will, among other measures, install PV or solar thermal on all of the federal administration's and parastatal enterprises' buildings' roofs or facades, with certain exemptions, including for protected buildings. Since 2017, the

RUMBA mandates the federal administration to focus on measures targeting buildings, paper consumption and service travel. Despite the progress made, there is still potential to further reduce consumption, particularly in the heating, electricity and mobility sectors.

Recommendations

The government of Switzerland should:

- ☐ Establish the energy efficiency first principle in the energy and climate legislation to ensure it is considered and implemented in all relevant policies and plans.
- ☐ Assess the extent of the split incentive problem in the rental sector and consult with landlord and tenant groups on measures to address the issue.
- ☐ Place a greater emphasis on avoiding car journeys by further encouraging modal shift, such as through disincentives for driving in cities.
- ☐ Ensure that the exemplary role of the public sector in energy efficiency and renewables set out in the RUMBA is realised, for instance by urgently implementing the renovation plan for the public sector and encouraging cantons to develop similar strategies for their own public sectors.

4. Renewable energy

Key data (2021)

Renewables in total final energy consumption (TFEC):* 205.4 PJ or 27% of TFEC; (hydro 112.5 PJ, bioenergy** 70.3 PJ, solar 12.1 PJ, wind 0.48 PJ)

Renewables in electricity generation: 42.0 TWh or 66.6% of electricity generation (hydro 37 TWh, bioenergy** 2.1 TWh, solar 2.8 TWh, wind 0.15 TWh)

Renewables by sector: 34.6% in buildings, 26.9% in industry, 7.1% in transport

*Total final energy consumption excludes non-energy use, which is counted in total final consumption.

***Bioenergy* includes solid biomass, liquid biofuels, bioenergy (electricity) and biogas.

Source: IEA (2022), World Energy Balances.

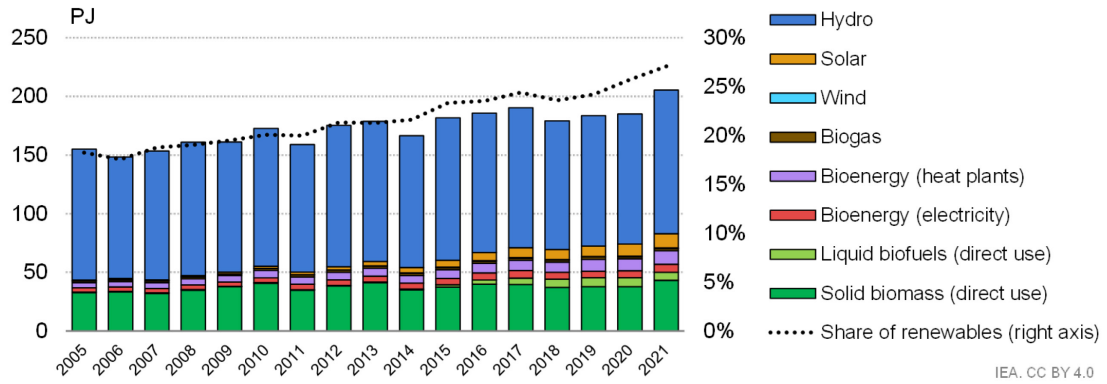
Overview

Renewable energy will play a crucial role in filling the gap of nuclear power, which is to be phased out, to maintain and even further enhance the low-carbon intensity of the Swiss power sector to achieve net zero emissions by 2050. Beyond hydropower, solar PV is expected to contribute the most to the growth of renewables. Achieving these goals requires a more effective policy framework and better-targeted support programmes, resulting in higher deployment rates. The government has launched new laws and other initiatives to support the construction of new renewable projects to address the issue of the complex and long approval processes.

Switzerland has the tenth-highest share of renewable energy in TFEC among IEA member countries. In 2021, 27% of TFEC[5] came from renewables, while the IEA average was 13% in 2021. The main renewable energy source in Switzerland is hydropower, followed by the direct use of solid biomass (Figure 4.1). TFEC of renewables has increased by 29% since 2011, mainly due to the increase of energy from solar and liquid biofuels. In 2021, the share of hydro was the second largest (14%) in TES and the third largest in electricity generation (59%) among IEA member countries. Both solar and biofuels increased steadily from 2015 to 2021, from 0.8% of TFEC to 1.7% and from 0.3% to 0.9%, respectively.

[5] TFEC excludes non-energy use, which is counted in total final consumption (TFC). TFEC provides a more accurate assessment of the share of energy demand covered by renewable energy and is better aligned with the European Union's gross final energy consumption metric, which is used to set EU member states' renewable energy targets.

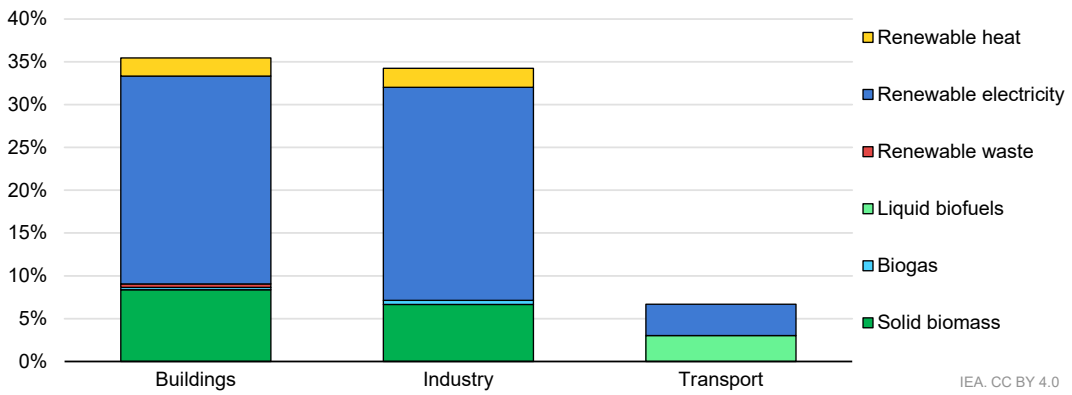
Figure 4.1 Renewable energy in total final energy consumption in Switzerland, 2005-2021



Source: IEA (2022), World Energy Balances.

In 2021, renewables provided 35% of TFEC in buildings, 27% in industry and 7.1% in transport. Renewable electricity was the main source of renewable energy, covering 24% of buildings TFEC, 17% of industry and 4% of transport. Solid biomass provided 7.6% of energy in buildings and 8.3% in industry; liquid biofuels had a share of 3.4% of transport energy demand (Figure 4.2).

Figure 4.2 Share of renewable energy by source in each of Switzerland's sectors, 2021



Source: IEA based on data from Eurostat

Renewable energy policies

There are no national targets for the share of renewables in TES or TFC; instead, targets are set for renewable electricity generation only. This is mainly because building policy and hence heating and cooling is the prerogative of the cantons; the federal government only has limited policy-making power in those sectors. In the transport sector, the government is implementing a set of voluntary measures to increase the use of renewables, which is guided by the overall target for meeting the commitment under the Paris Agreement and eventually the net zero emissions target for 2050.

The SwissEnergy Programme, a unit under the SFOE, supports households, industry and the service sector in undertaking voluntary measures for energy efficiency improvements and a shift to renewable energies to advance the implementation of Swiss energy policy

and the ES2050. For the second phase (2011-20), the SwissEnergy Programme implemented measures to support the government targets of increasing the share of renewable energy in TFEC by at least 50%, to eventually reach a share of 24% renewable energy in TFC. Though its share in TFEC did not increase by 50% from 2011 to 2020, it was, however, 25.7% in 2020.

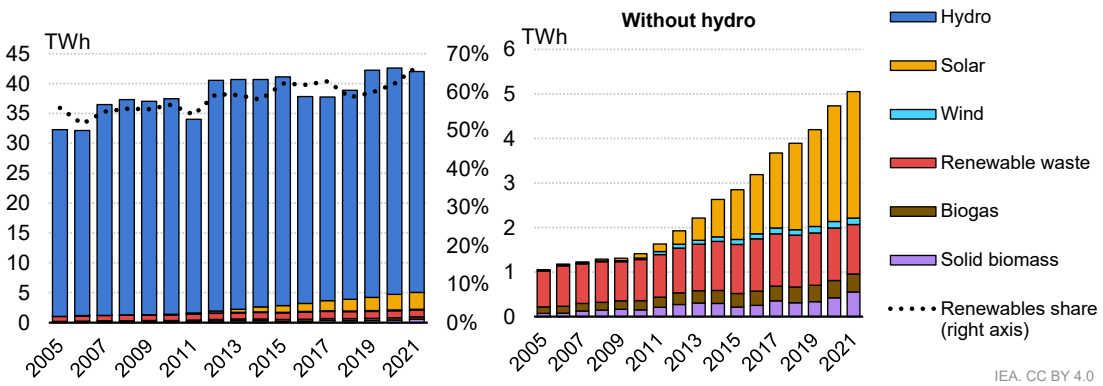
Now in its third phase (2021-30), the programme focuses on three priority areas: 1) energy efficiency in buildings and renewable energies in private households; 2) mobility for private households and businesses; and 3) installations and processes in industry and the service sector. However, no new quantitative targets appear to have been set for the third phase.

Renewable electricity

In 2021, 42 TWh (67%) of the 63 TWh of total electricity generation came from renewable energy sources (Figure 4.3). In the same year, hydropower accounted for 59% of total electricity generation. Since 2010, the share of renewables in electricity generation has been increasing, despite minor fluctuations.

Renewable electricity generation rose by 24% from 2011 to 2021. Electricity from hydro increased by 14%, but solar PV experienced the largest growth: it increased from just 0.17 TWh in 2011 (0.3% of total electricity generation) to 2.8 TWh in 2021, which accounted for 4.5% of total electricity generation. The increase in electricity generation from solar PV accounted for one-third of the total growth of electricity generation from renewables between 2011 and 2021.

Figure 4.3 Renewable energy in electricity generation in Switzerland, 2005-2021



Source: IEA (2022), World Energy Balances.

Renewable electricity policies and measures

Switzerland has set indicative targets for renewable electricity generation in the ES2050. The fourth monitoring report of the ES2050 from December 2021 noted that Switzerland achieved the targets for 2020, with generation from renewable energies, excluding hydro, reaching 4.7 GWh against a target of 4.4 GWh. However, the development differs per technology, with the strongest growth from solar PV. To reach the target for renewable generation (excluding hydro) of 11.4 TWh in 2035, an annual net growth of 450 GWh is required.

With the commitment to net zero emissions in 2050, the indicative targets set under the ES2050 are no longer sufficient as Switzerland prepares for rapid electrification in the transport and building sectors. The renewable electricity generation targets have been revised upward under the EP2050+ and consequently transposed into the federal Act on the Secure Electricity Supply with Renewables to make them binding (see Table 1.2 in Chapter 1). The so-called energy amendment package is currently under parliamentary debate and is not expected to enter into force before 2025.

The enhanced target for renewable generation by 2035 of 17 TWh, excluding hydro, requires a net growth of 820 GWh annually, the majority of which would come from solar PV. In 2035, solar PV would produce 14 TWh, compared to 2.9 TWh in 2021. This would use about one-third of the estimated potential of solar PV installations on existing building roofs. For solar, reaching the generation target by 2035 would require doubling the annual installation rate from 1 000 MW in 2022 to 2 000 MW by 2030. In addition to solar, the government also plans to accelerate the roll-out of wind power, though significant hurdles will need to be overcome. Parliament has decided to increase the target for non-hydro renewable electricity from 17 TWh to 35 TWh for 2035.

Switzerland has been wanting to explore its geothermal energy potential for a long time. Geothermal energy is a cantonal responsibility and as such, different regulations exist in each concerned canton. However, with the country's commitment to reaching net zero emissions in 2050, interest in geothermal and financial support schemes is growing, as it has the potential to contribute to electricity generation, heating and cooling needs, and provide energy storage.

The key policy instrument to support renewable electricity was a cost-reflective feed-in tariff (FiT), introduced in 2009. Solar, wind, biomass, geothermal and small hydro plants with a capacity of up to 10 MW were eligible technologies. Large hydro plants did not qualify for the FiT. The FiT scheme was so successful that applications vastly exceeded the available funds, which are collected through the network surcharge levy that was successively increased. The government introduced several changes to the FiT scheme by excluding certain types of renewable projects and instead offering them a one-time investment aid. Other projects were offered the same investment aid or the choice to stay on the ever-growing waiting list for the FiT without any guarantees that the projects would eventually receive the FiT.

The ES2050 legislative package comprehensively revamped the support mechanisms for renewable electricity technologies in 2018. They were recalibrated to address the problems encountered with earlier support programmes, facilitate market integration of renewable power facilities and achieve the long-term renewable generation targets. The new financial support mechanism for renewable electricity under the ES2050 consists of three pillars, which are all financed from the network surcharge: 1) move from FiT to feed-in premiums and direct marketing; 2) broaden eligibility criteria for the one-time investment support; and 3) sunset clauses for support for all new installations. Plants that receive FiT can continue receiving it until their remuneration period is expired.

To further ensure the ramp-up of renewable electricity generation in line with new, more ambitious targets, the government is making further revisions to the support instruments and non-financial framework conditions. Several legal proposals are at various stages:

(i) The "Uniform support for renewable energies" amendment to the Energy Act entered into force on 1 January 2023. It implements the switch from feed-in

premiums to one-time investment support for wind, biogas, geothermal and new small hydro plants from 1 MW to 10 MW. Available funds for large-scale hydropower plants will be doubled. The one-time remuneration for large solar PV (> 150 kilowatts) without self-consumption will be tendered. This change only impacts new plants. As specified by parliament, the law anticipates an additional 11 TWh produced by renewable sources by 2030, compared to 2021; 75% of this would be solar PV, 11% large hydropower and 7% biomass.

(ii) The energy amendment package is currently under deliberation and includes the revision of the Electricity Supply Act and the Energy Act. The draft includes a provision that for some specific strategic hydropower plants, reaching the renewable electricity production targets should take priority over environmental legislation and should not be constrained by environmental requirements.

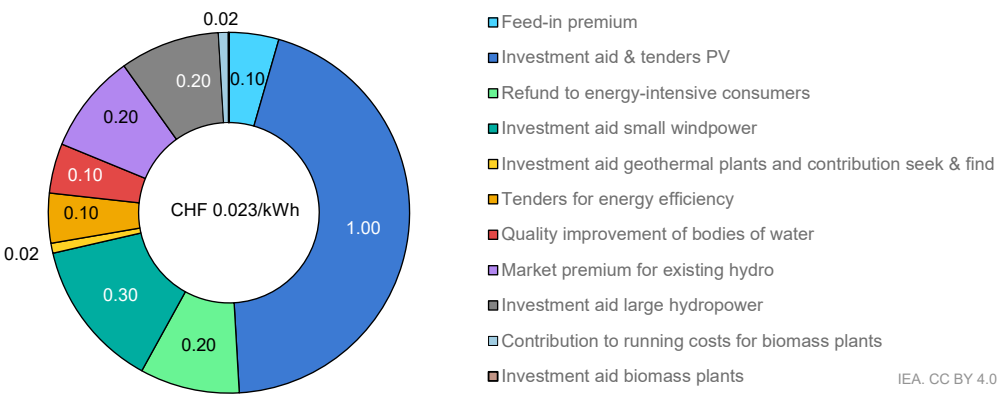
(iii) The revision of the Energy Act includes the following main elements:

a. Targets for 2035 for hydro and non-hydro renewable electricity.
b. An extension of the provision of the one-time investment support from 2030 to 2035 to align with the period for which the targets are set to provide planning security for investors.
c. The introduction of a right to choose between one-time investment support and so-called market premium (contract-for-differences).
d. Several proposals to provide faster and simplified approval procedures. In particular, hydro and wind power projects are currently delayed due to long and complex procedures.

(iv) The long- and short-term wind power initiatives aim to speed up the approval processes, which have been the main reasons for the rather slow expansion of wind power in Switzerland.

Since 1 January 2018, the network surcharge has been 0.023 CHF/kWh and continues to be the main funding source. It has a fixed allocation for specific technologies and support mechanisms (Figure 4.4). The grid surcharge will continue to fund the projects until 2035, though the surcharge will not be increased any further. About CHF 1.3 billion per year are collected through the network surcharge.

Figure 4.4 Allocation of network surcharge by funding mechanism in Switzerland, 2022



Source: IEA based on information provided by the SFOE.

Measures to strengthen hydro production

Hydropower is the largest power generation source in Switzerland, accounting for more than 50% of total generation, albeit with notable annual fluctuations. Hydro is expected to make up for parts of the lost nuclear generation from the planned phase-out. Hydro generation is expected to increase from 36 TWh in 2020 to 37.4 TWh in 2035. This would require annual net growth of about 70 GWh.

Existing large hydro plants benefit from a market premium, which is financed by the network surcharge to help plants compete in the electricity market. The market premium was introduced to cover losses of Swiss hydro generators when European wholesale prices were below the generation costs of many Swiss plants. As wholesale prices increased, disbursements decreased. The network surcharge is also used for investments in new, expanded and renewed large-scale hydropower. New small hydro projects (< 1 MW capacity) typically do not receive support, as they are seen as carrying too high environmental costs.

Hydro plant operators typically operate under concessions from cantons and local authorities that last 60-80 years. Cantons and local authorities receive a so-called water royalty that often constitutes a major part of income, especially in smaller, less economically diversified communities. A number of those concessions will expire in the coming decades starting in 2030, and some cantons have expressed an interest in taking over the operation and management of those hydro facilities themselves. Under Swiss law, a change of concession would introduce stricter targets for residual water flows (that cannot be used for electricity production). The government estimates that a change in concession could result in a loss of around 1.9 TWh of annual hydro production.

A roundtable of hydropower consisting of a large number of diverse stakeholders has identified 15 hydro storage projects that would enable the production of 2 TWh from seasonal storage facilities by 2040. The draft law providing the framework conditions for a fast implementation of the 15 identified hydro storage projects will be introduced for a first reading in parliament in the first half of 2023. Key provisions in the law are that a planning permit is only required for projects in new locations and is limited to the structural plan for spatial planning. Further, for the first time, implementing these 15 hydro storage projects is considered to be of higher national importance than other concerns – and this would also be extended to future solar and wind power installations if certain measures to protect the landscape and biodiversity are complied with.

Addressing the winter shortage of domestic electricity generation

Typically, during the winter season, Switzerland is a net electricity importing country as hydro inflow is low. Imports from France make up a large part of the deficit. For the winter of 2022/23, however, given the low availability of nuclear power in France, Swiss policy makers geared up to address possible short- and longer term winter electricity shortages (see Chapters 1 and 6). The situation also gave renewed impetus for earlier initiatives to facilitate the construction of solar projects in environmentally more sensitive areas, increase the dam height of certain hydro projects and introduce an obligation for new buildings above a certain size to use solar for part of their energy consumption to address longer term climate and energy targets. The target is to install an additional 6 TWh of renewable capacity by 2040 to ensure security of supply in winter.

The so-called alpine solar initiative, included in the officially entitled "Urgent measures to ensure the short-term security of electricity supply in winter" was introduced by the upper chamber of parliament, representing the cantons, before being discussed and modified by the lower chamber, representing the popular vote, and sent back to the upper chamber. The change of law came into effect on 1 October 2022. The provision in the law is only valid for three years.

The change of law was initiated to facilitate the construction of two large solar PV installations in the canton of Wallis/Valais and provides the legal framework for similar initiatives in other mountain areas that were earlier protected from large constructions. However, certain environmental restrictions still exist, and all large alpine solar projects will still be subject to an environmental impact assessment. The law includes a provision that the facilitation of such large projects in the mountains will only be allowed until an annual production of 2 TWh from those installations is reached. Projects will be eligible for a federal subsidy of up to 60% of investment costs, with each project individually decided upon. The subsidies will be funded from the grid surcharge.

A key argument in favour of these projects is that they would be installed at heights that offer substantially greater production potential, up to 40% by some estimates, compared to installations at lower heights. However, the connection to the electricity grid would generally be more costly than for PV installations in the existing distribution network. Moreover, they are available in winter, when large parts of lower Switzerland are often covered with fog and/or clouds. But they are expensive; some estimates put their production price as double or triple those of solar parks at lower heights, and their long-term funding is uncertain. Moreover, the installation of large solar parks in mountainous areas brings environmental concerns, as a large part of the potential sites has so far been exempted from construction.

Switzerland has also permitted the construction of some floating PV installations on lakes/hydro waters as well as PV installations on the dams of large reservoir lakes. The rationale is that they are not using additional free areas and benefit from longer and more intense sunshine in winter when Switzerland needs the electricity most.

Regarding hydropower, the law intends to resolve the 30-year-long legal fight about the increase of the dam of the Grimsel hydro plant in the canton of Bern. The dam would be raised by 23 metres, which would almost double the capacity of the storage basin. However, the project still needs to receive a construction permit, which again would be open to legal opposition. Though some environmental groups have now signalled support for the project as the additional electricity production is part of the country's net zero emissions goal for 2050, local opposition continues. Given the administrative process and the complexity of the actual construction, the increased dam would be completed at the earliest in the second half of the 2020s.

In September 2022, the Federal Council approved a time-limited measure to increase hydropower availability during the winter of 2022/23. Plants that meet increased ecological requirements were allowed to use more water for electricity production from 1 October 2022 to 30 April 2023, equal to an additional production potential of 150 GWh.

Wind power initiatives

Switzerland has a significantly larger wind power potential than previously assumed, provided the necessary framework conditions are put into place. There is a small but very

active opposition to wind energy in Switzerland, and it can take up to 20 years from the start of a project for it to receive a legally binding permit. At the same time, wind is identified as a major complementary power-producing source to solar and hydro generation.

Hence, the government is discussing two wind energy offensives – one on a short-term basis and the other on a long-term basis – to speed up the approval processes, the main reasons for the rather slow expansion of wind power in Switzerland. If passed, the short-term wind offensive would be applied to at least six wind parks in the next two or three years: three in the canton of Vaud, one in the canton of Solothurn, one in the canton of Valais and one in the canton of Neuchâtel. The quicker approval process would be applicable until a total of 600 MW of additional wind power has been installed.

The long-term wind offensive will reduce the protracted planning process and is contained in the single amending act. The proposed new framework will prescribe that wind energy projects be planned and approved in one combined procedure (land-use planning together with a construction permit). This would mainly reduce the possibilities for objections, which have always been used in recent years and have led to long delays in the realisation of the projects.

Simplifying and shortening approval processes for renewable projects

The key challenge for renewable projects, but also power grid extensions, is the long permitting process, which is mostly due to the complex administrative procedures where permits are partially granted by the cantons and/or the municipalities and partially at the federal level and due to very far-reaching possibilities for objections. A way forward would be to streamline the process by assigning a single point of contact for project developers either at the cantonal or federal level (see Chapter 1).

Already today, the federal level operates the so-called "guichet unique" for wind power projects. This single point of contact co-ordinates all the procedures at the federal level and also acts as a competence centre to answer questions about the procedures. Still, the *guichet unique* cannot intervene with procedures and decisions at the cantonal and municipal levels. The government should consider introducing the concept of a fast-track permitting procedure for very large projects, in which the administration has a time limit, for instance, three years, to issue final permits for prioritised renewable projects.

Since 2018, large hydro and wind projects have been considered of national interest, meaning that for these projects, the environmental and energy interests are valued as equal. However, the relative weights assigned to priorities should be better aligned with national interests in energy security of supply, reaching the net zero emissions target and preserving the environment. Assigning a higher priority to renewable energy in the spatial planning and permitting assessment would be an important step forward. This could also result in better co-ordinated and more proactive spatial planning that reflects the high priority of renewable energy projects, among other interests.

Another way to enhance public acceptance is by facilitating multi-stakeholder roundtables for renewables that should focus on engagement and dialogue and take into account preferences at the local level. Further, this process could focus on increasing the understanding of the need for developing renewable energy projects and try to find good local solutions for siting different projects. The roundtable has previously worked well for assessing possibilities for hydro projects in Switzerland and the experiences and results from this process could be used again.

An important aspect is the time spent settling disputes over conflicts of interest. Now, small interest groups and even individuals can lodge an official complaint over project plans and stall the progress for several years due to court cases. There are examples of projects where the permitting has taken decades. Project development with such a timeline is incompatible with the urgency to significantly increase renewable electricity generation in the period to 2030. Enhanced government efforts to maintain the rights of citizens and interest groups to express their opposition to project proposals while ensuring that projects are not delayed excessively would be a welcome development. In some countries, disputes are settled with a simplified procedure without involving the court system; decisions are then taken by a public institution specialised in handling disputes over energy and environmental issues.

Renewable heating and cooling

Renewables account for 10% of TFEC in buildings, of which renewable electricity alone covers almost one-quarter of TFEC. Buildings are the legal prerogative of the cantons. The cantons independently determine which policy measures to take to reduce emissions from the building sector and what support measures to offer even if the MuKEn are the common basis for their energy policies (see Chapter 2).

The cantonal building programme is co-ordinated through the harmonised funding model of the cantons that ensures the co-ordination of the areas of intervention. Even so, incentives for promoting renewables in the heating sector can vary between cantons. Moreover, there are no country-wide targets for increasing the share of renewables in building sector energy consumption. The MuKEn already focus on the replacement of fossil heating systems in the building sector and several cantons have already banned the installation of new fossil fuel heating systems (see Chapter 3). The use of renewable energy for heating more than doubled from 2000 to 2022, using a menu of heat sources such as solar and ambient heat, geothermal energy, and wood, which accounts for the largest share.

The federal government's policy-setting powers are limited, focusing on advice and technical and financial support. One recent federal initiative taken by the SwissEnergy Programme is to require energy consultants to complete training on replacing heating options in different types of buildings. This feeds into a new provision from 1 April 2022 offering free advice to homeowners wishing to replace their fossil fuel or direct electric heating systems that are more than ten years old.

Space heating in many buildings is still oil-based. Most cantons have incentives for phasing out oil use for space heating and installing renewable systems instead. All cantons also focus (but in different intensities) on the expansion of district heating in more densely populated areas. The municipalities exert the greatest influence on the expansion of thermal networks. Waste heat from waste incineration is currently the most widely used energy source in district heating. Some cantons use an obligation to ensure the use of excess heat, although the regulations are tied to economic viability. Switzerland has a significant and underused potential for expanding district heating, estimated to be between 17 TWh and 22 TWh annually.

In general, there is a large potential to increase renewables in the heating sector in Switzerland, with a wide range of solutions such as district heating, solar heat, thermal heat storage, and further use of small- and large-scale electric heat pumps. A Heat Strategy was published in early 2023.

A new law entered into force on 1 October 2022 making it mandatory to install solar PV in all new buildings larger than 300 m^2 in those cantons that do not yet have such regulation since they are not yet applying the MuKEn 2014 (see Chapter 3). In the concerned cantons, 70% of new constructions are excluded from the requirement to install solar PV due to the threshold. Concerned cantons are free to set a solar PV requirement also for buildings below the 300 m^2 threshold, but as of 1 January 2023, none had done so. However, several more have introduced the MuKEn 2014.

Several pilot projects have shown how to integrate PV installations into different types of buildings, including protected ones. This has increased the acceptance of solar PV, which is further strengthened by the recently introduced self-consumption-regulation and communities' models. Under current Swiss law, self-consumption is exempt from charges for using the electricity grid and from additional levies on electricity purchases.

Renewable transport

The transport sector is the largest consumer of fossil fuels in Switzerland and is thus responsible for the largest share of GHG emissions in the economy. The two key policies for increasing the share of renewables in transport are the shift to electric mobility and the use of biogas/biogenic fuels. Further, the government is using voluntary measures and indicative targets to promote renewables in the transport sector.

Under the proposed CO_2 Act currently in the legislative process, the Swiss government will provide substantial resources to extend the charging infrastructure in the country; promote the roll-out of electric and hydrogen-powered buses; and enhance the availability of international rail connections, including through night trains. Existing tax exemptions for heavy goods vehicles using electricity and hydrogen will be extended until 2030.

The Swiss roadmap for electromobility has substantially overachieved its indicative target for 2022 of 15% plug-in EVs among newly registered passenger vehicles, reaching almost 26%. The government subsequently extended the roadmap to 2025 and set a new, more ambitious target to reach 50% of plug-in EVs among newly registered passenger vehicles for that year. Switzerland is also initiating the roll-out of vehicle-to-grid and smart charging technologies that would allow the use of EV batteries to store energy and balance power grids.

Notwithstanding the high share of renewables in the electricity mix, it will take some time for EVs to make a significant contribution to GHG emissions reductions, even though the average age of a passenger car in Switzerland was only 9.3 years in 2021, almost one-third lower than the EU average of 12 years.

The proposed CO_2 Act also contains a blending mandate for biofuels, and Switzerland has put in place sustainability criteria for the biofuels used. Starting in 2025, it would become compulsory to reduce carbon emissions by 5-10% annually by using biofuels. The proposed CO_2 Act also includes a new policy instrument requiring aviation fuel suppliers to blend aviation kerosene with 2% sustainable aviation fuels as of 2025, similar to guidelines in the European Union (see Chapters 2 and 9). Since 1 July 2021, the import

and sale of SAF are permitted. Switzerland does not produce SAF. Already, compressed natural gas sold to vehicles must contain a 20% share of biogas. As Switzerland only allows the use of waste for the production of biodiesel, the domestic production potential is limited and most of the consumed biodiesel is imported.

Biogenic fuels benefit from tax relief if they comply with certain ecological and social requirements set out in the Mineral Oil Tax Ordinance (see Chapter 9). The proposed CO_2 Act foresees abolishing the mineral oil tax refund for public transport vehicles in a push to promote alternative fuel vehicles. With the anticipated phase-out of natural gas from the Swiss energy sector by 2050, almost all future gas used in the transport sector will be synthetic or biogas.

Hydrogen already plays a role in heavy transport. At the end of 2022, 12 hydrogen filling stations were in operation in Switzerland, supplied with green hydrogen. One vehicle manufacturer has chosen Switzerland as a pilot market for fuel cell trucks, and more than 40 of these vehicles are currently in operation. In addition, several projects are being planned to produce green hydrogen from hydropower. The government is working on a hydrogen strategy, expected in 2023, that will explore in more detail how hydrogen and power-to-X can further accelerate the decarbonisation of the transport sector in a cost-effective way.

Assessment

Renewable energy will play a crucial role in reaching Switzerland's net zero emissions target by filling the electricity supply gap of nuclear power, which will be phased out by 2050. Switzerland has no national targets for the share of renewables in TES or TFC; instead, targets are set for renewable electricity generation. An overall renewables target for the energy mix could have advantages, as this would place the focus on the need to expand renewables across the board (heat, transport, gas) and not just in the electricity sector. If Switzerland eventually signs an electricity agreement with the European Union, it would oblige the country to transpose the relevant European Renewables Directive.

In 2021, Switzerland had the tenth-highest share of renewable energy in TFEC among IEA member countries at 27%; the IEA average was 13% in 2021. The main renewable energy source in Switzerland is hydropower, which is expected to continue, although Switzerland has ambitious targets for rolling out solar PV. The longer term future of bioenergy for power generation and heating is uncertain, as domestic production potential is limited and most biofuels are imported. Instead, the government could consider promoting the use of biomass in sectors that are more difficult to decarbonise, such as process heat in industry.

The building sector had the largest share of renewables in 2021, accounting for over one-third of TFEC, with electricity being the single largest renewable source. Renewables accounted for over one-quarter of the industry sector's TFEC but for only 7% in the transport sector.

Renewables in electricity

In 2021, 67% of total electricity generation came from renewable energy sources; hydropower alone accounted for 59%. Electricity generation from renewables other than hydro increased threefold from 2011 to 2021. The largest increase came from solar PV.

A large share of the hydropower potential has been already exploited and due to their environmental impact, the potential for new hydro projects is rather limited in Switzerland. Additional renewable electricity production will thus have to come from technologies that currently do not play a large role. Accordingly, renewable electricity generation from solar PV, in particular, and to some extent wind and bioenergy, should become more dominant. Switzerland has achieved the indicated targets for renewable electricity generation, excluding hydro, for 2020. To reach the 2035 target for renewable generation (excluding hydro), an annual net growth of 450 GWh is required.

However, with a view to reaching net zero emissions by 2050, Switzerland is preparing legislation to increase the renewable electricity generation target for 2035 even further. Reaching the proposed enhanced and eventually binding target would require annual net growth of at least 820 GWh, excluding hydro. Hydro generation is supposed to increase from 36 TWh in 2020 to 37.4 TWh in 2035. This would require a net growth of about 70 GWh annually. For this, the existing framework conditions need to be adjusted.

Switzerland regularly adjusts the support mechanism for renewable electricity. In January 2023, a revised legislative package entered into force for all new plants. It implements the switch from feed-in premiums to one-time investment support for all available technologies. The one-time remuneration for solar PV is going to be tendered. However, to reach the ambitious targets, more is needed than just a change to the support mechanism. In particular, the long and complex approval processes must be streamlined if Switzerland is to reach its net zero target.

The anticipated 2022-23 winter situation for electricity has shown that Switzerland, like many other countries, can act quickly and resolve even long-standing policy issues if security of supply is threatened. While Swiss policy makers were preparing to address short-term winter electricity security of supply, they revisited several earlier initiatives that had been blocked for many years. They included facilitating the construction of solar projects in high-irradiation Alpine areas, increasing the dam height of certain hydro plants and building new hydro plants, and introducing an obligation for certain types of new buildings to use solar for part of their energy consumption. The government should leverage these agreements to augment the longer term institutional framework conditions for the build-out of renewable energy as part of the country’s energy transitions. Several draft laws that are in the legislative process aim to address some of these issues.

With the current large share of hydro and the abundant interconnections to neighbouring countries, the integration of variable electricity generation will not be a challenge at the transmission level, at least in the medium term. Studies carried out by research institutes in Switzerland point to this. Further, other studies have found that wind projects could play a greater role than previously assessed, although permitting for wind projects is unusually long.

The government’s long-term wind offensive targets an improvement to the protracted planning process that can currently extend over several decades. Instead, the government proposes one single combined procedure for obtaining a land-use planning and construction permit. This would reduce one level of possible objections and hopefully the excruciating length of the process before projects are realised.

This is a concern to the build-out since wind turbine technologies and other renewable technologies develop quickly; there is thus a significant risk that projects will be technically outdated or likely more expensive than necessary once the permit is eventually approved.

Alternatively, under the current legal framework, if the developer wants to use updated technology, the application process for the project has to start all over again, as permit assessments are based on the specific project design and description. General permits could help solve this issue.

There is great potential to improve the support instruments for renewable electricity in Switzerland. The cost of building renewable energy technologies such as solar PV and wind is coming down quickly, and there are several examples of renewables that have been realised with no need for financial support. One instrument that has contributed to this is the use of well-designed tenders based on competitive bidding. This instrument is highly useful as a cost-effective level of support, especially for larger projects such as solar PV parks.

Competitive bidding is only effective as an instrument if there is sufficient competition and if projects are mature in the sense that all permitting is ready and there is a project pipeline that developers want to realise. The experience from the first tenders in Switzerland with large-scale solar PV could be used to evaluate the design, broaden the scope of tenders and consider tenders for a range of other technologies, when appropriate.

Technology open tenders, with diverse technologies competing for operating support, will bring more bidders and thus enhance competition. However, this will require having several different projects in the pipeline and more predictable permitting processes. One option would be to focus the tender on winter generation capacity. The government should ensure a streamlined process with an announced calendar for the planned tenders and the budget for each round. This will allow investors to start planning and preparing their bidding strategies and the permitting.

Planning the tenders and announcing tender designs in an open dialogue with developers would also increase the attractiveness of the design and balance the risks between investors and the government. This process could enhance cost-effectiveness in the long term. Since Switzerland currently has rather limited solar PV and wind generation capacity, this approach can contribute to rapidly scaling up variable renewables in the electricity sector. Other technologies, such as biomass co-generation or biogas, can also be included in tenders at a later stage, either separate or with the other technologies. Moving away from the existing scheme with investment contributions would likely have a major effect on the budget needed to fund new renewables projects if there are enough projects to have a competitive bidding process. Cost reductions achieved through these schemes in other countries (e.g. Denmark) have been significant.

Renewables in heating and cooling

Energy policy for buildings is the legal prerogative of the cantons and the federal government's policy-setting powers are limited. There are no country-wide targets for increasing energy efficiency (e.g. through thermal insulation) or the share of renewables in building sector energy consumption. Further, the incentives for promoting renewables in the heating sector vary between cantons and there seems to be a potential for sharing best practices and lessons learnt among cantons. In a welcome development, since January 2023, solar PV has become mandatory for all buildings above a certain threshold. Cantons are free to set tighter thresholds individually.

Space heating in many buildings is still oil- and gas-based; Switzerland has the fifth-highest share of oil use in heating among IEA countries. Most cantons have incentives for

phasing out oil use for space heating, and proposed alternatives reflect the individual situation of the cantons. While some encourage the installation of heat pumps, other, more densely populated cantons close to industrial sites also focus on the expansion of district heating, which is estimated to have significant underexploited potential.

In January 2023, the government issued a Heat Strategy covering a variety of renewable energy resources, such as bioenergy, geothermal and ambient heat, as well as lost heat and excess heat from industrial processes. The strategy also addresses the potential of underground resources such as geothermal for heating and storage. A more detailed analysis on how to shift the use of biomass in heating towards uses in other sectors, such as high-temperature industry, would be valuable.

One new and very commendable federal initiative requires energy consultants to complete training on replacing heating options in different types of buildings. This supports the new provision of 1 April 2022, which offers free advice to homeowners who wish to replace their fossil fuel or direct electric heating system that is more than ten years old. This initiative also addresses the need to continuously qualify the existing workforce in new technologies to further support the energy transition (see Chapter 1).

Renewables in transport

The transport sector has the lowest share of renewables, at just over 7% in 2021, and is responsible for the largest share of GHG emissions in the economy. The shift to electric mobility is a key transport policy given the already high share of renewables and nuclear generation in the power sector. Switzerland has overachieved its indicative 2022 target for a 15% share of plug-in EVs among new passenger car registrations and the government consequently set a more ambitious target for 2025: 50%. Given the country's electricity mix, the electrification of the transport sector has a very high medium-term potential. But with a view to the time it takes for a full passenger fleet turnover, the government could also consider the uptake of low-carbon fuels in transport to realise short-term emissions reductions.

Already today, compressed natural gas used in vehicles must contain a 20% share of biogas, which benefits from tax relief if complying with certain ecological requirements set out in the Mineral Oil Tax Ordinance. With the anticipated phase-out of natural gas from the Swiss energy sector by 2050, almost all future gas used in the transport sector will be bio- or synthetic gas. Like biogas, all biofuels, such as bioethanol and biodiesel, are already exempt from tax.

The proposed 2025-2030 CO_2 Act contains a blending mandate for biofuels, and Switzerland has put in place sustainability criteria for the biofuels used. As part of the new Act, several of the EU legislative proposals in the "Fit-for-55 package" will be implemented to promote lower emissions standards for vehicles and blending mandates for sustainable aviation fuels. Finally, the role of hydrogen and e-fuels, as well as other renewable gases, needs to be covered by a government strategy to explore how hydrogen and power-to-X can contribute to the decarbonisation of transport in a cost-effective way, including in the aviation sector.

While the government is preparing a hydrogen strategy that is expected for 2023, the use of hydrogen is already noticeable, especially in heavy transport, with 40 fuel cell trucks already on the road. This is also thanks to the fact that one vehicle manufacturer has chosen Switzerland as a pilot market for fuel cell trucks.

Recommendations

The government of Switzerland should:

- ☐ Set an ambitious binding target for the share of renewables in the energy mix, not only for renewable electricity, and allocate the necessary funding for new projects according to the target.
- ☐ Speed up permitting of renewable energy projects, for example by strengthening the national interest of renewable plants in designated zones for renewable energy plants, developing multi-stakeholder roundtables and creating dispute settlement arrangements for out-of-court settlements.
- ☐ Broaden market-based incentives such as tenders for large-scale projects that will ensure a cost-effective and fast uptake of renewables in the electricity sector.
- ☐ Encourage cantons to develop co-ordinated roadmaps for all renewable heat and cooling options.
- ☐ Develop a strategy for renewable gases and power-to-X focusing on the role of hydrogen and e-fuels in hard-to-decarbonise sectors.
- ☐ Better align monetary incentives to the net zero strategy, i.e. by shifting the use of biomass from space heating towards industry for high-temperature processes; find a renewable solution for the peaks in district heating, and better explore and use the underground resources for heating and storage.

5. Energy research, development and demonstration

Key data (2021)

Government energy research, development and demonstration (RD&D) budget: USD 413.5 million (nominal)

Energy RD&D budget as a share of GDP: 0.051% of GDP (IEA average:* 0.035%)

* Average of 25 IEA member countries for which 2021 data were available.

Source: IEA (2023), Energy Technology RD&D Budgets.

Overview

Switzerland is considered one of the most innovative economies globally and was ranked in 1st place by the World Intellectual Property Organization in 2022 – for the 12th year in a row. The World Intellectual Property Organization rates countries based on investment, patent filings, scientific publications, institutions and other innovation metrics. Switzerland ranks particularly high in achieving outputs compared to the inputs.

Historically, nuclear was a core focus of Switzerland's energy research, development and innovation (RD&I). However, with the phase-out of nuclear from the energy mix, RD&I spending now focuses more on new technologies required to achieve net zero emissions by 2050. Knowledge and technology transfer for start-ups is also growing in importance.

Key actors in the energy innovation ecosystem

Overall, research and innovation is the responsibility of the State Secretariat for Education, Research and Innovation. The Federal Energy Research Commission is a consultative body for the Department of the Environment, Transport, Energy and Communication. It prepares the Federal Energy Research Masterplan, which is updated every four years in collaboration with the SFOE. The SFOE implements the energy master plan and establishes an energy research concept that needs to be adhered to by the various energy research programmes. The SFOE is also the link between the Swiss national research community and the international one. It serves as the Secretariat for the Federal Energy Research Commission, runs inter-ministerial working groups and writes position papers.

The Swiss National Science Foundation funds basic research in all academic disciplines, including energy. Its national research programme has two dedicated programmes for the energy sector. One of the projects it supports looks at finding new substitutes for rare earths and developing new recycling modes.

Since 2018, Innosuisse has supported knowledge transfer from academia to industry. It promotes science-based innovation across all areas of economic and societal interest in accordance with the subsidiarity principle. It only supports research if the innovation could not be implemented and the market potential not tapped without its funding. It is especially active in promoting SMEs, start-ups and other smaller Swiss organisations in their research, development and demonstration (RD&D) activities to strengthen the long-term competitiveness of the Swiss economy. About 20% of the total funding is dedicated to energy and environmental issues.

Swiss universities and the two federal institutes of technology and affiliated research institutes are free to undertake their own research and are not bound by the official Swiss research strategy or the energy research master plan. This has at times in the past created a void between national priorities and the research actually undertaken. Nuclear research is performed by the Swiss Federal Nuclear Safety Inspectorate, one of the federal institutes of technology, and the Paul Scherrer Institute, the leading Swiss energy research institute.

Resource push

Public spending on energy RD&D

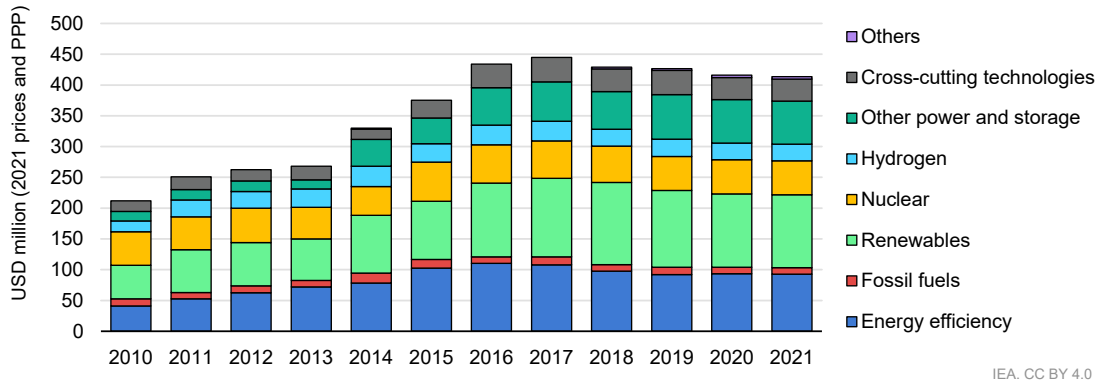
In 2021, Switzerland's public budget for energy-related RD&D was USD 413.5 million, 7% lower than in 2017, when it peaked at USD 445 million (Figure 5.1). The budget more than doubled between 2010 and 2017 before slightly decreasing through 2021. However, in 2021, the Swiss RD&D budget was still 95% higher than in 2010. In 2021, the budget for energy-related RD&D accounted for 0.051% of GDP, the eighth-highest share among IEA countries (Figure 5.2). This was 45% higher than the IEA average of 0.035%.

In 2021, renewables accounted for the largest share (29%) of the public budget on energy-related RD&D, followed by energy efficiency (22%), the equivalent of USD 119 million and USD 93 million, respectively. Other power and storage accounted for 17% of the RD&D energy-related budget and has recorded the greatest increase since 2010. In 2021, nuclear accounted for 13%, cross-cutting technologies 9%, hydrogen 7% and fossil fuels 3%. From 2010 to 2021, the share of the total budget in nuclear halved from 26% to 13%, that of renewables increased from 26% to 29%, and that of other power and storage technologies increased from 7% to 17%.

Switzerland has very strong data collection for publicly funded RD&I, including for energy, but it does not collect data from the private sector. Private sector RD&I funding is collected biannually through surveys undertaken by the Swiss Federal Statistical Office. Companies selected to participate in the survey are legally obliged to do so. There is no breakdown of energy sub-categories.

The data collected for private sector spending appears low, however, compared to IEA countries for which data are available and compared to the economic strength of Switzerland. According to the data, the Swiss private sector spent EUR 515 million annually, compared to EUR 566 million by Austria and EUR 566 million by the Czech private sector, all in 2019.

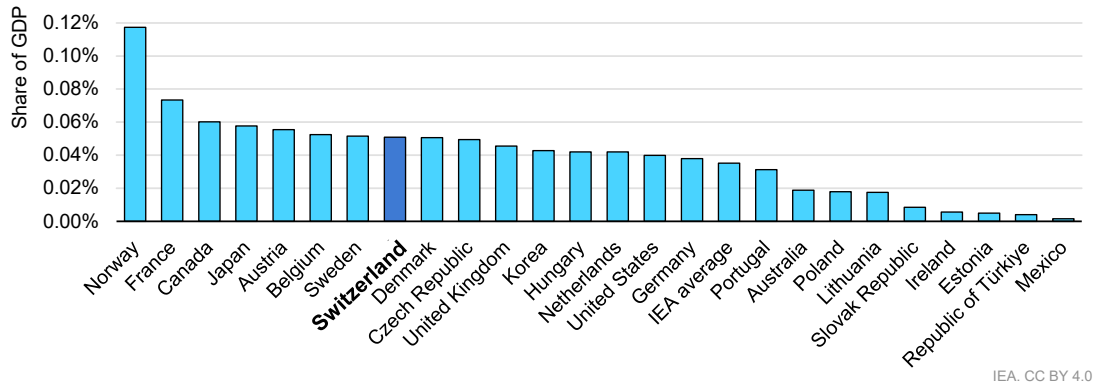
Figure 5.1 Energy-related public RD&D budget by sector in Switzerland, 2010-2021



Note: PPP = purchasing power parities.

Source: IEA (2022), World Energy Balances.

Figure 5.2 Energy-related public RD&D spending per GDP in IEA countries, 2021



Note. Data are unavailable for Finland, Greece, Italy, Luxembourg, New Zealand and Spain.

Source: IEA (2022), IEA World Energy Balances.

Energy innovation policies, priorities and programmes

The Energy Research Masterplan 2021-2024 is the planning instrument for all federal research funding bodies. It sets five priority areas for medium- to long-term research that are carried forward across the master plans. The current plan increases the holistic view of the energy system by letting economic and social science drive technology research programmes. Short-term goals are set for each four-year plan period. The masterplan contains scientific research and pilot and demonstration programmes.

Switzerland promotes programmes for basic research, applied research and development, pilot and demonstration projects, and market roll-out at the national and international levels through various funding and support schemes. The key focus is on research related to the expansion of renewables and energy efficiency.

The SFOE supports many programmes for energy RD&I and has targeted expansions of pilot, demonstration and flagship programmes. In addition to the overall RD&I budget, the SFOE has its own research budget, which in 2020 accounted for CHF 35 million to

advance the ES2050 and support the country's energy research masterplan. This is part of the overall CHF 310 million for energy-related RD&I in the same year.

Switzerland has increased its funding for energy research since 2015, primarily in relation to the implementation of the ES2050 and the "Coordinated Energy Research in Switzerland" action plan. Different funding instruments are in place that cover the whole value chain, from basic research to market-oriented approaches.

To support the EP2050+'s aim for a carbon-neutral Switzerland by 2050, the Swiss Energy Research for the Energy Transition (SWEET) programme was launched in early 2021. It funds inter- and transdisciplinary research and innovation activities that support the ES2050 and the country's long-term climate policy. SWEET has a high degree of flexibility in thematic coverage and focuses on finding solutions towards 2050 instead of being technology-specific. For example, a call for proposals is made to find a solution for energy storage instead of inviting RD&I proposals focusing on solid-state batteries.

Research areas that can apply for funding under the SWEET programme are energy efficiency, renewable energy production and consumption, storage, networks, society and energy, and security and safety of critical energy infrastructure. Based on these themes, the SFOE issues calls for proposals in consultation with the Federal Energy Research Commission.

As the SWEET programme supports inter- and transdisciplinary research, consortia of research and implementation partners respond to the calls. They propose portfolios of interrelated research projects that build on each other and should cover significant parts of the innovation system. SWEET project funding is usually provided for over six to eight years. As of July 2022, four calls had been issued and three more were at various stages of preparation and will be published in 2024 and 2025. They cover topics such as critical infrastructure, climate change and the resilience of the Swiss energy system. They pay special attention to advancing RD&I in hard-to-abate sectors.

The SWEET programme is complemented by the SOUR (SWEET outside-the-box-rethinking) programme that focuses on promoting unconventional and high-risk research projects that are potential game changers. Funding under SOUR is limited to 6-18 months and research is undertaken by either individual researchers or small teams. The first call for SOUR followed the themes covered under the first SWEET call and resulted in support for four projects. A second SOUR call is planned for 2023.

The two programmes are expected to run until 2032. The total budget of CHF 136.4 million allocated for the 2 programmes for the entire 11-year period is already fully committed. There is currently no funding available for any calls in the second programme phase from 2026 to 2032. The SFOE plans to request additional funding of around CHF 180 million to allow for more calls to be issued between 2026 and 2032 and proposes to extend the programme from 2032 to 2036.

Several initiatives are underway to include RD&I policy and initiatives in new legal frameworks under deliberation. The draft federal Act on the Secure Electricity Supply from Renewables includes a provision for funding research topics related to the ES2050 and the EP2050+. Topics include underground thermal energy storage. The ongoing revision of the Energy Act also includes provisions to improve funding for pilot and demonstration

projects with a special focus on early and high-risk research. In parallel, the SFOE undertakes an internal evaluation to identify hurdles for implementing pilot and demonstration projects.

A regulatory sandbox project to explore experimental legislation is to be introduced under the proposed revised Electricity Supply Act. The sandbox will help gain experience with new regulations that deviate from applicable laws over a limited period, such as looking at new tariff models. And the revised CO_2 Act under discussion includes funding for companies for RD&I on renewable synthetic aviation fuels (see Chapter 1 for details on the legislation under revision).

The SFOE is operating the Knowledge and Technology Transfer programme that informs about energy-related innovation promotion services and supports innovative projects, initiatives and networks. Beyond the outreach function to share knowledge, it primarily targets support to SMEs, start-ups and utility companies. Support for start-ups is growing in importance in Switzerland's innovation policy.

Among the best practices in the Knowledge and Technology Transfer programme is a lighthouse project on the electrification of heavy goods transport under which the SFOE promoted the development of battery-electric 26-tonne vehicles for waste disposal. The programme resulted in the establishment of a company – design werk – that now offers a range of commercial EVs. Over 115 vehicles are currently in use and production for over 100 new vehicles is ongoing.[6] The Knowledge and Technology Transfer programme has also supported the demonstration of a 36-tonne prototype fuel cell truck as a co-operation between private institutions and Swiss universities. This has resulted in the roll-out of clean fuel cell trucks in distribution operations through a private initiative, a first worldwide.

In its long-term, low-emission development strategy, for the first time, Switzerland recognised that reaching net zero in 2050 will require using CCS technologies. Specifically, the strategy estimated that 7 Mt CO_2 of CCS, including bioenergy CCS, will be needed. However, the federal government is currently legally limited in the development of CO_2 transport and storage infrastructure because surface and subsurface territorial planning are under the competence of cantons.

Different cantons have different views on the development of CCS projects within their legal remit. In 2020, parliament mandated the government to develop a programme for exploring the subsurface, including for CO_2 storage. More clarity on potential legal and regulatory modifications that could unlock this situation is expected in 2024.

The federal government plans to fund research projects to further explore the potential of CCS and CDR in Switzerland. Moreover, Switzerland has already signed a joint declaration of intent with Iceland (on co-operation in the field of CCS and CDR) and a memorandum of understanding with the Netherlands (on co-operation in the field of CCS and CDR).

In 2021, a study funded by the SFOE examined the feasibility and cost of building a network in Switzerland that would allow the transport of captured emissions to storage places outside of Switzerland, currently primarily in the Northern Sea. The study found that

[6] For more details see: https://www.futuricum.com.

it would be technically feasible to build the network but that several other aspects would still need to be analysed in more detail. The costs would be about 35 EUR/t CO_2.

Further, in May 2022, the government published a study on how CCS and NETs could gradually contribute to reaching the country's climate targets. The study set out concrete steps to be undertaken to 2030, including creating the legal, strategic and operational framework and providing sufficient funding, as well as the more general steps needed for the period 2031-50.

Addressing Covid-related impacts

The global pandemic did not have an influence on the RD&I budget for energy-related research. Delays in supported projects due to the pandemic were accepted and necessary contract adaptations were issued. Innosuisse and the Swiss National Science Foundation created mechanisms to cover additional related costs. Support was also given to start-ups through the provision of a federal loan guarantee system.

In 2021, Innosuisse launched two new initiatives: the "Swiss Innovation Power" and the "Flagship Initiative". They both aim to strengthen the long-term competitiveness of the Swiss economy, address the impacts of Covid-19, and ensure SMEs could continue research and innovation projects during the pandemic. The Flagship Initiative specifically supports transdisciplinary innovations. Flagships are delivered through consortia consisting of at least two industry and three research partners that collaborate through interdependent and interrelated projects, a structure similar to the SWEET programme.

Monitoring and evaluation

The SFOE prepares an annual monitoring report for the implementation of the ES2050, which also includes RD&I. *Ex post*, progress made in energy RD&I to support the ES2050 is primarily judged based on the available funding, not on any other qualitative or quantitative indicators. According to the government, this decision reflects the fact that it would be difficult to develop indicators applying to the many different technologies and the different stages of their development. Only public funding from the federal and cantonal levels is considered, not private funding.

The federal government operates an information system that includes all research and innovation projects funded or executed fully or partially by the federal government. Through the database, the federal government undertakes annual monitoring of projects under the research priorities for the period 2021-24.

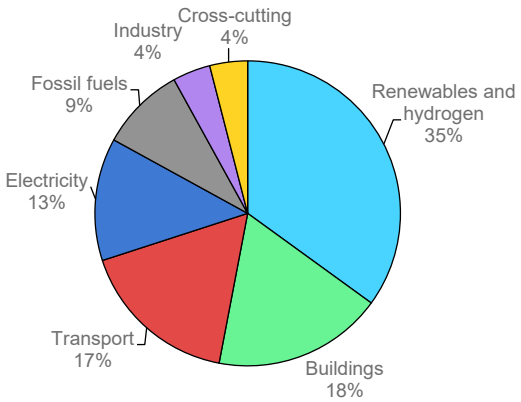
The SFOE is preparing for an impact analysis of the SWEET programme, primarily to design a successor programme. No details on the criteria for the impact assessment are available. However, given that SWEET has so far been rather successful, it is not obvious why a new funding instrument would be needed instead of further optimising the existing SWEET process.

Knowledge management

International collaboration

Switzerland is very actively engaged in the IEA's Technology Collaboration Programme (TCP) and participates in a total of 23 TCPs. Switzerland is represented at the Executive Committee level in 16.

Figure 5.3 Switzerland's participation in IEA technology collaboration programmes



Switzerland does not participate in the Clean Energy Ministerial or Mission Innovation (MI). Switzerland had substantially increased its public budget for energy-related RD&D after deciding on the nuclear exit. Membership in MI would have required doubling the country's energy RD&D budget, which was not considered realistic. Moreover, Switzerland does not see any added value from joining either initiative, as key learnings from the Clean Energy Ministerial and MI are shared through the IEA TCPs, which are considered better value for money. As stated above, Switzerland participates in a number of TCPs related to MI and is hence indirectly working with MI.

Switzerland also closely engages with Horizon Europe and related programmes as a non-associated third country and is especially active in the ERA-Net initiatives and its follow-up activities, such as the Clean Energy Transition Partnership. As Swiss researchers cannot access EU funding under Horizon, the Swiss government issued calls for funding that allow Switzerland to participate in about two-thirds of the Horizon programmes and related programmes and initiatives (Euratom, Digital Europe Programme, ITER research infrastructure). Yet, Swiss stakeholders cannot co-ordinate the Horizon projects and their access to the European laboratories is limited.

Switzerland is an active member in the new European Partnerships in the energy domain and is represented in the steering boards which select the topics for RD&I. Switzerland is also active in the international platform "Renewable energy, energy and resource efficiency promotion in developing and transition countries", whose primary objective is to transfer knowledge and technology.

Gender equality in the energy sector

The international energy community recognises the importance of encouraging more females to be involved in the clean energy transition. There are more females than males

obtaining a bachelor's degree in Switzerland overall, but this picture changes when focusing on graduates in science, technology, engineering and mathematics (STEM). Females only account for 28% of students in STEM.

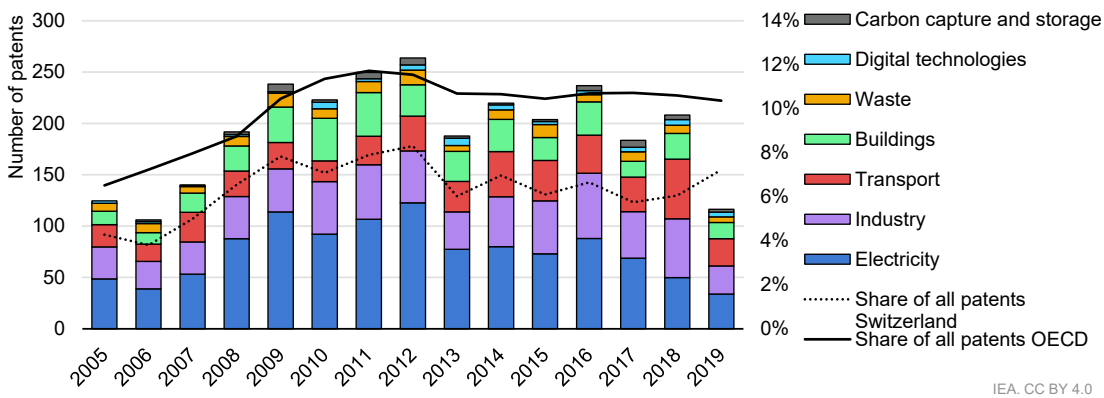
Switzerland has the second-highest share of males and the fourth-highest share of females obtaining a doctoral or equivalent tertiary education level among OECD countries. However, only 16% of tertiary graduates study engineering and 7% natural science, mathematics and statistics. While Switzerland remains above the OECD average in both fields, its share of engineering graduates is not only lower than that of its direct neighbours Austria and Germany – from which it tends to recruit into the Swiss labour market – but shows an important difference between male and female graduates. The share of female tertiary graduates in engineering is lower than the OECD average and compared to Austria and Germany. The share of female senior managers in Swiss energy sector companies is lower than the share in non-energy sector companies, and lower than the IEA and OECD averages.

Switzerland's education sector is characterised by the option of combining academic studies with practical work experiences in the relevant sector. This allows students to integrate early into practical work and facilitates absorption into the workforce. However, enrolment in engineering, manufacturing and construction programmes is lower in Switzerland than the OECD average.

Intellectual property

The number of patents in energy-related climate change mitigation technologies has decreased since a peak in 2012. The drop was particularly notable from 2018 to 2019. Most of the patents related to electricity (29% in 2019), industry (24%) or transport (23%) technologies, with a notable share of buildings (14%). A smaller number of patent applications were submitted for waste, digital technologies and CCS sectors. The share of new patents in climate change mitigation technologies over all patent applications has been consistently lower in Switzerland than the OECD average: in 2021, 7% compared to 10%, respectively.

Figure 5.4 New patents in energy-related climate change mitigation technologies, Switzerland, 2005-2019



Source: OECD (2022), OECD Patents by technology.

Assessment

Switzerland's public budget on energy-related RD&I almost doubled from 2010 to 2021, even though it has been on a declining trend since 2018. Funding for renewables and energy efficiency accounted for over 50% of total public energy-related RD&I in 2021, more than double the share of 2010. The IEA commends Switzerland for its flexibility during the global pandemic, which did not have an impact on the public energy RD&I budget. All project delays resulting from the pandemic were accommodated through the issuance of contract adaptations that also covered related additional costs. A special federal loan guarantee system was created especially to support start-ups during the pandemic.

Switzerland collects comprehensive data on energy RD&I but limited to public funding only. Having more complete data about private sector energy RD&I could be of strategic importance when designing public sector research programmes and would also allow exploiting complementarities, establishing synergies and better leveraging public funding.

Since 2021, the SWEET programme has funded inter- and transdisciplinary research and innovation activities undertaken by consortia to support the ES2050 and the country's long-term climate policy. This reflects a recommendation made in the IEA's 2018 in-depth review that suggested establishing a formal connection between the ES2050 and RD&I activities. However, there is still room to strengthen the alignment of RD&I funding priorities with the ambition to decarbonise the energy system by 2050 beyond the realms of the SWEET programme.

The SWEET programme is complemented by the SOUR programme, which focuses on promoting unconventional and high-risk research projects that are potential game changers. SOUR funding is for a maximum of 18 months, compared to up to 8 years for SWEET projects, and is undertaken by individual researchers or small teams, not by large consortia.

As the SWEET programme supports inter- and transdisciplinary research, consortia consisting of research and implementation partners respond to the calls. They propose portfolios of interrelated research projects that build on each other and should cover significant parts of the innovation system. Project funding is usually provided for over six to eight years. As of July 2023, five calls had been issued and three more were at various stages of preparation. They cover topics such as critical infrastructure, decarbonisation and the resilience of the Swiss energy system and sustainable fuels.

The SWEET and SOUR programmes run from 2021 to 2032. The first phase of the two programmes runs until 2025, when the last call will be made. However, the entire budget allocation for the 11-year period has already been pledged for the first phase. No decision has yet been taken about a second phase of the SWEET programme. The government should quickly decide on the future of the programme to ensure certainty for the Swiss research community.

Like the SWEET programme, Innosuisse launched a new support initiative, the "Flagship Initiative", that works with the consortia of several actors and covers interlinked projects. The Flagship Initiative aims to strengthen the long-term competitiveness of the Swiss economy, with a special focus on promoting SMEs, start-ups and other smaller Swiss organisations in their RD&D activities.

However, it appears that the Flagship Initiative and the SWEET programme could enhance their co-operation and also better align their strategies at the programme level. Co-operation seems to be limited by existing privacy barriers that prevent the creation of a co-ordinated exchange of information on activities – privacy concerns seem to go beyond the two programmes but appear to be a concern for the broader Swiss energy community.

Clear demarcation lines between funding instruments and communication about available call openings should be provided to the potentially interested RD&D entities. Moreover, the links between RD&I activities should be strengthened by frequent knowledge transfers between various actors in the Swiss energy research community and could relate to currently carried out research programmes, tested pilots and demonstrations as well as data collection and modelling to enhance synergies.

There are selective *ex post* monitoring and evaluation processes in place for Swiss energy research activities. Progress in energy RD&I is also judged based on the available funding, not on other quantitative and qualitative indicators. As a result, the government hardly assesses the effectiveness of activities undertaken to deliver on the strategy. As part of the government's plan to develop an impact analysis for the SWEET programme, this could be used as an initial step for the development of a broader and more comprehensive monitoring and evaluation system for energy RD&I.

Recommendations

The government of Switzerland should:

- Strengthen the alignment of RD&I funding priorities with the ambition to decarbonise the energy system by 2050, including carbon removal technologies and the required framework conditions for its eventual employment, while respecting the freedom of academic research.
- Quickly move towards ensuring funding for the second phase of the SWEET programme that is set to end in 2025.
- Ensure better co-ordination between key federal funding agencies (the SFOE Fund, Innosuisse), so that communication about available research support is transparent and application processes for grants more efficient.
- Improve communication between academia, think tanks and research institutes to facilitate co-ordination between all stakeholders about current and upcoming RD&I programmes, projects, data, and ideas for prospective projects.
- Create an independent and comprehensive monitoring and evaluation system for the overall energy RD&I programme based on qualitative and quantitative targets and criteria defined in advance.
- Start to regularly collect data on private sector spending on energy RD&I projects.

6. Electricity

Key data (2021)

Electricity generation: 63.1 TWh (hydro 58.6%, nuclear 30.7%, bioenergy and waste 5.2%, solar 4.5%, natural gas 0.8%, wind 0.2%, oil 0.05%), +0.4% since 2011

Electricity net imports: 2.4 TWh (imports 31.5 TWh, exports 29.1 TWh)

Electricity consumption: 58.1 TWh (residential buildings 35%, industry 32%, service sector buildings 28%, transport 6%), -1% since 2011

Peak load: 10.2 GW (December 2021)

Installed capacity: 23.1 GW (2022)

Source: IEA (2022), IEA World Energy Balances, IEA (2022), IEA Electricity Information.

Overview

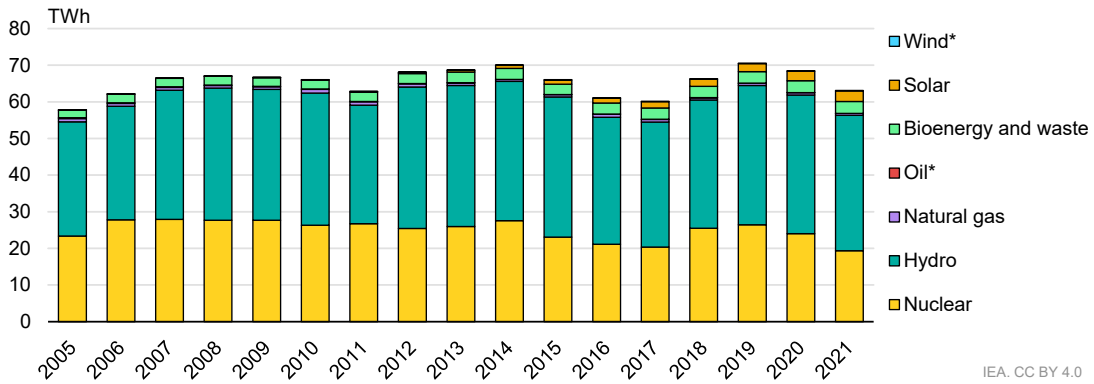
Switzerland's electricity sector will undergo major changes with the gradual phase-out of nuclear, the accelerated electrification of the heating and transport sectors, and the need to ramp-up generation from renewable electricity to ensure the net zero emissions trajectory to 2050. Solar PV is expected to fill the gap from the phase-out of nuclear power. The Swiss electricity system has a very high degree of flexibility thanks to its large installed capacity of pumped hydro storage. Moreover, the energy crisis in Europe has compelled Switzerland to take urgent measures to ensure the security of electricity supply while also ensuring it can reach its climate targets for 2030 and beyond.

Electricity supply and demand

Hydro has historically been the main source of electricity generation in Switzerland, covering at least 50% of generation. The share of hydro peaked in 2021 at 59% (37 TWh) as total generation decreased in that year and the first nuclear power plant closed (Figure 6.1). The second main source of generation is nuclear. Hydro and nuclear together accounted for almost 90% of total generation in 2021, given Switzerland's electricity sector a low-carbon intensity.

The share of nuclear declined from 42% in 2011 to 31% in 2021 (19 TWh), partly due to the Mühleberg nuclear power plant (NPP) closing in December 2019 for commercial reasons. Bioenergy accounted for 5.2% in 2021. The share of solar has been growing and accounted for 4.6% in 2021, up from 0.3% in 2011. Minor shares came from natural gas (0.8%), wind (0.23%) and oil (0.05%).

Figure 6.1 Electricity generation by source in Switzerland, 2005-2021



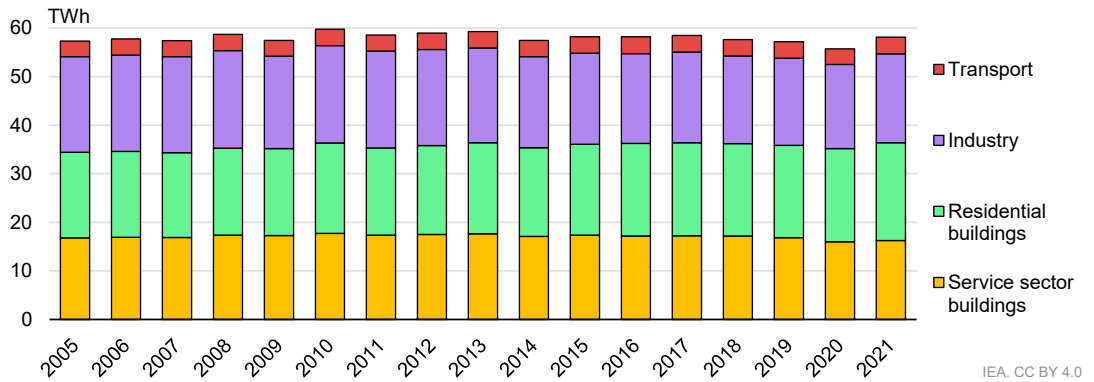
* The share of oil and wind are not visible on this scale and represented 0.03% and 0.23% in electricity generation in 2021, respectively.

Source: IEA (2022), IEA Electricity Information.

Demand

Electricity demand in Switzerland was 58 TWh in 2021. The same year, the residential sector was the main electricity consumer (35% of the total), followed by industry (32%), the service sector (28%) and transport (6%) (Figure 6.2).

Figure 6.2 Electricity demand by sector in Switzerland, 2005-2021

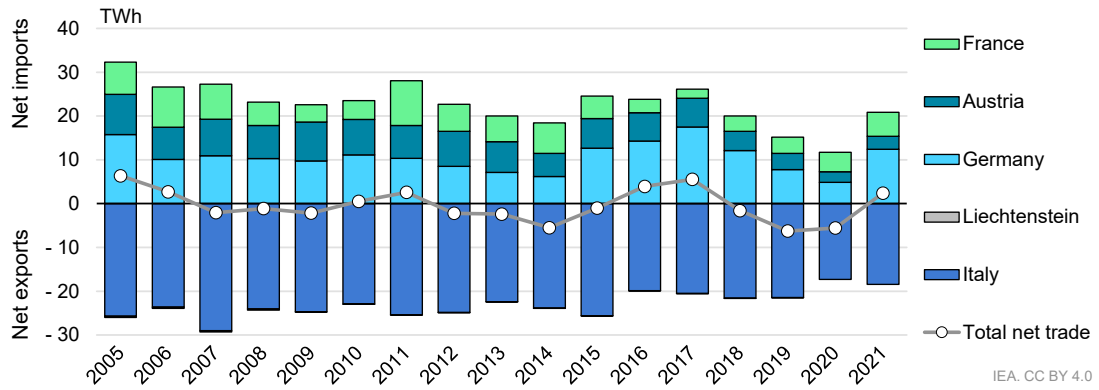


Source: IEA (2022), IEA Electricity Information.

Switzerland's highest recorded peak electricity demand was 10.2 GW in December 2021, with installed capacity of more than twice the peak demand. Yet, Switzerland is increasingly becoming import-dependent in the winter months. The energy storage capacity of all Swiss hydropower reservoirs is 8 885 GWh, or about 58 days of average winter electricity demand. But reservoirs run low towards the end of the winter while electricity demand peaks in winter due to higher demand for heating.

On an annual basis, Switzerland varies between being a net importer and a net exporter of electricity. Electricity imports are mainly from Germany, Austria, France and Liechtenstein. Switzerland exports electricity mainly to Italy (Figure 6.3).

Figure 6.3 Switzerland's electricity imports and exports, 2005-2021



Source: IEA (2022), IEA Electricity Information.

Future electricity mix

Switzerland is committed to phasing out nuclear power, but no specific end date has been set. Nuclear plants can operate if they are considered safe by the mandatory regular safety assessments (see Chapter 8). The EP2050+ has run scenarios for the future electricity mix, assuming the lifetime of a nuclear plant to be 50 or 60 years. The key difference between the scenarios is the electricity import balance. However, by 2050, all existing nuclear plants are assumed to cease operations.

In 2020, total installed capacity was 22.9 GW, significantly higher than the peak load of 9.6 GW. Hydropower accounted for close to 68% of installed capacity, but storage capacity and water availability limit yearly production. The total hydro production in 2021 was approximately 40 TWh, including pump energy of about 4 TWh, yielding a net generation of 36 TWh. Hydropower capacity is followed by nuclear (3.3 GW); solar (3 GW); and combustible fuels, mainly waste and some minor fossil fuel (0.9 GW). According to the scenarios prepared for the EP2050+, Switzerland's generation capacity would increase to 29.1 GW in 2030, driven by the build-out of solar PV (to 9.8 GW) and hydro (17.1 GW). Nuclear capacity will halve by 2030 (see Chapters 1, 4 and 8).

All other energy sources will continue to play only a minor role to 2030. This is largely due to challenges in installing wind turbines that remain unpopular in Switzerland and suffer from protracted approval processes, sometimes lasting several decades. However, for the period after 2030, Switzerland expects to see a stronger and faster build-out of wind power, as several legislative proposals to shorten the approval process are under consideration. Switzerland is also expecting a contribution from geothermal in the period after 2030.

Electricity generation is expected to grow from 63.1 TWh in 2022 to 67.7 TWh in 2028 as the contribution from solar PV more than doubles and hydropower also grows. Generation would then fall sharply in 2029 with the possible bur rather unlikely closure of one NPP, with almost the same level in 2030 as in 2022.

Industry structure

Most Swiss electricity companies are partly or wholly owned by public authorities (communes and cantons). Ownership structures are highly intertwined. The three largest generators – Axpo, Alpiq and BKW – accounted for more than half of total Swiss electricity production in 2020. Axpo and Alpiq supply their own shareholding utilities and the free

market, while BKW also has about 300 000 captive customers. The three large generators also jointly own many of the largest nuclear and hydropower plants. They operate at the national level and are active in international electricity trading.

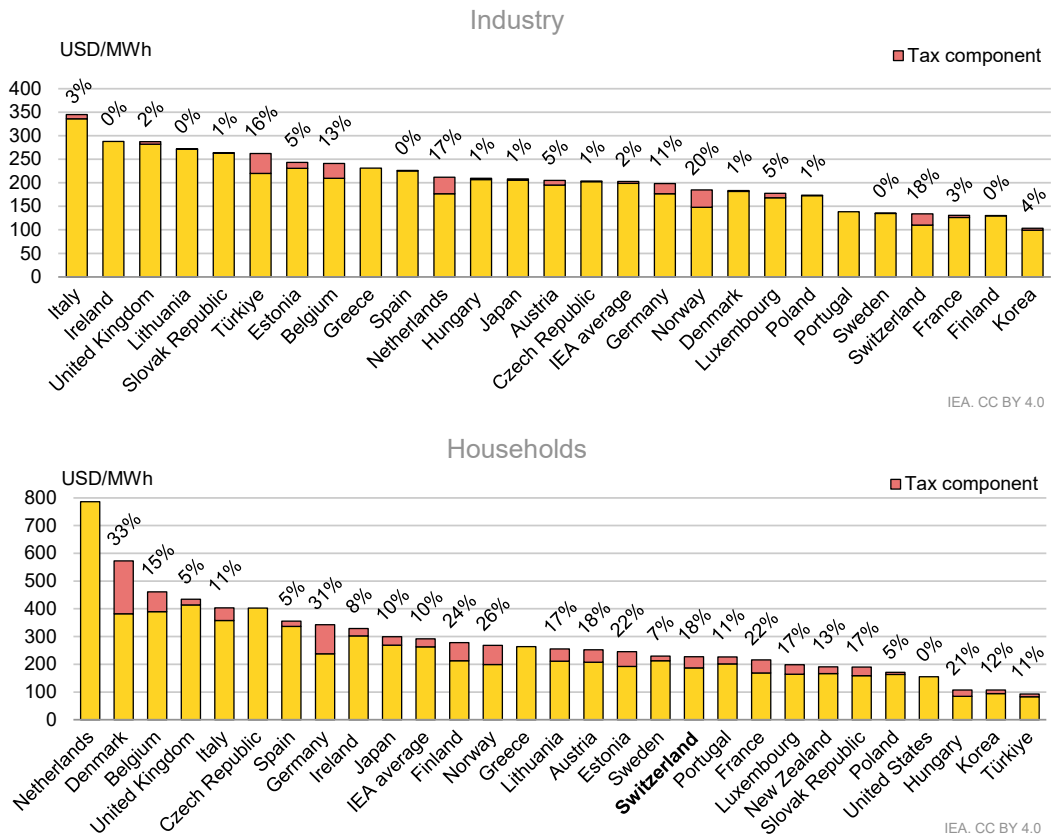
Switzerland has a highly segmented electricity industry. In 2020, about 620 small- to medium-sized municipal utilities oversaw distribution and retail, around the same number as in Germany. Several distribution companies also have shares in some of the larger power plants. A typical distribution grid operator is small, supplying just under 1 500 end consumers while the 10 largest grid operators supply 43% of the energy sold to end consumers on the distribution grid.

Swissgrid is the owner and operator of the Swiss transmission grid. By law, the majority of Swissgrid's shareholding must remain directly or indirectly with the cantons and municipalities.

Retail prices and taxes

Switzerland's industry electricity prices in the fourth quarter of 2022 were 134 USD/MWh (megawatt hours), with an 18% tax rate (Figure 6.4). The IEA average was 203 USD/MWh, with a 2% tax rate. Household electricity prices were 227 USD/MWh, with an 18% tax rate, lower than the IEA average of 291 USD/MWh, with a 10% tax rate.

Figure 6.4 Electricity prices for industry and households in IEA member countries, 4Q 2022



Notes: Industry and/or household price data are not available for Australia, Canada, Mexico or New Zealand. The household tax component is unavailable for the United States.

Source: IEA (2023), IEA OECD Energy Prices and Taxes Quarterly

Electricity policy

Several legislative initiatives for the electricity sector are at various stages of debate in the two houses of the Swiss parliament. The key initiative is the energy amendment package, which includes a revision of the Electricity Supply Act and the Energy Act. The bill is not expected to enter into force before 2025 (see Chapters 1 and 4).

The energy amendment package aims to support the rapid expansion of domestic renewable electricity production given the shift towards the electrification of the heating and transport sectors and to facilitate the integration of variable renewable electricity into the grid. Other notable proposed changes to the electricity policy and legal framework are discussed below.

Further electricity market liberalisation

The Swiss retail electricity market was opened for competition in 2009. Only large consumers with an annual consumption of over 100 MWh, including those participating in a consumer community, are free to select their electricity provider. Once in the free market, a consumer can no longer return to the cost-based price regulation for basic supply. In 2021, less than 1% of end consumers were entitled to free market access, of which just over two-thirds exercised their rights.

The government proposed full market opening in the revision of the Electricity Supply Act, which is currently being debated in parliament, to strengthen decentralised renewable electricity production and enable innovative business models. However, a regulated basic supply option would continue, and no consumer would be forced into the open market. Given the growing scepticism regarding the full market opening due to the high energy prices, support for this proposal is waning and there is little probability that complete electricity market opening will find a political majority. By May 2023, both parliamentary chambers have expressed their objection. Instead, the government will likely propose measures to facilitate the creation of more local electricity communities.

At the same time, the high electricity prices have increased consumer interest in the free market to return to the captive market. In 2022, ElCom, the Swiss Federal Electricity Commission, specified rules allowing consumers to return to the captive market by either forming or extending an existing energy community in the captive market. These rules state that energy communities must have a minimum share of 10% of self-supply and an obligation to stay in the captive market for at least seven years.

System flexibility

Switzerland's large installed hydro storage capacity (15.6 GW/8TWh in 2021) gives the power system flexibility over different time scales and will facilitate the integration of more variable renewables. However, the flexibility is currently mainly connected to the higher voltage part of the electricity system.

Today, some distribution system operators (DSOs) switch certain consumers (like heat pumps) on and off to manage demand peaks in their network. This has opened an opportunity for independent aggregators to offer balancing services to the transmission system operator (TSO) by aggregating small sources of flexibility. However, current efforts to create a market for flexibility are limited by unresolved questions about ownership of the flexibility. To clarify the situation, the revision of the Electricity Supply Act proposes that

end consumers, storage facility operators and electricity producers can offer their flexibility to third parties through contractual agreements. DSOs could then use the flexibility in their area against remuneration and reflect it in their network planning. The possibility of curtailing renewable production will also be regulated.

However, the current hydro storage capacity is not sufficient to make up for the demand and production gap between summer and winter (see Chapter 1). Battery and EV solutions do not help to close this gap as they are applicable for daily balancing but are not suitable for seasonal balancing. Switzerland plans to further expand overall hydropower capacity to ensure security of supply and create a hydro reserve which will support security of supply and help address future flexibility needs (see Chapters 1 and 4).

Swissgrid is keen to also deploy more innovative storage solutions, including on the demand side, as they are increasingly relevant for the secure grid operation. Demand-side flexibility currently only plays a limited role in the Swiss electricity system.

Grid development and regulation, data and metering

The Swiss electricity grid needs to be prepared to deal with the triple challenge of a strong increase in electricity demand, growing decentralised production with more storage options and the phase-out of nuclear in tandem with an increasing share of variable renewable energy sources. While Switzerland has a strong electricity grid, the current market structure is not suited to accommodate the planned solar PV capacity additions. It does not provide the necessary incentives for developing new flexibility and demand response business models.

Moreover, the expansion of the transmission grid suffers from the same lengthy procedures as wind power (see Chapters 1 and 4). Switzerland's most recent high-voltage transmission line went into operation in 2022, 36 years after first initiating the project. On average, approval processes take 5-13 years. The federal Act on the Conversion and Expansion of the Electricity Grid entered into force in 2019 and aims, among other aspects, to optimise the approval procedure and reduce the process length to four to eight years. For this, Swissgrid is developing a strategic grid plan covering transmission and distribution lines with a cross-regional character to ensure the future electricity grid supports the requirement deriving from the energy transition.

The DSOs all set their own tariffs and conditions for connecting solar PV and they also have different feed-in tariffs, which should be harmonised with the new legislation. Moreover, given that most DSOs are very small, interested solar PV investors face long waiting times for grid connections. The small DSOs also tend to lack the necessary digitalisation to handle the grid connection requests and the inflow of variable generation into their system. An enabling regulatory framework is needed to ensure that the Swiss energy transition is not held back by insufficient grid infrastructure and technology. Regarding alpine solar PV systems, connection issues occur more frequently at the transmission level, as those systems are likely located far away from the existing infrastructure.

The creation of a smart grid is an important pillar of the ES2050. By 2027, 80% of all meters within a grid area will need to upgrade to smart meters to comply with minimum technical standards, including for cybersecurity, as set out in the electricity supply regulation of 2018. In 2021, only 20% of all Swiss electricity consumers had a smart meter installed. In 2022, the government introduced a dashboard to monitor important indicators of the electricity

and gas system, increase transparency, and inform on the electricity savings in the winter (see Chapter 1). Data for the dashboard are collected from a variety of sources. Many of those sources are public, such as ENTSO-E- or ENTSO-G and Swiss federal offices; other data are provided by the industry itself.

Recently, six DSOs connected to the dashboard and send consumption data from already installed smart meters. These data are then extrapolated to a national scale with advanced machine learning algorithms. The government works continuously to expand the content of the dashboard and increase the quality of data; however, digitalisation in the electricity sector must be accelerated on a national scale.

The government plans to build a data hub to be completed at the beginning of 2028. In revising the Electricity Supply Act, the government proposes providing digital data, such as smart meter load curves and real-time data from a local consumer interface, to authorise third parties to assure secure and efficient data processes in the electricity market. At the moment, this is barely possible. The industry lacks digital interfaces at a system level to access smart meter load curves. Moreover, accessing data from the local smart meter interfaces is blocked for several reasons, such as fragmented and/or untransparent proprietary solutions.

The proposed revision of the Electricity Supply Act includes a provision to allow virtual metering points to pool self-consumption, which would be the interface to the electricity grid. This would help small producers, typically households, access the market.

Relations with the European Union

Although Switzerland is not part of the European Union and does not participate in the common electricity market, it is the second most connected European country, with 41 interconnections with its neighbours that account for close to 20% of cross-border capacity in Europe. This not only benefits Switzerland but contributes to European security of supply too. In 2021, total import capacity was 6 562 MW and export capacity 8 289 MW (Table 6.1). Given its generation mix and demand pattern, Switzerland has net exports in summer and net imports in winter.

Table 6.1 Main cross-border interconnection capacity by source in Switzerland, 2021

Cross-border Interconnection capacity (MW)	2021	
	Export	Import
France	1 136	2 944
Austria	659	1 052
Italy	2 792	1 722
Germany	3 629	1 264
Total	**8 289**	**6 562**

Source: Information provided by the Swiss Government

In 2007, Switzerland and the European Union launched negotiations on a bilateral agreement in the electricity sector. Since mid-2018, the negotiations have been suspended. For negotiations to recommence, some institutional aspects that are beyond the electricity sector need to be resolved first (see Chapter 1).

Following the suspension of negotiations, Switzerland is increasingly excluded from the European Union's grid and market processes and bodies. This is of particular concern, as the regulations and requirements of the European internal electricity market have developed considerably since the start of negotiations on an electricity agreement in 2007. In particular, the European Union's "Clean Energy Package", which lays down new rules for electricity trading and technical grid operation since 2020.

Among other things, Switzerland is affected by the 70% rule, according to which all EU member TSOs must keep at least 70% of cross-border grid capacities free for cross-zonal electricity trading from 2025. How the cross-border capacities to third countries such as Switzerland are to be considered is not regulated in the EU legislation. However, this requirement could significantly restrict available exports from EU member countries to Switzerland.

Switzerland also risks losing access to EU balancing markets in the continued absence of an agreement. In addition, unplanned electricity flows into Switzerland caused by electricity trading between neighbouring countries could increase further and thus endanger grid stability in Switzerland as well as in the wider region. Swissgrid has already invested in installing shifters to deal with the loop flows. Up to 30% of the power traded between France and Germany flows through the Swiss transmission system. Swissgrid has signed bilateral agreements with TSOs of the neighbouring capacity regions to continue technical co-operation. The lack of an electricity agreement with the European Union is seen as one risk to the security of electricity supply in the medium term.

Security of electricity supply

Switzerland has a very high standard of security of electricity supply as seen by the various standard indicators. Compared to other European countries, Switzerland consistently scores in the top group together with Denmark, Germany, Luxembourg and the Netherlands when assessing the average length of an unplanned supply interruption.

Considering the changing electricity mix in Switzerland and the possible import risks after 2024, ElCom regularly undertakes mid- and long-term system adequacy studies. The latest has a time horizon to 2030. ElCom's studies build on the methodology used for the mid-term adequacy forecast undertaken by ENTSO-E and uses data from ENTSO-E for the generation capacity availability in the European Union. The study uses Swiss demand data from ES2050 and considers different climatic and weather conditions and their influence on water availability and production from variable renewable generation sources but also unscheduled outages of generation facilities to run simulations. The latest system adequacy study also considers possible reductions in net transfer capacities after 2025.

The last system adequacy study shows that security of electricity supply is assured for all hours by domestic production and imports at least until 2030. However, the study also states that a combination of unfortunate events could lead to supply shortages already in 2025 due to the uncertainties regarding the continuous sufficient imports of electricity. The parliament is therefore discussing measures to ensure that Switzerland will not import more than 20% of the average electricity consumption during winter over the previous three years. Among the measures under discussion are bilateral commercial contracts with neighbouring countries to ensure necessary import quantities will be available but also the expansion and more efficient operation of the network, increasing voltages/capacities in

the transmission system, a focus on reducing demand through higher energy efficiency, and capacity additions as discussed above.

The 2022 energy crisis highlighted the need for a new comprehensive legal and regulatory framework to allow the government to take more and earlier action in crisis preparation and the management of an actual crisis. The government acknowledged that it took a long time to establish a crisis management system in 2022 and that the situation showed the limits of the subsidiary principle under which the electricity (and gas) industry would need to act first, which did not happen as expected. The highly fragmented electricity sector showed its lack of efficiency in a crisis. Among the issues the government plans to address are establishing who oversees security of electricity supply in Switzerland and clarifying the roles among the various stakeholders during a security of supply crisis.

To address the growing winter supply gap, in 2022, the government implemented several initiatives to strengthen electricity security in winter, including creating an energy reserve. The energy reserve consists of two distinct parts. First, a hydropower reserve under which operators of hydropower storage plants and reservoirs are obliged to retain a certain amount of water/energy, which can be called upon when needed. Second, the government has commissioned the construction of reserves, mainly gas power plants that will only be operated during shortages that cannot be addressed through other measures. The thermal plant operators are compensated for the provision of capacity (see Chapter 1).

The government proposed a winter surcharge of CHF 0.2 cents/kWh for supply security to be added to the network charges to fund the increase of the hydropower storage reserve through higher dams. However, this surcharge has been rejected by both chambers of parliament due to the high electricity prices. It will be important that the transmission grid usage fee is allowed to increase to ensure sufficient funding is available for the required expansion of the transmission system.

The government has initiated a pilot project to analyse how to pool emergency generators into a virtual power plant. The pilot looks at contracting and pooling around 280 MW of existing capacity from 300 private emergency generators; only some of these currently offer ancillary services. Only generators with a capacity of more than 1 MW and with fuel reserves to operate 24-48 hours are eligible to participate in the pilot. In total, Switzerland had 600 MW of emergency generator capacity in 2022, a substantial share of which comes from data centres that are booming in the country.

Assessment

Switzerland's electricity generation has historically been dominated by hydro, covering a share of at least 50% of generation. Nuclear, the second-largest generation source, will continue shrinking in the coming decades after the Swiss population voted in 2017 to phase out nuclear and ban the construction of new nuclear power plants. The share of renewable energy has been growing over the past years. The government aims to continue rapidly growing the share of solar and other renewables to replace nuclear while keeping the electricity mix nearly carbon-free.

Switzerland is a net importer of electricity in winter and a net exporter in summer. This seasonal pattern is due to the high availability of hydropower in summer, while near the end of winter, hydropower reservoirs are at their lowest. The seasonal pattern is likely to remain or even grow, as nuclear will be replaced mostly by solar energy, which also peaks

in summer, and winter electricity demand is expected to grow due to the electrification of heating. In response to this situation, the revised Electricity Supply Act, currently being debated in parliament, includes a proposal to limited imports to not more than 20% of the average electricity consumption during winter over the previous three years. The government is hence facilitating more generation capacity with winter production; the focus is on the fast expansion of new renewable capacity, including wind and alpine solar, and is complemented by the creation of a water reserve in the hydropower storage plants and the construction of new gas-fired plants to enhance security of supply.

Electricity demand in Switzerland was just over 58 TWh in 2021. The electricity demand of the building sector accounted for close to two-thirds of total electricity demand in 2021, followed by industry and transport. Reaching net zero in 2050 would see electricity demand rise sharply to about 84 TWh in 2050. The increase is mainly attributable to the electrification of heating and transport. Demand is expected to grow faster than production, as nuclear capacity will be phased out while the build-out of new generation capacity may well be slower than initially planned due to issues related to planning, permitting and local acceptance. To maintain the desired level of self-sufficiency, the roll-out of new generation capacity should be accelerated.

The Swiss electricity market was partially opened for competition in 2009. Consumers with an annual consumption exceeding 100 MWh, including those participating in a consumer community, can choose to leave the captive market and choose their electricity supplier. Consumers with lower annual consumption, representing about 99% of Swiss consumers and about 50% of total electricity demand, are unable to leave the captive market.

Once in the free market, a consumer cannot return to the captive market. But during the 2022 crisis, interest increased among consumers in the free market due to drastic price increases wishing to return to the captive market. In response to the growing interest in 2022, the government specified the rules for the return to the captive market, although with high barriers. To do so, consumers need to form or join an existing consumer community in the captive market.

The captive market is subject to cost-based price regulation. Prices in the captive market are set by utilities annually, subject to scrutiny by the regulator, and can vary greatly between utilities, largely explained by differences in procurement strategies. Under cost-based regulation, utilities with captive customers are not incentivised to minimise grid costs or have an efficient procurement strategy, as they are guaranteed a return; tariffs are, however, supervised by ElCom.

The government proposed a revision of the Electricity Supply Act in 2021 which included full market opening for the retail market and metering services. Full market opening would establish effective competition, giving all consumers a free choice of supplier and providing a stronger enabling framework for innovation. It would also better align the Swiss electricity market with the European Union. However, the government acknowledges that soaring electricity prices for eligible consumers in the current situation makes full market opening politically unviable.

Reflecting the growing scepticism, both chambers of parliament removed full market opening from the draft revised Electricity Supply Act. The revised draft bill does allow captive consumers to form local energy communities, grouping their production and consumption to meet the minimum threshold for accessing the free market. Considering

the threshold is 100 MWh, a few dozen households are needed to create such communities. Metering is to remain the exclusive competence of the local utility. The lower chamber is yet to debate the issue.

Switzerland is highly interconnected and strongly reliant on electricity trade with its neighbouring countries for security of supply, and cross-border electricity trade is of mutual economic benefit. However, Switzerland is not part of the single electricity market of the European Union. Integration into the EU electricity market would require Switzerland to align with relevant EU electricity market regulations, including on full market opening and state aid. Negotiations on an electricity agreement were suspended in 2018.

In the absence of an electricity agreement, continued technical co-operation with neighbouring countries is needed to maintain grid stability. Part of the electricity traded among neighbouring EU countries that surround Switzerland flows through the Swiss electricity grid, following physical laws. With trade between EU countries expected to grow, these unplanned flows will also grow, increasing the need for balancing and redispatching in Switzerland. Grid management costs are expected to continue to rise as a result.

Switzerland has a well-defined target for the roll-out of smart meters: 80% of connections are to have a smart meter by the end of 2027. Smart meters are necessary for the development of a smart grid, which would facilitate market use of decentralised assets such as PV, e-mobility, storage, and demand response. By optimising the use of decentralised production and consumption, smart grids contribute to system security and can help manage emergencies. However, the deployment of smart meters in Switzerland is lagging. About 20% of connections currently have a smart meter installed. With an observed annual instalment rate of about 3%, Switzerland must accelerate its efforts to reach its target.

Data collected from smart meters are important for efficient grid operation and development and can contribute to security of supply and lower grid management costs. Swiss privacy regulations offer clear rules for using the data collected from smart meters for grid purposes. Digital data can be used to benefit the system without jeopardising privacy. The regulation allows sharing the data with third parties, but the network operator remains responsible for keeping up with the regulations. Today, only a few distribution companies use the data for purposes other than billing and accounting, if they collect the data at all.

Distribution grid development is fragmented, as it remains a competence of individual DSOs. Many of the DSOs are small and lack the required experience, scale and access to data to effectively prepare for the expected rapid roll-out of solar panels and the electrification of mobility and heating, which will require demand flexibility and capacity in the distribution grid. To prevent the distribution grid from becoming a bottleneck in the coming years, the government should ensure long-term planning of the distribution grids and the roll-out of smart meters, for example by designating a central authority to co-ordinate distribution grid planning and establish an annual plan for purchasing smart meters as well as planning their installation.

Grid management and development costs are financed through a grid usage charge. End users pay tariffs for grid usage, remuneration for ancillary services and also the grid surcharge which is fixed by law and that supports the roll-out of renewables. The grid usage part is dedicated to investments into and operation of the grid. Households with solar panels for own consumption are exempt from the grid usage charge for the amount

of electricity they produce and consume simultaneously but not for their consumption from the grid. They represent a fast-growing share of connections in line with government policy.

Grid fees are adjusted annually and approved by the regulator. Financial constraints do not slow grid development, but permitting delays do. Nevertheless, with the strong growth of private solar PV production, it is necessary to create a framework where grid usage charges remain sufficient to cover the transmission and distribution grid expansion costs.

Recommendations

The government of Switzerland should:

- ☐ Align its electricity market regulations with those in the European Union, including on full market opening, to benefit from compatibility with the internal electricity market and prepare for a future electricity agreement.
- ☐ Continue allowing the transmission grid usage charge to rise as needed in line with rising grid costs to maintain investment capacity in the transmission grid.
- ☐ Ensure long-term planning of the distribution grids and the roll-out of smart meters to prepare for the rapid expansion of distributed assets and the growth of energy communities.
- ☐ Push forward digitalisation in electricity by regulations and voluntary measures such as innovation projects. Foster access to digital data for consumers and eligible third parties and support more and better open energy data.

7. Natural gas

Key data (2021)

Net imports: 3.8 bcm, +11 % since 2005

Share of gas: 16% of TFC, 14% of TES, 12% of heat generation, 1% of electricity generation in 2021

Gas consumption by sector: residential buildings 41.3%, industry 30.8%, service sector buildings 20.4%, electricity and heat generation 4.8%, other 2.2%, transport 0.5%

Share of biogases in TFC: 0.25% (0.21% in 2011)

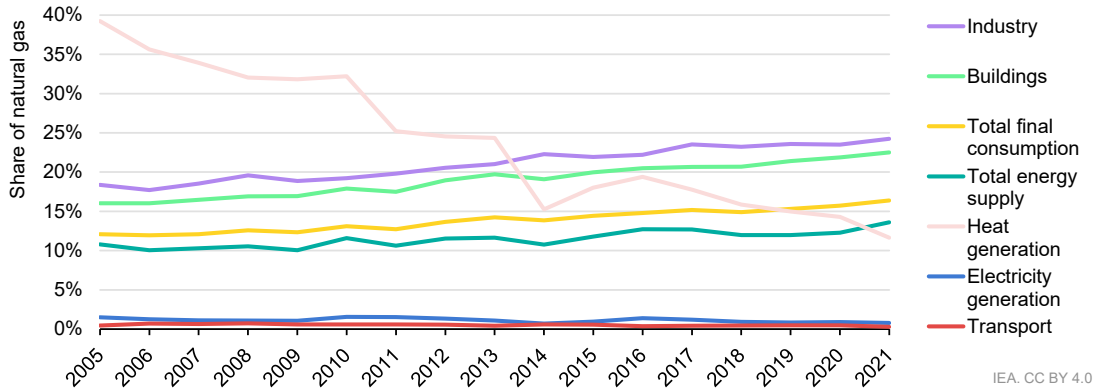
Source: IEA (2022), Natural Gas Information.

Overview

Switzerland does not produce natural gas. Between 2005 and 2020, the use of natural gas in TES was stable at around 119 PJ, representing an average share of 11% (Figure 7.1). In 2021, natural gas consumption increased to 129.8 PJ, reaching 14% of TES. Natural gas covers just 1% of electricity generation.

Switzerland has not directly imported natural gas from the Russian Federation (hereafter “Russia”) since 2015 but it has imported from European countries which relied heavily on Russian natural gas until 2022. There is thus no direct impact of the 2022 interruption of gas deliveries from Russia. However, high gas prices and supply issues resulting from the 2022 Russian invasion of Ukraine are of great concern for the gas security of Switzerland. To address the situation, the government implemented various measures to prepare for the winter of 2022/23, including storing the equivalent of 15% (around 6 TWh) of annual gas consumption abroad (Switzerland does not have underground storage) and securing non-Russian gas supply options. Switzerland aims to achieve carbon neutrality by 2050. The role of natural gas is therefore anticipated to decline significantly.

Figure 7.1 Share of natural gas in Switzerland's energy system, 2005-2021



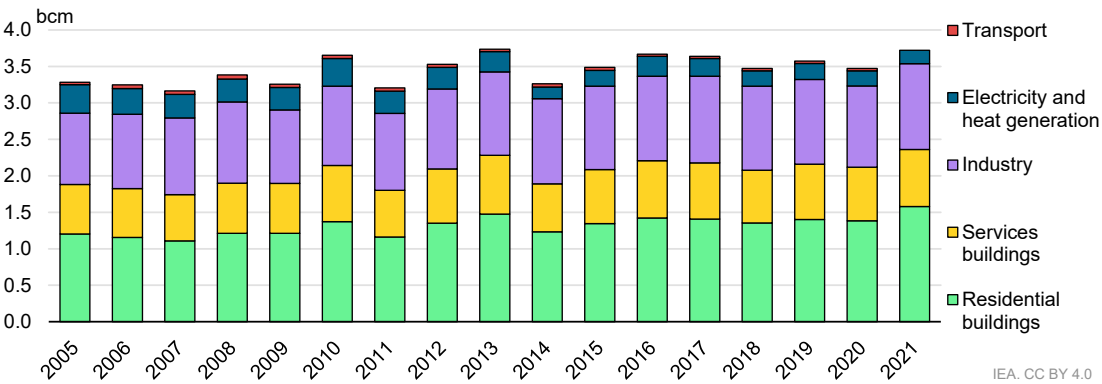
Note: The IEA defines heat production to include all heat produced by main activity producer co-generation and heat plants, as well as heat sold by autoproducer co-generation and heat plants to third parties.

Source: IEA (2022), World Energy Statistics and Balances.

Gas supply, demand and trade

Switzerland's demand for natural gas is met by imports (except for biogas, which accounts for 1.5%), which reached a record high of 3.8 billion cubic metres (bcm) in 2021. Most gas demand comes from buildings (62%), followed by industry (31%), electricity and heat generation (4.8%), and transport (0.5%). Demand for buildings has been on a general slight upward trend and in 2021 was 31% higher than in 2011. Demand from industry increased 12% during the same period, while demand from electricity and heat generation decreased by 40% and that from transport by 55% (Figure 7.2).

Figure 7.2 Natural gas demand by sector in Switzerland, 2005-2021



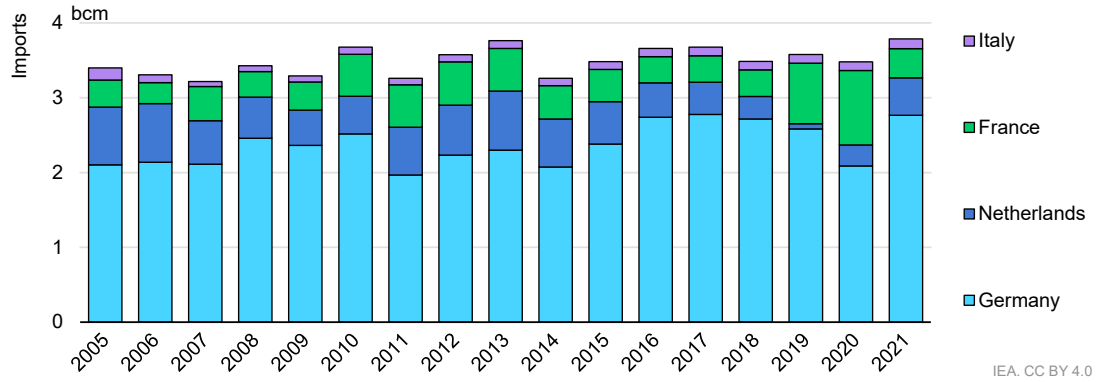
Note: Industry includes non-energy use. Buildings includes residential and commercial and public services.

Source: IEA (2022), Natural Gas Information.

In 2021, Switzerland's major trading partner for natural gas was Germany, which represented 73% of imports (around 2.8 bcm), followed by the Netherlands (13%), France (10%) and Italy (3%). France supplies Western Switzerland, while the Italian-speaking part of the country is exclusively supplied by Italy. From 2011 to 2021, natural gas imports increased from 3.3 bcm to 3.8 bcm. While Switzerland has not imported natural gas directly

from Russia since 2014, it has imports from European countries which relied heavily on Russian natural gas until 2022. Switzerland does not export natural gas, but significant volumes transit through the country.

Figure 7.3 Switzerland's natural gas trade by country, 2005-2021



Source: IEA (2022), Natural Gas Information.

Market structure

Switzerland has over 100 gas utilities, typically local monopolies owned by municipalities. Some are involved in other activities, such as supplying electricity, heat, water or glass fibre. Because of decarbonisation strategies, some cities plan to decommission larger parts of the gas distribution network by the mid-2030s.

Vertical integration in gas transmission and distribution is strong. To purchase gas, local utilities have set up five regional associations. Each association operates its own grid and supplies gas to its owners at cost. At the transmission level, only the region of Ostschweiz (Eastern Switzerland) is unbundled; all others are still vertically integrated. Furthermore, there is no Swiss gas regulator at the national level. There is no legal provision for medium to small customers for free choice of natural gas supplier.

Swissgas, the former procurement organisation of the gas industry, has not been active in purchasing since 2019 and only handles older long-term contracts. Swissgas operates its own high-pressure transport grid and holds a stake in Transitgas. A large majority of gas transit through Switzerland is handled by FluxSwiss, majority controlled by the Belgian TSO Fluxys.

The Swiss gas market is liberalised only for large consumers, who can choose their supplier and have third-party access to the high-pressure grid by virtue of the Federal Pipelines Act of 1963. Grid tariffs are not regulated but fixed by industry agreements, with different conditions for the six network areas, for instance concerning measurements or balancing. Access to the grid is still decided on a case-by-case basis and four separate accounting zones continue to exist in Switzerland in addition to the two isolated regions.

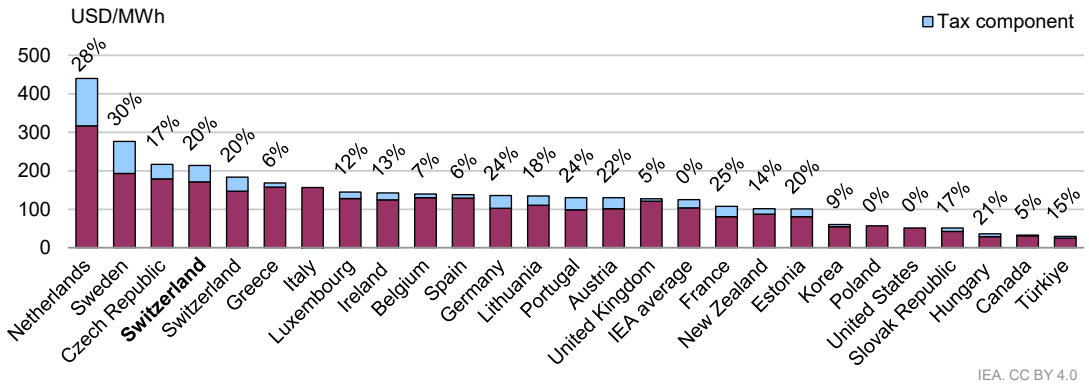
All other consumers are captive. A significant ruling towards market opening for all consumers was taken with the binding decision of the Competition Commission (ComCo) of 25 May 2020. ComCo ruled that the refusal of two network operators to allow third-party access constituted an unlawful denial to do business. Yet, in the absence of a legal

framework to enforce ComCo's ruling and ensure effective competition for the whole of Switzerland, the market remains *de facto* only opened for large consumers.

Prices and taxation

In the fourth quarter of 2022, natural gas household prices in Switzerland were the fifth-highest among IEA countries at 183 USD/MWh, with a tax rate of 20% primarily attributed to the CO_2 levy applied to stationary fuels (see Chapter 2). In comparison, the average price of the IEA member countries was 125 USD/MWh, with an average tax rate of 14%. (Figure 7.4).

Figure 7.4 Natural gas prices for households in Switzerland, 4Q 2022

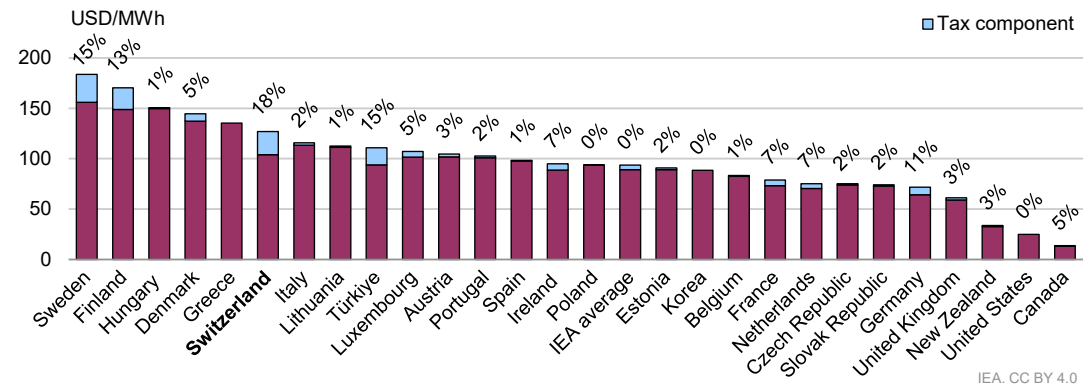


Notes: Tax information is not available for Poland or the United States. Prices are not available for Australia, Finland, Japan, Mexico or Norway.

Source: IEA (2023), Energy Prices (database).

In the same quarter, natural gas industry prices in Switzerland were the sixth-highest among IEA countries at 127 USD/MWh, with a tax rate of 18% (Figure 7.5). The average price of the IEA countries was 94 USD/MWh, with an average tax rate of 4%.

Figure 7.5 Natural gas prices for industry in Switzerland, 4Q 2022



Notes: Tax information is not available for the United States. Prices are not available for Australia, Japan, Mexico or Norway. The negative value for Greece refers to subsidies.

Source: IEA (2023), Energy Prices (database).

Natural gas infrastructure

The SFOE is the supervisory authority responsible for gas (and oil) pipelines at pressures of 5 bar and above. For lower pressures, this competence rests with the cantons. The Federal Pipeline Inspectorate carries out the technical inspections.

Pipelines

Switzerland is an important gas transit country. The 292-kilometre Transitgas pipeline mainly delivers natural gas from northern Europe via Germany or France to Switzerland and onwards to Italy. Transitgas can be operated in reverse flow among all three neighbouring countries since 2018. Its total capacity is 18 bcm per year, about 5 times Switzerland's domestic consumption. In addition to Transitgas, there are regional interconnectors with neighbouring countries.

The Transitgas pipeline is owned and operated by Transitgas AG, which is owned 51% by Swissgas, 46% by FluxSwiss (acting as the commercial TSO) and 3% by German Uniper. The compressor station at Ruswil is the operational centre. The Transjura gas pipeline in Western Switzerland is linked with the gas storage facility in Etrez, France.

Switzerland's total gas transport system measures around 20 430 km in length. The high-pressure network comprises 2 271 km and the total distribution network is 18 159 km. Swissgas is the *de facto* technical TSO and manages the co-ordination of supraregional measures during technical disruptions. Studies are ongoing to enhance the undersized transmission capacity between the western and eastern parts of the country.

Storage

Switzerland has no underground gas storage due to its geology. Prior to Russia's invasion of Ukraine in 2022, gas importers contracted seasonal storage in various EU countries. Gas suppliers Gaznat and GVM own a share in the French storage at Etrez (3 TWh, or 8% of Switzerland's demand). The right of the Swiss suppliers to draw on stored gas in case of a crisis is guaranteed by an agreement with France. The Transjura system connecting Etrez with Switzerland extends further into France, supplying French consumers. In March 2022, the government mandated that importers store the equivalent of 15% of annual demand in storages. This target was achieved. The mandate was renewed for the winter of 2023/24.

The country's gas storage infrastructure consists entirely of above-ground facilities in the form of line-packs and spherical storage tanks, which are used for daily balancing and peak shaving purposes. Dual-use facilities, which primarily run on natural gas, are required to maintain fuel oil stocks to replace gas during supply shortages for at least 4.5 months.

A gas utility is evaluating the potential for a liquefied natural gas terminal for Rhine barges near Basel. Gaznat is evaluating a possible storage facility (up to 1.5 TWh) at Oberwald near the Transitgas pipeline. No final investment decision has been taken. Commissioning could take place in 2030 at the earliest.

Natural gas policy

Switzerland is committed to reaching carbon neutrality by 2050. The Zero Base scenario of the EP2050+ (see Chapter 1) foresees a 95% reduction in natural gas demand by 2050, to be replaced with biogas, hydrogen and renewables-based synthetic gases. The remaining natural gas will be used for cement production, combined with CCS (see Chapter 2).

Switzerland lacks a dedicated legal and regulatory framework for natural gas. A federal gas supply act has been mooted for several years. It aims to establish a legal and regulatory framework for the Swiss gas market. The current *de facto* partial market opening, the absence of a regulator and negotiated third-party access prove unsatisfactory. The shortcomings of market oversight have been exacerbated by the 2022 gas crisis. Consultations on a draft Gas Supply Act started in 2019 but were then suspended in 2020. The government will discuss how to proceed with the Gas Supply Act during 2023, taking into account the lessons learnt from the winter of 2022/23. Although the Gas Supply Act is to introduce considerable harmonisation with EU gas legislation, some crucial issues, such as full market opening, may prove politically controversial.

The government does not have a roadmap for the gas sector. Instead, the Swiss Association of Gas Industry (Association Suisse de l'Industrie Gazière, ASIG) is guiding the decarbonisation of the sector. It groups 90 gas distributors of different sizes, mainly the public. In 2022, ASIG set out five pillars to achieve carbon neutrality in the gas sector by 2050.

The first pillar is the decarbonisation of the gas grid in stages: i.e. with renewable gas blending targets set at 15% for 2030, 50% in 2040 and 100% in 2050. Renewable gases include biogas (whose domestic production accounted for 1% of natural gas demand in 2021) and green hydrogen. The second pillar is to enhance the resilience of the energy system through gas and electricity sector coupling. Excess electricity could be stored as hydrogen. The third pillar relates to gas market evolution based on gas sales scenarios. The fourth pillar relates to converting part of the grid to hydrogen. The last pillar is to set a framework for the opening of the gas market.

A national hydrogen strategy is under development. It will outline the role of hydrogen in achieving carbon neutrality. However, the government notes that, compared to other countries, the demand for hydrogen will be rather low, given that there are relatively few heavy industries. According to ASIG, Transitgas is evaluating hydrogen transport through one of its lines. Hydrogen can be blended with natural gas up to 10% currently, according to the latest guideline of the Swiss Gas and Water Association.

Gas prices are not regulated in Switzerland. They have been monitored and published by the Federal Price Surveillance Authority since 2011. This authority does not have any tariff-setting power but may open an investigation and make price recommendations to industry associations in case of abuse of market power. Retail gas prices and tariffs are set by the utilities, without the oversight of a regulator. Some local authorities can approve gas tariffs, but as these local governments are often also owners of the utilities, there can be a conflict of interest in setting prices.

Biogas

In May 2022, the government stated that it wants to support biogas plants that feed into the natural gas network in the same way as biogas plants that produce heat and electricity. Estimates show that up to CHF 5-7 million per year of subsidies over six years could be needed.

Natural gas security

Natural gas emergency response organisation

In Switzerland, security of gas supply is the responsibility of several entities. The gas industry is responsible for ensuring short-term security of supply through market-based measures. If the industry is no longer able to remedy a disruption on its own, the competence is transferred to the National Economic Supply (NES), which can resort to non-market based measures. This situation is defined as a "serious shortage" in the National Economic Supply Act. The NES constantly monitors the country's natural gas supply.

Natural gas emergency response preparedness and measures

- **Switching dual-fuel consumers to oil**

  In the event of a severe shortage of natural gas, dual-fuel installations would be instructed to switch from gas to oil. The share in total gas demand of dual-fuel consumers is about 20%.

- **Compulsory stocks for gas-to-fuel switching**

  A compulsory fuel oil stockholding is set up for dual-fuel consumers. This reserve is equivalent to 4.5 months' consumption of dual-fuel consumers and must be built up by gas importers. These reserves would be released in the event of a simultaneous gas and fuel oil market shortage.

- **Call for savings**

  In parallel to the switch to dual-fuel installations, the government would call for savings on gas and a reduction of heating demand.

- **Consumption restriction**

  If the above measures were insufficient, the use of gas in special areas (such as leisure and wellness) and non-operational applications could be banned. In addition, a heating temperature limit of 20°C may be imposed on indoor spaces heated by gas or by a gas-fired district heating network. This also applies to hot water production, which can be limited to 60°C.

- **Contingency of unprotected customers**

  A contingency would be introduced by ordinance as a last resort. The concept envisages a partial or total reduction in gas demand for non-protected customers. Protected customers such as households and basic social services would not be affected.

The Russian invasion of Ukraine in 2022 posed serious gas challenges. Although Switzerland does not import natural gas from Russia directly, the tight natural gas market in Europe required Switzerland to take action to prepare for natural gas security in the winter of 2022/23. In May 2022, a government ordinance mandated the Swiss gas industry to store 15% of the annual consumption in foreign storage and buy gas options for about 20% of the winter consumption; 6 TWh were stored in neighbouring countries and the Netherlands. The government extended the ordinance in February 2023 for the winter of 2023/24, but only with regard to gas storage.

In addition, the government adopted a voluntary savings target of 15% for gas for the winter (from the beginning of October 2022 to the end of March 2023), following the European Union's targets. Through this period, gas savings amounted to 21.8%, or 16.4% on a temperature adjusted basis. To reach the goal, the government recommended that dual-fuel consumers switch to oil on a voluntary basis starting on 1 October 2022. To facilitate the switch, the government relaxed air pollution and CO_2 emissions norms for dual-fuel plants over the winter of 2022/23. Furthermore, the government launched a nationwide gas (and electricity) savings campaign in co-operation with the business community.

Assessment

The Swiss Constitution and the Energy Act provide a general framework for a secure natural gas supply. The Federal Pipelines Act of 1963 obligates network operators to conclude contracts with third parties for the transport of gas, providing this is technically possible, economically feasible and the third party provides appropriate compensation. However, Switzerland has no comprehensive legal framework to ensure effective competition in the sector and no gas regulatory agency. The establishment of an "Associations Agreement on Gas" regulates access to the high-pressure network for large industrial customers, while medium to small consumers remain captive. The Federal Gas Supply Act, which is under development, would establish the legal and regulatory framework for the Swiss gas market. The current legal framework does not attribute clear roles and responsibilities to the natural gas sector actors. The 2022 gas crisis has revealed the importance of a clear and legally binding definition of roles and responsibilities.

The government aims at net zero emissions by 2050, which entails a quasi-total phase-out of natural gas. The EP2050+ foresees that the remaining gas demand be covered with biogas, hydrogen or renewable electricity-based synthetic gases. However, Switzerland has not prepared a national roadmap for the transition from natural gas to decarbonised gas. A gas sector roadmap with medium- to long-term scenarios would support gas market planning.

The phase-out of natural gas will affect import patterns, infrastructure and heating sector investment. Without regulatory and legal clarity, Switzerland may miss opportunities to strengthen innovation, competition and efficiency in the gas sector.

The government is developing a national Hydrogen Strategy. It anticipates that the demand for hydrogen will be rather low. Additionally, the government recognises that the country lacks incentives to develop or import hydrogen. Switzerland participates in incipient harmonisation efforts for the hydrogen market in the Pentalateral Forum. Still, a national hydrogen strategy and a co-ordinated regional hydrogen strategy would allow it to benefit from a regional market. At the same time, Switzerland has been successfully

promoting (indirectly through tax exemptions) the development of a hydrogen ecosystem for fuel cell trucks, with electrolysers, filling stations and the procurement of fuel cell trucks.

Regional alignment is not limited to the hydrogen strategy. It also applies to long-term gas planning, given the country's linkage with neighbouring EU countries and lack of gas storage. As prospects to resume negotiations on an electricity agreement with the European Union appear more likely, Switzerland may consider subsequent negotiations on gas and hydrogen.

The SFOE issues rulings on a case-by-case basis in the event of a dispute over contracts between pipeline operators and natural gas shippers. Additionally, ComCo can enforce the right to grid access based on the 1995 Cartel Act. It can also address collusion, monopolies, abuse of market position and merger agreements. For instance, in 2020, ComCo ruled that all consumers should be able to choose their natural gas supplier. Yet, ComCo has little leverage on how the market is shaping. In addition, retail gas prices and tariffs are set by the utilities themselves, without the oversight of a regulator, like in the electricity sector. It would, therefore, be useful to encourage ComCo to play a more active role in enhancing gas market transparency.

Recommendations

The government of Switzerland should:

- ☐ Pass the Gas Supply Act to create a uniform federal regulatory environment.
- ☐ Create a long-term and comprehensive strategy for gas to 2050, including hydrogen and other renewable gases under the EP2050+, aligned with the ongoing efforts of its neighbouring countries.
- ☐ Encourage the Competition Commission to enhance market transparency by increasing the visibility of gas prices and enforcing fair market practices.
- ☐ Clarify the role and responsibilities of the actors involved in the natural gas sector.

8. Nuclear

Key data (2021)

Number of reactors: four reactors, three power plants

Installed capacity: 2 973 MW

Electricity generation: 19.4 TWh, -28% since 2011

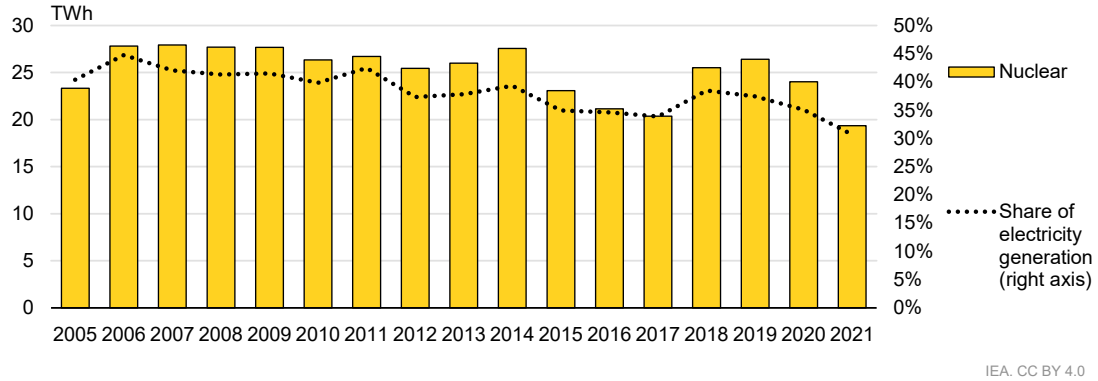
Share of nuclear: 22.5% of total energy supply, 30.9% of electricity generation

Source: IEA (2022), World Energy Balances.

Overview

Nuclear electricity generation accounted for 22% of Switzerland's TES and 31% of total generation in 2021 (Figure 8.1). Nuclear power has been the second-largest source of electricity in Switzerland for decades. In 2021, Switzerland had the eight-highest share of nuclear power in electricity generation among IEA countries.

Figure 8.1 Nuclear electricity generation in Switzerland, 2005-2021



Source: IEA (2022), World Energy Balances.

A gradual phase-out from nuclear was decided in 2011, leading to the drafting of the ES2050, which was approved by referendum in 2017. The ES2050 prohibits the construction of new nuclear power plants and the granting of new general licences while allowing existing plants to run as long as they comply with safety regulations. It also leaves the backdoor open for future safer nuclear technologies. The first plant shut down in 2019, albeit for financial reasons.

The background for the nuclear phase-out was that the Swiss public opinion became anti-nuclear following the 2011 Fukushima accident due to earthquake and subsequent tsunami. At the time, three new NPPs were under consideration and their licensing would have required parliamentary approval, which would have been challenged by a referendum. Nevertheless, in 2016, a popular initiative calling for a defined shutdown date for existing NPPs was rejected by a majority of voters.

In parallel, Switzerland is preparing its deep geological disposal strategy to manage its radioactive waste on its soil in the application of the “polluter-pays principle”. The chosen site was announced in September 2022.

Status of the Swiss nuclear fleet

The first Swiss nuclear plant, Beznau I, was commissioned 1969 and has been since 2012 the world’s oldest operating NPP. Two years later, a second reactor was commissioned at Beznau. Both are pressurised water reactors (PWR). A boiling water reactor (BWR) was then introduced with the Mühleberg NPP in 1972; followed by a PWR at Gösgen in 1979 and a BWR at Leibstadt in 1984. The two youngest NPPs have a significantly larger capacity than the earlier NPPs. The five NPPS are sourced from three different vendors.

Table 8.1 Status of Swiss nuclear power plants as of 2021

Reactor unit	Type	Status	Operator	Technology vendor	Year of first grid connection	Shutdown date	Net capacity (MWe)
Beznau 1	PWR	Operational	Axpo	Westinghouse	1969		365
Beznau 2	PWR	Operational	Axpo	Westinghouse	1971		365
Mühleberg	BWR	Permanent shutdown	BKW	General Electric	1972	2019	373
Gösgen	PWR	Operational	KKG**	Siemens KWU	1979		1 010
Leibstadt	BWR	Operational	KKL***	General Electric	1984		1 233
Total*							**2 973**

*Total of reactors in operation; the capacity of the Mühleberg reactor is excluded.

**KKG is a consortium owned by 40% Alpiq, 25% Axpo, 15% the City of Zurich, 12.5% Centralschweizerische Kraftwerke (CKW), 7.5% the City of Bern.

***KKL is a consortium owned by 27.4% Alpiq, 22.8% Axpo Power, 16.3% Axpo Trading, 13.6% CKW, 14.5% BKW Energie, 5.4% AEW ENergie.

Note: Mwe = megawatt electrical.

Source: IAEA (2022), Country Nuclear Power Profile 2022 - Switzerland.

The production capacity of each reactor was increased due to advances in components and performance improvement, and therefore power upgrade. This resulted in a peaking capacity at 3.3 GW for the NPPs between 2014 and 2018. Since the Mühleberg reactor was shut down at the end of 2019, total installed nuclear capacity reduced to 2.97 GW in 2021, equal to 13% of Switzerland’s total installed capacity in the same year.

The two nuclear reactors of Beznau are owned and operated by Axpo, one of the largest utilities in Switzerland, whereas the NPPs of Gösgen and Leibstadt are owned by a consortium of energy utilities, with majority ownership by the three large Swiss electricity utilities (Alpiq, Axpo and BKW) and their subsidiaries. BKW was the operator of the Mühleberg NPP, which is in the process of decommissioning.

All nuclear fuel is imported, as Switzerland does not have uranium reserves. Uranium is instead procured on world markets; its enrichment is provided by a variety of contractors, and fuel fabrication is similarly diverse, which greatly reduces supply disruption risks.

- European producers supply the enriched uranium of the Gösgen reactor, while the fuel assemblies are manufactured in Europe.
- The Leibstadt plant obtains enriched uranium from Russian and European suppliers. Orano (ex-Areva) and Westinghouse supply fuel assemblies, with production in Lingen, Germany, and Västeras, Sweden.
- The Beznau NPPs procure exclusively ready-to-use nuclear fuel supplied by Orano and produced at MSZ (Mashinostroitelny Zavod) in Russia.

Previously, Swiss spent fuel was reprocessed in other countries such as France or the United Kingdom. However, for the past two decades, the reprocessing of spent fuel has been banned and the fuel must now be disposed of as radioactive waste.

Power generation

Nuclear energy has provided a stable share of around 30% of Switzerland's electricity supply since the 1990s. Overall, nuclear generation has been trending slightly downward due to the permanent shutdown of the Mühleberg NPP, spurred by economic reasons. The Swiss nuclear fleet is operated in baseload mode only and does not provide ancillary services to the grid.

Observed sharp drops in nuclear production are explained by prolonged plant outages for maintenance, inspection and/or refurbishment. This was the case in 2015-17 and again in 2021 when the long annual maintenance inspection was compounded by refurbishment works of the Leibstadt NPP, which lasted six months.

In addition to electricity generation, the Beznau and Gösgen NPPs supply district heating to surrounding areas. Beznau has a 130-kilometre distribution network serving 11 nearby towns and a capacity of approximately 80 MW, which offsets 12 000 tonnes of fuel oil consumption per year.

The role of long-term operation of Swiss nuclear power plants in the generation mix

Switzerland's Long-Term Climate Strategy assumes an operating period of 50 years for the country's NPPs, although reactors have an indefinite operating licence as long as they are deemed safe. At the end of 2022, the average operation time of Switzerland's nuclear fleet was over 46 years. Three of the four nuclear reactors are already considered to be operating "long-term", as an operating period of 40 years is generally assumed for light water reactors.

The NPP operators now envision a progressive shift toward 60 years of operation, as the Beznau I and II reactors already operate longer than 50 years. Based on 60 years of operation, the closure dates would then be 2029 for Beznau I, 2032 for Beznau II, 2039 for Gösgen and 2044 for Leibstadt. From a technical perspective, long-term operation should not face major generic technical barriers if utilities implement enhanced ageing

management programmes using the technical evidence already available while performing the necessary repairs and replacements.

In Switzerland, operators are required to perform regular in-depth safety reviews with the Swiss Federal Nuclear Safety Inspectorate (ENSI). ENSI is also responsible for verifying and enforcing the legal requirements for nuclear safety. These reviews are conducted every ten years and notified to ENSI before each ten-year operating period expires. They are also required for long-term operation beyond 40 years.

Before reaching 40 years of operation, each NPP operator has to submit – along with the periodic safety review – proof of safety for long-term operation to ENSI. This proof of safety must include information such as the planned period of operation, proof that the design limits of the safety-relevant parts of the system will not be reached during the planned period of operation, the planned backfitting and measures intended to guarantee sufficient workforce availability with the required expertise for the planned period of operation. If, at any time, ENSI determines that safety cannot be guaranteed, the operating licence can be withdrawn. In such a case, the operator has two choices: permanent shutdown or performing refurbishment works to comply with safety requirements.

Each periodic review can last for several months. Often, safety improvements or refurbishment works are carried out in parallel. Table 8.2 summarises the main steps for the refurbishment of the fleet since 2019 with a view to long-term operation.

Table 8.2 Major modernisation and/or refurbishment of nuclear operating plants in recent years in Switzerland

Reactor	Work
Beznau I and II	• In August 2022, system controls and tests, as well as planned maintenance work, were carried out on various components.
Leibstadt	• In 2022, the renovation of the instrumentation and control systems was carried out. • In 2021, for six months, KKL conducted deep refurbishment works by replacing the condenser and transforming the recirculation system.
Gösgen	• Since 2019, the Gösgen nuclear power plant has been the subject of ongoing modernisation and safety improvement projects, including the modernisation of the reactor protection system in 2021.

Thus, nuclear power can remain an essential component of Switzerland's high share of low-carbon electricity generation as long as safety can be regularly demonstrated. This condition seems to be satisfied by the operators who are continuously upgrading their plants for long-term operation. In addition, nuclear power provides a reliable baseload supply that complements the role of hydropower, particularly during the winter months when Swiss demand peaks and hydropower resources dwindle as the winter progresses.

As part of the long-term energy strategy, the EP2050+ foresees a considerable increase in solar capacities over the next two decades to achieve net zero in 2050 (see Chapter 1). In this context, the long-term operation of the NPPs could complement the expansion of variable renewable capacities.

Moreover, the long-term operation of existing NPPs can bring sizeable benefits from a plant-level and a system-level perspective. A 2020 joint study by the IEA and the Nuclear Energy Agency indicated costs of around 30 USD/MWh (levelised cost of electricity) for continuing operation of Swiss NPPs for a minimum of either 10 or 20 years at a broad range of discount rates. Presently, the investment plans of Swiss NPP operators for

replacement and refurbishment projects, depreciation, and resource planning are designed for these reference operating lifetimes. From a system-level perspective, a mix of power generation from long-term nuclear operation from Switzerland's two youngest NPPs and variable renewable energy sources – mainly solar PV – is a cost-effective solution to reach the Swiss net zero target by 2050.

Switzerland is preparing a hydrogen strategy as the government sees the demand for hydrogen to grow strongly in the coming years. In this context, the government could also explore how the long-term operation of existing NPPs could contribute to producing hydrogen for industrial needs pending the establishment of a hydrogen network in Switzerland and more generally in Europe. In this way, hydrogen production could become an additional source of income for NPP operators and improve their economic performance.

Radioactive waste management strategy

According to the Nuclear Energy Act and in application of the "polluter-pays principle", producers of radioactive waste are responsible for its safe management and disposal and thus obligated to bear the associated costs. The responsibility for conditioning and storage of radioactive waste from NPPs remains with the NPP operators, while the federal government assumes responsibility for collecting, conditioning, storing and disposing of radioactive waste generated by the use of radioisotopes in medicine, industry and research. The producers of these radioactive wastes are charged a service fee.

The NPP operators and the federal government created the National Cooperative for the Disposal of Radioactive Waste (Nagra) to prepare and implement solutions for the disposal of all radioactive waste categories. As part of its responsibilities, Nagra regularly updates its waste inventory (every five years) necessary for designing any waste disposal facilities based on the envisaged operation duration of the fleet. The inventory includes waste already produced as well as future waste.

In the most recent inventory, Nagra plans to manage over 57 500 m^3 of all types of radioactive waste, taking into account an operation duration of 60 years for the currently operating power plants and 47 years for the Mühleberg NPP. High-level waste, including spent nuclear fuel, will represent 10% of the total volume and 99% of the radioactivity of all radioactive waste. Low- and intermediate-level waste will comprise 97% of the total volume of waste.

Switzerland has opted to manage its radioactive waste storage only in deep geological repositories and therefore has excluded sub- and near-surface repositories. In addition, the Nuclear Energy Act and the corresponding regulations require raw waste to be minimised and conditioned as soon as possible.

Since no repositories are in operation yet, all radioactive waste is currently stored in the central interim storage facilities. In addition to on-site installations for the conditioning and storage of radioactive waste from NPPs situated in the vicinity of each NPP. In addition, storage capacity is available at the central interim storage facility (Zwilag) located in Würenlingen; adjacent to the Paul Scherrer Institut (PSI) research centre, where radioactive waste from medicine, industry and research is conditioned and stored.

Zwilag manages all types of waste and contains one central interim dry cask storage facility for high-level waste and operates facilities for incineration (in a high-temperature plasma oven), conditioning and storage of low- and intermediate-level radioactive waste.

The revised Nuclear Energy Act that came into force on 1 January 2018 prohibits the reprocessing of spent fuel assemblies. All radioactive waste resulting from the recycling abroad was thus returned to Switzerland. Spent fuel is now considered as radioactive waste in Switzerland and must eventually be disposed of in a deep geological repository.

Site selection process

Since 2008, Switzerland has been executing a robust three-stage procedure to identify and license one or several suitable site(s) for deep geological repositories for both low-, intermediate- and high-level waste (Table 8.3). In the framework of this sectoral plan, four key safety criteria were identified: 1) properties of the host rock and the effective containment zone; 2) long-term stability; 3) reliability of geological findings; and 4) engineering suitability.

Based on these, the first step was for Nagra to identify six potential sites by 2011. The second step, reached in 2018, was to narrow the choice down to three potential sites. The third and final stage of the plan indicates the selected site and the associated reasons.

Table 8.3 Timeline of the deep geological repository site selection process in Switzerland

Search for suitable sites for deep geological repositories (sectorial plan and general licensing procedure)	Duration
Development of the concept of the Sectorial Plan for Deep Geological Repositories with broad participation	December 2004 to April 2008
Stage 1: Proposal and official review of six potential geological siting areas, set-up of regional participation	April 2008 to December 2011
Stage 2: Location of surface facilities, involvement of regional conferences, narrowing down to at least two siting regions per waste category	December 2011 to November 2018
Stage 3: Deep boreholes, preparation of an application for a general licence, designation of sites, issue of a general licence	November 2018 to the end of 2029
Adoption by parliament of the government's decision concerning the general licence, possibly followed by a referendum	Beginning of 2030 to the end of 2031

Source: Country submission

On 12 September 2022, Nagra announced its intention to build one unique deep geological repository for radioactive waste at the "Nördlich Lägern" based on the opalinus clay and one conditioning facility for fuel elements at the site of the existing central interim storage facility in Würenlingen based on the opalinus clay. The sites are close to the Swiss-German border.

The government and Nagra have made significant efforts to involve stakeholders in the site selection process, especially those close to potential repository sites, including those

from across the German border. Stakeholders from local municipal authorities, regional planning agencies, non-governmental organisations and civil society were involved via participation in “regional conferences”. The framework of the sectoral plan also envisages negotiations about compensation for the affected municipalities during stage 3.

In line with the legislation, Nagra has clearly communicated that safety is the primary criterion for site selection. The government and Nagra have also worked with stakeholders on other issues, such as land-use planning. For example, the location of the surface facilities, as suggested by Nagra, was chosen as a result of a comprehensive participation process with stakeholders involving regional conferences.

The next step for Nagra is to prepare and submit a general licence application to ENSI and the SFOE between 2024 and 2029. As part of this submission, Nagra will carry out deep boreholes to consolidate the “dossier”. To assist in the assessment, Nagra envisaged plans to engage the international community. Based on current assumptions provided by Nagra, emplacement operations will start around 2050 for low- and intermediate-level radioactive waste and around 2060 for high-level radioactive waste.

Funding

Under the “user pays” principle, which is enshrined in the Nuclear Energy Act, operators are responsible for the disposal of radioactive waste and decommissioning of the plants and are required to bear the associated costs. These costs are guaranteed by two independent legal entities, referred to as the Decommissioning Fund for Nuclear Facilities and Waste Disposal Fund for Nuclear Power Plants (STENFO). STENFO is managed by a federally appointed management board and its annual reports are approved by the government.

These two funds have to guarantee all the costs related to decommissioning plants and the disposal of radioactive waste. In addition, until the full decommissioning of an NPP, operators have to continue making the necessary contributions to the two funds. NPP operators make annual contributions to STENFO. They are collectively responsible for covering the costs and, if one operator is unable to cover all of its costs, the other operators would be forced to cover any efficiencies. NPP operators have no direct access to the assets of the two funds.

STENFO calculates the costs for decommissioning and disposal every five years based on a methodology which complies with international standards. Since 2016, the methodology of the cost structure calculation consists of two steps. First, the calculation takes into account the base costs, consisting of the initial costs and the risk mitigation costs. It then adds the inaccuracy of cost estimation, costs of ignored hazards and opportunities, and an additional general safety margin to reach the total costs.

Second, each operator’s annual contribution is calculated based on the estimated decommissioning and waste disposal cost, the return on investment, the rate of inflation, and the operating lifetime that is assumed by default to be 50 years. STENFO’s next cost estimate will be released in 2023. STENFO also regularly evaluates challenges such as inherent risks, like insufficient investment returns or the economic instability of an NPP operator to mitigate them. Independent international experts review the cost studies.

While Nagra and the plant operators are already considering 60-year operation in their estimates, STENFO and the government still consider the operating lifetime to be 50 years.

Nagra estimates the total costs for decommissioning and disposal of the deep geological repository to be CHF 22 billion (decommissioning costs at CHF 3.7 billion, disposal costs at CHF 18 billion), taking into account 60 years of operation for the remaining NPPs, and a 50-year post-operational monitoring phase. Moreover, due to the selection of one site for all deep geological repository, cost estimates were reduced of CHF 2 billion compared to the first prevision. For the first time, the Decommissioning Fund has released funds for the decommissioning of the Mühleberg plant; the total costs for decommissioning the Mühleberg plant are budgeted at CHF 950 million.

Nuclear research

In 2020, nuclear research accounted for about 10% of public RD&I expenditure. Absolute spending on nuclear RD&I has been stable for a decade but down from a decade before. Within the framework of the Master Plan, the Energy Research Commission supports, as one of its main priorities for the next two years, ensuring safe operation know-how as well as research into the operational period of a nuclear reactor and the disposal of radioactive waste.

PSI, ETH Zurich and the Swiss Federal Institute of Technology Lausanne (EPFL) are the largest research centres for natural and engineering sciences, including nuclear energy. PSI, through the Nuclear Energy and Safety Research Division, is Switzerland's main institute for nuclear research. PSI is responsible for the hot laboratory, which includes so-called hot cells that are well-equipped and shielded areas for working with and researching radioactive materials. In 2019, approximately 8% of PSI's annual public funding of CHF 300 million was spent on nuclear research. In line with the national trend, the government's funding of PSI's nuclear energy research activities have been strongly reduced over the past two decades, even though this reduction was partly compensated by increasing external funding. A large part of funding is for long-term research contracts; almost 70% of the nuclear energy research at PSI focuses on reactor safety and safety-related operational aspects of Swiss NPPs, and around 25% on nuclear waste disposal.

Switzerland is also involved in long-term research, such as nuclear fusion. The Swiss Plasma Center at EPFL was created in 2015 to reinforce Switzerland's international influence and impact in plasma and fusion research. The state-of-the-art infrastructures currently being developed focus on the variable configuration tokamak. This enables EPFL to fulfil its obligations on the way to fusion energy in the broader context of Europe, the Euratom research and training programme, and ITER.

Assessment

Nuclear power has provided a high and stable share of around 25% of Switzerland's energy supply since the 1990s. Electricity from nuclear accounted for 22% of Switzerland's TES and 31% of electricity generation in 2021. Nuclear energy is the second-largest energy source in Switzerland in terms of electricity generation and installed capacity after hydroelectricity.

Switzerland is committed to a gradual nuclear exit; new constructions have been banned since 2018, but existing plants are not bound by a fixed end date and can operate as long as their safety can be demonstrated to the regulatory body. The Swiss nuclear commercial programme started in 1969 with the commissioning of Beznau I, which since 2012 has been the world's oldest NPP in operation.

The Swiss nuclear fleet comprises four operational NPPs located at three different sites. A fifth reactor, Mühleberg, has been under decommissioning since the end of 2019, upon the decision of its operator due to commercial reasons. The four Swiss NPPs are operated in baseload mode only and do not provide ancillary services.

As recently as 2021, the government used the assumption of a 50-year operation period for each NPP in its Long-Term Climate Strategy. However, the Beznau I and II reactors are already beyond this limit and in 2021, the average duration of NPP operation was over 46 years. NPP operators now envisage a progressive shift towards 60 years. Based on a 60-year operation period, the next plant closure would take place in 2029 (365 MW) and the last in 2044 (1 233 MW). However, a longer but also shorter period of operation is theoretically possible for each remaining NPP if safety is no longer ensured or economic investments are not sustainable from the operator's perspective.

The EP2050+ foresees a considerable increase in solar PV capacities over the next two decades to achieve net zero in 2050. With the triple objectives of reducing emissions from the energy sector, ensuring energy supply, especially during the winter and reaching the renewable electricity target, the use of nuclear power could complement the shift to solar PV.

The long-term operation of one or more of the existing NPPs could be an option from a cost-effective perspective, with a levelised cost of around 30 USD/MWh. Furthermore, in the light of the upcoming Swiss hydrogen strategy, the long-term operation of nuclear power to produce low-carbon hydrogen could be further explored.

According to the Nuclear Energy Law, producers of radioactive waste are responsible for its safe management and disposal, and thus obligated to bear the associated costs. Nagra is in charge of the disposal of all types of radioactive waste from industry, medicine and research. Since 2008, Nagra has implemented a national waste strategy that takes into consideration local interest, stakeholders from local municipal authorities, regional planning agencies, non-governmental organisations and civil society by way of participation in regional conferences.

After the two first steps in the site selection process, Nagra announced on 12 September 2022 its intention to build one unique deep geological repository for both low-, intermediate- and high-level radioactive waste. The “Nördlich Lägern” site has been selected based on safety considerations. The conditioning facility for fuel elements will be built at a separate site, located next to the existing central interim storage facility in Würenlingen. The repository site is adjacent to the German border, where local opposition is vocal.

The next step for Nagra is to prepare and submit a general licence application to the SFOE by 2024. International collaboration to ensure safety through peer review, in parallel with the SFOE’s and ENSI’s review of the general licence application, is also envisaged. Nagra currently expects construction and operation to start just before 2050 or in the second half of the century.

Uncertainties remain for four reasons. First, the timeline takes into account considerable long time scales. Second, the approval of the general licence is not certain, nor is the vote in parliament; the possibility of a referendum must also be considered. Third, the waste inventory, even if periodically reviewed, is subject to change depending on the indefinite

duration of the NPPs' operation. Fourth, social acceptance is never guaranteed, even though a thorough methodology involving local stakeholders has been implemented since the beginning of the project.

As for finances, STENFO is the administrative management body responsible for collecting and overseeing two independent nuclear funds: one for the costs related to decommissioning nuclear facilities and one for the disposal of radioactive waste. The methodology of cost calculation is well-established and fulfils international standards to secure funding of waste management and decommissioning. STENFO regularly calculates the costs to ensure their continuous adequacy if plant operations are extended beyond currently assumed limits. The Decommissioning Fund was used for the first time in 2019 for decommissioning the Mühleberg reactor.

In 2021, nuclear research accounted for 13% of the public expenditure on RD&I. Absolute spending on nuclear RD&I has been stable for a decade while its share of total spending has halved. The Federal Energy Research Masterplan includes ensuring the know-how for safe operation, research into the operational period of nuclear reactors and the disposal of radioactive waste among its main priorities.

The State Secretariat for Education, Research and Innovation has not taken any concrete actions to maintain the skilled workforce and the commitment to educate a new generation of students in the nuclear field. Nevertheless, Swiss universities are maintaining their competence in the area of nuclear-related research. In light of the nuclear phase-out, the federal government should maintain RD&I efforts in a way that sustains workforce capabilities in Switzerland. The uncertainties surrounding the nuclear phase-out could lead to a net loss of know-how that, if not properly managed, could have detrimental consequences in the future for Switzerland's ability to perform nuclear activities, including the long-term operation of the existent plants.

Recommendations

The government of Switzerland should:

- ☐ Together with industry, develop a roadmap to support research and development and training the skilled workforce needed for all nuclear-related activities, including non-energy related ones, such as decommissioning, waste disposal and storage.
- ☐ Continue and deepen engagement with communities to build public trust in the process of making the selected site for deep geological disposal repository operational.
- ☐ Foster collaboration among national and international organisations to continue benefitting from sharing knowledge and best practices, in particular in the key areas of long-term operation, waste disposal and decommissioning.

9. Oil

Key data (2021)

Net imports of crude oil:* 47.2 kb/d, -47% since 2011

Domestic oil products production: 50 kb/d, -47% since 2011

Net imports of oil products: 115 kb/d, -14% since 2011

Share of oil: 34% of TES,** 0.1% of electricity generation, 0.8% of heat generation, 44% of total final consumption

Oil consumption by sector: 185 kb/d (domestic transport 56%, buildings 27%, industry including non-energy consumption 8.2%, international bunkers 8.7%, electricity and heat generation 0.1%).

*Imports/exports of crude oil includes crude oil, natural gas liquids and feedstock.

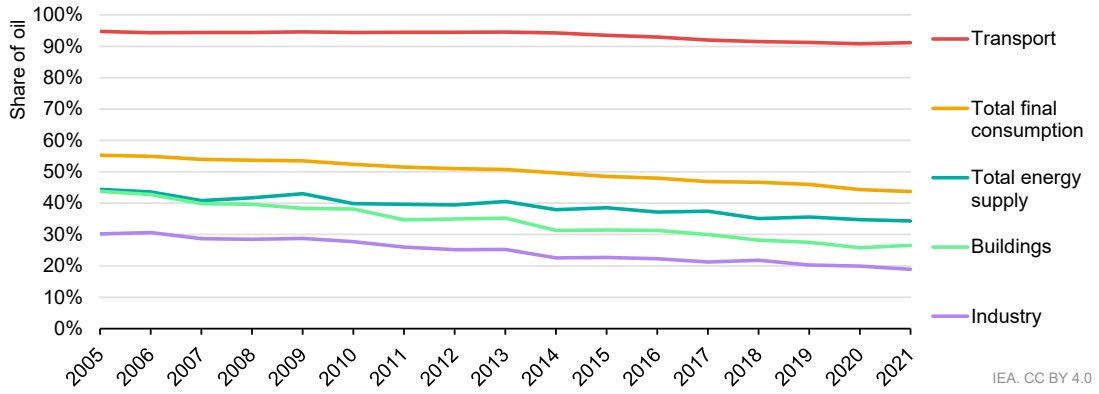
**Total energy supply does not include oil used for international bunkering.

Source: IEA (2022), Oil Information.

Overview

Despite a gradual decline, oil remains the most important source in Switzerland's energy system. In 2021, oil accounted for 34% of TES compared to 40% in 2011 and covered 44% of TFC (compared to 51% in 2011). Oil covered 91% of demand in the transport sector in 2021, and still plays a significant role in buildings (27%) and industry (19%). Oil use for electricity generation is only marginal, accounting for 0.1% in 2021. Switzerland's share of oil use in buildings is the fifth highest among IEA member countries. Switzerland does not have domestic production of crude oil.

Figure 9.1 Shares in oil in Switzerland's energy sector, 2005-2021



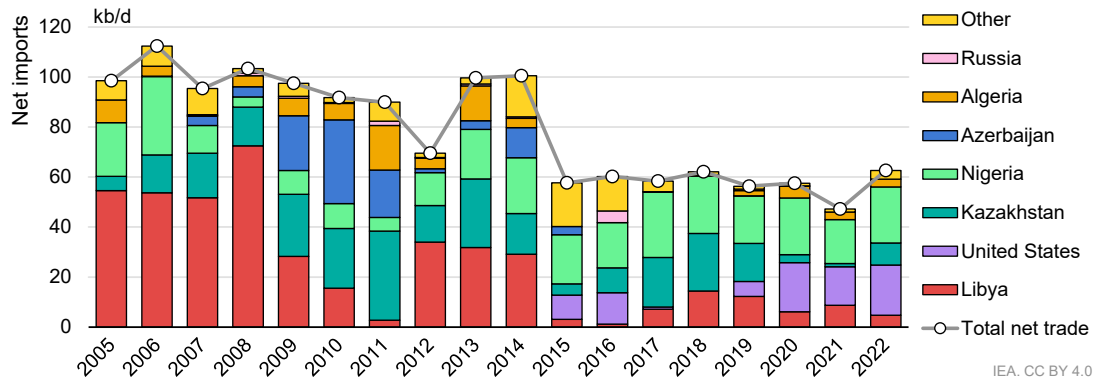
Source: IEA (2022), Oil Information.

Supply and demand

Crude oil production and trade

As Switzerland does not produce any crude oil, it depends on its imports. Of the 63 thousand barrels per day (kb/d) of crude oil imported in 2022, Nigeria accounted for the largest share at 36% (22 kb/d). The United States accounted for 32% (20 kb/d), Kazakhstan for 14% (9 kb/d), Libya for 8% (5 kb/d) and Algeria for 5% (3 kb/d). Crude imports drastically dropped as a result of the closure of the Collombey refinery in 2015. Switzerland has not imported crude oil from Russia since 2017 (Figure 9.2).

Figure 9.2 Switzerland's net imports of crude oil and refinery feedstock by country, 2005-2022



Note: Annual data were used for all years except 2022 (for which monthly data were used).

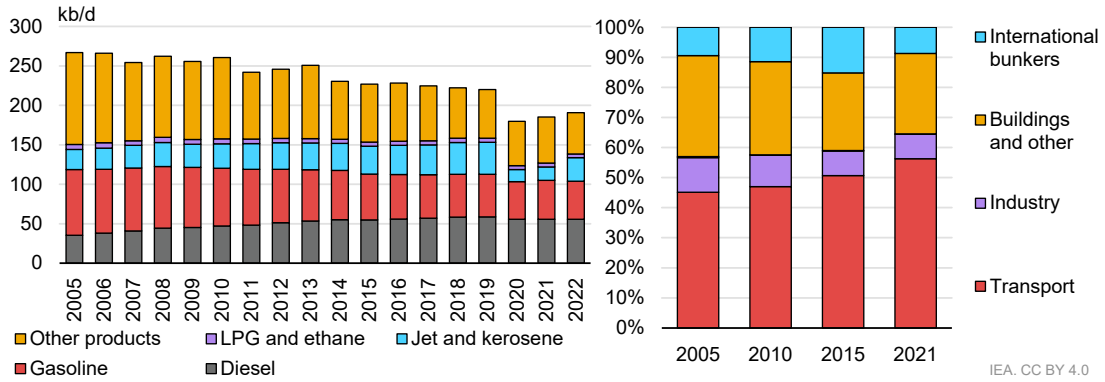
Sources: IEA (2022), Oil Information; IEA (2022), IEA Monthly Oil Statistics.

Oil products production, demand and trade

Between 2005 and 2019, Switzerland's oil consumption declined gradually, from 267 kb/d to 220 kb/d. It fell sharply to 180 kb/d in 2020 driven by a 62% drop in jet and kerosene due to travel restrictions in the wake of Covid-19. Demand for diesel increased by 66% from 2005 to 2019 and dropped to 55.6 kb/d between 2020 and 2022 while demand for gasoline decreased by 42% from 2005 to 2022. Switzerland's oil consumption rebounded by only 6% in 2022 as the aviation sector's demand remained well below its pre-Covid

levels. In 2021, the transport sector consumed 56% of total oil, followed by buildings (27%), industry (8%) and international bunkers (9%) (Figure 9.3).

Figure 9.3 Oil products demand by fuel (2005-2022) and sector (2005-2021) in Switzerland

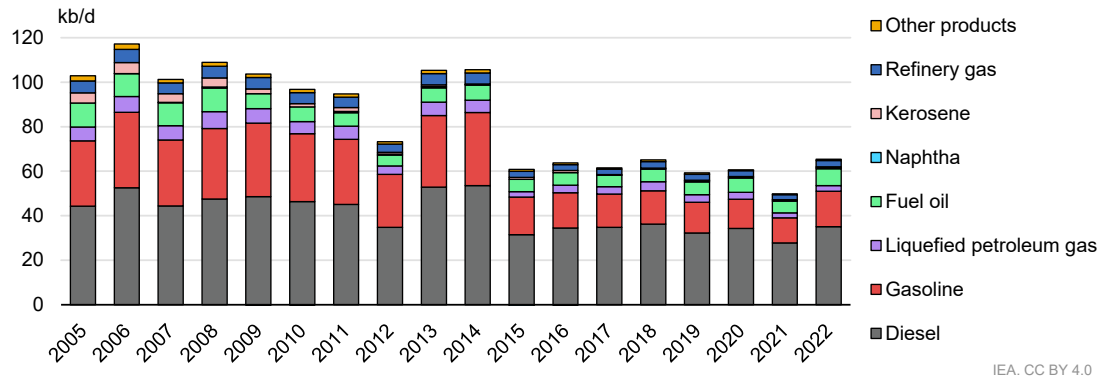


Notes: LPG = liquefied petroleum gas. The share of electricity and heat generation is not visible at this scale and was 0.1% in 2020.

Sources: IEA (2022), Oil Information. IEA (2022), IEA Monthly Oil Statistics.

In 2022, Switzerland produced about 34% of its oil product consumption (191 kb/d). Domestic refinery output has decreased by 38% following the closure of the Collombey refinery in 2015 (Figure 9.4). In 2022, Switzerland produced 35 kb/d of gas/diesel (54%), 16 kb/d of gasoline (25%) and 8 kb/d of fuel oil (12%).

Figure 9.4 Oil products production by fuel in Switzerland, 2005-2022

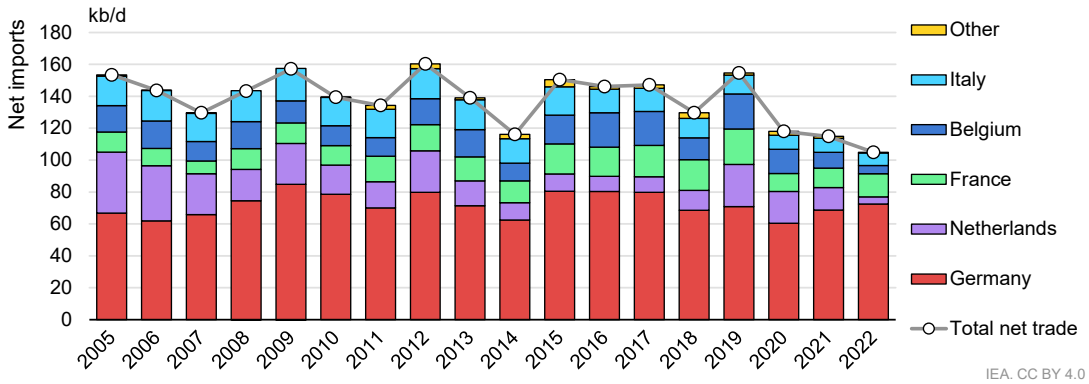


Note: Naphtha production is not visible at this scale and was 0.5 kb/d in 2022.

Source: IEA (2022), IEA Monthly Oil Statistics.

Switzerland is a net importer of oil products (Figure 9.5). Imports mainly come from European countries, and annual volume fluctuates. In 2022, the main source of imports was Germany, with 73 kb/d, followed by France (15 kb/d), Italy (8 kb/d), Belgium (5 kb/d) and the Netherlands (4 kb/d). Product imports dropped considerably in 2020 due to the Covid-19 pandemic and did not recover in 2022 in line with subdued demand for transport fuels.

Figure 9.5 Switzerland's net imports of oil products by country, 2005-2022



Source: IEA (2022), IEA Monthly Oil Statistics.

Oil policy

Switzerland is committed to reach net zero emissions by 2050 and consequently oil consumption must fall sharply and be almost completely replaced by renewable energies, synthetic fuels and non-fossil fuel electricity. In accordance with the subsidiarity principle, supplying the country with oil and oil products is the private sector's responsibility. The government only gets active once the private sector is unable to guarantee national economic supply in times of severe shortages.

Oil companies are obliged to offset an increasing percentage of the CO_2 emissions from the products sold. The obligation was introduced in 2013 and is expected to continue until 2030 (see Chapter 2). The offset obligation started at 2% of annual emissions and reached 12% in 2021. Compensation schemes are financed through a surcharge per litre of fuels. Under current legal provisions, the surcharge cannot exceed CHF 5 cents per litre. In reality, it amounts to CHF 1.5 cents. The Swiss oil industry created the KliK Foundation to manage projects and obtain compensation certificates.

While oil consumption has been decreasing over the last decade, Switzerland may experience a transient increase due to measures taken to hedge against possible natural gas and electricity shortages in winter. During the winter of 2022/23, the government contracted reserve power capacity, which can run primarily on gas, but also oil or hydrogen (see Chapters 1 and 6). In addition, the government recommended that dual-fuel end users switch to oil from 1 October 2022 onward to contribute to the voluntary gas savings target of 15%, which Switzerland, like the European Union, set for the period from October 2022 to March 2023. The contribution of oil switching to overall winter gas savings has not been quantified yet but is likely to be substantial. Given the uncertainties for the winter 2023/24, the government is likely to renew these measures.

Oil combustion emits more nitrogen oxides and CO_2 than natural gas. In September 2022, the government temporarily relaxed emissions norms provided in the CO_2 and Air Pollution Control Ordinances for dual-fuel users.

In addition to its participation in the IEA collective action of March 2022, Switzerland released additional stocks to respond to shortages resulting from the low water level of the Rhine River and rail import bottlenecks from Germany. From July to September 2022, the government temporarily lowered industry obligations by around 2 791 kb (443 734 m^3)

(around 11.3 % of their stockholding). In October 2022, compulsory stocks of jet fuel of 236.6 kb (37 616 m^3) were released (due to strikes in France and technical problems on a jet fuel pipeline).

Market structure

There have not been any major changes in the wholesale and retail market since the IEA's last energy policy review in 2018. The number of wholesale suppliers was reduced slightly from 56 to 52. These companies are obliged to hold compulsory oil stocks (equivalent to 4.5 months of demand for motor gasoline, diesel and heating oil and 3 months for jet fuel) and become members of the stockholding organisation CARBURA. There is a wide variety of importers, from international majors to national players. Some importers are active in various fuels (i.e. road fuels, jet fuel and heating oil) while others focus on specific types of products and sectors (i.e. aviation, heating oil). Eleven companies accounted for 79% of imports in 2021. As of 2022, Switzerland had 3 314 filling stations, compared to 3 424 at the time of the last review. There is a variety of ownership models, from independent stations to large importer-owned chains as well as franchise models. The retail market is fully open to competition and there are no market entry barriers.

Prices and taxation

There are no price controls in Switzerland for any oil products. Various taxes apply. Switzerland's automotive diesel prices, and in the first quarter of 2023 they were the third highest in the IEA (Figure 9.6). The average price of diesel was 2.21 USD/litre (compared to the IEA average price of 1.72 USD/litre) with a tax rate of 46% (compared with an IEA average tax rate of 37%). In the same quarter, Switzerland's unleaded gasoline price was the ninth highest among IEA member countries, at 2.71 USD/litre, with a tax rate of 50%, compared to the IEA average price of 1.71 USD/litre, with an average tax rate of 44% (Figure 9.7).

Biofuels are exempted from fuel excise taxes provided they meet sustainability criteria. To compensate for the fiscal loss, the excise tax on diesel and gasoline was increased by CHF 3.7 cents per litre on 1 January 2021. This is to stabilise fiscal revenues until the end of 2028.

Figure 9.6 Price comparison for automotive diesel in the IEA, 1Q 2023

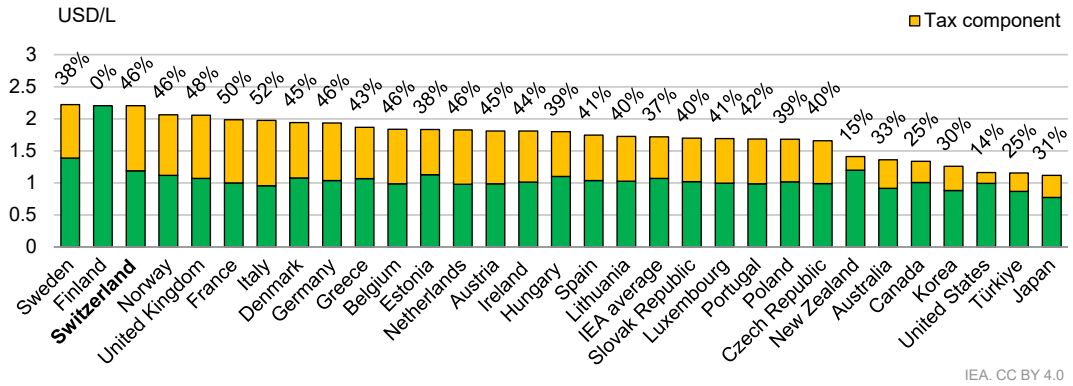
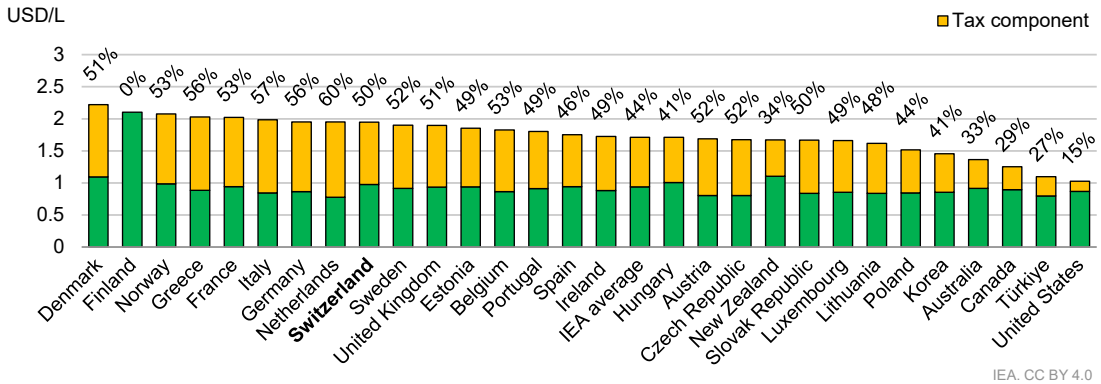


Figure 9.7 Price comparison for unleaded gasoline (95 RON) in the IEA, 1Q 2023



Notes: Automotive diesel data are unavailable for Denmark, Italy and Mexico for 3Q 2022; premium unleaded gasoline (95 RON) data are unavailable for Denmark, Italy, Japan and Mexico for 3Q 2022; tax component data of both automotive diesel and premium unleaded gasoline are unavailable for Finland for 3Q 2022.

Source: IEA (2023), Energy Prices (database).

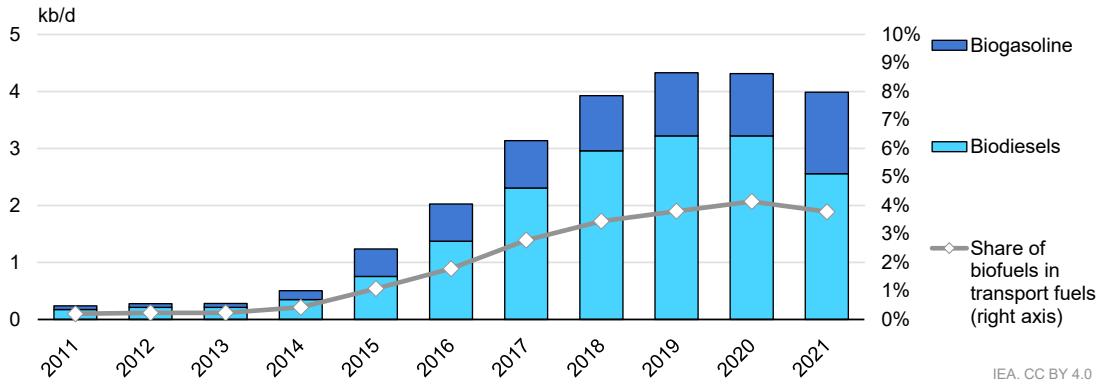
Biofuels

Biofuels represent a small but increasing market share of transport fuels. Biofuels accounted for 3.8% of transport fuels in 2021, compared to less than 0.2% in 2011 (Figure 9.8). In 2021, biodiesel accounted for 64% and biogasoline for 36% of total biofuels. Switzerland has ten small-scale biofuel production plants, while the major share is imported. Since 2021, biofuels can also be mixed with heating fuels.

The increasing uptake of biofuels is the outcome of the offset obligation on the fuel importers. KliK's financial resources provided seed funding for biofuels production capacity (biodiesel, hydrogenated vegetable oils and bioethanol, provided they meet sustainability requirements for exemption from the mineral oil tax). The KliK programme also covers imports.

The draft proposed CO_2 Act, expected to enter into force by 2025, introduces a blending mandate for biofuels, in addition to the CO_2 offset obligation for fossil fuels. This reflects a recommendation from the IEA's last energy policy review. The blending mandate also covers SAF, i.e. 2% in 2025, aligned with the EU target. At this stage, there is no clear plan for how this SAF will be procured or what the prices will be.

Figure 9.8 Switzerland's biofuels and shares in transport fuels, 2011-2021



Source: IEA (2022), Renewables 2022 dataset.

Biofuels offer a complementary decarbonisation pathway to electrification in the short to medium term. However, incentives for biofuels should not contradict the electrification of the transport sector and lead to lock-in effects, especially as Switzerland only produces small amounts of biofuels.

Infrastructure

As oil supply is the responsibility of the oil industry, there is no government strategy for planning and developing oil infrastructure. The major infrastructure challenge is the tightening of import and internal transport capacities. These have repeatedly required the government to release emergency stocks.

Another issue is growing opposition to renew lease contracts for tank farms near urban areas. This especially affects tank farms at the receiving end of the product pipeline in Geneva.

Refineries

Switzerland only has one operational oil refinery, in Cressier, operated by Varo Energy BV (partly owned by the oil trading company Vitol), with a total distillation capacity of 68 kb/d. In 2022, Switzerland produced 35 kb/d of gas/diesel (54%), 16 kb/d of gasoline (25%) and 8 kb/d of fuel oil (12%).

Switzerland's second refinery, Collombey, closed in 2015. It had a capacity of around 58 kb/d. Dismantling is to be completed by 2024.

Transportation

Crude oil is imported via the Oléoduc du Jura Neuchâtelois, with a capacity of 91 kb/d (4.5 Mt per year), connecting the refinery in Cressier with the SPSE (Société du pipeline sud-européen) pipeline at Fos-sur-Mer on the French Mediterranean coast. The refinery accounted for 27% of oil product supply in 2021.

Oil products are supplied by pipeline, rail, river barges and trucks, depending on the type of product and the location of the demand centres. In 2021, 31% of oil products were imported via rail, 29% via the Rhine River, 7% via the Société du Pipeline à produits pétroliers sur territoire Genevois (SAPPRO) product pipeline (connecting Fos-sur-Mer in

France with the tank farms in Geneva) and the remaining 6% via road trucks. The share of transport mode for oil products fluctuates annually.

Switzerland has two oil product receiving terminals in the Basel region along the Rhine River. Between 25% and 30% of imports arrive via barge; in 2021, the share was 29%. This share has increased following the closure of the Collombey refinery in 2015. The river transport is especially important for the import of gasoil (road diesel and heating oil). Gasoline is predominantly imported via rail. The SAPPRO product pipeline supplies the tank farms in Geneva with gasoil and jet fuel for Geneva airport. Delivery by truck is especially important for the Italian-speaking region of Ticino, which is supplied mostly from Italian refineries.

Switzerland has faced logistic issues with the import of oil products. One major issue relates to the low water level of the Rhine River, an occurrence that is increasing in frequency due to prolonged dry weather periods. This strongly limits ship loads into Switzerland. Also, Switzerland is increasingly experiencing problems with rail imports from the north. There are several reasons for this: lack of staff (especially train drivers), limited access to railway routes, maintenance work of railway routes in Southern Germany and a shortage of rail cars. Refinery outages due to incidents or maintenance in neighbouring countries is another concern, especially since Switzerland only has one operating refinery since 2015. Overall, the supply of oil products is well diversified.

The government can address these challenges through stock releases. However, in line with falling demand for oil and oil products, related stock levels are reduced too. This, in turn, impacts on the availability of logistical facilities to quickly react to shortages. A further compounding aspect is the increased use of oil as an alternative to gas in dual-fuel installations, for power back-up generators and in the reserve power plants that are under construction.

Storage

Switzerland only stores products, except at the refinery, and all storage is above-ground. At the end of 2021, Switzerland had a total storage capacity of just below 6.9 million cubic meters (mcm), compared to 7.5 mcm at the time of the last review. There were 57 tank farms, with volumes between 31.4 kb (5 000 m^3) and 4.7 mb (750 000 m^3). Most storage in Switzerland is used for compulsory stockholding. Tank farms are mostly supplied by train, except for the tank farms in Geneva and Basel, which are supplied via pipeline and Rhine barges respectively.

Oil emergency policy and stockholding

Stockholding

The National Economic Supply Act of 2017 sets the basis for Switzerland's emergency response policy. It confers statutory power to the government in the case of an emergency for demand restraint measures and stock releases, including implementation of IEA collective actions. Switzerland meets its stockholding obligation to the IEA with a compulsory stockholding obligation on industry. Private sector CARBURA is tasked with carrying out and controlling compulsory stockpiling for oil products, issuing import permits, managing guarantee funds that compensate stockholders for their costs, co-operating in matters of national economic supply and collecting statistical data.

There is no obligation to stockpile crude, and almost all stocks are held as products. In terms of dedicated emergency stocks, all stocks are held in products. Oil importers are obliged to hold stocks equivalent to 4.5 months of deliveries for motor gasoline, diesel and heating oil, and 3 months for jet fuel.

Switzerland has a strong record of compliance with the IEA 90-day obligation. In February 2023, Switzerland held 163 days of net imports, all industry stocks. Switzerland joined the IEA collective action in March 2022, pledging 350 kb. Switzerland did not participate in the IEA collective action in April 2022. Furthermore, Switzerland released additional stocks in 2022 responding to different and cumulative import problems, such as the low water level of the Rhine River, problems in the neighbouring German rail transport system, industrial actions in France as well as particle pollution in the SAPPRO product pipeline, all leading to substantial supply losses.

Draw-down procedures and demand restraint measures

The structure and organisation of NES mirrors the Swiss economy. It comprises around 250 representatives from various sectors of private industry, such as the oil, natural gas and electricity sector. These industry representatives co-operate voluntarily with the NES on a part-time basis. The government also participates in the NES. The government guarantees the necessary co-ordination and strategic planning, which is carried out by a small core team (around 40 people) of the Federal Office for National Economic Supply.

Stock release is the principal means for Switzerland to address an oil supply disruption, and supply- and demand-side measures are implemented when a supply crisis is severe and longer lasting. In the event of an oil supply disruption, any member of the management team of the NES is allowed to activate the crisis management process. This process includes an initial meeting, where decisions will be taken on whether or not to trigger the crisis management process and who is to join the crisis reaction team.

Demand restraint is a secondary emergency response measure that complements a stock draw-down if it becomes apparent that the disruption is likely to last more than six months. Soft demand restraint instruments range from promoting eco-driving and carpooling to more severe measures such as Sunday driving bans and setting a maximum for tank fill of 50% for heating oil to avoid panic buying. Heavy-handed demand restraint includes road fuel rationing or quota allocations for heating oil and jet fuel.

Assessment

With Switzerland's net zero emissions goal by 2050, the consumption of oil products will be almost entirely phased out. However, during the transition, oil will continue to be an important energy source, particularly in the transport sector and to a lesser degree for heating. In accordance with the subsidiarity principle, the private sector takes primary responsibility for oil supply security.

Switzerland already has a diversity of countries for imports of crude oil and oil products. While stocks procurement is a task of the private sector, it will be important for the government to monitor the oil supply chain, through, for example, regular reporting by industry and to the IEA. It will be critical for the government and industry to work together to address any supply chain vulnerabilities or disruptions that may emerge. As the private

sector's decisions have a significant impact on the country's overall oil policy and security, it is important that the government has a clear understanding of any investment and dis-investment plans of the oil industry.

Switzerland has recurrently faced logistic issues stemming from various factors (low level of the Rhine River, lack of alternative transportation options), which resulted in stock releases. Stock releases address short-term difficulties. But the government should not rely only on stock releases. Instead, it should actively co-ordinate with the private sector on how to remove the logistical bottlenecks and plan the medium- and long-term infrastructure requirements, while keeping in mind the overall aim to significantly reduce the share of oil in Switzerland's energy mix.

There are opportunities to displace the use of oil in sectors where alternative technologies are readily available, including in buildings, or EVs. While transport is the largest consumer of oil at 56%, the buildings sector is a disproportionately large consumer of heating oil, accounting for 27% of total oil consumption. Current technologies are available to replace oil products in buildings, including through greater energy efficiency measures, and replacing fossil heating systems with heat pumps, district heating or wood heating systems. The cantons play a critical role in the decarbonisation of the building sector and the government is already in close co-ordination with cantons to reduce oil consumption in buildings.

The use of biofuels in the transport sector has increased as a direct outcome of tax exemptions and the offset obligation for fuel importers. The proposed blending mandate for transport fuels is a welcome move. So is the possibility to blend biofuels with heating oil, which was introduced in 2021.

Recommendations

The government of Switzerland should:

- ☐ Develop a structured dialogue with the oil industry on short- to long-term oil policy issues, demand outlooks, and infrastructure and logistic needs.
- ☐ Together with the cantons, develop strategies and measures to reduce oil use in the building sector.

ANNEX A: Organisations visited

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the IEA's in-depth reviews.

Review team and preparation of the report

The in-depth review team visit took place in Bern from 21 to 28 November 2022. The review team met with government officials, energy suppliers, market participants, interest groups in the public and private sector, consumer representative associations, research institutions, and other organisations and stakeholders.

The report was drafted based on the information obtained during these meetings, the team's preliminary assessment of Switzerland's energy policy, the government's responses to the IEA energy policy questionnaire, and information on subsequent policy developments from the government and private sector sources. The members of the team were:

IEA member countries

Alexander Folz, Germany (team leader)

Lars Martin Jensen (Denmark)

Eileen O'Connor (Ireland)

Paul Baal (Netherlands)

Anne-Laure Mazauric (Nuclear Energy Agency)

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International Energy Agency

Dagmar Graczyk, Senior Energy Policy Analyst (Overall review and IDR co-ordination)

Kiyomi Hyoe, Energy Policy Analyst (Emergency Response Review co-ordination)

Luca Lo Re, Energy Policy Analyst (Climate and environment)

Aad van Bohemen, Consultant, Energy Policy and Security Division

The team is grateful for the co-operation and assistance of the many people it met during the visit. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable.

The team wishes to express its gratitude to Benoît Revaz, Director, Swiss Federal Office for Energy, Federal Department of Environment, Transport, Energy and Communications for his personal engagements in the meetings and for taking the time to share his views with the team, which helped frame all discussions during the review visit.

The team is also grateful to Ambassador Jean Christophe Füeg, Head, International Energy Affairs, Swiss Federal Office of Energy; Dr Lukas Gutzwiller, Energy Policy Expert, Swiss Federal Office for Energy; and Claire Cance, formerly with the Swiss Federal Office for Energy, as well as their many colleagues for sharing their views and answering the team's numerous questions during the review week, for their time and encouragement, tireless efforts and professionalism in planning and organising the review visit, and their patience and diligence in supporting the team throughout the review process.

The review was prepared under the guidance of Dan Dorner, Head, Strategic Initiatives Office, IEA. Dagmar Graczyk is the main author of the report and managed the preparation of the report. Kiyomi Hyoi wrote Chapters 7 and 9 and the section on electricity security. Luca Lo Re wrote Chapter 2 and Anne-Laure Mazauric Chapter 8. Alessio Scanziani, Anders Caratozzolo, Su Min Park, Eléonore Carré, Ismail Aykin and Hanyoung Chang prepared and drafted the sections relating to energy data contained in each chapter. Aad van Bohemen, consultant to the Energy Policy and Security Division, IEA, provided advice throughout the review process.

Helpful comments, chapter reviews and updates were provided by the following people: Yasmin Abdelilah, Simon Bennett, Araceli Fernandez Pales, Zoe Hungerford, Emma Mooney, Brendan Reidenbach, all from the IEA as well as by Jan Horst Keppler from the Nuclear Energy Agency.

Special thanks to the IEA secretariat with regard to the data, publication and editing. Alessio Scanziani ensured the preparation of the design of the report with figures, tables and maps. Steve Gervais, Roberta Quadrelli and Zakia Adam from the Energy Data Centre participated in the data and statistics discussions during the visit. Victor Garcia Tapia, Suzy Leprince, Domenico Lattanzio, Jungyu Park and Roberta Quadrelli provided support on statistics and data. Isabelle Nonain-Semelin and Therese Walsh managed the editing process and Astrid Dumond managed the production process. The report was edited by Jennifer Allain.

Organisations visited

ABB
Agence CleanTech (ACT)
Alpiq
Avenergy Suisse (Liquid fuels and combustibles importer association)
AXPO
Bern University of Applied Science (BFH)
Biomass Suisse
BKW
CleantechAlps (Western Switzerland Cleantech Cluster)
Competition Commission (ComCo)
CORE (Swiss Federal Energy Research Commission)
Designwerk – Innovation electromobility
DSV (Dachverband Schweizer Verteilnetzbetreiber/Association of Swiss Distribution System Operators)
EconomieSuisse (Confederation of Swiss Industries)
Eidgenössische Elektrizitätskommission (ElCom Electricity Regulator)
EnAW (Energy Agency of Economy)
EnDK (Conference of Cantonal Energy Directors)
ETHZ (Swiss Federal Institute of Technology in Zurich, Energy Science Center)
Geothermie Suisse
IGEB (Interessengemeinschaft Energieintensive Branchen/Association of Energy Intensive Industries)
Innosuisse (Swiss Innovation Agency)
KLIK (Stiftung Klimaschutz)
NAGRA (National Cooperative for Disposal of Radioactive Waste)
NES (National Economic Supply, Federal Department of Economic Affairs, Education and Research)
Osterwalder AG (private sector company in energy efficiency innovation)
OSTRAL (Organisation for Power Supply in Extraordinary Situations)
State Secretariat for Education, Research and Innovation (SERI)
STENFO (Decommissioning Fund for Nuclear Facilities & Waste Disposal Fund for Nuclear Power Plants)
Swiss Federal Office of Energy (SFOE)
Swiss Federal Office of the Environment (FOEN)
Swiss Federal Office for National Economic Supply (FONES)
Swiss Federal Office of Transport (FOT)
Suisse éole (Association for the promotion of wind energy)
Swiss Consumer Protection Foundation
Swissgrid (electricity transmission system operator)
Swisspower
Swissolar
SWV (Schweizerischer Wasserwirtschaftsverband Swiss/ Association for Water Management)
Transitgas (Gas Pipeline Company)
Umweltallianz (Climate and Renewable Energies of Swiss Energy Foundation)
University of Basel
VSE (Verband schweizerischer Elektrizitätunternehmen/Swiss Electricity Industry Association)
VSG (Verband der schweizerischen Gasindustrie/ Swiss Gas Industry Association)

ANNEX B: Glossary and list of abbreviations

In this report, abbreviations and acronyms are substituted for a number of terms used within the International Energy Agency. While these terms generally have been written out on first mention, this glossary provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ASIG	Swiss Association of Gas Industry /Association Suisse de l'Industrie Gazière
BEV	battery electric vehicle
BWR	boiling water reactor
CCS	carbon capture and storage
CDR	carbon dioxide removal
CHF	Swiss franc (currency)
ComCo	Competition Commission
DACS	direct air capture and storage
DETEC	Department of the Environment, Transport, Energy and Communications
DSO	distribution system operator
EnDK	Conference of Cantonal Energy Directors
ENSI	Swiss Federal Nuclear Safety Inspectorate
EPFL	Swiss Federal Institute of Technology Lausanne
ETS	Emissions Trading System
EU	European Union
EV	electric vehicle
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gas
IEA	International Energy Agency
ITMO	Internationally transferred mitigation outcomes
LULUCF	land use, land-use change and forestry
MI	Mission Innovation
MukEN	Model Regulation of the Cantons in the Energy Sector
NDC	Nationally Determined Contribution
NEA	Nuclear Energy Agency
NES	National Economic Supply
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
PHEV	plug-in hybrid electric vehicle
PPP	purchasing power parity
PSI	Paul Scherrer Institute
PV	photovoltaics
PWR	pressurised water reactor
RD&D	research, development and demonstration
RD&I	research, development and innovation

RUMBA	Resource Management and Environmental Management System of the Federal Administration
SAF	Sustainable aviation fuel
SAPPRO	Société du Pipeline à produits pétroliers sur territoire Genevois
SFOE	Swiss Federal Office for Energy
SME	small and medium-sized enterprise
SOUR	SWEET outside-the-box-rethinking
STEM	science, technology, engineering and mathematics
STENFO	Decommissioning Fund for Nuclear Facilities and Waste Disposal Fund for Nuclear Power Plants
SWEET	Swiss Energy Research for the Energy Transition
TCP	Technology Collaboration Programme
TES	total energy supply
TFC	total final consumption
TFEC	total final energy consumption
TSO	transmission system operator
UNFCCC	United Nations Framework Convention on Climate Change
ZERO	base scenario

Units of measure

bcm	billion cubic metres
g CO_2/km	gramme of carbon dioxide per kilometre
GJ	gigajoule
GW	gigawatt
GWh	gigawatt hour
kb/d	thousand barrels per day
kg CO_2-eq/USD	kilogramme of carbon dioxide per United States dollar
km	kilometre
km^2	square kilometre
kWh	kilowatt hour
mcm	million cubic metres
MJ	megajoule
Mt	million tonnes
$MtCO_2$-eq	million tonnes of carbon dioxide-equivalent
MW	megawatt
MWe	megawatt electrical
MWh	megawatt hour
PJ	petajoule
t CO_2	tonne of carbon dioxide
TWh	terawatt hour

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Switzerland 2023

Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices and experiences to help drive secure and affordable clean energy transitions.

Switzerland has enshrined its 2050 net zero target in law, for the first time acknowledging the role of negative emission technologies and carbon capture and storage to address emissions from hard-to-abate sectors. Switzerland today has a low emissions electricity system, with significant production from both hydropower and nuclear. The country also shows a notable decoupling of energy consumption and economic growth.

However, current policy measures are not sufficient to reach Switzerland's mid-term emissions reduction target for 2030. The gradual phase-out of nuclear power and the accelerated electrification of the heating and transport sectors pose challenges. Meanwhile, Switzerland is dependent on electricity imports during the winter months and needs to swiftly expand renewable energy capacity, and in particular technologies that offer more generation during winter A key obstacle to Switzerland's energy transition is the permitting processes for energy projects, which reflect complex, time-intensive governance and legal structures.
In this report, the IEA provides energy policy recommendations to help Switzerland effectively manage the transformation of its energy sector in line with its climate targets.