ENERGY POLICIES OF IEA COUNTRIES

Switzerland

2018 Review

International Energy Agency
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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development but also encourages the exchange of and learning from international best practices and experiences. In short, by seeing what has worked – or not – in the "real world", these reviews help to identify policies that achieve objectives and bring concrete results.

Recently, the IEA has moved to modernise the reviews by focusing on some of the key energy challenges in today's rapidly changing energy markets.

This report focuses on two specific areas that were selected by the Swiss government: electricity market design and climate policy post-2020. These are related and important issues for the country because Switzerland's electricity sector is on the verge of a major transition with the gradual phase-out of its nuclear power plants. This transition will require careful management if system reliability and electricity security are to be maintained and an increase in carbon emission is to be avoided. In this review, we recommend the full opening of the Swiss electricity market to bring benefits of innovation and greater choice to consumers.

We also recommend a suite of policies be implemented without delay to meet the country's climate commitments. I am pleased to see that Switzerland's carbon levy on stationary fuels has proven to be an effective policy instrument, driving emission reductions in the building and industry sectors. A similar instrument is now needed in the transport sector where emissions are not on track to meet government targets.

The aim of this report is to support Switzerland in its quest for a secure, affordable and environmentally sustainable transformation of its energy sector. It is my hope that it will guide Switzerland in its energy transition and support its contribution to a cleaner, more sustainable and secure global energy system.

Dr Fatih Birol

Executive Director

International Energy Agency

ENERGY INSIGHTS

1. Executive summary 11

Overview 11

Energy Strategy 2050 11

Electricity market design post-2022 12

Climate policy post-2020 13

Relations with the European Union 14

Policy co-ordination 15

Energy security 15

Key recommendations 16

2. General energy policy 17

Overview 17

Supply and demand 20

Institutions 23

Key policies 24

Security of supply 30

Assessment 31

Recommendations 34

ENERGY SECURITY

3. Oil 35

Overview 35

Supply and demand 36

Infrastructure 39

Market structure 42

Biofuels 43

Prices and taxes 44

Security of supply 46

Assessment 47

Recommendations....48

4. Natural gas 49

Overview....49

Supply and demand....50

Infrastructure....52

Legal and regulatory framework....54

Industry structure....56

Security of supply....56

Emergency response policy....57

Emergency response measures....58

Prices and taxes....58

Assessment....60

Recommendations....61

5. Electricity....63

Overview....63

Supply and demand....64

Institutions....68

Legal framework....68

Industry structure....69

Transmission and distribution networks....70

Cross-border transmission capacity....71

Prices and taxes....74

Focus Area I: Electricity market design post-2020....75

Assessment....83

Recommendations....85

6. Nuclear....87

Overview....87

Institutions....90

Policies and regulations....91

Assessment....95

Recommendations....97

ENERGY SYSTEM TRANSFORMATION

7. Energy and climate 99

Overview 99

Energy-related CO_2 emissions 100

Institutions, policies and targets 102

Focus area II: Climate policy post-2020 109

Assessment 113

Recommendations 116

8. Energy efficiency 119

Overview 119

Energy consumption by sector 121

Institutions 124

Sectoral policies and measures 126

Assessment 134

Recommendations 136

9. Renewable energy 137

Overview 137

Supply and demand 138

Policies and measures 140

Renewable heat 148

Renewable energy in transport 149

Assessment 150

Recommendations 152

10. Energy technology research, development and demonstration 153

Overview 153

Public energy RD&D spending 154

International co-operation 158

Assessment 158

Recommendations 160

ANNEXES

ANNEX A: Review team and organisations visited 163

ANNEX B: Energy balances and key statistical data 166

ANNEX C: International Energy Agency “Shared Goals” 170

ANNEX D: Glossary and list of abbreviations 172

LIST OF FIGURES, TABLES AND BOXES

Figures

2.1 Map of Switzerland 18
2.2 Policy-making cycle in Switzerland 19
2.3 Population growth in Switzerland and selected IEA countries, 2000-17 20
2.4 Energy production, TPES and TFC by fuel and sector, 2016/17 21
2.5 TPES by source, 1973-2017 21
2.6 TPES by source in IEA member countries, 2017 22
2.7 TFC by sector, 1973-2016 23
2.8 TFC by source and sector, 2016 23
2.9 Key developments in Switzerland’s energy policy 26
3.1 Share of oil in different energy supplies, 1977-2017 35
3.2 Crude oil imports by country, 2007-17 36
3.3 Oil product net imports by country, 1990-2017 37
3.4 Oil consumption by sector, 1978-2016 37
3.5 Oil supply by product and consumption by sector, 2016 38
3.6 Oil infrastructure in Switzerland 41
3.7 Liquid biofuel consumption in the transport sector, 2010-16 44
3.8 Fuel prices in IEA member countries, second quarter of 2018 45
4.1 Share of natural gas in different energy supplies, 1977-2017 49
4.2 Natural gas imports by country, 1990-2017 50
4.3 Natural gas supply by consuming sector, 1974-2016 51
4.4 Natural gas infrastructure in Switzerland 53
4.5 Natural gas prices in IEA member countries, 2017 59
4.6 Natural gas price trends in Switzerland and selected IEA member countries, 1997-2017 59
5.1 Electricity generation by source, 2017, and consumption by sector, 2016 63
5.2 Electricity generation by source, 1973-2017 64
5.3 Electricity generation by source in IEA member countries, 2016 65
5.4 Carbon intensity of power and heat generation in Switzerland and selected IEA member countries, 1990-2016 66
5.5 Electricity imports and exports by country, 1990-2017 66
5.6 Electricity consumption (total final consumption) by consuming sector, 1973-2016 67
5.7 Monthly electricity generation by source, Jan 2013 – July 2018 67
5.8 Development of Switzerland’s electricity legal framework 69
5.9 Map of Switzerland’s transnational electricity network and 2016 trade flows 72

5.10 Industry electricity prices in IEA member countries, 2017 74
5.11 Household electricity prices in IEA member countries, 2017 74
5.12 Electricity price trends in Switzerland and selected IEA member countries, 1997-2017 75
5.13 Spot market prices in Switzerland and neighbouring countries, 2007-17 76
6.1 Share of nuclear in electricity generation in IEA member countries, 2017...........87
6.2 Nuclear power supply and its share in power generation, 1973-2017 89
6.3 Annual capacity factors for Swiss nuclear reactors, 2005-17..............................89
6.4 Timeline of major Swiss nuclear policy events 91
7.1 GHG emissions by sector, 1990 and 2016 100
7.2 Energy-related CO_2 emissions by sector, 1990-2016 100
7.3 Energy-related CO_2 emissions by fuel, 1990-2016 101
7.4 Energy-related CO_2 emissions and main drivers, 1990-2016 102
7.5 Energy-related CO_2 emissions per unit of GDP in IEA member countries, 2016.. 102
7.6 Climate policy and measures to 2020... 104
7.7 Switzerland's climate policy post-2020 110
8.1 Energy demand and drivers, 2000-16... 119
8.2 Energy intensity (TFC/GDP) in IEA member countries, 2016 120
8.3 Energy consumption (TFC) per capita in IEA member countries, 2016............ 120
8.4 TFC in residential and commercial sectors by source, 1973-2016 121
8.5 Residential energy consumption by end use, 2016.. 122
8.6 Residential energy intensity, 2000-16... 122
8.7 TFC in transport by source, 1973-2016 123
8.8 Transport energy demand by transport mode and fuel, 2016 123
8.9 TFC in industry by source, 1973-2016... 124
8.10 TFC in industry by sector, 2016 124
8.11 ES 2050 targets on TFC and electricity consumption per capita, 2000-50 125
8.12 Space heating requirements in new buildings since 1975 127
9.1 Share of renewable energy in different energy supplies, 1977-2017................ 138
9.2 Renewable energy and waste in TPES, 1973-2017.. 138
9.3 Biofuels and waste by fuel and consuming sector, 2016.................................. 139
9.4 Renewable energy and waste as a percentage of TPES in IEA member countries, 2017 139
9.5 Renewable energy and waste in electricity generation, 1973-2017.................. 140
9.6 Renewable energy as a percentage of electricity generation in IEA member countries, 2017... 140
9.7 ES 2050 targets for renewable electricity generation, 2020-50......................... 141
9.8 Allocation of network surcharge by funding mechanism 143
10.1 Government energy RD&D spending as a ratio of GDP in IEA member countries, 2016.. 154
10.2 Public energy RD&D spending by category, 2009-17 155
10.3 Swiss RD&D institutional framework... 156

Tables

2.1 Key indicative energy efficiency and renewable targets of the ES 2050..............25
5.1 Installed electricity generating capacity (megawatts), 2000-16............................65
6.1 Nuclear power reactors in Switzerland, 2017 88
6.2 Ownership of Swiss nuclear power reactors, 2017 90

7.1 Swiss ETS auction prices, 2014-17 107
7.2 Sectoral emissions reductions, 1990 and to 2020 and 2030........ 110
7.3 Emissions reductions to 2030 from additional measures under the proposed new CO_2 Law 111
8.1 Comparison of Swiss and EU regulations 129
10.1 Participation of Switzerland in IEA TCPs, 2018........ 158

Boxes

2.1 Electricity agreement between Switzerland and the European Union 29
3.1 Temporary reduction of the stockholding obligation in 2015........43
5.1 Switzerland and the PLEF........73
5.2 Water royalties 78
7.1 Impact assessment of the building refurbishment programme........ 106
7.2 Impact assessment of the CO_2 levy........ 112
9.1 Obstacles to accelerated hydro and wind power development........ 147

1. Executive summary

Overview

Switzerland has made commendable progress in its energy and climate policies since the previous in-depth review in 2012. Its energy consumption has decoupled from economic and population growth. The country's total final consumption of energy in 2016 was at the same level as in 2000, despite a population growth of 15% and a gross domestic product growth of close to 32%, measured in purchasing power parity. Switzerland has the lowest carbon intensity and the second-lowest energy intensity of all International Energy Agency (IEA) countries. The country's carbon dioxide (CO_2) emissions per capita are significantly below the IEA average.

Making progress against such a low-carbon baseline is challenging. However, the country has committed to short- and medium-term energy and climate targets, and has even set aspirational goals towards 2050.

This IEA in-depth review comes at an interesting time for Switzerland. The Swiss people voted in 2017 on a legal package to implement the Energy Strategy 2050 (ES 2050) and to phase out nuclear power gradually. This decision has stimulated debate on fundamental issues such as energy market design, generation adequacy, integration with European energy markets and policies needed to meet Switzerland's international climate commitments.

Depressed wholesale electricity prices are affecting Swiss nuclear and hydro generators. A domestic debate continues on whether Switzerland should be self-sufficient in electricity throughout the year, including during the cold winter period when it relies on imports from the rest of Europe.

Energy Strategy 2050

The ES 2050 is a legal and policy package to advance the energy transition of Switzerland towards a low-carbon economy. The first package of measures of the ES 2050 entered into force on 1 January 2018. The strategy addresses the impact of the country's decision for a progressive withdrawal from nuclear energy.

Existing nuclear power stations will shut down at the end of their technically safe operating life and will not be replaced with new ones. The first nuclear generator will close (for commercial reasons) in 2019 and the last one not before the mid-2030s. Nuclear energy provides about 35% of Switzerland's electricity generation. The consequent generation gap will need to be filled by other options while maintaining low-carbon generation and high standards of supply security.

Market reform measures and a revision of the CO_2 Law are being prepared to set the country on course for its 2030 climate target and aspirational 2050 goals.

The Swiss government aims to harvest existing potential for energy efficiency and further develop renewable sources of energy to maintain the current low-carbon intensity of its energy supply. However, these measures are unlikely to suffice. The government anticipates increasing imports to fill the generation gap, and does not exclude the possibility of resorting to gas-fired combined-cycle plants.

The strategy sets ambitious, yet indicative, energy efficiency and renewable targets for 2035. It also defines a framework for the country's energy policy objectives in coming years. All financial support programmes to promote energy efficiency and renewables have specific end dates, with the last one expiring in 2030. The ES 2050 is guided by the ambitious aspirational long-term climate goal of reducing CO_2 emissions per capita to 1.0-1.5 tonnes by 2050.

Electricity market design post-2022

Switzerland's electricity sector will undergo a considerable transition with the phase-out of nuclear power and a strong increase in distributed generation. It has sufficient installed capacity to meet its peak demand, and has been a net exporter in most years. The country exports in summer, and imports in winter when its hydro reservoirs are running low; while nuclear energy provides the baseload. The net annual export balance has been dwindling over recent years and is expected to turn negative when nuclear energy is phased out.

Expansion of hydropower is an important component of the ES 2050. However, low wholesale prices, which are below the generation cost of hydro, have stifled investment. The royalties that hydro producers pay to cantons and communes for use of their waters exacerbate the financial difficulties. The IEA encourages the Swiss government to initiate a comprehensive restructuring of water royalties, with the aim of linking them more closely to market prices for electricity.

The government does not expect supply gaps for more than a few hours in the medium term, even under extreme scenarios. This is based on several system adequacy studies, including those with neighbouring countries, provided Switzerland remains fully part of the European electricity market.

The government proposes a strategic energy reserve as a last resort to address specifically the low hydro production at the end of the winter. This would be to withstand extreme situations and in case markets fail. Such a mechanism should be technology neutral and minimise the impact on the energy-only market and the financial burden for end consumers.

Interconnection with neighbouring countries allows Switzerland to secure flexible energy supplies. Market coupling with the European Union would improve the efficiency and co-ordination of transmission flows and benefit domestic consumers.

The government plans to fully open the market, independent of an electricity agreement with the European Union, for which full market opening is a precondition. Full market opening will help Switzerland to modernise its electricity system and provide benefits for consumers through innovation and choice.

Smaller customers are captive, with the exception of those benefiting from a programme that allows prosumers in a district with a single distribution grid connection to trade electricity among themselves. The distribution segment is fragmented, with over 600 distribution services operators. The government needs to consider how the regulatory framework can be strengthened to provide greater network efficiencies.

Only large consumers are free to choose their suppliers. Prices for these customers have significantly dropped below prices for captive customers. Low wholesale prices create an opportunity to open the electricity market to all consumers.

Switzerland's electricity generation has a large renewable share. However, the share of variable renewables is under 3% and not yet posing any integration issues. Hence, the development of a transmission grid strategy and the rollout of a smart network are timely developments in anticipation of future flexibility needs. By the end of 2027, 80% of all metering points (production and consumption) must be equipped with smart meters.

Switzerland has a dense network of electric charging stations, but it does not have a national strategy for electric mobility. Instead, it is relying on the private sector to lead. The IEA encourages the government to prepare a strategic vision for the rollout of electric mobility. This should be linked to the new electricity market design and the possibilities provided by digital technologies. The potential for electric mobility to contribute to demand response and the associated multiple benefits, including use for public transport, should be considered.

Climate policy post-2020

Switzerland has legislated short- and medium-term climate targets under the Kyoto Protocol and also its nationally determined contributions (NDCs) under the Paris Agreement. It is committed to reducing its greenhouse gas (GHG) emissions by 20% by 2020, and by 50% by 2030 against the 1990 base year level (at least 30% of which is to be achieved domestically). Switzerland has also set aspirational goals for the period to 2050.

Switzerland's GHG emissions have declined, but progress is mixed across sectors. Reductions in the building and industrial sectors outperformed intermediate milestones; these two sectors are on track to reach their sector-specific 2020 targets. In contrast, emissions in the transport sector are not meeting their required pathway.

Switzerland has implemented policy measures under its CO_2 Law for the period to 2020. The key instrument is the CO_2 levy on stationary fuels, such as heating oil and natural gas; however, the levy excludes the transport sector. Making fossil fuels more expensive is meant to be an incentive to use them more economically and to switch to lower carbon sources. A key advantage of this instrument is the automatic upward adjustment of the CO_2 levy rate if Switzerland fails to meet its emissions pathway.

The CO_2 levy has proven to be an effective instrument for the industry sector. Many medium-sized players have entered into strict emissions reduction agreements to be exempt from the levy (larger players are in the Swiss emissions trading system).

Some of the receipts from the CO_2 levy are used to fund a building refurbishment programme. This programme improves the building shell and replaces oil heating systems, which still dominate in the existing building stock. It has proven to be a useful tool. The IEA encourages Switzerland to extend the building refurbishment programme beyond its planned expiration in 2025 and to correct the missing incentive of the CO_2 tax for the high percentage of rental properties by addressing the principal-agent problem.

Cantons introduced a tightened cantonal model building prescription in 2015, further harmonising codes across the country and setting standards for zero energy buildings in line with European Union (EU) recommendations.

Switzerland pursues decarbonisation of the transport sector through expansion and optimisation of the public transport network and through a modal shift for freight, including transit, from road to rail. However, passenger vehicles are the dominant form of transport as well as the largest emitter of CO_2. Passenger transport offers potential, but current initiatives appear to be modest. The key instrument towards increasing transport efficiency is continuation of the alignment of vehicle emissions regulations with EU standards.

The increasing uptake of biofuels is due to the offset obligation introduced in 2013, whereby motor fuel importers must compensate a percentage of the annual CO_2 emissions from the use of fossil fuels. The offset obligation increases automatically if interim targets are not met. However, it is unlikely that current policy measures will be sufficient to reach expected efficiency and climate targets in the transport sector, based on experience so far.

Switzerland requires more-stringent measures to ensure that the country stays on track to achieve its targets towards 2020, and to put it on a pathway to achieving the medium to long-term targets under the NDCs and the ES 2050. Parliament is debating a revision of the CO_2 Law, tightening existing and introducing new policies for the period 2021-30. Switzerland is unlikely to meet its 2030 domestic reduction target of 30% in the absence of these and additional measures.

Switzerland also needs to consider how current measures will affect future projections, and the types of policies that will be needed in the long term beyond 2030. The IEA encourages Switzerland to give further consideration as to how emissions reduction efforts link with broader energy strategy goals. This includes issues around electrification, market reform and transport.

The Swiss emissions trading system (ETS) has not functioned well. This is because many emission allowances were allocated free of charge, resulting in low prices that did not create sufficient reduction incentives for participants. The signing of an agreement in 2017 between Switzerland and the European Union to link their ETSs starting in 2020 was a welcome development.

Relations with the European Union

Switzerland's energy markets are closely interconnected with European markets, even though the country is not a member of the European Union. Switzerland is a key gas transit country. Its importance is set to grow once the reverse flow of the Transitgas pipeline becomes operational in the second half of 2018, which will allow gas to flow from Southern to Northern Europe.

The electricity flows passing through Switzerland's borders exceed the country's production and consumption. The country's large amount of hydro pumped storage offers storage for the growing share of variable renewable energies in Europe. Switzerland's hydro installations are also contributing to ensuring grid stability in the European Union by offering balancing services. Hence, an electricity agreement between the European Union and Switzerland is in the interest of both parties and entails social welfare gains.

Switzerland and the European Union have been negotiating an electricity agreement since 2007. They have made substantive progress on technical issues, but some are yet to be resolved. An agreement would require full opening of the Swiss electricity market; only large consumers are currently eligible to choose their suppliers. The government plans to address the issue of market opening as part of the electricity market design post-2020, irrespective of negotiations with the European Union.

The IEA encourages efforts to bring the ongoing negotiations to a successful outcome. The IEA also supports the government's plans to establish a regulatory framework for the gas market largely in line with EU requirements.

Policy co-ordination

Switzerland's federal structure of 26 cantons and its use of the subsidiarity principle, which devolves policy implementation to the lowest possible level, can make achieving goals in energy and climate policy difficult. For example, while the federal government is responsible for emissions reduction targets, it has limited control in areas such as buildings to require cantons to reduce emissions towards the national target.

Cantons set their own energy policies, which are not necessarily aligned with federal policies. Exploring ways to enhance co-ordination between the federal government and cantons will help to achieve national policy objectives.

Energy security

Switzerland imports all fossil fuels and also counts nuclear fuels as energy imports. Oil supply routes and suppliers are well diversified. Switzerland consistently holds more oil stocks than required under the IEA stockholding obligation. The government has recently adapted legislation to allow liquid biofuel stocks to be held as compulsory stocks, as their share in the total final consumption in the transport sector grows.

Natural gas is also sourced from several countries. Switzerland has had a compulsory stockholding organisation for the gas sector since 2015. Its key task is to monitor the obligation of gas importers to hold the required amounts of heating oil to cover at least 4.5 months of gas consumption of industrial users with dual-fuel capacity.

Reducing import dependency is a driver for the ES 2050, which sets per capita energy consumption objectives. Consumption of liquid heating fuels is decreasing as buildings become more efficient and switch to renewable energies. Demand for natural gas has remained stable, although with sizeable yearly fluctuations depending on the weather and thus the number of heating days. The demand for transportation fuels has begun a slow decline, supported by stricter vehicle emissions standards and investments to facilitate modal shift, as well as by the recent uptake of biofuels.

Key recommendations

The government of Switzerland should:

- Continue to develop a framework linking climate and energy goals to 2050, outlining Switzerland's pathways to achieving the ES 2050.
- Proceed with plans to open Swiss energy markets to support the country's future energy needs and climate targets by progressing with revision of the Electricity Law and introducing a Gas Supply Law.
- Ensure timely entry into force of the revised CO_2 Law, to support continued climate policy post-2020 and help Switzerland achieve its binding 2030 climate and indicative 2035 energy goals.
- Develop a long-term strategy for transport to 2050 that contributes to domestic decarbonisation pathways by providing stronger market signals.
- Continue efforts to integrate Swiss energy markets with the European Union.

2. General energy policy

Key data

(2017 provisional)

TPES: 24.0 Mtoe (oil 36.9%, nuclear 22.2%, natural gas 12.5%, hydro 12.2%, biofuels and waste 11.2%, electricity imports 2.0%, geothermal 1.7%, solar 0.8%, coal 0.5%), -6.7% since 2007

TPES per capita: 2.8 toe (IEA average: 4.1 toe)

TPES per unit of GDP: 52.0 toe/USD 1 million PPP (IEA average: 106 toe)

Energy production: 11.4 Mtoe (nuclear 46.8%, hydro 25.7%, biofuels and waste 22.2%, geothermal 3.5%, solar 1.7%, wind 0.1%), -9.9% since 2007

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

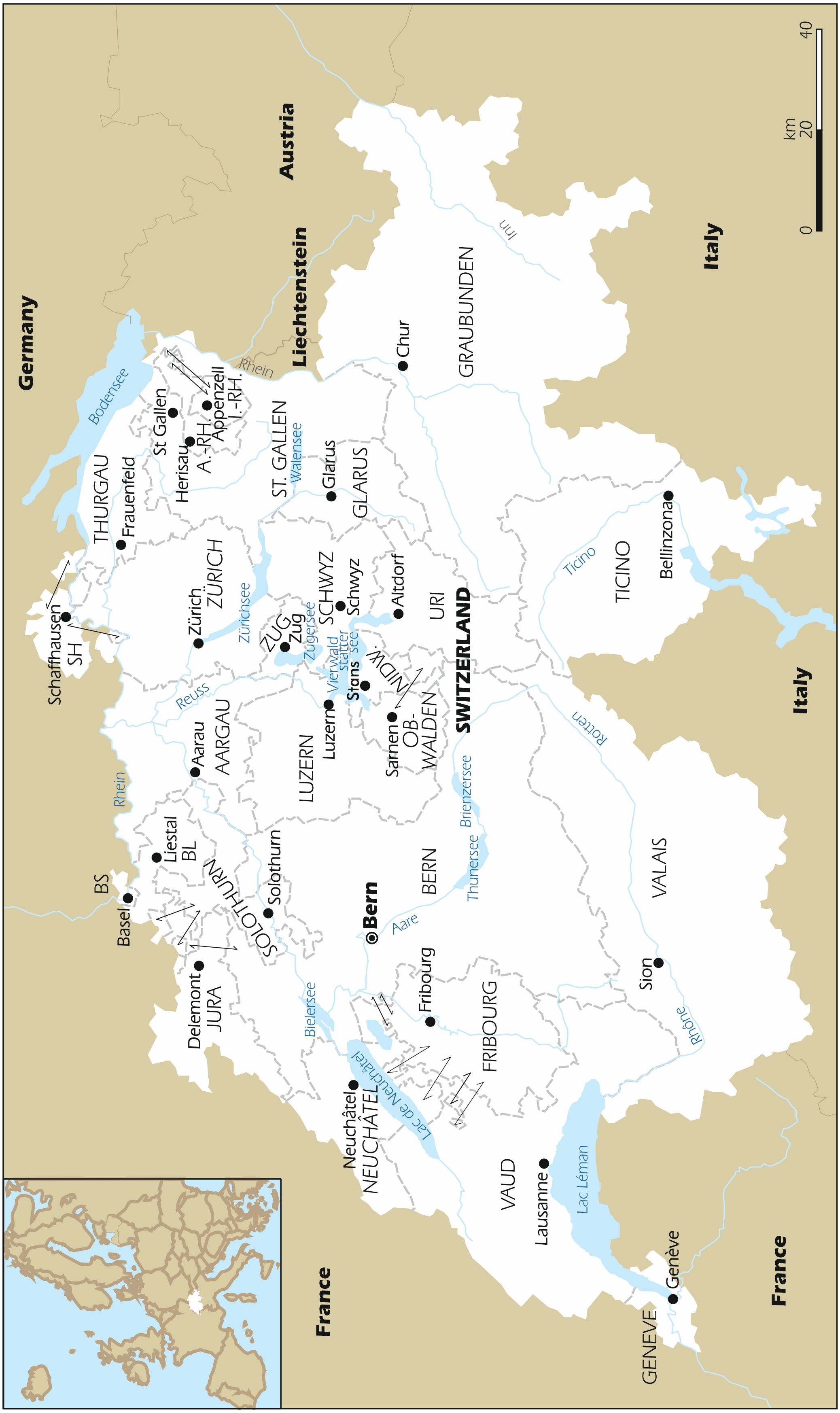
Overview

Switzerland is a small, mountainous, landlocked country in the centre of Western Europe (see Figure 2.1). Bordered by Germany, France, Italy, Austria and Liechtenstein, the country has an area of 41 285 square kilometres, of which two-thirds are mountainous terrain. It had a population of 8.3 million in 2016. Switzerland has four official languages, with German being the mother tongue for 63% of the population, French for 22%, Italian for 9% and Romansh for just under one percent. The capital of Switzerland is Bern, with around 130 000 residents; other major cities include Basel, Geneva, Lausanne and Zurich.

Switzerland's climate is temperate but can vary across regions, ranging from glacial freeze and frequent cold spells on the mountain tops to an almost Mediterranean climate at the southern tip. Precipitation is spread evenly throughout the seasons, with little variations.

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 cantons.

Figure 2.1 Map of Switzerland

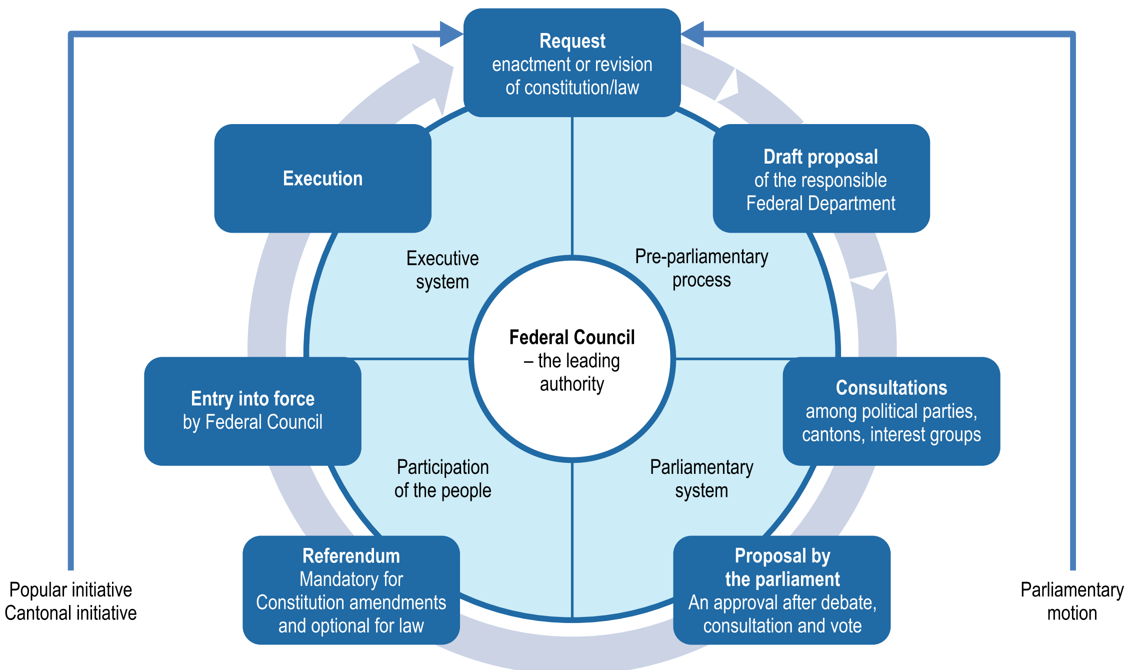


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The federal legislative power is vested in the bicameral parliamentary body, 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 highly 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 a specific time frame can initiate a referendum, and 100 000 signatures are required to launch a popular initiative demanding a constitutional amendment. The verdict of the people is essentially binding and has an immediate effect (see Figure 2.2).

Figure 2.2 Policy-making cycle in Switzerland



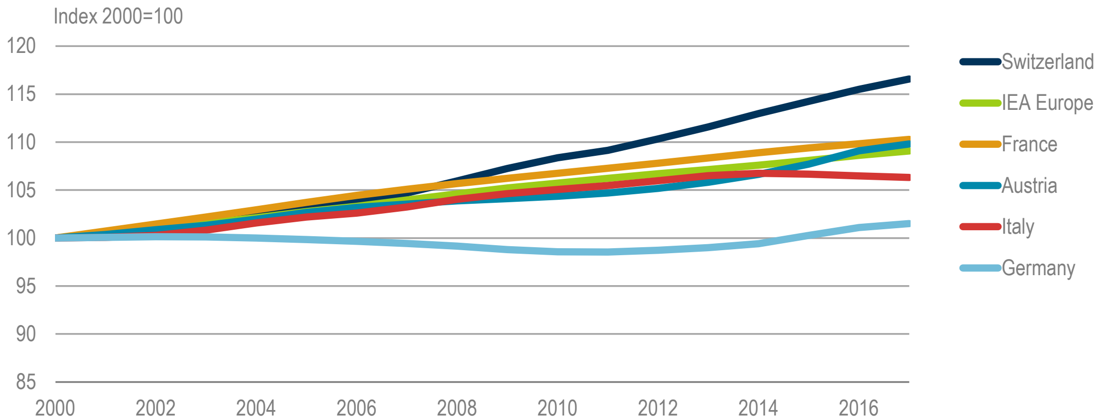
Source: IEA based on Linder, W. and A. Iff (2011), *Swiss Political System*, www.wolf-linder.ch/wp-content/uploads/2010/11/Swiss-political-system.pdf.

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

Switzerland's gross domestic product (GDP) (at market prices) reached USD 64 000 (United States dollars) per capita in 2016. This was the third-highest among Organisation for Economic Co-operation and Development (OECD) member countries, after Luxembourg and Ireland. Unemployment, at 4.8% in 2016, was lower than the OECD average of 5.8%. The service sector generates about 74% of the Swiss GDP, 25% from industry and less than 1% from the agricultural sector (OECD, 2017).

Switzerland's population grew by over 16.5% between 2000 and 2017. This was much higher than in neighbouring countries and the ninth-highest growth among International Energy Agency (IEA) member countries (see Figure 2.3). Switzerland expects its population to reach 9.5 million by 2030.

Figure 2.3 Population growth in Switzerland and selected IEA countries, 2000-17



Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

The Swiss franc (CHF) is one of the world's strongest currencies, and has a low, stable inflation rate. The Swiss National Bank abandoned the CHF peg to the euro in 2015, which resulted in strong appreciation of the CHF.

Although Switzerland is not a member country of the European Union, it maintains close engagements with the European Union, which is the country's largest trading partner (EC, 2018). Around 60% of Switzerland's imports originate from the European Union, and 45% of its exports are to the European Union. Switzerland participates in the Council of Europe, the European Free Trade Association and the Schengen Agreement.

Switzerland is also a member of the United Nations, the International Monetary Fund, the World Bank, the OECD, the World Trade Organization and other international organisations.

Supply and demand

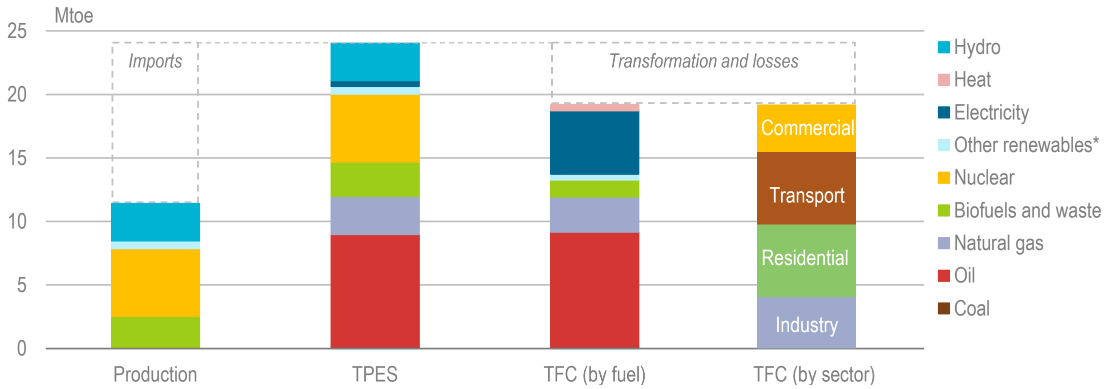
Switzerland's energy production is dominated by large shares of nuclear power, hydropower and domestic biomass resources (see Figure 2.4). The country does not produce hydrocarbons, and relies on imports of oil and natural gas. Oil accounts for over one-third of the country's total primary energy supply (TPES[1]) and nearly one-half of the energy in the total final consumption (TFC[2]). The residential and commercial sectors account for around half of the TFC, mainly consumed in buildings, and the transport and

[1] TPES is made up of production + imports - exports - international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use.

[2] TFC is the final consumption of fuels (e.g. electricity, heat, gas and oil products) by end users, not including the transformation sector (e.g. power generation and refining).

industry sectors account for the other half. Oil dominates energy consumption in the transport sector and is also the most important heating fuel in the residential sector.

Figure 2.4 Energy production, TPES and TFC by fuel and sector, 2016/17



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

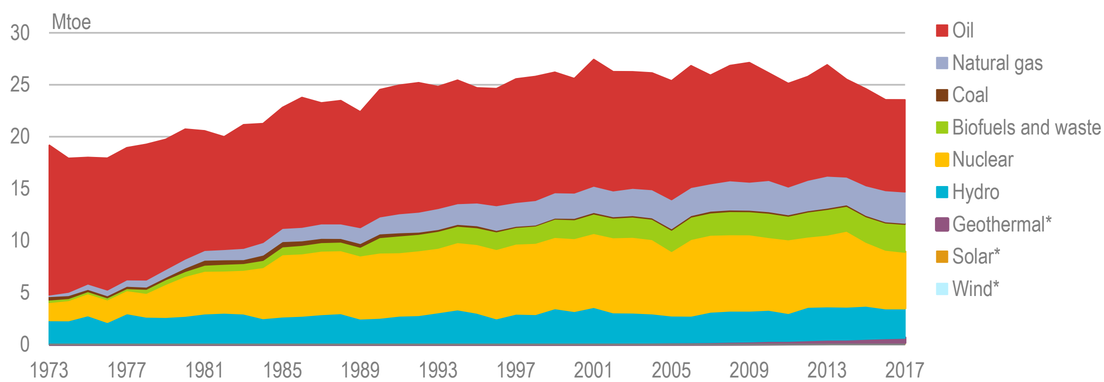
Note: TFC data are 2016. Production and TPES data are 2017 provisional.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Primary energy supply

Switzerland's TPES was 24.0 million tonnes of oil equivalent (Mtoe) in 2017; a decline of 75 from 2007 and 11% from the peak level (27.1 Mtoe) in 2006 (see Figure 2.5). This decline corresponded to a decrease in oil and a temporary decrease in nuclear supply, which are the two largest energy sources. Oil supply declined by 15% from 2007 to 2017. Natural gas supply increased by 14% over the same period, partly replacing oil as a fuel in industry processes as well as for heating in the residential and commercial sectors.

Figure 2.5 TPES by source, 1973-2017



* Negligible.

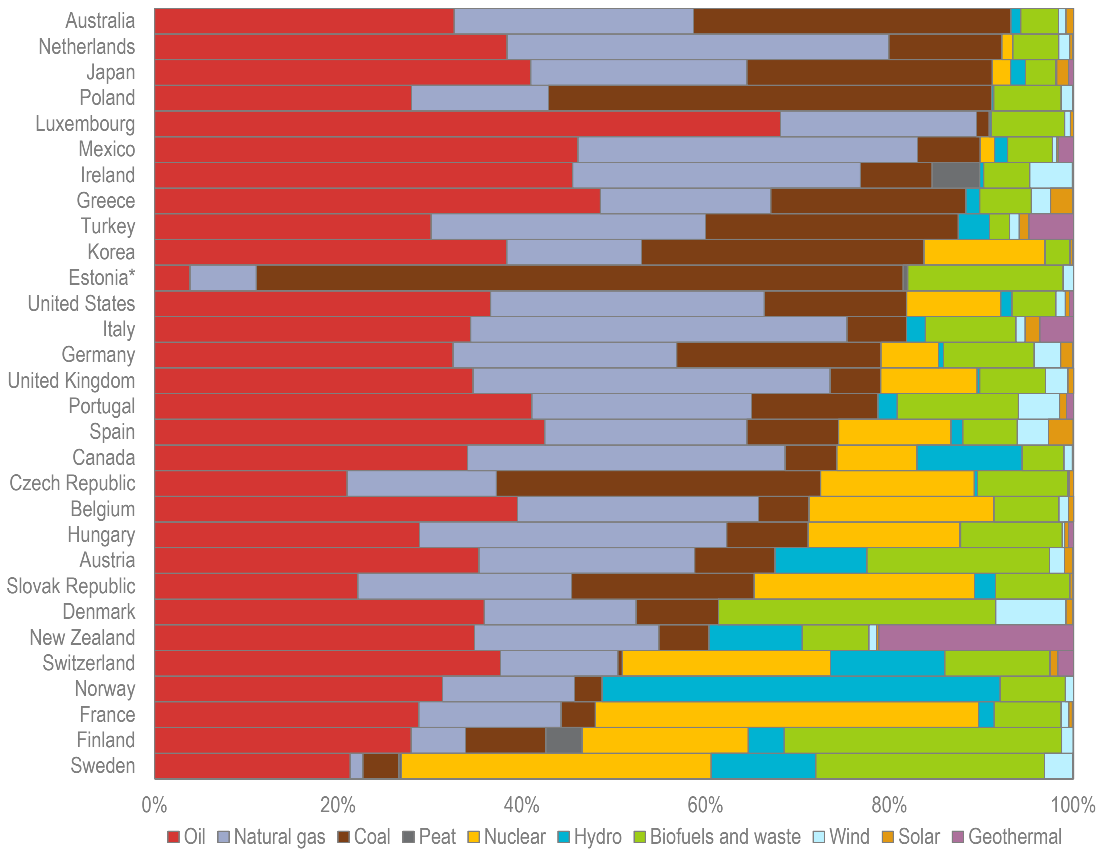
Notes: Electricity imports and exports are not included in the figure. Data are provisional for 2017.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Nuclear supply declined in 2015 due to the temporary shutdown of several reactors, which affected nuclear power generation in 2015-17. All nuclear reactors were back in production as of March 2018 (see Chapter 6, "Nuclear").

Owing to its large nuclear and hydro resources, Switzerland has the fifth-lowest share of fossil fuels among IEA member countries, after Sweden, Finland, France and Norway (see Figure 2.6), and the lowest share of coal at 0.5% of the TPES.

Figure 2.6 TPES by source in IEA member countries, 2017



* Estonia's coal is represented by oil shale.

Note: Data are provisional.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

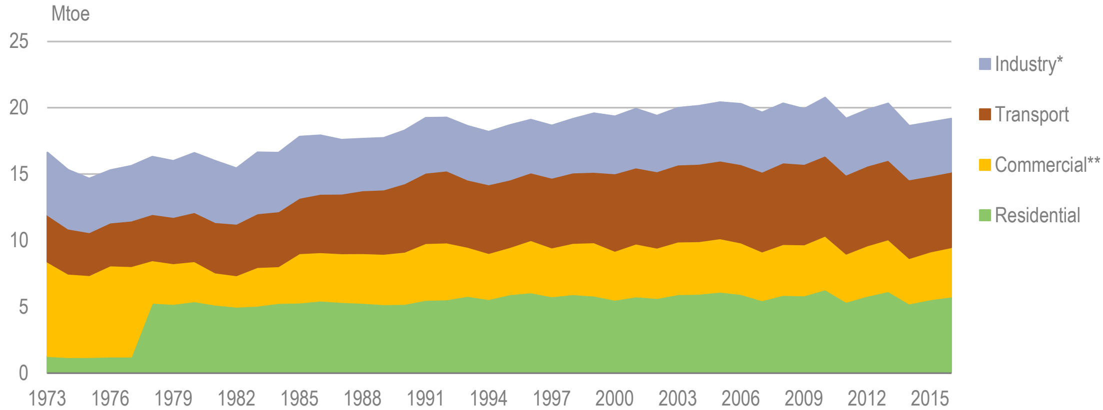
Energy consumption

Energy consumption in Switzerland has decoupled from economic and population growth. Switzerland's TFC was 19.2 Mtoe in 2016, almost the same level as in 2000, despite a significant increase in population. Energy consumption has decreased across all sectors, with the largest decline of 12% in the industry sector (see Figure 2.7).

The industry sector accounted for 21% of the TFC in 2016, which is one of the lowest shares among IEA member countries. This reflected the displacement of industry and in particular the suspension of operations of one of the country's two refineries in 2015. The residential sector was the largest energy consumer, with a 30% share of the TFC, one of the highest in IEA member countries. Heating of buildings accounted for the main part of residential energy consumption, and the sector's demand varied with outside temperature.

The residential, commercial and industry sectors have similar consumption patterns, with large shares of electricity and oil, followed by natural gas and biofuels, and small shares of other renewable sources of energy (other renewables), coal and district heating (see Figure 2.8). The transport sector stands out with its large dependence on oil although the use of biofuels has increased in recent years. Electricity used in the rail sector accounts for a large part of total transport consumption. Its use in rail transport accounted for 5% of the TFC in transport in 2016, which was the highest share in IEA member countries.

Figure 2.7 TFC by sector, 1973-2016



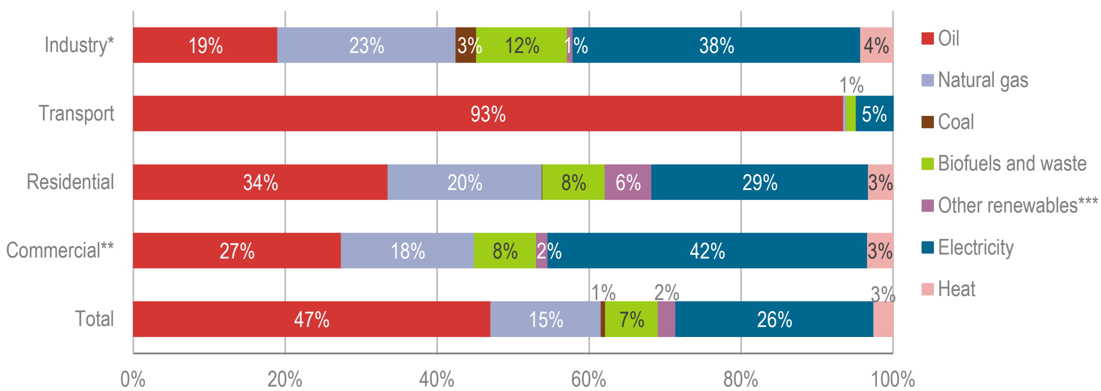
* *Industry* includes non-energy consumption.

** *Commercial* includes commercial and public services, agriculture and forestry.

Note: Change in data definitions for oil consumption led to a break between residential and commercial in 1978.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 2.8 TFC by source and sector, 2016



* *Industry* includes non-energy consumption.

** *Commercial* includes commercial and public services, agriculture and forestry.

*** *Other renewables* includes geothermal and minor shares of solar.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Institutions

Policy making and legislation, including for energy, are devolved to the lowest possible state level. Consequently, the federal state is responsible for energy issues of national importance such as nuclear, oil and gas infrastructure, most energy and carbon dioxide (CO_2) taxation, efficiency standards for energy-consuming products and certain facets of electricity.

Wherever feasible, energy regulation is devolved to cantons, such as for buildings, permitting (except nuclear) or hydro regulation. To increase their efficiency, some policies (such as building codes) have been harmonised across cantons in recent years and thus have curtailed some cantonal leeway.

The Department of the Environment, Transport, Energy and Communications (DETEC) is the leading ministry in charge of Switzerland's energy policy formulation and implementation. The integration of energy, environment and transport under one institutional umbrella is intended to promote sustainability in energy policy making.

The Swiss Federal Office of Energy (SFOE) is responsible for practical management of national energy policy within DETEC. The SFOE also co-operates and consults with other offices and ministries on a wide range of energy-related issues. These include promoting energy efficiency and renewable energy, creating necessary conditions for efficient electricity and gas markets, and ensuring high safety standards in energy supply and use.

Cantons are consulted during federal energy policy and law-making processes. They have much leeway in adopting their own energy laws, policies and measures, within the boundary set by federal legislation. This results in a diversity of cantonal policies and measures. Cantons play an important role in energy policy making and implementation, zoning and permitting for energy infrastructure, and providing occasional complementary support programmes for renewables and efficiency, as well as through their ownership of utilities. Energy tax issues may heavily affect cantons, as Switzerland is fiscally decentralised. The Conference of Cantonal Energy Directors (EnDK) also has a powerful voice in Swiss policy making.

The Competition Commission (Comco) is an independent federal authority and is responsible for combating harmful cartels and monitoring dominant companies for signs of anticompetitive conduct, for example. Within the energy sector, Comco is of particular importance in the gas sub-sector due to the absence of a gas law.

Further information about key institutions is available in the sectoral chapters of this report.

Key policies

Energy Strategy 2050

The Energy Strategy 2050 (ES 2050) is a strategic policy package for advancing the energy transition of Switzerland towards a low-carbon economy. It consists of a comprehensive set of new and revised laws and ordinances, as well as policy measures that will be implemented in phases.

The complete revision of the Energy Act of 1998, which entered into force on 1 January 2018, jointly with related new and revised laws and ordinances, is central to the strategy. The ES 2050 has three pillars: *i*) withdrawal from nuclear energy, *ii*) reduction of energy consumption and emissions per capita and *iii*) promotion of renewable energy sources and energy efficiency.

Table 2.1 provides an overview of the ES 2050 targets. The indicative targets for 2020 and 2035 are stipulated in the Energy Law, which entered into force on 1 January 2018. The 2050 aspirational targets were set by the government in its nuclear phase-out decision of 25 May 2011. They are based on the Scenario New Energy Policy of the Energy Perspectives 2050, as outlined in the submission to Parliament on 4 September 2013 by the SFOE of a draft total revision of the Energy Act (SFOE, 2013).

Table 2.1 Key indicative energy efficiency and renewable targets of the ES 2050

Energy efficiency (indicative/non-binding targets)	Per capita energy consumption	-16% by 2020 vs. 2000 level -43% by 2035 vs. 2000 level -54% by 2050 vs. 2000 level
	Per capita electricity consumption	-3% by 2020 vs. 2000 level -13% by 2035 vs. 2000 level -18% by 2050 vs. 2000 level
Renewable electricity (indicative/non-binding targets)	Average yearly production of renewable electricity excluding large hydro	By 2020: 4 400 gigawatt hour (GWh) By 2035: 11 400 GWh By 2050: 24 200 GWh
	Average yearly production of large hydropower	By 2035: 37 400 GWh By 2050: 38 600 GWh

Source: Swiss Federal Office for Energy.

Energy efficiency measures are focused on the buildings, industry and transport sectors. The ES 2050 has also strengthened standards for appliances; some now even exceed those for European Union (EU) countries. Tax incentives for building renovations have been widened and administration of the building refurbishment programme streamlined. Industry now has to meet lower prerequisites for a refund of the electricity network surcharge. The obligation under binding target agreements to invest part of the refund in “uneconomical” energy efficiency measures, meaning those with long payback times, has been repealed. This will streamline the instrument covering about 100 energy-intensive companies. Emissions standards for passenger vehicles are being strengthened, and emissions standards for light commercial utility vehicles and light semi-trailers are being introduced.

Support measures for renewable energy include a change from cost-covering feed-in remuneration to a feed-in premium with direct marketing. This will allow better market integration of renewables and incentivise production to be better aligned with demand.

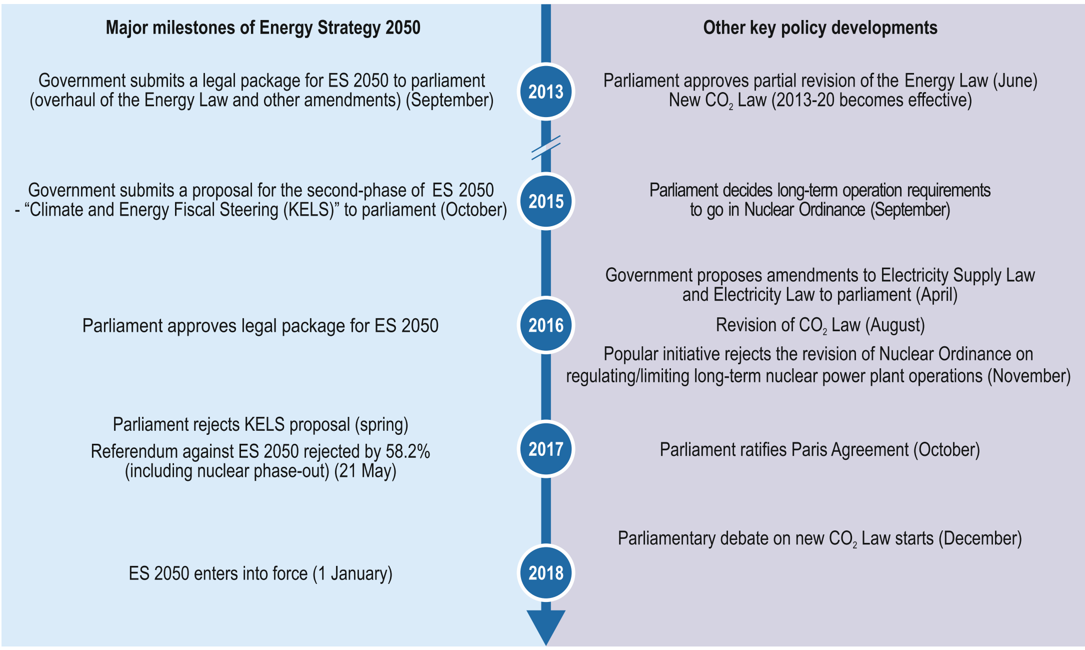
Eligibility for investment aid has been widened to include new installations and renovation of existing facilities. Hydro producers are now eligible, under certain conditions, to benefit from a market premium that compensates for the difference between production costs and market prices. This will help to address their short-term financial viability issues. All promotional measures have sunset clauses.

The network surcharge has been increased, albeit temporarily in line with the duration of the promotional measures, to finance the measures of the ES 2050. The ES 2050 also includes non-monetary measures aimed at shortening and streamlining licensing procedures for renewable energy and network expansions. It also accords renewable energy the status of national interest on a par with environmental and landscape protection.

Parliament approved the ES 2050 in 2016, and the Swiss people approved it through a referendum on 21 May 2017. Subsequently, on 1 November 2017, the Federal Council ordered the entry into force of the new Energy Act and its corresponding ordinances by 1 January 2018 (see Figure 2.9).

The ES 2050 addresses the impact of the country’s decision on a progressive withdrawal from nuclear energy production. Existing nuclear power stations will be shut down at the end of their technically safe operating life and will not be replaced with new ones. The consequent electricity generation gap will be filled by renewable electricity sources while maintaining high standards of supply security.

Figure 2.9 Key developments in Switzerland's energy policy



Source: IEA based on information provided by the Federal Swiss Office for Energy.

The ES 2050 was set up in two parts: measures targeting promotion of renewable energy and energy efficiency, and the Climate and Energy Fiscal Steering System (KELS), aiming to increase the cost of energy consumption and emissions by shifting from subsidies to pricing mechanisms after 2025.

The first part entered into force on 1 January 2018, but the KESLS was rejected by parliament in 2017. With KELS no longer being pursued, the government reiterated its long-term climate goal in its climate policy package published on 1 December 2017. This was for a 70-85% reduction of greenhouse gas (GHG) emissions by 2050 compared to the 1990 level.

Climate policy towards 2030

Switzerland's binding target under the Kyoto Protocol is to reduce GHG emissions by 20% below the 1990 level by 2020. Its nationally determined contributions under the Paris Agreement commit the country to reducing GHG emissions by 50% (of which at least 30% are to be achieved domestically) below the 1990 level by 2030. In addition, the energy perspectives to 2050 included in the revised energy act outlines a pathway for how the aspirations of reaching about 1.0-1.5 tonnes of carbon dioxide (tCO_2) emissions per capita by 2050, and of reducing electricity consumption per capita by 18% and the TFC per capita by 54%, against 2000 levels, could be met.

The CO_2 Law expires at the end of 2020. It entered into force in January 2013, with the objective of a 20% domestic CO_2 reduction in line with Switzerland's commitment under the Kyoto Protocol. The key instruments are a CO_2 levy on stationary fuels and an emissions trading system (Swiss ETS).

The government proposed a new CO_2 law, for the period 2021-30, to parliament on 1 December 2017. The draft law is based on the existing one but includes additional emissions abatement measures and maintains automatic increases in the climate taxation of stationary fuels if emissions deviate from the target trajectory. The new CO_2 law is expected to enter into force in 2021.

Switzerland faces many challenges to meeting its 2020 climate target by domestic measures alone. However, the target remains within reach, if influential factors develop favourably and hence emissions evolve along the lower end of trajectory projections. If emissions evolve along the centre of projections, the target will be missed by 1.6 million tonnes of carbon dioxide equivalent. Accounting for carbon sinks and other measures that were not accounted for when projections were originally made may close the gap.

Reliance on existing measures without additional support from the proposed CO_2 Law would also make meeting Switzerland's 2030 target challenging. A seamless continuation of enhanced policy measures between the two periods to 2020 and to 2030 is therefore critical. With new policies and measures in place after 2020, emissions will likely decrease faster, thereby increasing the probability of meeting the 2030 climate targets.

Emissions reductions in the transport and building sectors are challenges for Switzerland at the sectoral level. Existing measures have lacked incentives to provide optimal emissions reductions in these two sectors. The new CO_2 Law will need to address sector-specific difficulties. It will be important to addressing the split incentives for building refurbishment, resulting from the high percentage (around 60%) of rental properties, in the building sector.

The Swiss government has introduced more-stringent emissions standards for new vehicles (in line with the European Union), and is continuously supporting a modal shift to address the high carbon intensity of the transport sector. The creation and expansion of an advanced biofuels market is also laudable. Electricity sector decentralisation and digitalisation increase opportunities for the government to develop a strategy for promoting electric mobility.

Replacing nuclear generation

No new nuclear power plants will be licensed, and the existing moratorium on spent fuel reprocessing will become permanent, in accordance with the ES 2050. Existing nuclear plants may run as long as they are declared safe.

Nuclear power accounts for around 35% of electricity generation and is also a major contributor to the low-carbon intensity of the country's TPES. Switzerland has introduced extensive measures to support renewable power generation capacity, without excluding the possibility of resorting to gas-fired combined-cycle plants. This is because securing low-carbon alternatives to nuclear power is a key government key objective.

Switzerland exports electricity in summer and imports it in winter, although the net export balance has been dwindling in recent years. Nuclear power provides around 45% of the power generation in winter when hydro reservoirs run low. Switzerland is therefore primarily facing an energy and not a capacity challenge. However, the need to cover the growing winter gap is posing security of supply questions that need addressing.

The Swiss government considers expansion of hydropower as an important part of its strategy to meet domestic demand in the longer term. Several measures are being discussed, because the financial situation of utilities does not allow for adequate investment in hydro capacity additions.

Obstacles are partly due to low wholesale prices, which are below the generation cost of hydro. The payments that hydro producers make to cantons and communes for the use of their waters exacerbate the financial difficulties (see Chapter 5, “Electricity”). The government needs to urgently initiate a comprehensive restructuring of water royalties, with the aim of linking them closer to market prices for electricity.

The government has undertaken extensive studies to assess generation and system adequacy against nuclear phase-out. The different scenarios considered all concluded that, in the medium to long term, security of electricity supply is guaranteed. This is provided Switzerland is fully integrated into the European internal electricity market, given that the country will require an increasing share of imports to meet winter peak demand.

The government is therefore expecting that electricity imports will partially cover any future demand and supply gap, but it is also exploring policy options to address specifically its low hydro production during winter months.

Market integration and market opening

Electricity market design post-2020 is a key parameter for ensuring security of supply and for supporting electrification of the energy sector. Full integration with the European internal electricity market is an important objective of the government (see Box 2.1). Full opening of the Swiss electricity market is therefore required.

The Swiss parliament approved a comprehensive Electricity Grid Strategy in December 2017, which is expected to come into force in the second quarter of 2019. The strategy will facilitate expansion and modernisation of the transmission network to accommodate increasing imports to meet winter peak demand, and integration of decentralised electricity, by addressing long and congestive permitting procedures.

Switzerland secures flexible energy supplies by interconnection with neighbouring countries. This alleviates the need to implement capacity-based remuneration mechanisms, coupled with the fact that installed capacity is almost double the peak demand.

Risk may stem from insufficient energy when hydro reservoirs run low at the end of the winter before the snow melts in the mountains. The government is therefore proposing an “energy reserve” (stored reservoir water or co-generation[3]), which is to be activated as a last resort when all market measures fail. Market coupling with the European Union would improve the efficiency and co-ordination of transmission flows. Linking with the EU Emissions Trading System will also help the country’s industry pursue its emissions target at the lowest possible cost.

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[3] *Co-generation* refers to the combined production of heat and power.

Box 2.1 Electricity agreement between Switzerland and the European Union

Switzerland is remarkably well interconnected with its EU neighbours. The electricity flows passing through its borders exceed the country's production and consumption. Cross-border electricity flows in Switzerland correspond to about 10% of the physical cross-border flows in Central Europe and Italy. Switzerland is third to Germany and France in its importance as a major electricity transit country.

Switzerland's extensive hydro pumped-storage and reservoir capacity are of strategic importance to the European Union. The country is instrumental in supporting the growing share of variable renewable electricity in Europe and contributing to ensuring grid stability by offering balancing services. Hence, an electricity agreement between the European Union and Switzerland is in the interest of both parties and entails strong social welfare gains.

Negotiations on an electricity agreement between Switzerland and the European Union have been ongoing since 2007. The original scope of negotiations was enlarged to cover aspects of the EU third market liberalisation package and the EU renewables directive.

However, in 2012, the European Union requested that the conclusion of an electricity agreement hinge on an institutional framework agreement to govern all EU–Swiss market access agreements. Such an institutional agreement is to include highly sensitive political aspects such as dispute resolution, adoption of future acquis (common rights and obligations that are binding on all EU countries) and state aid surveillance.

Extensive progress has been made towards transposing the electricity acquis, although some issues still need finalising. But progress on the electricity agreement is determined by larger institutional questions. One outstanding issue is the full opening of the Swiss electricity market.

Electricity trading continues, albeit in a suboptimal way and to the detriment of all market participants, as EU network codes and guidelines have successively been introduced since August 2015. EU regulation on capacity allocation and congestion management, forward capacity allocation and balancing explicitly excludes Switzerland from market coupling for the day-ahead and intraday markets, until the country adopts EU legislation on electricity and signs a bilateral agreement with the European Union. Furthermore, the introduction of flow-based market coupling with no computation of network capacity at the Swiss borders has massively increased uncontrolled loop flows.

In 2016, the social welfare loss at the Swiss border from suboptimal trading due to the exclusion from market coupling was estimated at around 80 million euros (ACER, 2017). Those losses might increase in the future as additional network codes become effective, and Switzerland would be excluded from an expanding area of co-operation.

Source: Information provided by Swiss Federal Office for Energy.

When Switzerland opened the electricity market for large consumers (>100 megawatt hours per year) in 2009, it anticipated, based on legislation, full market opening by 2015. However, public opinion has not been supportive of full market opening, and the possible lower prices for end consumers do not appear to significantly affect their views. Nonetheless, in late 2017, the government decided to move ahead with full market opening as part of the revision of the Electricity Supply Law, which will be introduced for public consultation in October 2018.

Low wholesale electricity prices have changed the economic basis for those Swiss utilities that lack captive end consumers (captive end consumers can be charged full generation costs). These few utilities bear hydro and nuclear generation costs higher than wholesale market prices. They therefore sell their production at a loss, often to regional retailers, some of which happen to be their own shareholders. Hence, loss-making hydro is to be supported through a market premium from 2018 until 2022, in the hope that wholesale electricity prices rebound to levels that incentivise investment again.

Switzerland lacks a dedicated legal and regulatory framework for the natural gas sector. The gas industry has voluntarily moved to improve conditions for competition and third-party access to the high-pressure gas network since 2012. Access is regulated under private law and applies to about 30% of the total gas market. Changes in EU gas markets and ensuing new business models have seen a growing interest by Swiss gas consumers for further market opening. The Swiss government is preparing a draft Gas Supply Law to respond to this desire. Further market opening will likely proceed in phases, as in the electricity sector.

Security of supply

Switzerland has high standards for oil and gas security, because all fossil fuels are imported. Oil supply routes and suppliers are well diversified. Sources of crude oil and product imports show large annual variations, reflecting the effectiveness of the Swiss oil industry in adapting to changes in the global oil market. Switzerland consistently holds more oil stocks than required under the IEA stockholding obligation.

The revised National Economic Supply Act lets liquid biofuel stocks be held as compulsory stocks as their share in the TFC in the transport sector grows. However, there is no obligation to hold a certain amount of biofuels as compulsory stocks.

Over 75% of total gas imports to Switzerland pass through Germany. Switzerland is also an important gas transit country in Europe. The inauguration of reverse flow of the Transitgas pipeline in 2018 will enhance the security of gas supply for Switzerland and the rest of Europe, as it will allow transportation of gas from Southern to Northern Europe.

There are two additional policy measures to support gas supply security in Switzerland. First, the gas industry must maintain compulsory stocks of heating oil to cover at least 4.5 months of consumption of industrial users with dual-fuel capacity. And, second, around 40% of the gas contract volume is interruptible. This share will continue declining with increased energy efficiency and a shift towards renewable energy in industry.

Switzerland has had a compulsory stockholding organisation (Provisiogas) for the gas sector since 2015. Membership in Provisiogas is mandatory for all gas importers. The organisation monitors and verifies all obligations applicable to gas importers.

Switzerland is consistently one of the European countries with the highest quality of electricity supply. Nonetheless, it will need to increase investments in its transmission and distribution infrastructure to maintain security of supply due to increasing electricity imports and a move towards more-decentralised generation.

Switzerland is well placed to benefit from digitalisation of the energy sector. However, to turn the potential into a reality, it needs to prepare a comprehensive roadmap for the deployment of smart grid and digital infrastructure to accelerate innovation activity in this area. Further market opening and consolidation of the distribution segment will also enhance security of supply.

Assessment

Energy consumption in Switzerland has decoupled from economic and population growth. Switzerland's TFC of energy was at the same level in 2016 as it was in 2000, despite a population growth of 15% and a GDP growth (in purchasing power parity) of over 30%. Switzerland is among the leaders in energy transition in IEA countries. It had the second-lowest energy intensity (TPES/GDP) and the lowest carbon intensity (CO_2/GDP) of all IEA countries. Its TPES and CO_2 emissions per capita are also significantly below the IEA average.

Making progress towards meeting the government's long-term climate and energy targets from such a strong baseline has its own challenges, as many high-yield policies have already been deployed. Challenges are compounded by the country's decision to gradually phase out nuclear power and the consequent need to seek closer integration with European energy markets, which requires a rethink of the country's energy market design.

ES 2050

The Swiss population voted to implement the ES 2050 on 21 May 2017, and it entered into force on 1 January 2018. The first nuclear plant (Mühleberg) will shut down in 2019 by decision of its operator.

Nuclear power has historically accounted for almost 40% of Swiss electricity production. The decision of the Swiss people to withdraw from nuclear power has a significant impact on the country's electricity supply. The Swiss government is implementing a multipronged strategy to continuously guarantee a secure electricity supply. This includes: expansion of domestic generation; renovation, expansion and digitalisation of the country's electricity networks; and increased importation.

The ES 2050 sets ambitious, yet indicative, energy efficiency and renewable energy targets. It also defines a framework for the country's energy policy objectives in coming years. The ES 2050 envisages decreasing per capita energy demand by 54% compared to the year 2000 and yearly per capita emissions to reach about 1.0-1.5 tCO_2, by 2050. The ES 2050 contains a package of legislation promoting greater energy efficiency and a higher share of renewables, and builds on existing policies.

The existing framework of target agreements to implement energy efficiency and emissions reduction projects in the industry sector is highly effective. Emissions reductions in the building and transport sectors appear to be more challenging. Cantons have successfully tightened standards and moved towards harmonisation for new buildings across the country. However, the building refurbishment programme appears to ineffectively cover a large share of the building stock, given the high percentage of rental properties (60%), which are affected by split incentives and where the CO_2 tax is thus ineffective.

The transport sector offers a significant opportunity for improvement, but current initiatives appear to be modest. Improving emissions standards for new vehicles in synchronisation with EU standards is welcomed. Work on establishing a market in advanced biofuels is also to be applauded. So are the government's considerable efforts for a modal shift. However, the government should consider how electric vehicle uptake could be better supported.

The government needs to outline its strategy and plans for additional measures to put Switzerland on a pathway to achieving its medium and long-term energy and climate targets. Tightening of existing policies and introduction of new policies under the revised CO_2 Law, covering 2021-30, is being debated in parliament. Switzerland is unlikely to meet its 2030 domestic emissions reduction target in the absence of these measures.

Further work is also needed to consider how current measures will affect future projections, and the types of policies that will be needed in the long term. This is because the KELS (aiming to increase the cost of energy consumption and emissions by shifting from subsidies to pricing mechanisms) was rejected by parliament in 2017.

There also needs to be consideration of how emissions reduction efforts link with broader ES 2050 goals. This includes issues around electrification, market reform and transport. Ensuring that the planning periods for the energy and environment sectors overlap would enhance synergies and make studies and findings more comparable.

Alternatives to nuclear

The options for Switzerland to replace its nuclear fleet with other, carbon-free, generation in a timely manner appear to be limited without further support. They will likely require additional imports, and the need to add gas-fired generation cannot be excluded in the interim.

The ES 2050 includes extensive measures to support a wide range of renewable power generation capacity. Financial incentives alone will not be sufficient to stimulate investments. Measures to simplify and secure permitting procedures, which can lower the time and cost of investment projects, need to be expanded.

Support for expanding hydro capacity is a positive step. It needs to be accompanied by reforms to water royalties, which strongly affect the financial viability of a large share of hydro production. The IEA supports alternative ideas proposed by the government that would align water royalties more closely to the market value of the resource.

The new Energy Law will support deployment and self-consumption of small-scale solar photovoltaics. Development of large-scale stand-alone solar and wind projects is limited due to concerns about the landscape.

Market integration and market opening

The IEA believes that continuing integration of Swiss energy markets with broader European markets will be increasingly beneficial to Switzerland and its EU neighbours, and that it should be pursued. Switzerland and Europe are well placed to mutually benefit from their energy transitions, particularly from Switzerland's significant hydro resources, which offer substantial storage potential.

Extensive interconnection with Europe should also provide Switzerland with secure supplies at lowest possible costs, reducing the need to implement capacity-type remuneration mechanisms. Market coupling between Switzerland and the European Union will improve efficiency and enable better co-ordination of transmission flows.

Full market opening, a condition for concluding an electricity agreement with the European Union, should also bring benefits independently. It will help Switzerland to modernise its electricity system and provide benefits for consumers through innovation and choice.

Choice for small customers is constrained, with the exception of reforms to allow consumers to group together to access market offers within the prosumer programme. The distribution segment is fragmented, with over 600 operators. The government therefore needs to consider how the regulatory framework can be strengthened to provide greater network efficiencies.

Future planning and policy co-ordination

Governance structures in Switzerland require policy makers and industry to plan well in advance when implementing reforms. Law making is the product of extensive stakeholder consultations and carefully crafted compromises, because it is subject to a popular vote if 50 000 signatures are collected for a referendum. This increases the lead time for legislative proposals considerably compared to other IEA countries. On the other hand, once a policy is accepted by both parliament and a possible popular vote, it usually proves to be a stable policy. This environment requires great stewardship and forward-looking policy making from the Swiss government.

Market conditions can change suddenly, for example, through an earlier than expected closure of nuclear plants, increased network congestion or system security issues. This may leave the country exposed to risk. The IEA therefore supports strategic planning exercises such as system adequacy analysis, the country's energy research programmes and development of regulatory frameworks, which remove inefficient regulatory barriers and enable government and business to respond quickly if required.

Switzerland's federal structure of 26 cantons and the subsidiarity principle, which devolves policy implementation to the lowest possible level, the canton or municipality level, can make achievement of policy goals in the energy and climate policy areas difficult. For example, while the federal government is responsible for emissions reduction targets, it has limited control in areas such as buildings to require cantons to reduce emissions towards the national target. Exploring ways for better co-ordination between the federal government and cantons will help to achieve national policy objectives.

Recommendations

The government of Switzerland should:

- ☐ Continue to develop a framework linking climate and energy goals to 2050, outlining Switzerland's pathways to achieving the ES 2050.
- ☐ Proceed with plans to open Swiss energy markets to support the country's future energy needs and climate targets.
- ☐ Continue to progress efforts to integrate Swiss energy markets with the European Union.
- ☐ Support planning exercises on energy and climate policies that can identify market needs early to aid Switzerland's ability to respond to new challenges and address risks in a timely manner.
- ☐ Consider establishing a process for aligning federal and canton-level energy and climate goals to support achieving Switzerland's policy ambitions.

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3. Oil

Key data

(2017 provisional)

Crude oil production: nil

Import of crude oil: 2.9 Mt

Oil products production: 2.9 Mt

Net import of oil products: 7.3 Mt (7.7 Mt imported, 0.4 Mt exported)

Share of oil: 36.9% of TPES and 47.1% of TFC (2016)

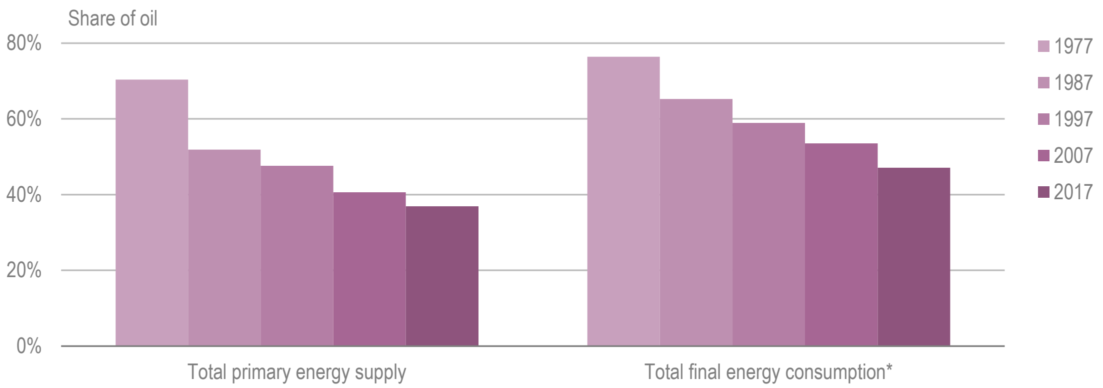
Consumption by sector (2016): 8.7 Mtoe (transport 57.7%, residential 20.9%, commercial 11.1%, industry 8.3%, other energy 1.8%, power and heat generation 0.1%)

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

Overview

Oil remains the most important source in Switzerland's energy system, despite a gradual decline in its supply. Oil supply was 8.9 million tonnes of oil equivalent (Mtoe) in 2017, accounting for 36.9% of Switzerland's total energy primary supply (TPES). This was slightly above the International Energy Agency (IEA) average share of 35.8%, but a fall from 40.6% in 2007. Oil has shown a similar fall in the country's total final consumption (TFC), with its share declining from 54.6% in 2006 to 47.1% in 2016 (see Figure 3.1).

Figure 3.1 Share of oil in different energy supplies, 1977-2017



*Latest consumption data are 2016.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

The role of oil will continue declining in line with Switzerland's ambitious climate policies post-2020, which aim to further support energy efficiency, renewable sources of energy (renewable energies), a shift in transport modes and the use of electric vehicles (EVs) (see Chapter 2, "General Energy Policy", Chapter 7, "Energy and Climate", and Chapter 8, "Energy Efficiency"). However, oil will remain a significant share in Switzerland's energy mix.

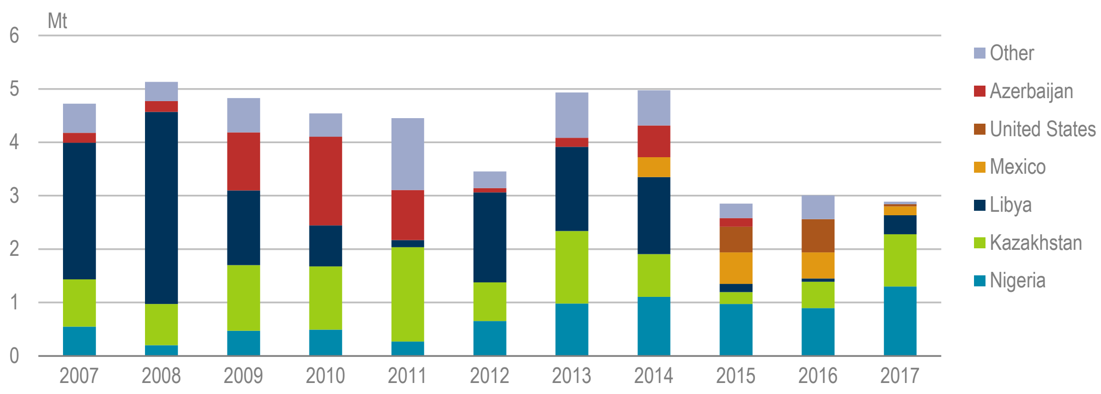
Supply and demand

Production, imports and exports

Switzerland does not produce any crude oil and is a net importer of oil. Oil is crucial for the country's energy system, but to an increasingly smaller degree. Oil in the TPES fell by 15.1% from 10.5 Mtoe in 2007 to 8.9 Mtoe in 2017.

The suspension of operations at the Collombey refinery in 2015 resulted in a strong decline in crude oil imports. There have also been noticeable changes in the main oil import countries in recent years (see Figure 3.2). The importance of Libyan crude oil declined from 29% in 2014 to 12% in 2017. Following the suspension of operations at the Collombey refinery, owned by the Libyan state oil company Tamoil, Nigeria overtook Libya as the largest supplier of crude oil. In 2017, Nigeria accounted for 45% of total imports, ahead of Kazakhstan with 34%. Mexico and the United States have emerged as important crude oil suppliers since 2014, but declined again in 2017. Crude oil from the two North American countries accounted for 36% of total imports in 2016 but fell to 7% in 2017.

Figure 3.2 Crude oil imports by country, 2007-17

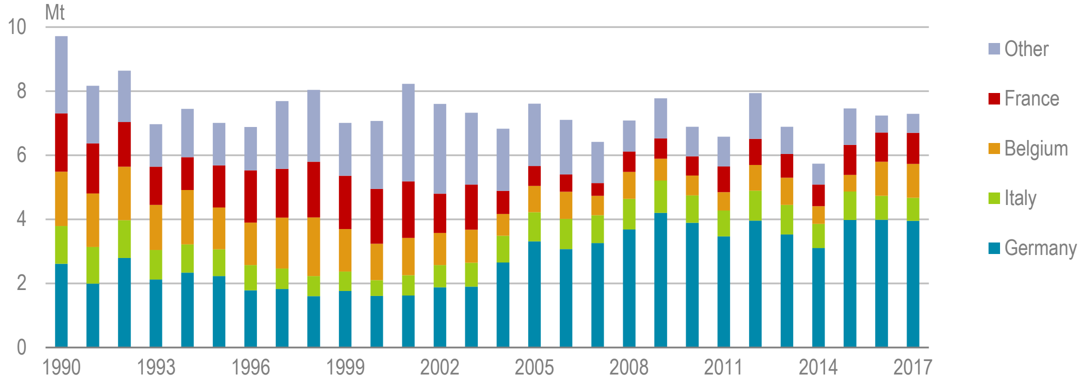


Note: Data are provisional for 2017.

Source: IEA (2018b), *Oil Information 2018*, www.iea.org/statistics/.

For oil products, domestic production of 3.0 million tonnes (Mt) accounted for 28% of the total supply, and imports from nearby European Union (EU) members accounted for the rest in 2017. Germany maintained the dominant share with 54% of imported oil products, followed by Belgium with 14%, France with 13% and Italy with 10% (see Figure 3.3). Switzerland exported 0.4 Mt of refined oil products, mainly to Germany (41%), the Netherlands (27%), Italy (18%), and France (6%). Switzerland has seen a considerable shift in its trade relations for refined oil products, with Germany becoming an increasingly important oil product trading partner.

Figure 3.3 Oil product net imports by country, 1990-2017



Note: Data are provisional for 2017.

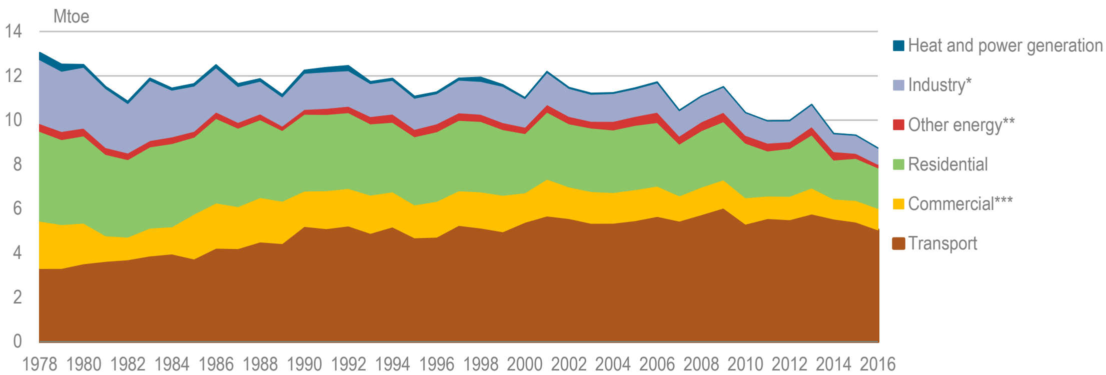
Source: IEA (2018b), *Oil Information 2018*, www.iea.org/statistics/.

Consumption

Total oil consumption decreased by 25.4% in ten years, from 11.7 Mtoe in 2006 to 8.7 Mtoe in 2016. Oil accounted for 47.1% of the TFC in 2016.

Transport remains the largest oil-consuming sector. In 2016, transport accounted for 57.7% of the total oil consumption, followed by the residential sector with 20.9%, the commercial sector with 11.1%, industry with 8.3%, other energy with 1.8%, and heat and electricity with 0.1% (see Figure 3.4). Oil demand is projected to decrease with the implementation of the Swiss Energy Strategy 2050 (ES 2050) as oil is substituted by low-carbon sources and higher efficiency standards are implemented.

Figure 3.4 Oil consumption by sector, 1978-2016



* *Industry* includes non-energy use.

** *Other energy* includes petroleum refineries and energy own use.

*** *Commercial* includes commercial and public services, agriculture, forestry and fishing.

Note: Total primary energy supply of oil by consuming sector.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

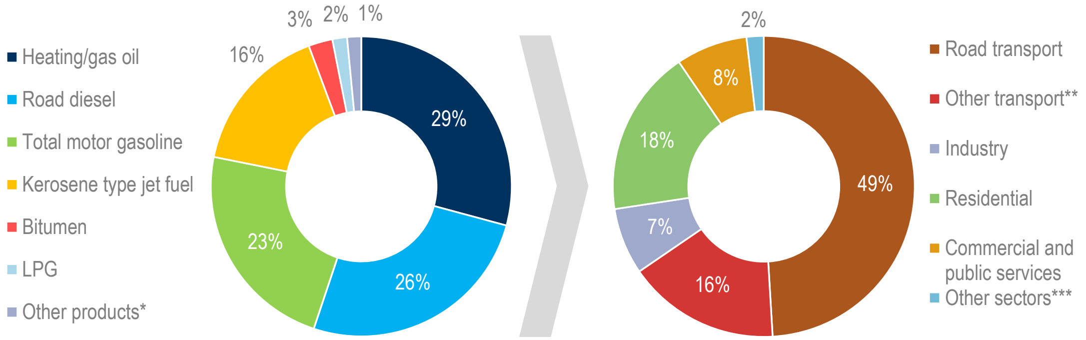
The share of transport in the TFC has gradually increased in the past decade, from 48.2% in 2006 to 57.7% in 2016. However, actual oil consumption in the transport sector decreased by 10.8% over the same period due to higher vehicle fuel efficiencies, an increase in the use of biofuels and EVs, and shifts in the transport mode. The exception to the trend is kerosene-type jet fuel, for which consumption grew by 38% from 2006 to 2016. This is expected to continue with sustained increase in flight traffic. The increased share of transport in the TFC reflects that steeper rates of decline from other sectors cause the decrease in Switzerland's oil consumption.

Road transport accounts for half of the total consumption within the transport sector. Diesel is the most used oil product for road transport, accounting for 26% of total oil consumption, followed by motor gasoline (23%) and kerosene-type jet fuel (16%) (see Figure 3.5). The demand for motor gasoline declined by 30% between 2006 and 2016, while the demand for road diesel fuel increased by 47%, reflecting the growth in sales of diesel cars. The distribution of diesel versus gasoline car sales is around 2:3, and a continuous increase in the share of diesel cars is expected.

However, there is no particular policy to promote diesel over gasoline cars. Cantons adopt different vehicle taxing systems, which are mainly aimed at promoting EVs and hybrid vehicles. Additionally, fuels for motor vehicles are subject to an excise tax, which has a slightly higher rate imposed on diesel compared to gasoline vehicles. Gasoline demand is expected to decline by 60% by 2050, while diesel demand is projected to remain stable, according to the ES 2050.

The building sector is the second-largest oil-consuming sector, with the use of gas oil for heating purposes. In 2016, gas oil accounted for 29% of total oil consumption. Oil accounted for a third of final energy consumption in Switzerland's residential sector, which was the third highest share in the IEA. However, the share of gas oil in energy consumption in buildings has gradually declined. From 2006 to 2016, gas oil consumption decreased by 33%; contributing to the reduction of total oil consumption.

Figure 3.5 Oil supply by product and consumption by sector, 2016



* *Other oil products* includes petroleum coke, biodiesel, naphtha, fuel oil and other products.

** *Other transport* includes aviation and minor shares used in navigation and railway transport.

*** *Other sectors* include energy transformation, and other non-specified sectors.

Note: LPG = liquefied petroleum gas.

Source: IEA (2018b), *Oil Information 2018*, www.iea.org/statistics/.

The Carbon Dioxide (CO_2) Law of 2008 introduced a levy on oil for stationary use. The initial levy was CHF 12 (Swiss francs) per tonne of carbon dioxide (tCO_2), and it is increased every two years if the CO_2 reduction targets are not met. The levy has increased sharply since its introduction, reaching CHF 60/tCO_2 in 2014 and CHF 84/tCO_2 in 2016. The levy increased to CHF 96/tCO_2 on 1 January 2018, because Switzerland failed to meet its target again.

The levy has contributed to a sharp fall in demand for heating oil. The Swiss Oil Industry Association reported a demand reduction of 18.7% within the one year 2015/16. Due to weather variations the number of heating days increased by 6.7% over the same period.

One reason for the sharp reduction of demand was consumers filling their heating oil tanks in late 2015 in anticipation of the increase in the CO_2 levy, thus underlining how the levy influences consumer behaviour.

It is important to separate two effects of the levy. The first is the adoption of alternative heating modes and higher building efficiency measures. The second is the change in buying behaviour, which will likely have a rebound effect in consequent years. The degree of rebound is subject to the number of heating days in a given winter.

Energy policies pertinent to the building sector are a cantonal remit in Switzerland. However, the CO_2 Law requires cantons to define standards for continuous emissions reduction in new and old buildings. An important measure is the 2014 building code guidelines that stipulate a minimum use of at least 10% renewable energies when replacing a heating system. The revised CO_2 Law, currently being debated in parliament (see Chapter 7, "Energy and Climate"), considers a ban on all oil heating systems by 2050.

Infrastructure

Refining

One of Switzerland's two refineries, Collombey, suspended operations in early 2015, resulting in the loss of 57 thousand barrels per day (kb/d) of crude oil distillation capacity. The country's remaining refinery at Cressier has a crude oil distillation capacity of 68 kb/d. Varo Energy, which is partly owned by the oil trading company Vitol, is the refinery operator. Varo Energy acquired the Cressier refinery in 2012, together with related infrastructure assets. These assets include the *Oléoduc du Jura Neuchâtelois* pipeline, which connects Cressier with the *Société du Pipeline Sud-Européen* (SPSE) crude pipeline in France, from which it draws all its crude oil supply. The previous owner had decommissioned the Cressier refinery in 2012, but Varo Energy resumed its operation in 2013.

Varo Energy has recently invested CHF 50 million in renovation, showing confidence in the future of the Swiss refining sector. Technical upgrades include enabling the blending of 5% bioethanol produced from renewable sources, in line with EU standards. The investment also includes a partial conversion of the refinery's own fuel sourcing to natural gas. This will reduce the CO_2 emissions of the refinery in line with Varo's target agreement with the government.

Cressier had an output of 3.0 Mt in 2016, of which 92.5% was for the domestic market and covered 27% of the domestic product demand (24% of transport fuels and 38% of heating fuels). Domestic refining output from the two refineries accounted for around 40% of Swiss oil product demand at the time of the 2012 in-depth review.

Storage

Switzerland had a total storage capacity of about 52.45 million barrels (mb) (8 339 million cubic metres (Mm^3)) at the end of 2017. Of the total capacity, 7 766 Mm^3 was available for oil importers; of this, 4 769 Mm^3 was industry compulsory stocks. There were 63 above-ground tank farms, mainly concentrated in the highly populated areas between Geneva and Lake Constance. Joint ventures of oil importers operated most of those tank farms.

The Federal Office for National Economic Supply (FONES) deals with short-term energy security in Switzerland. On behalf of FONES, CARBURA, a private petroleum importers association founded in 1932, is responsible for ensuring and monitoring stockholding compliance.

Storage capacity is adapted to reflect changes in product demand. Storage volumes declined by 624 000 cubic metres (m^3) between 2013 and end of 2017. Switzerland completed elimination of all compulsory stocks of heavy heating oil in 2015 (Carbura, 2016). Compulsory stocks for diesel and kerosene increased to reflect rising demand in the same period. Compulsory stocks of gasoline fell by approximately 230 000 m^3 between 2015 and the end of 2017. This reflected a change to fuel-efficient and diesel-engine vehicles.

Fuel tourism (European neighbours crossing the border into Switzerland to buy cheaper fuel) declined due to a strong CHF, reducing demand for gasoline. Demand for heating fuels also continues to decline due to replacement of oil-fired heating systems by other fuels. Compulsory stocks of heating oil decreased by about 327 000 m^3 from 2015 to the end of 2017. Stockholding obligation targets (days of coverage) remained unchanged for all products (except heavy heating oil, see above).

Switzerland has a strong record of compliance with the IEA 90-day stockholding obligation, and relies solely on industry stocks to meet the obligation.[1] Using the IEA methodology for calculating emergency reserves, Switzerland's net imports in 2016 were 28.6 thousand tonnes of crude oil equivalent per day. To meet the 90-day obligation, this equates to approximately 2.6 million tonnes of crude oil equivalent (Mtcoe) (or 19.2 mb). As at the end of January 2018, the country held a total volume of approximately 4.8 Mtcoe (or 35.7 mb) of stocks. This was equivalent to 168 days of net imports, and approximately 2.2 Mt (16.5 mb) in excess of the required minimum.

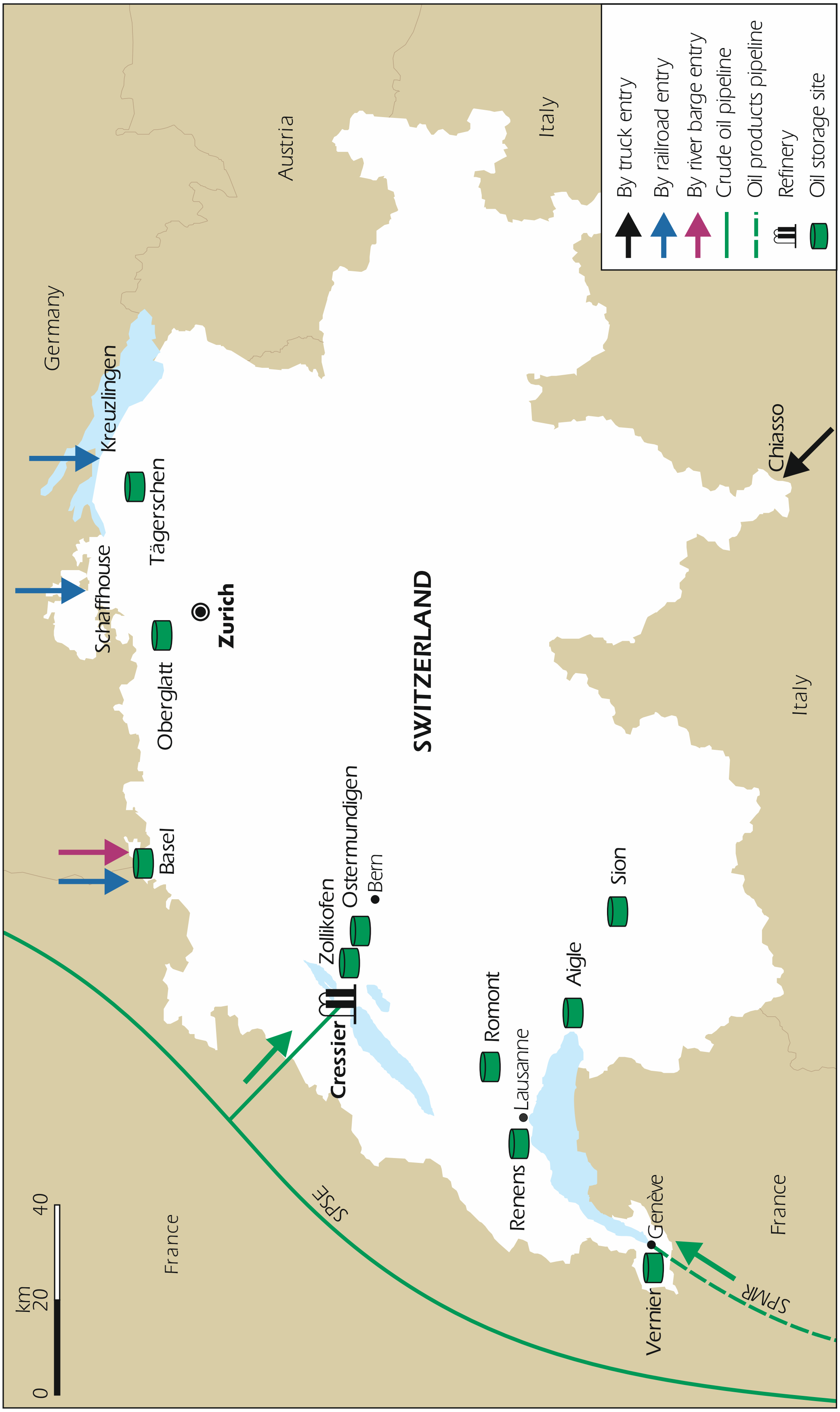
Those stocks mainly comprised middle distillates (67%) and motor gasoline (27%). The rest was crude oil (4%), residual fuel oil (1%) and other products (1%). As Switzerland has no public stockholding, all storage capacity is held within the supply chain. Crude oil is stored only at Cressier refinery for commercial purposes, as there is no compulsory obligation to hold crude oil. Compulsory stocks are held in accordance with stockholding contracts, which stipulate the full delivery of volumes must be guaranteed.

Pipelines and other transportation

Switzerland has two operating pipelines, the *Oléoduc du Jura Neuchâtelois* for supplying crude oil, and the *Société du Pipeline à produits pétroliers sur territoire Genevois* (SAPPRO) for transporting oil products. Both pipelines are connected to France. The *Oléoduc du Jura Neuchâtelois*, with a capacity of 4.5 Mt per year, connects the Cressier refinery with the SPSE, which originates from Fos-sur-Mer in the south of France and continues north to a large Rhine shipping port in Karlsruhe, Germany. All of Cressier's crude oil input is supplied via this pipeline.

1 For details, see the section on security of supply in this chapter.

Figure 3.6 Oil infrastructure in Switzerland



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The SAPPRO pipeline has a capacity of 1.5 Mt per year, and connects with the Pipeline *Méditerranée-Rhône* (SPMR) originating from Lavera, also located in the south of France, at Saint-Julien-en Genevois. The SAPPRO pipeline supplies diesel, heating oil, gasoline and kerosene to the terminal and tank farms in Geneva, and extends to around 12 kilometres in Switzerland.

The *Oléoduc du Rhône* crude oil pipeline (3.5 Mt capacity per year), which runs from Genoa in Italy to Collombey, was made obsolete with the suspension of operations at the Collombey refinery. Therefore, the share of oil supply via pipeline decreased by 15% over the period 2014-16, and was equivalent to 35% of total oil imports in 2016.

The products that were earlier produced at Collombey are now primarily imported by rail. The share of rail transport accounted for 34% in 2016, up from 23.5% in 2014. Delivery by river barges accounted for 23.4% in 2016, up from 18.7% in 2014, whereas imports by road remained constant at around 7%. Roads are the dominant means for transportation of petroleum products to final consumers within Switzerland.

Basel is Switzerland's only port for transport of oil products by barges on the River Rhine. Switzerland has three entry points for oil products arriving by train at the border with Germany. Oil products transported by truck arrive predominantly from Italy. Supply routes for oil products are well diversified, but there have been some unexpected disruptions in recent years.

A series of unexpected incidents in late 2015 caused a supply shortfall that commanded a temporary reduction of the stockholding obligation on some products by the Swiss authorities (see Box 3.1).

French strikes in 2010 and 2016 put constraints on domestic oil product supply, particularly the supply of jet kerosene for Geneva airport. An incident on the railway line between Karlsruhe in Germany and Basel, one of the main north–south rail corridors, caused an extended suspension of all cargo trains and interrupted most of the regular jet fuel supply to Zurich airport in August 2017. Rhine barges, train deliveries via alternative routes and contractual transfers of compulsory stocks among different locations swiftly replaced deliveries or increased commercial stocks at the airport. Therefore, the incident did not necessitate a compulsory stock release.

Market structure

In the absence of domestic crude oil production, the players in Switzerland's oil market are importers and retailers, and the remaining refinery at Cressier. There has been considerable consolidation in the number of importers from 88 in 1990 to 60 in 2011 and 56 in 2016.

All importers need to be licensed by CARBURA. Nine of its member companies accounted for 69% of the total imports in 2016. In addition, there were around 200 heating oil supply companies registered with the Swiss Oil Association, which accounted for about 90% of the Swiss heating oil market.

The retail market is fully open to competition. Switzerland had 3 424 retail stations operated by 20 companies in January 2017. Despite having exited the refining sector, Tamoil maintained its network of retail stations (261), the sixth-largest behind Avia (597), Agrola (425), BP (358), Ruedi Rüssel (328) and Migrol (313). The total number of retail stations has declined by 6% since the 2012 in-depth review, with most companies reducing their presence in the retail market. The exception was Ruedi Rüssel, which increased its number of stations.

Box 3.1 Temporary reduction of the stockholding obligation in 2015

An incident in the autumn of 2015, when Switzerland faced a shortage of road diesel fuel, motor gasoline and heating oil, proved the robustness of the Swiss stockholding model and its emergency preparedness procedures. However, the incident also underlined the country's vulnerability to disruptions in the transport chain.

Several events occurring in October 2015 caused a stock release. The unexpected outage of the Cressier refinery aggravated an existing tight domestic supply situation. Low water levels of the Rhine river limited capacity for oil product imports by barge from Germany. Rail routes from Germany were not able to make up for the additional import requirements. This was because some freight transport within Germany was diverted to the rail network due to the low water levels. The rail network therefore quickly became saturated. In addition, the suspension of operations of the Collombey refinery in early 2015 increased the country's reliance on product imports.

Turning towards the SAPPRO product pipeline did not yield the required relief. The rationing of its transport capacity by the French operators prevented utilisation of a portion of the pipeline's nominal spare capacity and effectively reduced the normal utilisation of the pipeline by Switzerland. Thus, in October and November 2015, Switzerland faced a shortage of road diesel fuel, motor gasoline and heating oil.

The Swiss Administration temporarily reduced the stockholding obligation on industry for road diesel fuel and motor gasoline as a relief measure. When the refinery outage was extended, and due to the continuing low Rhine water levels and a persistent incapacity to increase imports via the SAPPRO pipeline, authorities decided to lower stockholding obligations for a second time. With winter approaching, heating oil storage obligations were also reduced.

The Swiss Administration terminated the action by restoring the stockholding obligation to its usual level when domestic production and imports of petroleum products largely normalised in early December 2015. The total volume of stock made available to the market during October and November 2015 was 240 000 m^3 (3% of the country's total emergency stocks). Only 140 000 m^3 of this was taken up by the market.

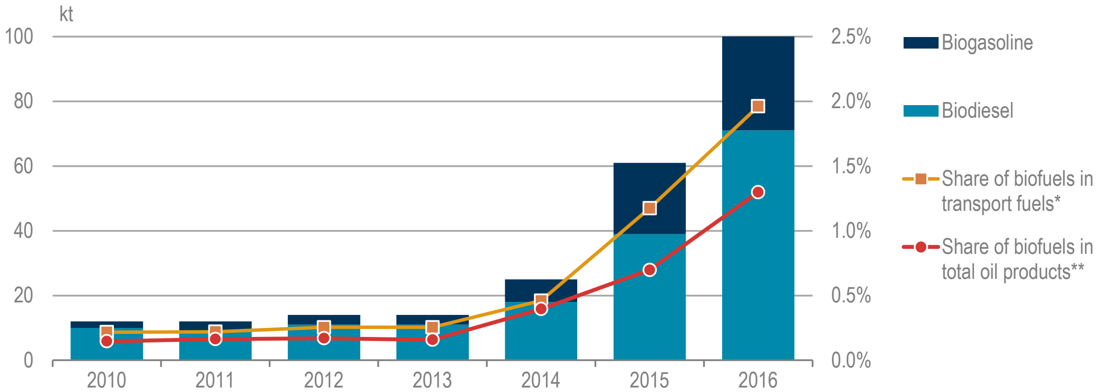
Source: IEA based on information provided by the Swiss Federal Office for Energy.

Biofuels

Biofuels represent a miniscule market share of transport fuels in Switzerland, but their importance is growing. Switzerland does not have a mandatory biofuel mixture obligation, and biofuels accounted for less than 0.1% of the total oil supply in 2011. The share of liquid biofuels reached 1.9% of the total volume of oil-based transport fuels (1.4% in energy terms), and 1.3% of the total energy supply from oil products in 2016. Biodiesel represented 70% of the total transport biofuels and bio gasoline the remaining 30%. The total consumption of biofuels in transport was 101 000 tonnes in 2016, an increase of 66% from 2015 the previous year (see Figure 3.7).

The increasing uptake of biofuels in Switzerland is due to the offset obligation introduced in 2013. Under this obligation, motor fuel importers must compensate for an increasing percentage of the annual CO_2 emissions from the use of fossil fuels. This compensation must be undertaken exclusively with domestic measures. The offset obligation started at 2% in 2014/15, increased to 5% in 2016/17, and it is expected to reach 10% by 2020. The CO2 Law stipulates that the compensation cost must not be higher than 5 Swiss cents per litre. The importers calculated that the obligation corresponds to a cost of about 1.8 Swiss cents per litre of motor fuel imported for 2017 and saves about 1-2 million tonnes of CO_2 per year until 2020 at a price of CHF 105/tCO_2. Importers that do not meet the mandatory CO_2 compensation certificates are subject to a penalty set at CHF 160/tCO_2. .

Figure 3.7 Liquid biofuel consumption in the transport sector, 2010-16



* Liquid biofuels as a share of total oil products in transport (in volume units).

** Liquid biofuels as a share of total of oil products in TPES (in energy units).

Sources: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/; IEA (2018b), *Oil Information 2018*, www.iea.org/statistics/.

Swiss fuel importers created the KliK Foundation to identify suitable projects and obtain the necessary compensation certificates. KliK's financial resources provided seed funding to promote the necessary infrastructure investments for a larger uptake of biofuels. By 2020, half of the offset obligation could be obtained from biofuels and hence directly in the transport sector. Beyond passenger transport, freight transport also has a high potential for biofuel uptake.

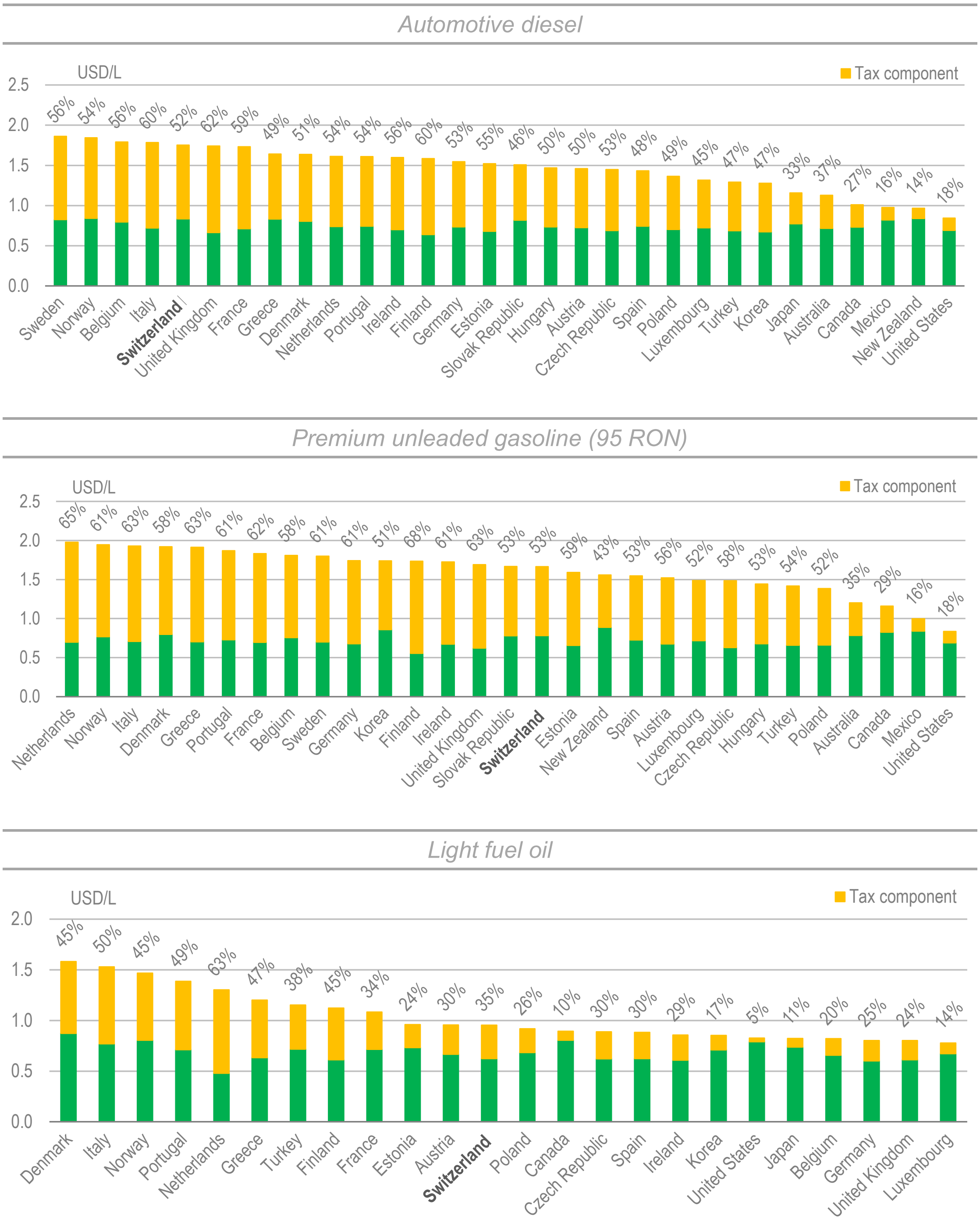
Prices and taxes

Swiss consumers paid the fifth-highest price for automotive diesel among all IEA countries in the second quarter of 2018, while premium gasoline prices were near the middle by comparison (see Figure 3.8).

The Swiss oil market does not have any form of price regulation. Prices for heating and transportation fuels are not regulated, although various taxes apply. Contributions to the Guarantee Fund ("Emergency Fund") are levied on imports of oil products to finance the stockholding regime.

Public transport and the agricultural sector benefited from a partial exemption from transport fuel duties. Total tax revenues amounted to CHF 5.6 billion in 2016.

Figure 3.8 Fuel prices in IEA member countries, second quarter of 2018



Notes: Gasoline data are not available for Japan. Light fuel oil data are not available for Australia, Hungary, Mexico, New Zealand, the Slovak Republic and Sweden. RON = research octane number; USD/L = United States dollars per litre.

Source: IEA (2018c), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Oil for stationary use is subject to the CO_2 levy, which was CHF 84/tCO_2 in 2017. The proposal to expand the CO_2 levy on stationary fuels to transport fuels faced strong political opposition. Therefore, the government will no longer pursue this policy initiative.

Security of supply

Stockholding

The revised National Economic Supply Act (NESA) of 2016 sets the basis for Switzerland's emergency response policy. It came into effect on 1 June 2017, and replaced the Act of 1982. It confers statutory power to the government in the case of an emergency for demand restraint actions and stock releases, including implementation of IEA collective actions. Under the authority of NESA, there are pre-prepared ordinances that provide the regulatory basis for requiring industry to implement specific emergency response measures. The revised NESA maintains existing regulations regarding the stockholding obligation. A change under the new law is the inclusion of biofuels in stockholding, details of which are expected to be issued during 2018.

Switzerland does not have any public oil emergency stocks or a public stockholding agency. It meets its stockholding obligation to the IEA with a compulsory stockholding obligation on industry. All emergency stocks are held as products. Oil importers are obliged to hold stocks equivalent to 4.5 months of demand for motor gasoline, diesel and heating oil, and 3 months for jet fuel. Jet fuel stocks were lower than the mandatory 3 months in the period 2013-17 due to insufficient storage facilities.

Work on expanding storage facilities is ongoing. Diesel stocks at the end of 2016 were lower than mandatory levels (4.2 months of coverage) because of increased demand. Emergency oil stocks are stored within the national territory, as NESA does not allow storage on foreign territory. However, Swiss companies hold small quantities of crude oil abroad.

CARBURA, founded in 1932, is an industry association with mandatory membership requirements for all oil importing companies. Its tasks include management of guarantee funds that compensate stockholders for their costs, co-operation in matters of national economic supply and collection of statistical data. The Swiss government assigned CARBURA to verify physical stock levels of each stockholder and issue or withdraw import licences. The government has legal powers to penalise non-compliant companies.

Importers can delegate up to half of their obligation to a substitute stockholder. Oil importers have some flexibility in the size of their stocks. Therefore, a common stockholder, owned by CARBURA, fills the difference between the obligation on industry and the sum of stocks held by individual importers and the substitute stockholder. Individual importers hold around 95% of the total compulsory stocks, and the common stockholder takes about 5%.

Draw-down procedures

Switzerland applies different stock draw-down procedures for national events and IEA collective action. In the case of IEA collective action, the government first relies on voluntary actions by oil importers to draw down stocks. If the voluntary draw-down is not sufficient, the government assigns quotas for each company, based on their shares of imports. In the event of a national supply disruption, the amount of stock release is calculated on a company-by-company basis, depending on how much their supply and delivery obligations are affected by the disruption.

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 longer than 6 months. Demand restraint instruments range from imposing speed limits and Sunday driving bans to more-severe measures such as a pro-rata allocation system for heating oil and a rationing system for transport fuels during an extended supply disruption.

Assessment

Oil is by far the largest energy source in Switzerland's TPES, but its share has gradually fallen. This trend will likely continue as alternative fuels substitute oil for heating. Oil consumption will be increasingly focused on the transport sector, where the switch to alternative fuels is more challenging than in other sectors.

Switzerland relies solely on imports for its oil supply. Sources of crude oil and product imports are varied, reflecting the effectiveness of the Swiss oil industry in adapting quickly to changes in the global oil market and contracting with alternative producers, if needed. This flexibility has facilitated replacement of the Collombey refinery output with increased product imports. However, the elimination of this supply source has had an impact on the security of supply.

A pipeline from France delivers all crude oil supplies. Supply routes for refined products are well diversified, relying mainly on rail and river barges, but also on pipelines and trucks. However, several incidents in recent years have shown that the transport chain poses the highest potential risk for the oil sector.

A combination of factors can produce a supply problem, as happened in 2015. This may result in the need to release compulsory stocks and a temporary lowering of mandatory stock levels. High utilisation rates of the transport network can cause complications in arranging alternative transport means. This was the case when strikes in France resulted in a shortage of jet kerosene delivery to Geneva airport. Authorities released a small quantity of compulsory stocks, because supply from other tank facilities in Switzerland could not be ensured.

Switzerland's key challenge in the oil sector is to guarantee the timely and needs-based transport of crude oil and products into and within the country. Swiss authorities and the oil industry need to maintain thorough preparedness to react quickly to disruptions in the transport chain. They also need to strengthen and diversify the existing transport chain, especially due to increasing capacity saturation. The IEA is confident the country can manage this task. Switzerland is well prepared to cope with disturbances on any single supply route because of its diversified system of supply sources and routes.

Under the offset obligation introduced in 2013, motor fuel importers have to compensate for an increasing share of CO_2 emissions from the transport sector with domestic measures, excluding the purchase of emission certificates. The share will reach 10% by 2020 and will most likely be even higher in the new climate legislation. Importers calculated that the obligation corresponds to a cost of about 1.8 Swiss cents per litre of motor fuel imported for 2017.

The compensation cost must not be higher than 5 Swiss cents per litre, as stipulated in the current CO_2 Law. This might be attained quickly as importers are running out of cheaper options. It is therefore recommended to widen the scope of eligible offsets and allow offsetting abroad, or include currently excluded domestic sectors. The government could consider including building refurbishments, or other programmes in the residential sector, once the ongoing building refurbishment programme is phased out by 2025.

Incentives for long-term domestic decarbonisation of the transport sector also need to be considered. This could include a modal shift and EVs. The certification of compensation projects should be standardised to make them administratively efficient to implement.

Using more biofuels is one way of limiting CO_2 emissions from the transport sector. Switzerland has no biofuel blending mandate, unlike its neighbours. The country has a restrictive environmental regime regarding biofuels extending beyond current EU standards. The uptake of biofuels in transportation is therefore cumbersome. However, the obligation for transport fuel importers to offset part of the CO_2 emissions, which was introduced in 2013, has boosted the adoption of biofuels, and their share has grown strongly. More still needs to be done to fully explore the potential of biofuels.

The government proposed to allow advanced biofuels into the Swiss market in accordance with the EU Renewable Energy Directive, as part of its post-2020 climate legislation. At the same time, the government also proposed to phase out the existing mineral oil exemption for biofuels after 2020. Instead, motor fuel importers would be mandated to offset 5% of CO_2 emissions from the transport sector by blending in renewable sources, including biofuels, biogas and synthetic fuels.

Promoting alternative fuels in the transport sector is a big challenge for all countries. Switzerland has made substantial progress through its current policies. The IEA encourages the government to consider maintaining the tax exemption for biofuels to exploit the biofuel potential.

Recommendations

The government of Switzerland should:

- ☐ Continue to monitor the adequacy of oil product transport infrastructure and alternative supply routes, so that it remains prepared for a significant disruption to one or more of the major supply modes (refinery production, and delivery by river barges, the rail network and product pipelines).
- ☐ Consider introducing cost-effective ways for offsetting the obligation on motor fuel importers by widening the range of eligible compensations and standardising their certification.
- ☐ Consider setting compulsory blending mandates to promote the use of biofuels in transportation.

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IEA (2018c), *Energy Prices and Taxes, Second Quarter 2018*, OECD/IEA, Paris, www.iea.org/statistics/.

4. Natural gas

Key data

(2017 provisional)

Natural gas production: nil

Imports: 3.7 bcm, +14.2% since 2007

Share of natural gas: 12.5% of TPES and 1.4% of electricity generation

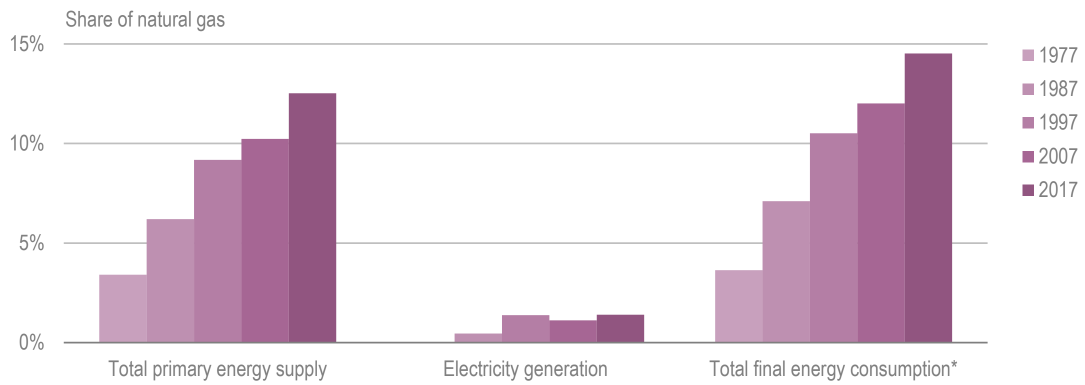
Consumption by sector (2016): 3.7 bcm or 3.0 Mtoe (residential 38.6%, industry 31.4%, commercial 21.6%, heat and power generation 7.5%, transport 0.7%, other energy 0.3%)

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

Overview

Natural gas accounts for a small share of Switzerland's energy system, but the importance of gas has increased for several decades (see Figure 4.1). It covers 12.5% of the total primary energy supply (TPES), which is the third-largest share after oil and nuclear. Most of the gas is consumed in the residential, industry and commercial sectors, and the fuel accounts for the third-largest share of the total final consumption. Gas power covers a small share of electricity generation, the third smallest among International Energy Agency (IEA) countries. Without any domestic production, Switzerland needs to ensure its gas supply through imports.

Figure 4.1 Share of natural gas in different energy supplies, 1977-2017



*Latest consumption data are 2016.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Supply and demand

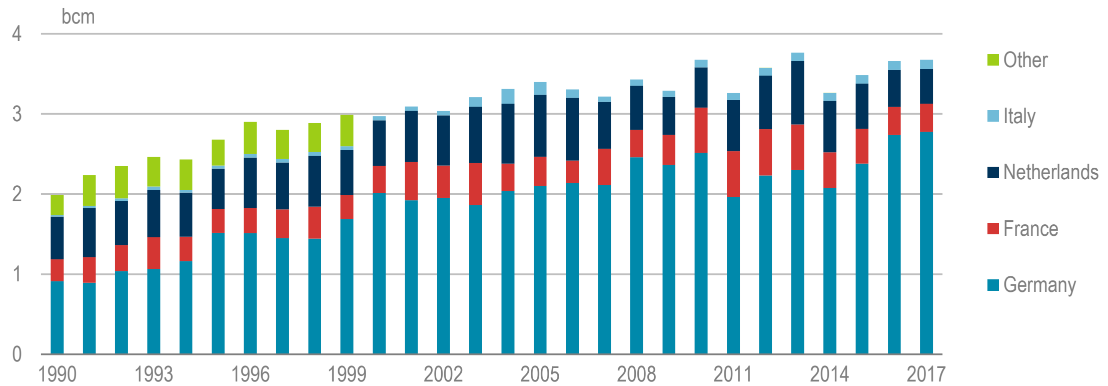
Imports

The total supply increased from around 2 billion cubic metres (bcm) in 1990 to 3 bcm in 2000 and to around 3.5 bcm in 2010, with large annual variations (see Figure 4.2). Total gas imports were 3.7 bcm in 2017, of which 76% came from Germany. Remaining shares were imported from the Netherlands (12%), France (10%) and Italy (3%, only to the Swiss canton of Ticino).

Germany has been the largest gas supplier to Switzerland since 1990, and its share in the total supply has increased over recent decades. However, Germany has a small domestic production and is dependent on gas imports, about half of which come from the Russian Federation. About one-third of total gas imports have originated from Russia since 2014, although Swiss companies do not have any direct contractual relation with the Russian company Gazprom.

A licence for trial gas exploration in Lake Geneva was awarded to a private company in 2014. However, all exploration is based on cantonal law in Switzerland, and the concerned canton, Vaud, introduced a moratorium on gas exploitation and gas fracking. Administrative review of the application has been ongoing ever since. Several other cantons have introduced a ban or a moratorium on fracking, fracking for unconventional gas or exploration of any hydrocarbons.

Figure 4.2 Natural gas imports by country, 1990-2017



Notes: There are no direct imports from Russia. However, in 2016, Germany's domestic gas demand was covered by nearly 90% imports, of which 60% came from Russia. Data are provisional for 2017.

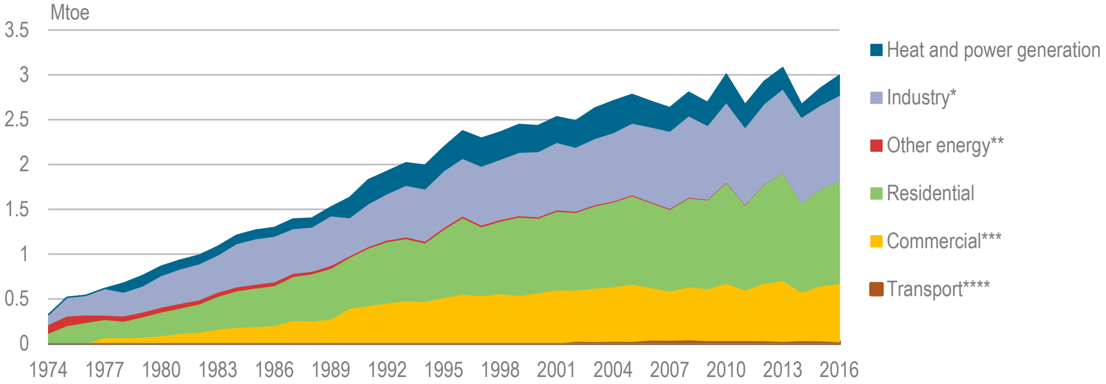
Source: IEA (2018b), *Natural Gas Information 2018*, www.iea.org/statistics/.

Switzerland has domestic production of biogas, mainly through fermentation of sludge and other organic matter, in addition to imports of natural gas. It produced 125 million tonnes of oil equivalent (Mtoe) of biogas in 2017. Heat and power generation accounted for 44% of the total biogas consumption (2016 numbers), and the rest was injected into the natural gas network (20%) or used in final consuming sectors in industry and other commercial use (36%). The biogas injected into the natural gas network was around 0.8% of the country's natural gas imports.

Consumption

Natural gas is consumed across several sectors, and the total demand increased steadily until 2005. Gas demand has since stabilised over the last decade, with annual variations depending on the number of heating days due to weather conditions. Demand is therefore seasonal, with a large gap between peak (winter) and off-peak (summer) demand. Residential demand also experiences large annual fluctuations, because gas used for heating also depends on weather conditions. The residential sector accounted for the highest share of nearly 40% of total gas consumption in 2016 (see Figure 4.3).

Figure 4.3 Natural gas supply by consuming sector, 1974-2016



* *Industry* includes non-energy consumption.

** *Other energy* includes the energy sector's own consumption and losses in oil and gas production and refineries.

*** *Commercial* includes commercial and public services, agriculture and forestry.

**** Negligible.

Note: Total primary energy supply of natural gas by consuming sector.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

The industry sector is the second-largest consuming sector, with around one-third of the total gas consumption. Gas is consumed in a wide range of industries, with the chemical and petrochemical industries accounting for the largest shares, followed by the food industry.

The commercial sector accounts for most of the remaining gas demand, whereas gas used in heat and power generation accounts for a small share of the total gas consumption. The transport sector also consumes a small share of natural gas, mainly for road transport and consumption in pipelines that transport gas. Gas power accounted for 1% of the total electricity generation in the country in 2016.

The stabilization of gas demand, subject to winter temperatures, is the result of divergent trends. The reduction of industrial gas demand due to ongoing de-industrialisation of the Swiss economy, in combination with increased efficiency gains, is being balanced by the substitution of oil heating with gas-fired heating and expansion of the natural gas network. Three-quarters of the Swiss population had access to the gas network at the end of 2015.

The future gas demand of Switzerland's electricity sector is uncertain. The Energy Strategy 2050 (ES 2050) includes several scenarios of how the nuclear phase-out might be compensated for by other fuels, including through the use of combined-cycle gas turbine (CCGT) power plants.

However, the recent strong addition of variable renewable energy generation sources has altered the economics of the European power market significantly, resulting in lower prices. This questions the viability of adding gas-fired power plants in Switzerland that is well interconnected with power markets in neighbouring countries. But the future addition of CCGTs cannot be excluded if power market conditions change and plans of neighbouring countries to exit from nuclear and coal-fired generation mature.

The possible additional demand from CCGTs is not expected to significantly affect the overall gas demand, as it will likely be offset by a continuous demand reduction in the residential and commercial sectors. Gas demand in Switzerland beyond 2020, excluding the power sector, is seen to continuously decline under all scenarios of the ES 2050.

Infrastructure

Pipelines

Switzerland is an important gas transit country located at the centre of the European gas market. It has 16 interconnectors that operate mostly in the entry mode. Important connection points are the northern entries at Wallbach (Germany) and Oltingue/Rodersdorf (France) to the Transitgas pipeline (see Figure 4.4).

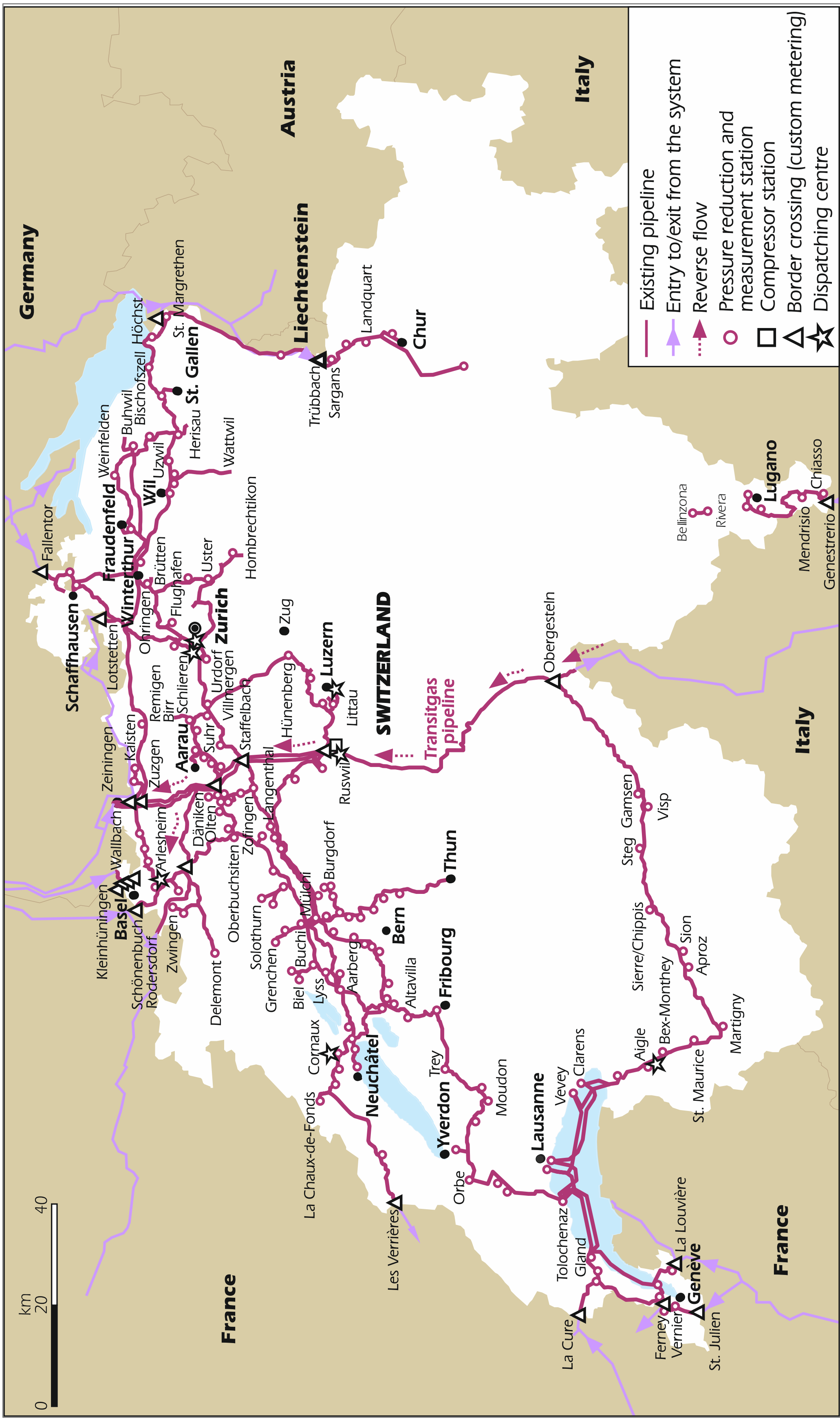
The Wallbach interconnector has a capacity of 51 million cubic metres per day (Mm^3/d), and is responsible for importing 80% of the annual Swiss gas demand. The entry point at Oltingue has a capacity of 22.2 Mm^3/d capacity. However, following an incident in 2017, there has been a disruption on one of the two strands of the connecting pipelines in Germany (Trans Europa Naturgas Pipeline 1). This is reducing the capacity from the Netherlands and Germany to Switzerland and to the south.

The Transitgas pipeline is a vertical transmission axis delivering gas originating from Northern Europe, mainly Norway and the Netherlands, and beyond to Switzerland and onward via the Griespass (59 Mm^3/d export capacity) to Italy. The Transitgas pipeline has a total length of 292 kilometres (km); its total capacity is 18 bcm per year, of which 2.5 bcm is reserved for Switzerland.

The Transitgas pipeline is owned, operated and maintained by Transitgas AG, which is owned 51% by Swissgas, 46% by FluxSwiss and 3% by Uniper of Germany. The compressor station at Ruswil is the operational centre of the Transitgas pipeline for maintaining and controlling the necessary transporting pressure in Switzerland.

FluxSwiss is majority owned by Belgian-based Fluxys and is the commercial transmission system operator of the Transitgas pipeline. It is responsible for marketing transit capacities on the gas pipeline network from the German-Swiss border and the French-Swiss border to the Swiss–Italian border. It commercialises around 90% of the system’s capacity. Swissgas is mainly in charge of the capacities needed for the supply of natural gas to Switzerland.

Figure 4.4 Natural gas infrastructure in Switzerland



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

In 2015, Fluxys made a decision to upgrade the Transitgas pipeline and the Trans Europa Naturgas pipeline, which connects to the Transitgas pipeline at Wallbach in Germany, to enable reverse flow. This will allow gas to flow from Italy through Switzerland to Germany and France, and between France and Germany, via Switzerland. This underlines the important role that Switzerland plays as a key gas transit country in Europe. The commercial reverse flow is expected to become operational in the second half of 2018. The reverse flow on the Transitgas pipeline will enhance the security of gas supply in Switzerland and also in Europe.

Switzerland's total gas transport system consists of 19 696 km of pipeline. The high-pressure transport network comprises 2 496 km of pipeline, and the low-pressure distribution network has an additional 17 200 km of pipeline. The reach of the natural gas network extended from 69% in 2012 to 75% of the Swiss population in 2017. Swissgas is the de facto technical transmission system operator and manages the co-ordination of supra-regional measures during technical disruptions.

Storage

Switzerland has no underground gas storage due to its geological conditions. Gas importers are not required to store natural gas. The country's gas storage infrastructure consists entirely of above-ground facilities in the form of pipelines and spherical storage vessels, which are used for daily balancing and peak shaving purposes. Several gas utilities have considered exploring potential sites for underground storage for close to a decade. A feasibility study for one potential site at Grimsel Pass in the canton of Valais is ongoing.

Dual-use facilities that primarily run on natural gas are required to maintain fuel oil stocks to replace gas used during supply shortages. These mandatory reserves must be sufficient to operate the dual-fuel installations with oil for at least 4.5 months. About 30% of the annual Swiss gas demand can switch to fuel oil, mainly in the industrial sector.

Gaznat, the regional gas company for western Switzerland, and Gasverbund Mittelland AG (GVM), its equivalent in north-western Switzerland, have acquired a stake in an underground gas storage facility in France. The two Swiss companies helped finance the facility at Étrez, which is directly connected to the Swiss gas grid. Their joint share is equivalent to 5% of the annual gas consumption of Switzerland. An agreement between Switzerland and France enables the two Swiss companies to use these capacities in an emergency on the same terms as French gas companies.

Legal and regulatory framework

Switzerland lacks a dedicated legal and regulatory framework for the natural gas sector. The main legal basis for the sector is the Pipeline Law of 1964, the latest revision of which was undertaken in 2007. It contains rudimentary provisions on commercial transport obligations for third parties, on the condition that they are technically and economically feasible. Essentially, gas sector activities are governed by the general competition law, and specifically by the Law on Cartels of 1995.

However, the expansion and liberalisation of European Union (EU) gas markets and the resulting new business models generated a growing interest for market opening by Swiss gas consumers. Since 1 October 2012 access to the high-pressure gas network has been regulated by an industry accord under private law among gas suppliers and two associations of energy-intensive consumers. The industry accord was the first step towards a more-formalised opening of the Swiss gas market, albeit only for large industrial consumers that require process gas. The initial threshold was set at 200 normal cubic metres per hour (Nm^3/h), but was reduced to 150 Nm^3/h in 2015. The approximate 400 customers with consumption above this threshold can choose their own supplier, implying a market opening of 30%.

The industry accord was submitted to the Competition Commission (Comco) for a preliminary assessment. Comco refrained from initiating an investigation but reserved the right to examine cases of possible infringement against antitrust law. Comco specifically recognised in its preliminary assessment that the threshold to gain third-party access to the gas pipelines was a potential violation of competition law, but that each case would have to be judged on its own merits.

This situation arose in July 2017, when a small customer lodged a complaint against its local utility for not being afforded third-party access. Comco subsequently opened a preliminary examination, and its ruling was outstanding as of April 2018.

The Swiss Federal Office of Energy (SFOE) is a quasi-regulator of the gas sector, and is involved in settling cases among different gas sector actors. It expressed an opinion in 2012 that the industry accord should not discriminate against small and medium-sized gas customers. For a long time, the government did not acknowledge the necessity of a more-elaborate legal framework for the gas sector.

The need for additional legislation was identified for three specific eventualities at the time of the last in-depth review in 2012. One was the need to keep up with evolving European legislation and regulation for the gas market. The second was the inability of the industry accord to appropriately account for the needs of industrial consumers. And the third if market players should call for legislation for third-party network access.

In 2014, however, the Swiss government stated that it was considering a further opening of the gas market and that the legal uncertainties in its gas market would be addressed by a new Gas Supply Law. The SFOE is working on a draft law building on the existing industry accord and aims for compliance with EU standards as much as possible, especially with (Regulation No. 715/2009 and Directive 2009/73/EC); (EU, 2009 [a] and 2009 [b]). Key objectives of the law will be guaranteeing security of supply, transparency and non-discriminatory third-party access, (SFOE, 2016).

The new Gas Supply Law will cover issues such as balancing rules, a network usage model, network pricing, security of supply, legal and regulatory matters (unbundling, network operators, regulators, etc.) and transversal issues (market opening, isolated regions, transparency, etc.). The intention is to identify the requirements for a framework for each thematic area, to ensure a functioning gas market and a secure supply, and to identify where legislation is required. The government plans to open a public consultation on the draft law in 2019. The Swiss natural gas industry announced plans to reduce the number of market balancing zones from five to one by 2022, to facilitate market opening and further integration.

The part of the Transitgas pipeline that supplies Switzerland would be gradually included in a unified balancing zone. There is no requirement that the pipeline operator supplies data on capacity utilisation. This leaves uncertainty about the extent to which competitive gas supplies can access the pipeline. It also raises questions about the degree of spare capacity that could be available during gas supply emergencies. Inclusion of the Transitgas pipeline into the unified balancing zone would likely improve efficiency, lower market entry barriers and contribute to more-equal opportunities for all gas market actors.

The SFOE clarified that the proposed Gas Supply Law would still only allow partial opening of the Swiss gas market, applying the same criteria as in the industry accord. However, the law would be framed in such a way that full market opening could be introduced in the longer term, if desired.

Industry structure

The Swiss gas market is dispersed. It has 86 gas utilities, which are mainly owned by cantons and municipalities and which enjoy local monopoly status, similar to the electricity utilities. As in the electricity sector, gas utilities vary strongly in size and often offer additional services beyond gas, including electricity, heat and water. In 2015, the nine largest gas utilities accounted for 50% of gas sales while the 42 smallest utilities sold 10% of the total.

Vertical integration in gas transmission and distribution is strong. Local monopolies have set up four regional associations: GVM AG, Erdgas Ostschweiz AG, Gaznat SA and Erdgas Zentralschweiz (EGZ). Each association operates its own high-pressure grid, and supplies gas to its owners at cost price. The gas utilities are mostly owned by cities and cantons, and they have no expansion plans. The four associations are majority shareholders of Swissgas AG, through which they obtain most of the imported gas at cost. The regional associations also have direct import contracts with foreign suppliers, with the exception of EGZ.

Swissgas is the main Swiss gas company. It also represents the Swiss gas industry abroad, including being an observer in the European Network of Transmission System Operators for Gas. It is responsible for issues of common interests to the gas industry, such as supply and infrastructure. Swissgas operates its own high-pressure transmission grid, and, through its stake in Transitgas AG, is involved in gas transit.

Security of supply

In October 2014, Switzerland carried out a “Risk Assessment of Natural Gas Supply in Switzerland”, in line with EU Regulation 994/2010 (SFOE, 2014; EU [2010]). The study analysed various scenarios and their potential risks, to ascertain whether existing emergency response measures were sufficient. The study concluded that Switzerland is well prepared for a gas supply disruption. This is mainly due to the country’s diversified and flexible supply sources and transport routes, and the high share of dual-fuel users that allow fuel switching.

Even in the event that the Wallbach interconnection (the most important entry point for gas, with 51 Mm^3/d capacity) fails, the remaining feed-in capacity into the Swiss system is sufficient to cover the daily demand of all customers (N-1: 153%)[1] and more than double the daily demand of non-interruptible consumers (N-1: 229%).

The SFOE published emergency and prevention plans in March 2016, based on the findings of the 2014 risk assessment and in line with EU Regulation 994/2010. However, since then, substantial changes in the Swiss energy policy have taken place. These are notably the decision to phase out nuclear power and similar policy changes by neighbouring countries. Changes to the EU internal market policy have also taken place since 2014. These changes combined have the potential to alter the European gas market dynamics in the future. It is advisable that Switzerland renews its vulnerability assessment, also taking into account the new EU regulations on security of gas supply.

Emergency response policy

The Ordinance on Strategic Stocks of Natural Gas (531.215.42) sets out a framework for Switzerland's gas supply security policies. It has been successively updated since first coming into force in 2003, to reflect changing market conditions. Switzerland does not hold any strategic natural gas or liquefied natural gas stocks. Instead, the obligatory strategic gas stocks are held as light fuel oil, to allow fuel switching by dual-fuel users during a gas supply crisis. They amount to the equivalent of 4.5 months of natural gas consumption of dual-fuel users, but are not counted towards oil emergency stocks.

The revision of Ordinance 531.215.42 in 2015 gave the natural gas industry the option of establishing a compulsory stock organisation and creating a guarantee fund to finance storage activities (Federal Council, 2015). Until the newly created Provisiogas began operating in 2015, the gas sector was the only sector covered by a compulsory stock obligation that did not have a private-sector support organisation.

The revised ordinance of 2015 also ensured better monitoring and enforcement of the stockholding obligation. This had become necessary with changes in the market framework. The partial opening of the Swiss gas market and the creation of a European wholesale gas market promoted the entrance of short-term-oriented companies into the Swiss market. This allowed some of them to evade their strategic stockholding obligation, thereby creating competitive disadvantages for companies with longer-term business models.

Provisiogas is empowered to co-ordinate, monitor and verify obligations applicable to all gas importers. It also calculates and collects contributions to the guarantee funds and the annual obligatory coverage level. The latest revision of the ordinance came into force on 1 June 2017, making membership of Provisiogas mandatory for gas importers and strengthening the responsibilities of Provisiogas (Federal Council, 2017).

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[1] The N-1 formula describes the ability of the technical capacity of the gas infrastructure to satisfy total gas demand in the event of disruption of the single largest gas infrastructure during a day of exceptionally high gas demand.

Emergency response measures

Switzerland employs market-based measures, such as increasing imports from other sources and using alternative gas transportation routes, in the initial stages of a gas emergency. If those measures are not sufficient to address the gas shortage, dual-fuel consumers will be requested to switch from gas to oil, based on the specific clauses in their pre-existing contracts with gas suppliers.

Non-market-based interventions will be employed if the supply crisis is especially severe or continues to deteriorate. This includes obligating consumers to undertake fuel switching to a level beyond that provided for in existing contracts. Dual-fuel units, which are mostly used in the industry sector, accounted for around 30% of Swiss gas consumption in 2016. This is a high percentage by international comparison. At the time of the 2012 in-depth review, dual-fuel installations accounted for 41% of the total gas consumption.

Release of compulsory stocks of light fuel oil is used to supplement mandatory fuel switching. The government is also developing an allocation programme that would limit the supply of gas to large, single-fuel consumers in the event that a non-contractual order to switch over dual-fuel systems is not sufficient to compensate for a gas supply shortfall. The Federal Office for National Economic Supply completed a study for this new measure at the beginning of 2016, and is now working on developing guidelines for implementation. Small gas users, such as households, would be subjected to light demand restraint measures, for example, appeals to reduce heating temperature and save warm water.

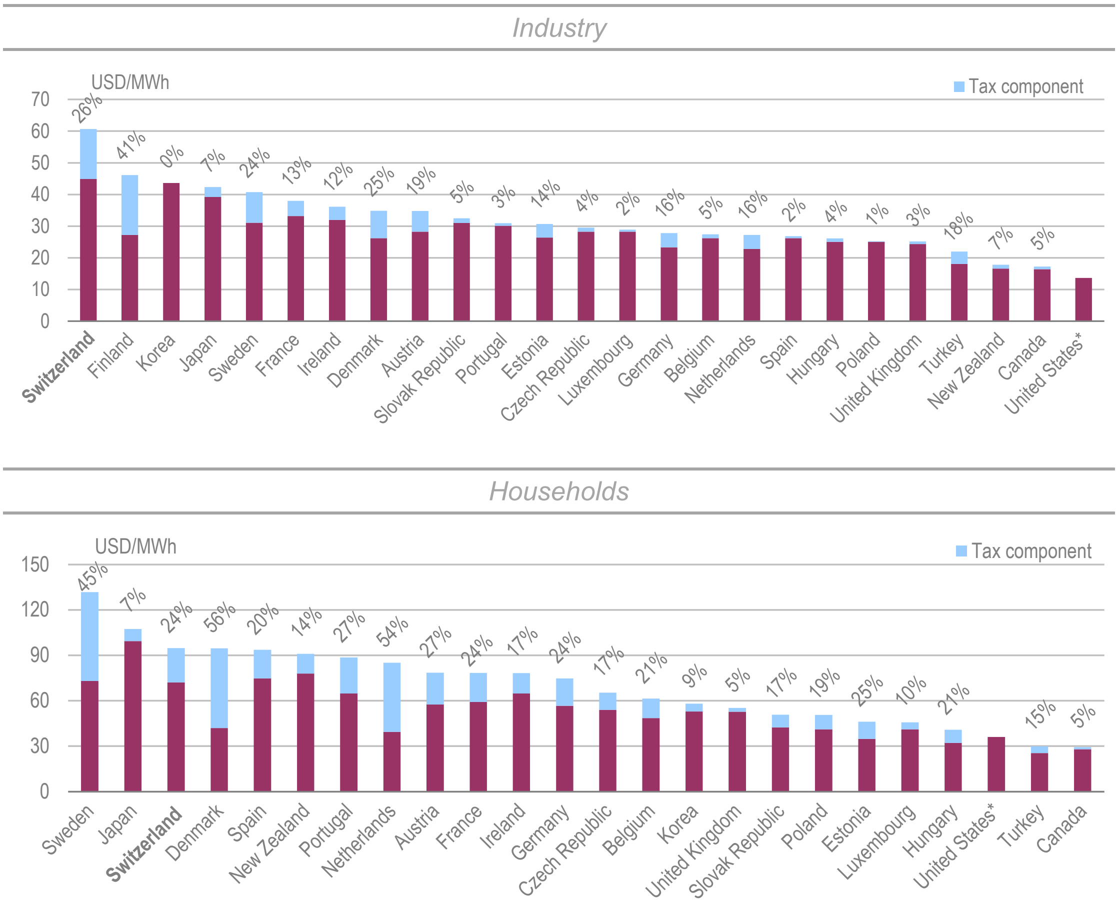
Prices and taxes

Gas prices in Switzerland are not regulated, but are published and monitored by the Federal Price Surveillance Authority. The authority can open an investigation if it finds indications of a lack of competition. As the gas market is largely closed to competition, the authority is using indicators such as comparing prices for different geographic monopolies and among different grid operators. Natural gas prices are high in Switzerland compared to other IEA member countries. The industry price is the highest in the comparison, and the household price is the fourth highest (see Figure 4.5).

In 2017, Swiss industries paid an average of USD 60.6 (United States dollars) per megawatt hour (MWh), of which 26% was taxes. This was significantly higher than any other IEA member country. In Finland, the second most-expensive country for industrial consumers, the price was 24% lower, despite 41% taxes levied on industrial consumption. Swiss households paid USD 94.9 per MWh, of which 24% was taxes. Gas for stationary use in industry and residential sectors is subject to the carbon dioxide tax, which has risen from CHF 12 (Swiss francs) per tonne of carbon dioxide (tCO_2) in 2009 to CHF 84/tCO_2 in 2016.

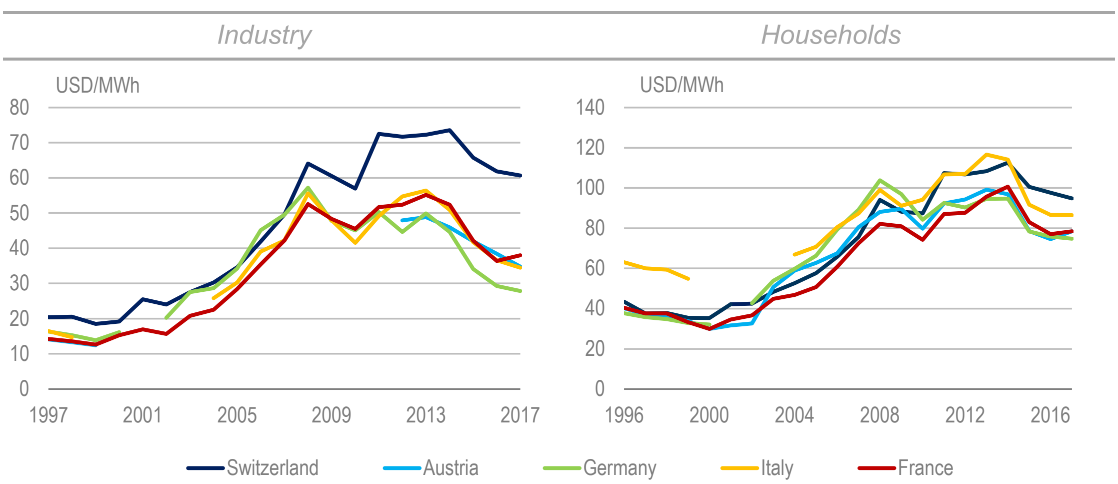
The trends for natural gas prices have been similar to those of neighbouring markets, with rapid price increases in the early 2000s, followed by a small decline in recent years (see Figure 4.6). Switzerland's industry price stands out in the comparison, and is substantially higher than in neighbouring countries.

Figure 4.5 Natural gas prices in IEA member countries, 2017



Note: Data are not available for Australia, Finland (households), Greece, Italy, Mexico and Norway.
Source: IEA (2018c), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Figure 4.6 Natural gas price trends in Switzerland and selected IEA member countries, 1997-2017



Source: IEA (2018c), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Assessment

Switzerland does not produce any natural gas, and relies solely on imports from four neighbouring countries. Natural gas accounted for 12.5% of the TPES in 2017, the fourth lowest share in the IEA and well below the median share of 23%. The residential sector consumes the largest share of gas, mostly for heating. Gas demand is therefore seasonal, with a large gap between winter and summer seasons, and fluctuates strongly annually depending on the number of heating days.

Future natural gas demand in Switzerland may be affected by the nuclear phase-out. An electricity supply scenario of the ES 2050 foresees the possible construction of one CCGT in the mid-term, to partially fill the gap between projected electricity supply and demand. In the longer term, possible incremental gas demand from the electricity sector is expected to be counterbalanced to some extent by declining residential commercial gas demand. Gas demand outside of the power sector will decline with implementation of the ES 2050.

The Swiss gas market is characterised by vertical integration combined with public ownership of regional and local monopolies. The structure has ensured a high level of supply security, albeit at high consumer prices. Gas market opening has not been an energy policy priority.

Switzerland lacks a dedicated legal and regulatory framework for the gas sector. An industry accord under a private law has regulated access for large consumers to the gas network since 1 October 2012. However, Comco did not give a definitive decision that all provisions in the accord could stand the test of the Law on Cartels. This legal uncertainty will be clarified in a new Gas Supply Law, which is in preparation.

The draft law builds on the industry accord, but also aims for the greatest possible compliance with EU legislation. The establishment of clear and transparent gas market rules and an independent gas regulator, the creation of a single gas balancing zone and the introduction of an entry-exit system are also steps towards facilitating an eventual framework agreement with the European Union.

Switzerland is well integrated in the European gas transport network. The Transitgas pipeline is key to transmitting gas from Northern Europe to Italy. This pipeline constitutes a cluster risk from a security of supply perspective, as it carries over 80% of the Swiss domestic supply, and Switzerland has no significant gas storage. However, the Swiss gas system has sufficient redundancies to cope with even a prolonged technical outage.

The importance of the Transitgas pipeline to European gas markets hedges the commercial supply risk to a certain degree. The pipeline is being retrofitted to allow physical reverse flow towards the end of 2018. This will improve security of supply for Switzerland and its EU neighbours by opening new transport routes.

Switzerland seeks formalised co-operation with European gas crisis management, to which it has been invited on a case-by-case basis since 2013. Swiss authorities carried out a natural gas supply security assessment, based on the EU assessment framework, taking another step towards formal co-operation. However, energy policy in Switzerland and its neighbouring countries has changed since 2014. It is advisable to update the assessment based on recent and expected future policy changes and due to infrastructure developments in Europe.

Fuel switching by domestic dual-fuel consumers is a key instrument during a gas emergency. The share of dual-fuel consumers in Switzerland is declining. This poses issues for security of gas supply. These should be addressed in a new risk assessment, taking into account the different scenarios for the Swiss energy mix under the ES 2050.

Switzerland is a supporter of the Trans Adriatic Pipeline, which will allow gas to flow from the Caspian Sea via Turkey, Greece and Albania to Italy, thereby opening new supply routes from the south. The reverse flow of the Transitgas pipeline is a key element. However, in the absence of a legal framework for gas pipelines, it is unclear whether the Transitgas pipeline is used to its full extent, or whether there is spare capacity that could be used for other purposes or which could be available during emergencies.

Recommendations

The government of Switzerland should:

- Establish clear market rules for the gas market (third-party access, consumer choice, protection of vulnerable consumers, etc.) via the Gas Supply Law (in preparation), seek alignment with EU legislation, and establish an independent and strong gas regulator.
- Facilitate completion and market accessibility of the reverse flow of the Transitgas pipeline, thereby contributing to market integration and improving the security of gas supply for Switzerland and Europe.
- Review the 2014 Risk Assessment of Natural Gas Supply Switzerland, taking into consideration the new EU regulation on security of gas supply (Regulation 2017/1938),(EU, 2017) and actively explore the potential for enhanced regional co-operation on gas emergency policy by inviting neighbouring countries to jointly work on preventive and emergency plans.

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5. Electricity

Key data

(2017 provisional)

Total electricity generation: 60.0 TWh, -9.7% since 2007

Electricity generation mix: hydro 56.8%, nuclear 34.0%, biofuels and waste 4.8%, solar 2.7%, natural gas 1.4%, wind 0.2%, oil 0.1%

Electricity net imports: 5.6 TWh (imports 36.5 TWh, exports 30.9 TWh)

Installed capacity (2016): 20.8 GW

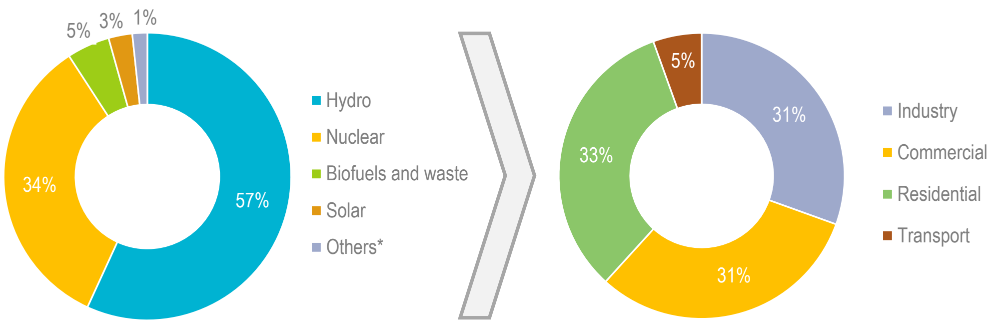
Electricity consumption (2016): 58.2 TWh (industry 30.5%, commercial 31.2%, residential 32.8%, transport 5.5%)

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

Overview

Electricity demand has been relatively stable, with annual consumption within 57-60 terawatt hours (TWh) over the last decade. Production of electricity has shown bigger variations between 62 TWh and 72 TWh, reflecting the large electricity trade with neighbouring countries. Switzerland's electricity generation has a low carbon intensity owing to large shares of hydro and nuclear, which together accounted for 90.8% of the total power generation in 2017 (see Figure 5.1).

Figure 5.1 Electricity generation by source, 2017, and consumption by sector, 2016



**Others* include natural gas, wind and oil.

Note: electricity generation data are provisional 2017 and consumption data are 2016.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Switzerland's electricity sector will undergo a considerable transition with the phase-out of nuclear power and a strong increase in variable renewable sources of energy (renewable energy) under the Energy Strategy 2050 (ES 2050). Continued market opening and further interconnection with neighbouring countries, with market coupling with the European Union, are key pillars that will shape the future of Switzerland's electricity sector.

Supply and demand

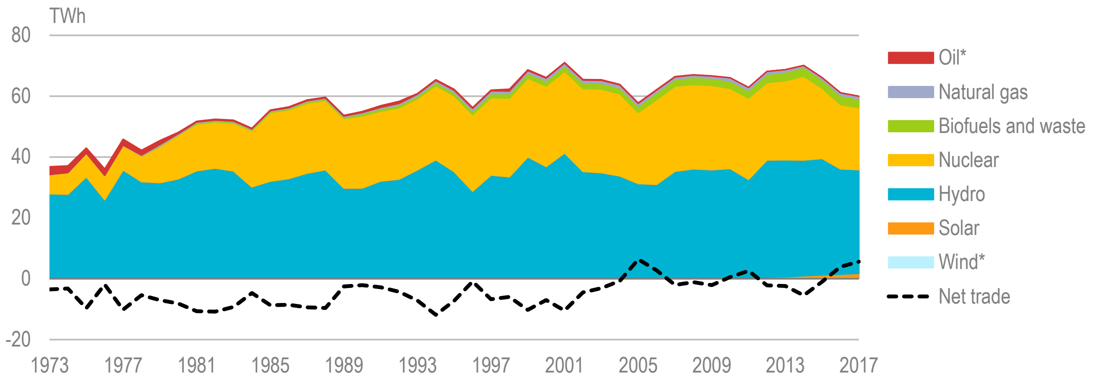
Switzerland has sufficient installed capacity to meet its total electricity demand in a year. It has been a net exporter in most years. The country usually exports electricity in summer and imports it in winter, when hydro reservoirs are running low. The net export balance has been dwindling over recent years, and this trend is expected to continue with the nuclear phase-out.

Generation and carbon intensity

Total electricity generation was 60.0 TWh in 2017, down from 66.4 TWh in 2007. Hydro accounted for 57% of the total generation, followed by nuclear (34%) and smaller shares of biofuels and waste, solar and other sources (Figure 5.2). Hydropower generation varies annually between 30-40 TWh, due to hydrological conditions. Nuclear power generation has been more stable at around 26-28 TWh, but it fell to 21.1 TWh in 2016 and 20.4 TWh in 2017 due to maintenance issues and prolonged shut-downs.

Installed capacity shows the changes to the electricity system without weather and operational effects. Switzerland's total installed power-generating capacity increased from 18.6 gigawatts (GW) in the 2012 in-depth review to 20.8 GW in 2016, equivalent to a 12% growth (Table 5.1). Hydro, including pumped hydro, grew by 7% and added 1 GW, while installed solar photovoltaics (PVs) almost quadrupled. Installed wind power capacity increased by close to 50%, but it remains small.

Figure 5.2 Electricity generation by source, 1973-2017



*Negligible.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Switzerland has the lowest share of fossil fuel use in electricity generation among International Energy Agency (IEA) member countries (Figure 5.3), due to its large shares of hydro and nuclear power. This provides the country with one of the lowest carbon intensities of power and heat generation among IEA member countries (Figure 5.4). In

2016, Switzerland emitted 41 grams of carbon dioxide per kilowatt hour (kWh) of heat and power. This is far below most other countries and comparable to the hydro-based system in Norway and the hydro/nuclear-based system in Sweden.

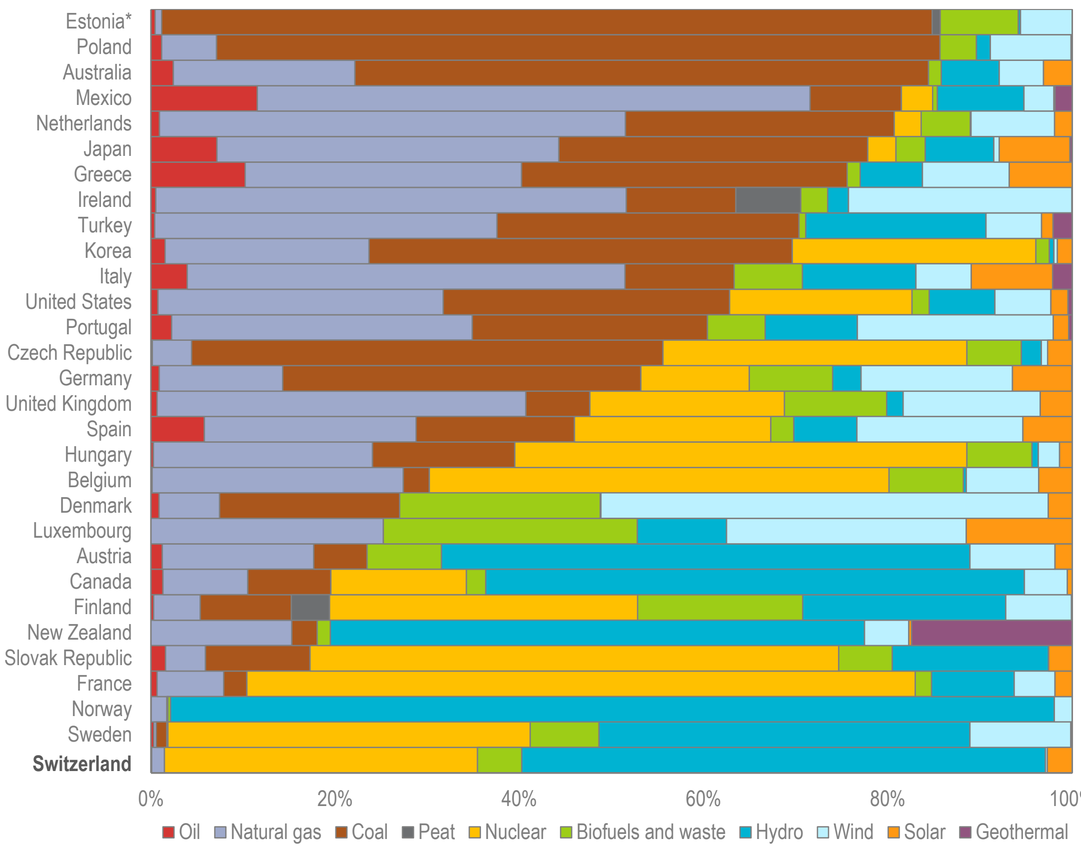
Table 5.1 Installed electricity generating capacity (megawatts), 2000-16

Energy source	2000	2005	2010	2011	2012	2013	2014	2015	2016
Nuclear	3 200	3 220	3 253	3 278	3 278	3 278	3 308	3 333	3 333
Hydro	13 239	13 355	13 723	13 769	13 802	13 817	13 743	13 815	14 806
of which pumped hydro*	1 756	1 699	1 839	1 839	1 839	1 839	1 839	1 852	2 589
Solar PVs	16	28	125	223	437	756	1 061	1 394	1 664
Wind	3	12	42	46	49	60	60	60	75
Combustible fuels	804	825	944	918	1 018	1 021	993	1 016	961
Total capacity	**17 262**	**17 440**	**18 087**	**18 234**	**18 584**	**18 932**	**19 165**	**19 618**	**20 839**

* Includes mixed plants and pure pumped storage plants.

Source: IEA (2018b), *Electricity Information 2018*, www.iea.org/statistics/.

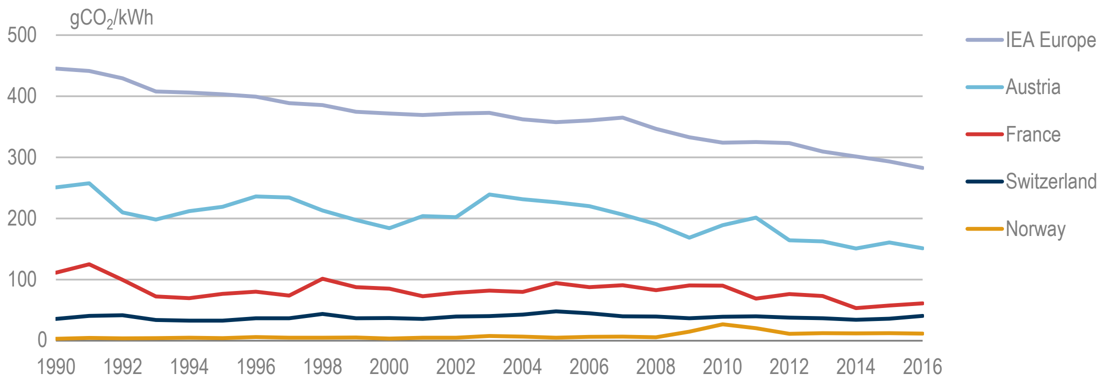
Figure 5.3 Electricity generation by source in IEA member countries, 2016



* Estonia's coal represents oil shale.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 5.4 Carbon intensity of power and heat generation in Switzerland and selected IEA member countries, 1990-2016

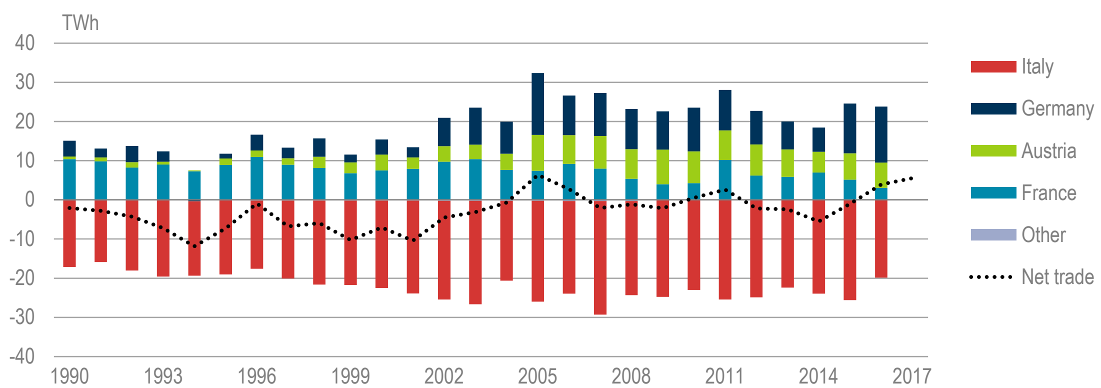


Source: IEA (2018c), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Imports and exports

Switzerland imported 36.4 TWh and exported 30.9 TWh of electricity in 2017. This resulted in 5.5 TWh net imports, which provided 8% of the total electricity supply (net imports plus domestic generation) in the country. Germany is the main exporter to Switzerland. In 2016, Germany provided 51% of Switzerland's electricity imports, followed by France (25%), Austria (20%) and Italy (4%). For exports, 70% was delivered to Italy and the rest to France (18%), Germany (10%) and Austria (1%). Over the past two decades, Switzerland has gone from being a net exporter of up to around 10 TWh to having net imports in some years (Figure 5.5).

Figure 5.5 Electricity imports and exports by country, 1990-2017



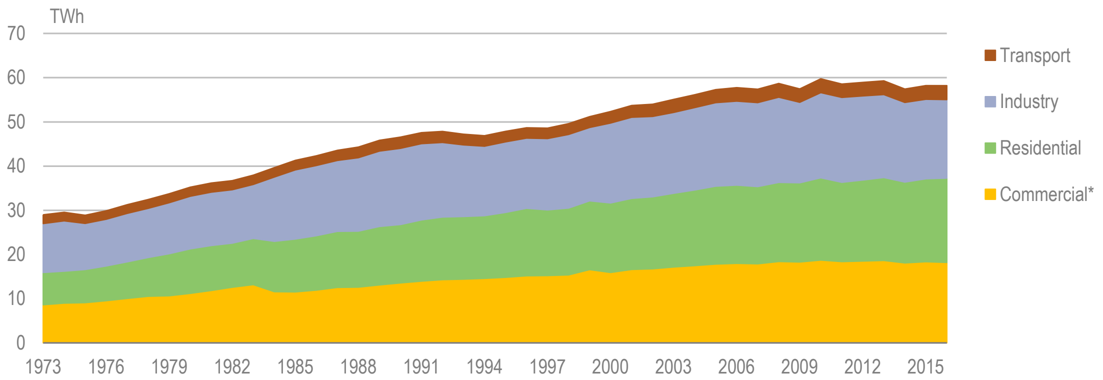
Note: Data not available per country in 2017.

Source: IEA (2018b), *Electricity Information 2018*, www.iea.org/statistics/.

Demand

Switzerland consumed 58.2 TWh of electricity in 2016, which is a marginal increase of 0.8% from 2006. The sectoral proportion of consumption is balanced, with the residential sector accounting for 32.8%, the commercial sector for 31.2% and the industry sector for 30.5% of the total consumption. The remaining 5.5% came from the transport sector (Figure 5.6).

Figure 5.6 Electricity consumption (total final consumption) by consuming sector, 1973-2016



* *Commercial* includes commercial and public services, agriculture and forestry.

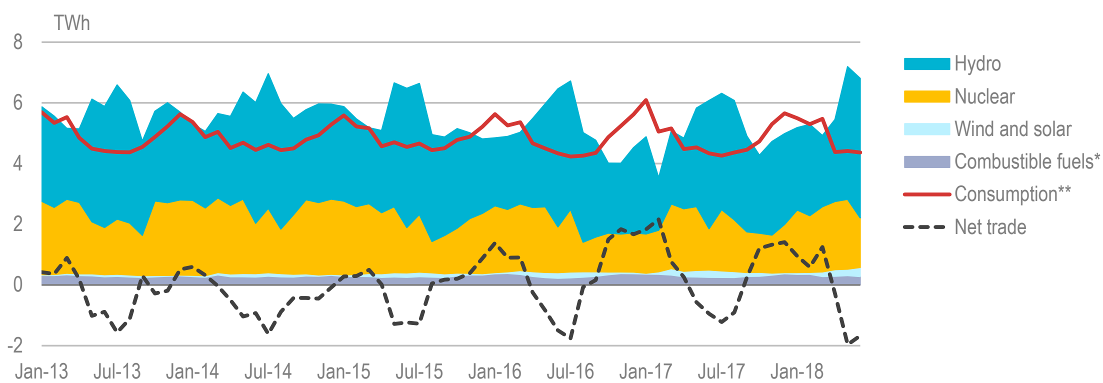
Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Balancing supply and demand over the year

Seasonal variation in production and trade of electricity is of crucial importance for security of supply (Figure 5.7). Electricity consumption peaks in winter due to the higher demand for heating. However, a lower hydropower capacity of run-of-river plants is available in winter due to hydrological conditions. Nuclear plants therefore normally undergo annual revision during the summer when hydro generation is running at high capacity.

Switzerland uses its interconnections to sell electricity in the summer and import it during the winter, to cover its winter peaks and to balance seasonal variations, and also for trade. The gap between winter peak demand and domestic power generation has increased in recent years, and electricity import has accounted for a growing share of Switzerland's electricity demand in recent winters. This is a trend that is likely to continue with the phase-out of nuclear power.

Figure 5.7 Monthly electricity generation by source, Jan 2013-July 2018



* *Combustible fuels* includes natural gas, oil, biofuels and waste.

** *Consumption* refers to final consumption including distribution losses.

Source: IEA (2018b), *Electricity Information 2018*, www.iea.org/statistics/.

Institutions

The Swiss Federal Office of Energy (SFOE) is the lead governmental body for electricity policy making. It is also the licensing authority for hydropower plants on international boundary rivers, nuclear plants and installations, and the transport of nuclear fuels. The SFOE also acts as the licensing authority for electricity transmission lines in cases when the Federal Inspectorate for Heavy Current Installations has not been able to overcome opposition. The SFOE is part of the Department of the Environment, Transport, Energy and Communications. The harbouring of the energy and environmental portfolios under a single ministry is intended to strengthen sustainability concerns in energy policy making.

ElCom is the independent regulatory authority of the Swiss electricity sector. Its main responsibilities are ensuring compliance with laws, and ensuring grid access and conditions for grid use. ElCom monitors electricity and grid tariffs ex post, and rules as the judicial authority on disputes relating to network access. It oversees electricity supply security and regulates issues relating to international electricity transmission and trading. It is responsible for ruling on disputes concerning feed-in tariffs and among network operators and independent producers. ElCom also monitors cross-border congestion management of the transmission system operator (TSO) and the use of cross-border capacity auctions.

Swissgrid (a TSO) is a national grid company that owns the country’s high-voltage grid. It is responsible for the safe operation, non-discriminatory access and maintenance of the national grid. It also co-ordinates cross-border exchanges as a member of the European Network of Transmission System Operators for Electricity (ENTSO-E).

Verband Schweizerischer Elektrizitätsunternehmen is the main association for the Swiss electric utilities. Swisspower groups the 22 largest city utilities (except for the city of Zurich utility). *Dachverband Schweizer Verteilnetzbetreiber* is the central association for distribution system operators (DSOs) and small utilities.

Legal framework

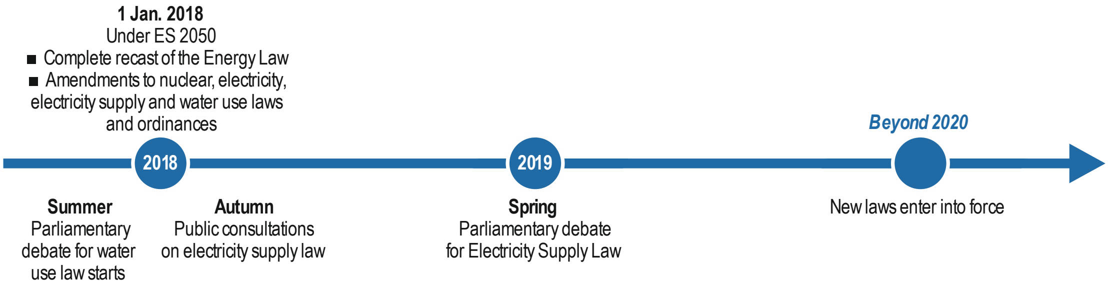
The Electricity Supply Law (ESL) of 2008 is still the main law in the electricity sector. The law is being partially revised under the legislative package of the ES 2050. The government is preparing to introduce a revised draft ESL for public consultation in the autumn of 2018.

The 2008 law provided the basis for reforming the Swiss electricity sector. It established an independent regulator, ElCom, and an independent TSO, Swissgrid. It also stipulated open and non-discriminate access to the grid and included provisions for consumer protection. The ESL opened the market for large consumers. End users with an annual consumption above 100 megawatt hours (MWh) have been able to freely choose their supplier since 2009. About 50% of total electricity consumption is above this threshold.

Other federal laws relevant to the electricity sector are: *i*) the 1902 Law on Electricity, regulating the construction, operation and maintenance of network and power plants; *ii*) the 1916 Law on the use of Hydropower Resources, which includes regulations for a royalty tax on water; and *iii*) the 2005 Nuclear Energy Law (see Chapter 6, “Nuclear”) and the 2018 Energy Law.

The legislative package of the ES 2050 included a complete revision of the 1998 Energy Law and substantial amendments to various laws and ordinances with effect from 1 January 2018. These include the Carbon Dioxide Law, the Law on Spatial Planning, the Water Use Law, the Nuclear Law, the Electricity Law and the ESL, ordinances on electricity supply, energy promotion, certificates of origin, energy efficiency and nuclear energy (see Figure 5.8). Additional legislation is under preparation to adapt the ESL and the Water Use law.

Figure 5.8 Development of Switzerland's electricity legal framework



Source: IEA based on information provided by the Federal Swiss Office for Energy.

Cantons and municipalities have their own regulations on service offerings. Cantons issue licences for fossil fuel power plants and for water use in hydro plants. They have the authority to issue licences for electricity distribution in their territory. The distribution grid is usually owned by the canton or municipality, which implies an option to set end user prices.

Industry structure

Switzerland has 650 utilities, which serve just over 5 million consumers. Their sales volumes range from 100 MWh to more than 10 TWh. About 600 utilities are small, local distributors and suppliers, operating at the municipal level as a local monopoly. While the utilities serve an average of 1 440 end consumers, only 77 supply more than 1 000 and just 11 have more than 100 000 end consumers. The distribution sector is continuously consolidating: from some 1 200 companies in the mid-1990s to around 850 in 2010 and about 650 in 2016. One factor is the merging of communes, whose numbers fell from 2 551 to 2 324 over the same period.

The public sector (mainly regional, cantonal and municipal utilities) partly or wholly owns most Swiss electricity companies along the value chain. In 2016, public entities held 85% shares of all electricity sector companies (60% owned by the cantons and 25% by municipalities). Swiss private financial entities owned 8.1%, while foreign owners held 3.3% and the remainder was free float. The two foreign shareholders were EdF of France, which held a 25% share in Alpiq, and Germany's E.ON, which held a 3.3% share in BKW.

Ownership structures in the electricity sector are highly intertwined. For example, Axpo, the largest Swiss producer, is 100% public sector-owned and holds an 81% share in *Centralschweizerische Kraftwerke*, the vertically integrated utility in central Switzerland.

Three large groups, Axpo, Alpiq and BKW, account for more than 50 TWh, or about 80% of generation in Switzerland. They jointly own most of the largest nuclear and hydro plants. The three companies operate at the supra-cantonal level and are active in international electricity trading. They supply their parent retail companies and the free market. BKW also has about 300 000 captive customers, unlike Axpo and Alpiq that sell at wholesale prices. BKW and smaller hydro producers owned by cantons and municipalities can charge their captive end-users the cost of their production, under ex-post supervision by Elcom regarding cost accounting.

Utilities generally enjoy operational independence while being subject to political directions. Utilities are expected to pay politically fixed dividends, which, in some municipalities, constitute a significant source of income. Utilities can then benefit from special public credits for certain projects.

Transmission and distribution networks

Swissgrid is the owner of the Swiss transmission grid, which has over 6 700 kilometres (km) of high-voltage (220/380 kilovolt (kV)) transmission lines and 141 substations. Swissgrid assumed responsibilities for operation of the country's transmission system in January 2008. Ownership of the grid remained with the previous owners, the utilities, until 2013 when they transferred their transmission assets to Swissgrid. The structure of Swissgrid is comparable to the Independent Transmission Operator (ITO) model of the European Union.

The ESL mandates that the ITO must be an independent company based in Switzerland and that the majority of ownership must remain with the cantons and communes, either directly, or indirectly through the cantonal or communally owned utilities. Swissgrid cannot be active in generation or distribution, nor have ownership in companies in the sector. The law also mandates that the majority of the management and board of Swissgrid, including the chairperson, may not have any connection with electricity generation and trade.

BKW and Axpo jointly own just over 68% of Swissgrid. Alpiq originally held a 34.7% share in Swissgrid, but since 2015, has divested it, except for a remaining 0.1% share. Other large individual owners are *Elektrizitätswerk der Stadt Zürich* (8.74%), *Société d'Investissement de Suisse occidentale* SA (4.42%) and *Centralschweizerische Kraftwerke* AG (4.24%). The remaining 14.52% share is held by 26 companies, mainly utilities, and also the Swiss Railway company.

The ESL requires Swissgrid to offer use of the transmission grid in a non-discriminatory way. There is a single tariff for the use of the Swissgrid control area, which is approved by ElCom on a yearly basis. The tariff has three components: 30% energy, 60% capacity and 10% basic tariff.

The distribution networks operate from 400 volt to 160 kV levels, and cover around 69 000 km. Cantonal and local utilities own most of the distribution networks. Traditionally, the utilities had monopoly status for retail in their geographic area, but the ESL of 2008 opened the distribution networks to non-discriminatory third-party access and imposed unbundling of distribution activities at the accounting level.

ElCom monitors distribution operations, including cost accounting, and it also settles disputes. ElCom reviews about 150 tariff submissions annually, to check for any potential errors in cost accounting, inconsistencies and implausible figures. It requires distribution network operators to undertake corrective action if needed. However, there are over 8 000 different tariffs in Switzerland; hence, ElCom's practical oversight and corrective interventions are limited.

Cross-border transmission capacity

Its geographical location at the centre of Europe makes Switzerland a major electricity transit and exchange point, second only to Germany (Figure 5.9). The country has 41 cross-border transmission lines, with up to 9 GW of available capacity. This is substantial compared to the 20.8 GW of installed capacity in Switzerland and the peak-load consumption of Switzerland (about 10 GW). In 2016, 72 TWh crossed Switzerland's borders, accounting for 11% of European cross-border flows in the total synchronised European continental grid. Switzerland therefore plays a key role in achieving a fully integrated European internal electricity market.

Swissgrid manages the interconnection lines in close co-operation with neighbouring TSOs. Swissgrid is a member of ENTSO-E and an observer to the Pentalateral Electricity Forum (PLEF) (Box 5.1).

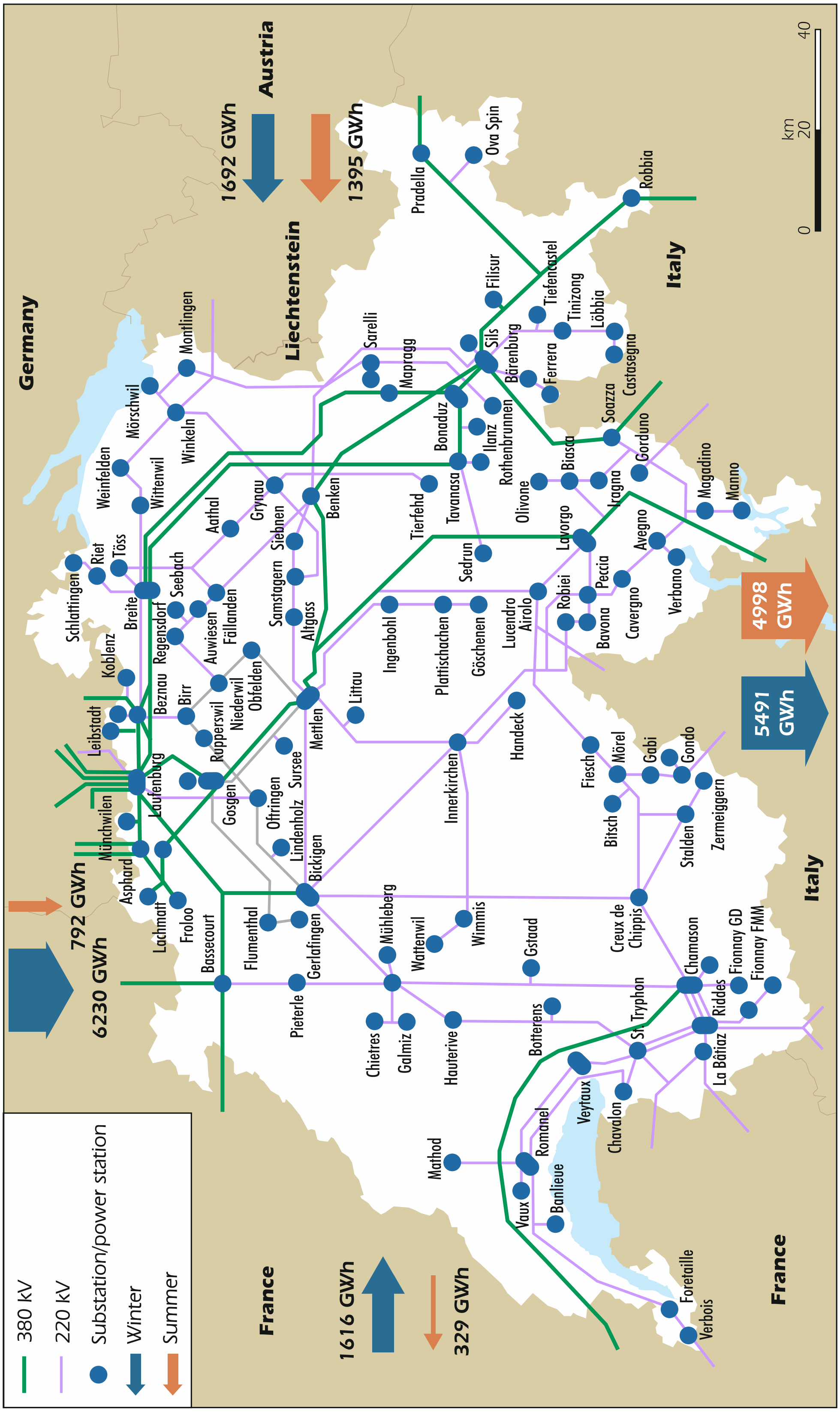
The ESL gives Swissgrid responsibility for cross-border congestion management. Available capacities can be allocated through market procedures such as auctions. However, the law also provides for exemptions from auctioning of capacities for several types of supplies. Those based on long-term international purchase and supply agreements that were concluded before 31 October 2002 and those from border hydropower plants have priority. The priority of supplies for captive customers and from renewable sources of energy in the event of network congestion was renounced from 1 October 2017, following a revision to the ESL.

The EU CACM entered into force in August 2015. This allowed for market coupling of cross-border day-ahead and intraday markets. The European Union excludes Switzerland from market coupling due to the absence of a bilateral electricity agreement. This is despite Switzerland's critical position for central European electricity flows and that the Swiss system is ready for market coupling. Hence, capacity allocation at Switzerland's borders is still based on the explicit auction principle, so cross-border capacities on Swiss borders are not optimally used. This has a negative impact on grid transmission security in Europe and entails social welfare losses.

The exclusion from market coupling limits Switzerland's ability to manage the presence of loop flows. These are unscheduled cross-border power flows. In the absence of a formal agreement, they can be managed through re-dispatch of local resources (i.e. generation within Switzerland). Left unchecked, persistent loop flows may endanger the security of the grid. Switzerland could invest in phase shifters, as an alternative to market coupling, which would allow it to dynamically restrict the flow of power across its borders.

Swissgrid plans to invest CHF 2.5 billion (Swiss francs) under its Strategic Electricity Grid to 2025. A key investment is uprating of the transmission line between Bassecourt and Mühleberg, from 220 kV to 380 kV, and the installation of a transformer at Mühleberg. This is being done in anticipation of the shutdown of Mühleberg nuclear power plant (NPP) in 2019, which will likely be compensated for by higher imports.

Figure 5.9 Map of Switzerland's transnational electricity network and 2016 trade flows



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: *Winter* refers to October to March and *Summer* refers to April to September.

Source: ENTSO-E (2018), *Physical Energy and Power Flows*, www.entsoe.eu/data/power-stats/physical-flows/.

Swissgrid is also investing to address tight network spots, especially at border crossings with Germany. Those are exacerbated by loop flows from neighbouring countries, which add additional stress on the Swiss network and require extra investments to maintain security of the network. Swissgrid is involved in three EU projects of common interest: two connecting to Italy (Verderlo and San Giacomo) and the Lake Constance interconnector with Germany.

Box 5.1 Switzerland and the PLEF

The PLEF is a framework for regional co-operation in Central Western Europe towards improved electricity market integration and security of supply. The PLEF was founded in 2007 with five original members: Belgium, France, Germany, Luxembourg and the Netherlands. In 2011, Austria joined as a member and Switzerland as an observer.

The PLEF is organised under a "bottom-up" principle, with its authority deriving implicitly from the competent authorities of the member countries. Efforts on ensuring security of supply have covered a broad set of areas, including development of a regional system adequacy forecast, harmonisation of how system incidents are defined and reported, development of a TSO co-operation platform and development of a regional transmission capacity plan. The PLEF generation adequacy assessment takes a regional perspective and holistic view on potential capacity shortages and therefore complements national studies.

Switzerland does not yet have an electricity agreement with the European Union, despite its high interconnection with European Union (EU) electricity markets. This limits Switzerland's involvement in the EU internal energy market and excludes its participation in the capacity allocation and congestion management (CACM) network code.

Consequently, Switzerland is unable to participate in flow-based market coupling with PLEF member states. Switzerland is actively involved in the PLEF as an observer, despite this obstacle to full participation. This allows Switzerland to stay actively involved in discussions on market design and resource adequacy issues, which may influence or feed into the future direction of the EU internal market.

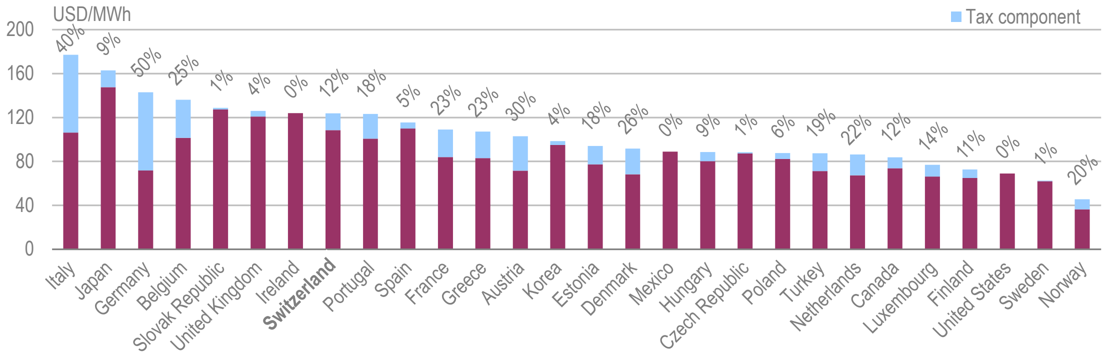
Switzerland co-chairs the PLEF working group on flexibility, and has participated in the PLEF regional resource adequacy assessment, despite being limited in the degree to which it is integrated into the regional market. Switzerland is a winter-peaking country whose large hydroelectric fleet produces mainly in the summer. It is therefore a net importer of electricity during the winter months. Much of its hydroelectric power is in reservoir or pumped-storage hydro, which can be sold into regional day-ahead markets, but which can also provide significant flexibility to the regional system.

Source: IEA (2016), *Insights Series 2016: Electricity Security Across Borders: Case Studies on Cross-border Electricity Security in Europe*, www.iea.org/publications/insights/insightpublications/ElectricitySecurityAcrossBorders.pdf.

Prices and taxes

Switzerland's consumers pay high electricity prices compared to the average among IEA member countries, despite low taxes. In 2017, industries paid USD 123 (United States dollars) per MWh, of which 12% was tax (Figure 5.10). This was the eighth-highest price in the IEA comparison, below neighbouring Germany and Italy, which have higher end prices because of higher taxes. The household price was USD 204 per MWh, which was the thirteenth-highest price in the IEA comparison (Figure 5.11). Electricity prices in Switzerland have followed similar trends to those in neighbouring countries in recent decades, but have not experienced the same large increases as in Italy and Germany (Figure 5.12).

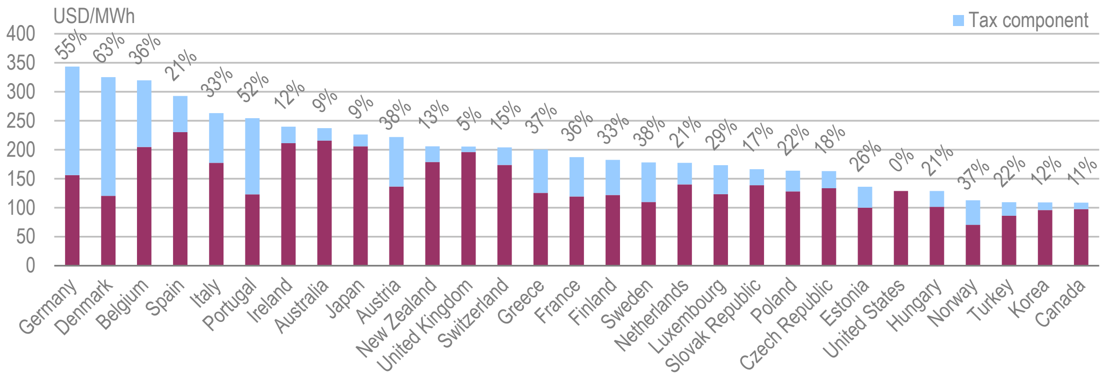
Figure 5.10 Industry electricity prices in IEA member countries, 2017



Note: Data are not available for Australia and New Zealand.

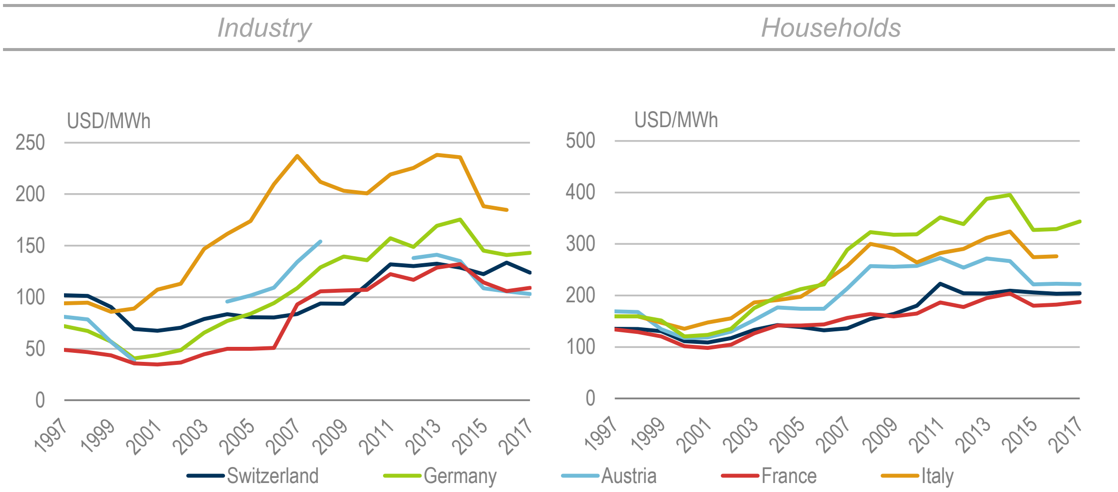
Source: IEA (2018d), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Figure 5.11 Household electricity prices in IEA member countries, 2017



Source: IEA (2018d), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Figure 5.12 Electricity price trends in Switzerland and selected IEA member countries, 1997-2017



Note: Price data are not available for Italy in 2017 and industry prices in Austria 2001-03 and 2009-11.
Source: IEA (2018d), *Energy Prices and Taxes, Second Quarter 2018*, www.iea.org/statistics/.

Focus Area I: Electricity market design post-2020

The first package of legislation for the ES 2050 was enacted on 1 January 2018. It set a base for the phase-out of nuclear energy in the coming decades. Three key factors will shape Switzerland's electricity market post-2020.

First, the nuclear exit starting in 2019 raises questions about ensuring security of supply, particularly during the winter months when Swiss electricity demand is already higher than domestic production. The exit will change the domestic production profile and reinforce Switzerland's net electricity trading position towards a larger share of imports.

Second, the indicative targets for the accelerated deployment of renewable energy sources of the ES 2050, in conjunction with the nuclear exit, will influence operation of the power system. Substantial investments to modernise and expand the transmission and distribution grids will be required to accommodate higher imports and variable renewables and to enable smart grid deployment.

Third, a further opening of the electricity market and the eventual electricity agreement with the European Union (see Chapter 2, "General Energy Policy") will change the institutional, financial and economic parameters that underpin electricity market organisation in Switzerland. The strongly decentralised system is costly, has lower efficiencies and is characterised by an exceptionally high degree of fragmentation compared to other IEA countries.

The government is considering options for the electricity market design post-2020. These will be reflected in the revision of the ESL, which is expected to enter into force around 2022. The key objective is to ensure security of supply through long-term system adequacy, while meeting climate goals and providing for an increase in renewable energy. The government plans to open public consultation on the draft ESL in autumn 2018 and to start the parliamentary debate by the end of 2019.

Maintaining medium- and long-term generation and system adequacy

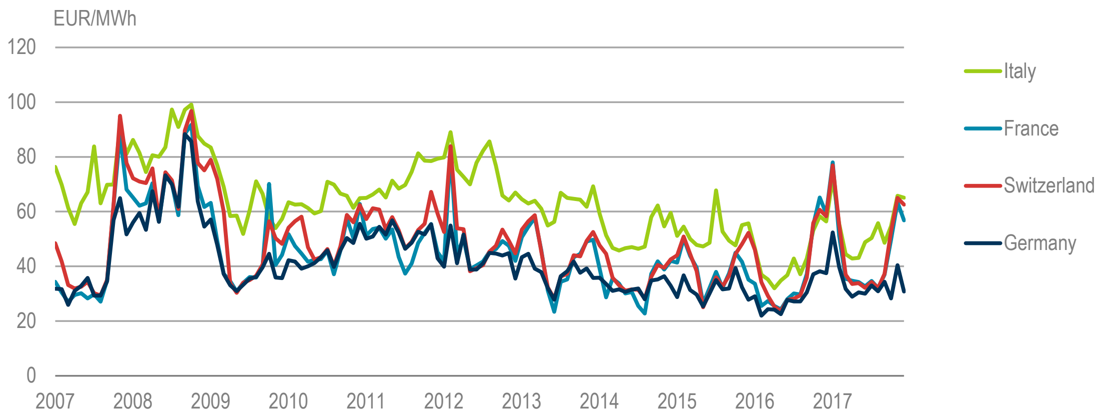
The new Energy Law of 2018 foresees a gradual exit from nuclear power as plants reach the end of their technically safe operational lifetime. Hence, there is no detailed timetable for the nuclear phase-out other than that the Mühleberg NPP will go off-grid in 2019 (by decision of its operator). Beznau-I and II reactors may close down in the 2020s due to of recurrent technical shut-downs.

Switzerland is set to lose 3.3 GW of its nuclear baseload by around the mid-2030s. This is equivalent to generation of about 14.5 TWh, or 45% of the total generation, during the winter season. Nuclear power is providing the necessary baseload during winter when demand is generally higher than in summer. The total storage capacity of Switzerland's hydro plants is 8.8 TWh, which is insufficient to make up for the loss of nuclear capacity in winter. Hence, Switzerland needs to pursue other means to fill the winter gap.

The Swiss government looks to the expansion of hydro and other renewable power sources as the main option for securing supply. The ES 2050 sets indicative targets for additional generation from large hydropower plants (37.4 TWh by 2035, maintaining the 2016 level) and variable renewables (4.4 TWh by 2020 and 11.4 TWh by 2035). Addition of gas-fired generation remains an option, but is uncertain in light of current wholesale market prices in Europe (see Figure 5.13).

Security of supply in Switzerland is a function of the interaction between domestic production and cross-border electricity flows. Changes to the electricity landscape in Europe, and especially the low wholesale market prices, have raised issues about the economic and financial viability of investments in existing and new generation capacities in Switzerland.

Figure 5.13 Spot market prices in Switzerland and neighbouring countries, 2007-17



Source: Epexspot (2018), "Market data", www.epexspot.com/en/market-data.

Addressing hydro plants short-term financial viability issues

Wholesale prices in the European market have weakened since 2008. This is due to several factors such as low fuel prices and the strong expansion of variable renewable production, which has affected the merit order and also created overcapacity because of reduced electricity demand. The weakening of the EUR against the CHF from 2011 onwards has increased the attractiveness of electricity imports for the specific case of Switzerland. However, this trend started to reverse in mid-2017, as the CHF weakened against the EUR.

Low wholesale prices particularly affect hydro production. The average production costs for hydro are in the range 3.7 to 6.9 Swiss cents per kWh. They are lower for run-of-river power plants and higher for storage or pumped storage plants. The costs include a weighted average cost of capital (WACC) of 5%. As the average Swiss wholesale price was 4.1 Swiss cents per kWh in 2016, some producers experienced an economically challenging situation.

However, overall Swiss hydro generation is not loss making. Around half the hydro production is sold to captive customers at cost-covering tariffs. Several hydro plants selling exclusively to the wholesale market were profitable in 2016. Flexible hydropower plants do not just earn the wholesale price, but can profit from their flexibility to optimise against market signals and produce during peak price times (and also sell ancillary services to the TSO).

The new Energy Law includes two instruments to ameliorate the financial situation of large hydro plants. These are both financed through the surcharge on the grid tariff (see Chapter 9, “Renewable Energy”). The first instrument is investment aid given for the construction of new hydro plants above 10 megawatts (MW) and investment support for capacity increases or substantial renovations of plants with a capacity between 300 kilowatts (kW) and 10 MW. A maximum of 0.1 Swiss cents per kWh of the grid surcharge is available for investment support, amounting to CHF 55-60 million per year. The instrument is limited until 2030. Pumped-storage plants and plants that have profitability above their WACC are excluded from applying for the support.

The second instrument is a market premium for large hydropower plants of more than 10 MW capacity, if they have to sell their power at prices below their production cost. Large hydro plants that sell into the captive market cannot apply for the premium. The grid surcharge for this instrument is limited to 0.2 Swiss cents per kWh, amounting to CHF 110-120 million per year. However, the premium payment cannot exceed 1 Swiss cent per kWh per loss-making power sales. The first call for applications for the market premium closed on 31 May 2018, with 25 requests filed, amounting to CHF 128 million. The Energy Law sees the market premium as a short-term relief measure limited to five years (i.e. up to the end of 2022).

However, the financial problems of large hydro producers are not only due to the low wholesale prices. Two additional aspects are affecting their profitability. Hydro producers have to pay a fee for the use of water, the so-called water royalties (see Box 5.2). The validity of the current water royalty, which fixes the maximum water royalty at the federal level, ends in 2019.

The government is working on finding a more flexible system to set the maximum level of the water royalties. It is also working on balancing the interests of the cantons that are receiving the royalties and the cantons that own, at least partially, the hydropower plants paying the water royalty.

Box 5.2 Water royalties

Hydro producers have to pay for the use of waters in the cantons and municipalities in which they are operating. These water royalties date back to 1918, and total revenues currently amount to approximately CHF 550 million annually. Water royalties are an important income for cantons and municipalities, contributing 20-25% of total annual revenues in some cantons and even up to 40% in some communes.

Hydro producers also have to undertake other compensation measures including maintenance of road infrastructure or delivering electricity at concessional tariffs, depending on each concession agreement. The concession for hydro projects typically runs for 80 years.

A 2008 law sets the maximum limit for the water royalties at CHF 110 per average kW gross capacity. The average gross capacity differs with local terrain characteristics and annual water flows. Hence, it is not fixed but calculated annually for each installation. The actual electricity production of the hydro installation is not taken into consideration because the calculation is based on gross capacity. Cantons and municipalities are free to set a rate lower than the legal maximum, but most apply the maximum amount.

The value of the water royalties has increased seven times since their introduction 100 years ago, and it has been de-coupled from actual inflation. The 2008 law provided for a two-step increase in the maximum water royalty value: from CHF 80 to CHF 100 in 2010 and to CHF 110 in 2015, which is still valid. The water royalty value accounts for about 1.2-1.6 Swiss cents per kWh, around one-third to one-sixth of the total hydro production costs.

When the 2008 law was approved, the Swiss power market had not yet been partially opened, and hydro producers could pass on the water royalties to consumers. However, large consumers can now source their electricity from other generators or from abroad, due to the partial opening of the power market. The sharp decline of electricity wholesale prices in Europe, and consequently also in Switzerland, has compounded the problem for those large hydro producers that no longer have a captive market.

The validity of the current water royalties ends in 2019. The government is working on finding a solution that balances the financial needs of the cantons and municipalities with the objectives of the ES 2050, which includes an increase of hydropower and a new electricity market design, including possible full market opening.

The Swiss government started a consultation process in 2017 to lower the water royalty rate to CHF 80 per kW, the same level as in 2008, for the years 2020-22 as an interim step towards a fundamental reform. Beyond 2022, the government proposed changing the way the water royalties are calculated and link them to developments of wholesale market prices. One option could be to have a guaranteed minimum rate and a variable rate adjusted to electricity prices.

The draft revision of the Water Use Law was introduced to parliament in May 2018. Parliament decided to maintain the royalty at its current level while extending the interim period to end-2024 to link the fundamental reform of the water royalty to the new electricity market design.

Source: IEA based on information provided by the SFOE and SFOE (2018a), *Rentabilität der schweizer Wasserkraft.*

Hydro producers are expected to pay large dividends to their shareholders, sometimes the same municipalities and cantons that charge the water royalties. The dividend payments reduce the amount of internal funding available for maintenance and investment. This potentially reduces the financial viability of hydropower plants in the longer term, although it does not affect operational revenues.

The IEA supports alternative ideas proposed by the government that would align water royalties more closely to the market value of the resource and to reduce market distortions through full market opening.

Assessing system adequacy

Several studies have assessed Switzerland's the generation and system adequacy for various time frames. In its Electricity Supply Security Report 2016 ElCom concludes that Switzerland's generation capacity remains adequate until 2020, with a winter capacity reserve of 500 MW (ElCom, 2016). The ENTSO E mid-term adequacy forecast (MAF) for 2020 25 came to the same conclusion. However, for the year 2025, the 2016 MAF observed a possible slight generation adequacy problem contrary to Swissgrid's expectations in its strategic network planning to 2025. The reason for this discrepancy was due to different models for hydro-optimisation and forced outages of thermal plants. However, it is important to note that the 2016 MAF was a generation adequacy forecast and not a network analysis.

Elcom consequently commissioned a System Adequacy 2025 Study (Elcom, 2018) that confirmed system adequacy to 2025 under the most likely scenarios while under two more severe scenarios (accelerated nuclear exit in Switzerland and accelerated exit from coal in neighbouring countries) a certain risk for supply interruptions exists but with a low probability. However, under all scenarios Switzerland will increasing rely on imports with the anticipated gradual nuclear phase-out.

To assess the prospects of longer-term security of supply, the SFOE initiated a study towards 2035, based on the parameters set by the ES 2050 (SFOE, 2017). The study specifically considers possible developments in the EU electricity market. The system adequacy study ran 26 scenarios, each of which considered nine different weather conditions, as those that influence electricity demand and supply in Switzerland and neighbouring countries.

The scenarios were derived by combining different electricity demand and supply options based on those modelled for the ES 2050. The EU reference scenarios of 2016 formed the basis to model demand and supply scenarios for Switzerland's neighbours, several of which have announced changes to their generation mix in the coming decades that would affect the availability of exports.

Germany would phase out nuclear power by 2025, while the phase-out in France would proceed more slowly, with a marginal reduction by 2035. Italy would significantly reduce thermal capacity to 2035. Renewable electricity would compensate for the phase-out of large central generation plants in the three countries.

Additional scenarios assumed a faster energy transformation in neighbouring countries by 2035, meaning a substantially higher share of variable renewables. Several extreme scenarios assumed massive unscheduled loss of generation capacities in all countries, combined with extreme weather phenomena. The most-extreme scenario postulated early retirement of 15 GW of conventional capacity with no replacement in France and Germany. This would be in addition to the retirement already contained in the EU reference scenarios, early retirement of all Swiss NPPs and low hydro availability. This would imply a loss of 4 GW of reservoir hydro and 1 GW of pumped storage.

Even under this extreme scenario, Switzerland would not face any loss of load (LOL) until 2025. The reduced domestic generation capacity in Switzerland would induce occasional negative reserve capacity margin values in winter, which could be compensated for by imports. Significant LOL may occur from 2025, if compensation by imports is inadequate. Extreme scenarios such as those modelled are unlikely to occur. However, if they did occur, they would constitute a shift in market fundamentals and would incentivise investment in new capacity. The question then remains of whether this new capacity will come on line in time.

The key findings of the study include:

- the security of electricity supply is guaranteed to 2035
- Switzerland does not have a capacity issue in the near future, because capacity amounts to about 20 GW while peak demand is about 10 GW; the seasonal energy shortage in winter can be covered through imports and by market mechanisms, which would offer price signals in the energy market only
- integration with neighbouring markets is indispensable for ensuring Switzerland's supply security; self-sufficiency is not a meaningful criterion to measure security of supply
- in the accelerated renewable scenario, Switzerland would not suffer any LOL until 2025, almost no LOL by 2030 and moderate LOL beyond 2030 (estimated at around 15 hours annually).

The system adequacy report showed that the possible LOL is linked to insufficient transmission capacities including at the local level. This highlights the importance of ensuring that the grid is strengthened at high-voltage levels and also at lower-voltage levels to exclude bottlenecks. Advanced demand-side management, on top of decentralised production and storage, will also play a critical role in ensuring security of supply.

Incentivising longer-term investment in capacity

The government has analysed measures to incentivise longer-term investment in new capacities, as part of the preparation work for market design post-2020. These included quota systems, tenders, off-take obligations, capacity auctions and strategic storage reserves for hydro plants. Industry has suggested possible measures including contracts for differences, and linking supply and climate-market objectives. The government concluded at the end of 2016 that these measures are not required and that most measures would either not be suited to the small size of the Swiss electricity market, or might possibly infringe on competition rules under the World Trade Organization.

The findings of the system adequacy assessment issued by the SFOE in November 2017 (SFOE, 2017) did not support the introduction of a capacity mechanism, but showed that Switzerland can rely on the energy-only market. The government plans to optimise the energy-only market, as part of the revision of the ESL. It plans to improve price signals for balancing and flexibility products, including for end users, through the introduction of smart meters and advanced demand-side management.

The government is also exploring the design of a possible mechanism for a storage reserve for energy, to supplement the energy-only market in extreme situations. Such a mechanism would be technology neutral and aim to minimise the impact on the energy-only market and the financial burden for end consumers.

Configuring the electricity grid for changes in the supply mix

The growth of variable renewables, the emergence of prosumers and the use of smart technology will shape the electricity sector in the future. A key enabler for these trends is the transmission and distribution grid, which is of central importance for the electricity supply system and which requires a holistic system management approach through an increased interplay between the TSO and DSOs.

The government has developed a comprehensive Electricity Grid Strategy as part of the ES 2050 (SFOE, 2018b). The strategy introduces new legal framework conditions for grid development by amending the Electricity Law and the ESL. Its aim is to optimise and streamline grid modernisation and expansion in a timely manner to guarantee supply security. The Swiss parliament approved the law proposal on 15 December 2017, and the amendments to the legislation are expected to come into force in the fourth quarter of 2019.

The four key aspects of the strategy are:

- criteria for the planning of electricity grids – grid optimisation precedes grid reinforcement, which precedes grid expansion
- optimisation of permitting and licensing procedures for transmission line projects to reduce the permitting process from the current 5-13 years to 4-8 years
- regulations for deciding whether to use cabling or overhead lines
- increased acceptance of transmission line projects through enhanced public consultation and information.

Development of a comprehensive grid strategy had become urgent, independent from the ES 2050, due to existing system bottlenecks and slow progress with grid modernisation and expansion. However, the ES 2050 is now actively promoting a decentralised energy supply structure that requires intelligent solutions at the low, medium and high-voltage levels.

The ensuing decentralised generation also offers flexibility options for demand-side management. DSOs are aiming to integrate growing decentralised PV production at mid-day. Moreover, the prosumer model introduced by the ES 2050 now incentivises homeowners to store excess electricity in stationary batteries.

The ES 2050 also strengthens the prosumer model by enabling trade among neighbouring plots, with a single connection to the DSO. DSOs are also obliged to accept and remunerate prosumer electricity, but are not obliged to remunerate guarantees of origin generated by prosumers (see Chapter 9, “Renewable Energy”).

The ES 2050 includes framework conditions for the roll-out of smart meters. By the end of 2027, 80% of all metering points (production and consumption) must be equipped with smart meters. The remaining 20% will be replaced at the end of their technical lifetime. The costs for this are estimated at CHF 1.3 billion. DSOs could install intelligent digital network control systems with user consent as of 1 January 2018. This shift to digitalisation requires the development of a strategy for data management.

Full market opening

The Swiss electricity market is only partially opened for end users with an annual consumption above 100 MWh. The second phase of market opening for all consumers was originally planned to become effective in 2015, but stakeholder consultations at the time showed a lack of political support. The partial market opening generates a severe distortion among producers and consumers. It excludes some consumers from the right to freely choose a supplier. But it also leads to two classes of generating companies: those with access to captive customers and those without. These distortions are a hindrance to efficient functioning of the Swiss electricity market.

The ES 2050 fundamentally changes the electricity market situation in Switzerland. Further market opening is now more urgent, with increasing import dependency in the medium term. The system adequacy assessment showed that Switzerland should be able to rely on the energy-only market and will not need to introduce capacity mechanisms.

However, the functioning of the energy-only market could be improved by the introduction of full market opening, which provides incentives to end customers for more flexible demand through price and tariff signals. Market opening is likely to give way to innovation and new business models, based on experiences in other countries. This holds especially for renewables, and would therefore promote the objectives under the ES 2050. The government plans to integrate full market opening into the revision of the ESL for the electricity market design post-2020.

Switzerland's large number of DSOs does not facilitate investment in smart grid platforms and innovation in service delivery. Moreover, the distribution segment is not yet unbundled. The operational and legal framework for the DSOs will need clarification within the revision of the ESL, to allow for the expansion of decentralised power generation.

ElCom will play a critical role in supporting the functioning of the new electricity market structure. Its responsibilities and authorities need to evolve with changes in the market framework. ElCom's rulings are frequently contested by market players. Courts have assumed an unintended role in interpreting electricity market regulation, and sometimes issue rulings that are counter to the original purpose. ElCom has therefore frequently sought recourse in parliament and suggested the introduction of legal amendments. This indicates that ElCom is not sufficiently equipped to properly execute its role as the market regulator and offer consistency and predictability to market players.

The further opening of the electricity market is a key requirement to advancing negotiations on an electricity agreement with the European Union and to proceed with full market coupling. Switzerland's pumped and storage hydro capacity has been acting as a storage battery for its neighbouring European countries and has contributed to the integration of a larger share of variable renewables throughout Europe. Hence, the European Union would benefit as much from the fast conclusion of the electricity agreement as Switzerland (see Chapter 2, "General Energy Policy", Box 2.1).

Assessment

Switzerland's electricity generation has a low carbon intensity owing to its large share of hydro and nuclear. Together, these accounted for 91% of generation in 2017. Electricity imports and exports show an explicit seasonal pattern, with most of the imports taking placing during winter when hydro reservoirs are running low and demand peaks. The net export balance has been dwindling over recent years.

The Swiss government developed the new ES 2050 with security of supply at the centre of its energy policy. The Federal Parliament approved legislation to implement the ES 2050 after thorough consultation and parliamentary debate. Following a referendum in May 2017, the new Energy Law entered into force on 1 January 2018.

The ES 2050 prohibits construction of new NPPs and allows existing ones to continue production for as long as they can safely do so. The first closure of an NPP is scheduled for 2019, and two more plants are expected to go off-grid in the mid-2020s. Switzerland expects to lose 3.3 gigawatt hours of nuclear baseload by the mid-2030s. This will increase the gap between winter peak demand and domestic production, and result in an increase of electricity imports, primarily during winter.

The ES 2050 places an emphasis on energy efficiency, expansion of hydropower, new renewable energy and possible electricity imports. However, it does not contemplate full market opening. The strategy considers using combined-cycle gas turbine plants for peak supply and co-generation[1] plants for baseload in winter. However, a recent Swiss system adequacy study indicated that security of electricity supply is guaranteed in the medium to long term, without requiring recourse to market interventions such as capacity mechanisms. Eventually, the energy-only market could be complemented by a storage reserve to specifically address the problem of availability of energy at the end of winter (when storage levels in hydropower plants run low).

The share of nuclear in power generation declined from 42% in 2007 to 34% in 2017 due to revision work that continued for longer than planned. Hydropower has been affected by low European wholesale prices since 2008, according to some industry players.

Market reform

Prices for eligible customers have become significantly lower than prices for captive customers since the partial opening of the market in 2008. Low wholesale prices create an opportunity to open the electricity market to all consumers, as retail consumers are subject to local monopolies and pay high prices. However, the government does not expect a large amount of switching following full market opening because captive customers appear to be not very price sensitive. The primary goals of market reform are to abolish distortions in the energy-only market and to promote introduction of innovative products.

The structure, ownership profile and diversity in scale of the Swiss electricity sector is remarkable. It poses some interesting questions for energy regulation in general, and for the Swiss energy regulator, ElCom, in particular.

[1] *Co-generation* refers to the combined production of heat and power.

There are around 650 DSOs in the electricity market. The scale of their sales ranges from 100 MWh for the smallest to over 10 TWh for the largest players. Most of the utilities are partially or wholly owned by the public sector, notably by the cantons (65%) and the municipalities (28%). This may result in a level of political participation through ownership not widely seen in other IEA countries.

Three large-scale undertakings represented over 50 TWh or 75% of generation in Switzerland in 2016, according to business reports. These large utilities are mainly owned by the cantons and municipalities. They own many of the large NPPs and hydropower plants, while also actively trading on international energy markets. Their generation assets are under financial pressure due to low European wholesale electricity prices. This led these companies to question the government's positive adequacy assessment, and they called for a variety of market interventions to further support hydro. They have also called for full opening of the electricity market and free choice of suppliers for all final customers.

Many of the DSOs also operate as suppliers and are not unbundled. DSOs are owned by the cantons and municipalities, and they sell to customers, many of whom have no choice of supplier. This structure has contributed to a variety of prices in the market, which change according to the location of the customer.

ElCom operates under the ESL of 2008. This law established ElCom as the regulator of the electricity market and gave the task of supervising partial opening of the electricity market to ElCom. This has been a positive development, and ElCom acts independently of the Federal Administration. With the changes brought by the ES 2050, ElCom needs a clearer legal basis to ensure it can properly execute its role as the market regulator and enforce decisions with respect to network tariff and energy price regulation. This would address the successive challenges to regulatory decisions in the courts that have occurred in recent years, for example, in the case of challenges to transmission and system services tariffs between 2013 and 2017.

Full market opening should be considered, along with providing the regulator with the necessary statutory powers to affect and supervise an open market, while also having the necessary powers to protect customers and ensure competition. This may be under consideration as part of the revision of the ESL, which the government is preparing for public debate as of autumn 2018.

System adequacy

System adequacy has been increasingly debated, because nuclear power is being phased out in the future. This has led to discussions on capacity mechanisms in Switzerland – the same discussions that are already being conducted in neighbouring countries. Switzerland is an important transit country, and capacity issues cannot be analysed in isolation of the situation in neighbouring countries.

Reaching self-sufficiency in all situations would probably be an expensive option. Solving the adequacy issue together with neighbouring countries seems a much cheaper and more effective solution, given the high level of interconnections. Switzerland's flexible hydropower resources usually do not have a problem covering its peak load, but there is an issue of availability of water in spring before the snow melts in the mountains. This adequacy issue can be addressed with targeted measures such as a strategic reserve, which do not induce high costs to the system. This has been demonstrated in New Zealand for instance.

Another reason for Switzerland to actively co-operate on system adequacy issues with neighbouring countries is that Switzerland's generation capacity could be gaining access to the capacity mechanisms of neighbouring countries. Hydro resources with quick reaction times are valuable for most existing and proposed capacity mechanisms abroad. The European Union is pursuing a policy to allow cross-border participation in capacity mechanisms.

Data management and transparency

Digitalisation is an important tool for helping to achieve energy policy goals by allowing efficient use of resources. The cornerstone of digitalisation is smart metering and smart control of grids. Switzerland is not at the front line of introducing smart meters, but has now decided to roll them out to 80% of end consumers within the coming decade. This allows learning from early experiences and profiting from best practices in this area.

It is important to have a clear framework for the rollout of smart meters in such a way that the interoperability of different equipment is guaranteed. Switzerland also needs to consider developing a data strategy that can support future market development, including the data needed for better system operation, market transparency and business development.

Interconnection

Although Switzerland is not a member of the European Union, it is geographically at the centre of Europe, which makes the country a main electricity transit and exchange point. Switzerland is already highly interconnected with European member states, with about 40 cross-border transmission lines totalling about 9 GW available capacity (about 21 GW physical capacity). This compares with a peak Swiss demand of up to 10.5 GW.

Commercial cross-border flows have not increased, but the physical flows have become more volatile, mainly due to increased variable renewable production in neighbouring countries. Loop flows have increased in Switzerland. The country lacks access to a tool to minimise the potential impact of loop flows, as it is not part of the flow-based optimisation algorithm used by EU countries.

Electricity imports are becoming increasingly vital for energy security in Switzerland, because nuclear power is set to be phased out. Integration with European energy markets is an important objective of the Swiss government. This will require a new design for the electricity market.

Recommendations

The government of Switzerland should:

- ☐ Continue with revision of the ESL, to implement full market opening and progressively allow all customer categories to choose their electricity supplier. Implement DSO unbundling and legislate for non-discriminatory third-party access for suppliers to distribution networks.

- Provide the electricity regulator with the necessary statutory powers to give effect to full market opening. Ensure the regulatory framework provides for network efficiency, including the regulation of network tariffs, market monitoring and consumer protection, ensuring customers benefit from competitive prices.
- Co-operate actively with neighbouring countries on system adequacy issues. When addressing reliability issues, especially during winter months, all market measures should be exhausted before considering targeted capacity mechanisms.
- Develop a clear and transparent framework for data exchange among TSOs, DSOs, generators, energy suppliers and potential third parties. This is to facilitate improved systems management, new products and services (e.g. demand response) while ensuring consumer protection and system security.
- Facilitate strengthening of the transmission grid in Switzerland to support network security and to provide this in an efficient and timely manner.

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6. Nuclear

Key data

(2017 provisional)

Number of reactors: five reactors at four sites

Installed capacity: 3.3 GW

Electricity generation: 20.4 TWh, -27.0% since 2007

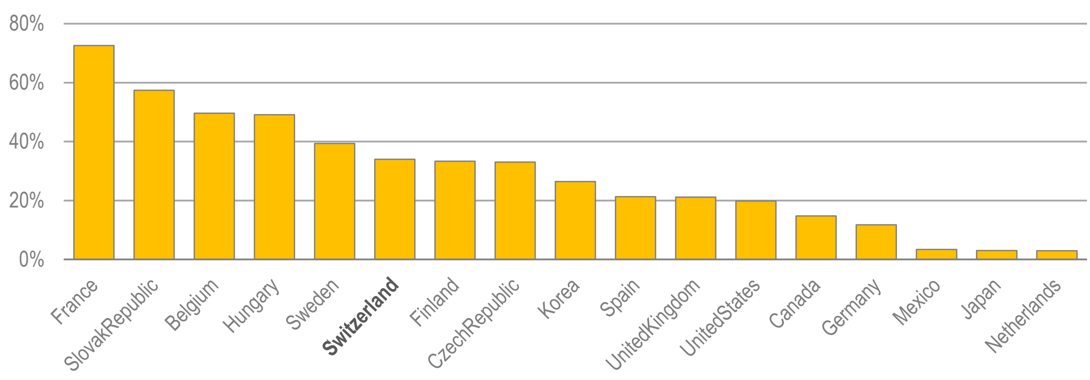
Share of nuclear: 34.0% of electricity generation, 22.2% of TPES, 46.8% of domestic energy production.

Overview

Nuclear power has provided a high and stable share of Switzerland's energy supply since the 1980s, accounting for 22% of the total primary energy supply in 2017. Nuclear accounted for 16% of the installed capacity in 2016 and generated 34% of total electricity in 2017, which was the sixth highest among International Energy Agency (IEA) member countries (see Figure 6.1).

However, the Energy Strategy 2050 (ES 2050), which came into force on 1 January 2018, prohibits the construction of new nuclear power plants (NPPs). Existing NPPs are allowed to continue operation until their technical lifetime comes to an end, and are subject to regular safety reviews. Therefore, the nuclear fleet will be closed down eventually, and will not be replaced by new reactors as previously intended. The first reactor closure is planned for 2019 due to commercial reasons.

Figure 6.1 Share of nuclear in electricity generation in IEA member countries, 2017



Notes: Charts includes only the countries with nuclear power. Data are provisional.

Source: IEA (2018), *World Energy Balances 2018* (database), www.iea.org/statistics/.

The ES 2050 envisions replacement of existing nuclear capacity by renewable sources of energy. The Swiss Federal Office of Energy (SFOE) has evaluated scenarios for how this can be achieved. However, such replacement capacity may not be in place in time for the nuclear phase-out, under current conditions and policy instruments. The government is aware that the electricity import balance is likely to increase during a transition period (see Chapter 2, "General Energy Policy", and Chapter 5, "Electricity").

Nuclear reactors

Switzerland has five operating nuclear reactors (see Table 6.1). The first two were pressurised water reactors (PWRs), built at the Beznau power plant in the north of the country, commissioned in 1969 and 1971. A boiling water reactor (BWR) was introduced at Mühleberg power plant in 1971. These were followed by a PWR at Gösgen in 1979 and a BWR at Leibstadt in 1984, both significantly larger than the previous reactors. The original total installed capacity was 2.9 gigawatts (GW), but all Swiss NPPs have had power uprates, increasing the net capacity to 3.3 GW.

The Beznau and Gösgen plants supply district heating to surrounding areas, in addition to electricity. Beznau has a 130 kilometre distribution network serving 11 nearby towns, and a capacity of approximately 80 megawatts (MW) to offset 12 000 tonnes of fuel oil consumption per year.

Nuclear fuel is imported as there is no domestic uranium mining in Switzerland. However, nuclear plants typically store one to two years' worth of fuel on site. Fuel costs comprise less than 30% of the annual operating costs and 10-15% of the total cost of generation. Fuel supply sources are diversified, greatly reducing supply disruption risks. Swiss NPPs consume 250-350 tonnes of uranium per year.

Table 6.1 Nuclear power reactors in Switzerland, 2017

Reactor	Type	Year commissioned	Net capacity (MW)	Electricity generation in 2017 (terawatt hours)
Beznau-1	PWR	1969	365	0
Beznau-2	PWR	1971	365	2.81
Gösgen	PWR	1979	1 010	8.15
Leibstadt	BWR	1984	1 220	5.62
Mühleberg	BWR	1971	373	3.00
Total			**3 333**	**19.59**

Note: Data on total electricity generation from nuclear power differ slightly from IEA data.

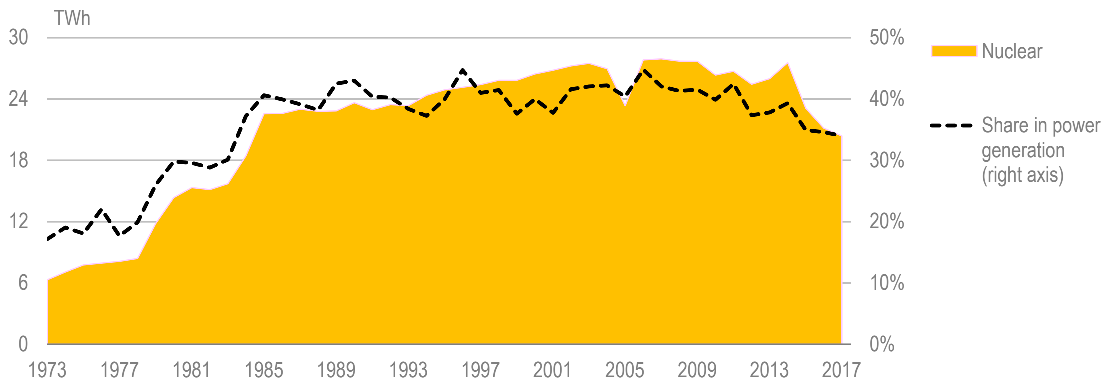
Sources: IAEA (2018), *Power Reactor Information System* (database), www.iaea.org/PRIS/home.aspx; WNA (2017), *Nuclear Power in Switzerland*, www.world-nuclear.org/information-library/country-profiles/countries-o-s/switzerland.aspx.

Electricity generation

Annual production has been around 25 terawatt hours (TWh) since the fifth reactor became operational in 1984, with the highest production of 27.9 TWh reached in 2007 (see Figure 6.2). Production dropped to 20.4 TWh in 2017, as a result of prolonged plant outages. Nuclear power accounted for approximately 40% of the total electricity generation from 1985 until 2014, but the share has recently been below 35%.

Nuclear power is a key component of Switzerland's high share of carbon-free electricity generation. Moreover, nuclear power has proven to be a reliable supplier of electricity during winter months when demand peaks and hydro resources are limited due to low water levels at the end of the period. The average lifetime capacity factor is more than 85%.

Figure 6.2 Nuclear power supply and its share in power generation, 1973-2017

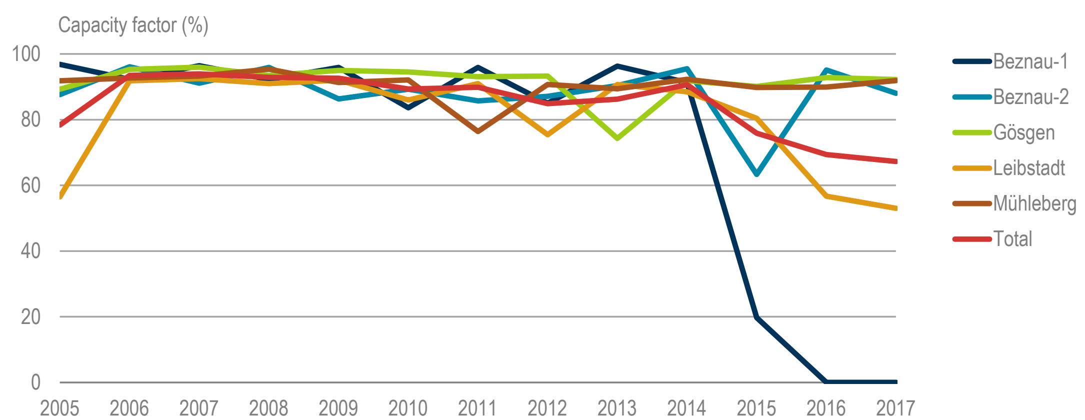


Note: Data are provisional for 2017.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

All Swiss reactors underwent tests and evaluation without significant service disruptions shortly after the nuclear accident at Japan's Fukushima Daiichi NPP in March 2011. These were carried out in co-operation with European Union (EU) stress tests conducted by the European Nuclear Safety Regulators Group. The plants were evaluated favourably on their ability to withstand natural hazards and "off-normal" events.

Figure 6.3 Annual capacity factors for Swiss nuclear reactors, 2005-17



Source: IAEA (2018), *Power Reactor Information System* (database), www.iaea.org/PRIS/home.aspx.

Unrelated issues with quality assurance and control of certain components have significantly affected operations recently. The Beznau-1 reactor was off line from March 2015 through to March 2018 while the operator worked with the regulator to demonstrate that material flaw indications identified in the reactor pressure vessel would not affect the ability to operate safely. The regulator approved restart of the reactor in March 2018.

Beznau-2 had a planned outage in 2015 that was extended due to questions about the carbon content in its steam generators. A planned outage at the Leibstadt reactor in 2016 was also extended due to higher-than-expected oxidation of some fuel cladding tubes.

After extensive reviews, the regulator determined that the issues did not affect the safety of the plant, and all five of the Swiss reactors were again operational as of March 2018. The effects of these perturbations on the capacity factors are evident in Figure 6.3, taking the total capacity factor of the fleet from approximately 90% in 2014 to 67% in 2017.

Nuclear industry structure

Most nuclear reactors are owned by three large, utilities: Alpiq, Axpo and BKW (Table 6.2). The Beznau and Mühleberg units are owned and operated by single public utilities, whereas Gösgen and Leibstadt are owned by multiple electric utilities, still with a majority ownership by the three groups and their subsidiaries.

The partial opening of the electricity market in Switzerland has created an environment where Axpo and Alpiq sell their share of electrical output into the competitive market at a significantly lower price than other companies with captive customers (Axpo, 2017 and Alpiq, 2017); (see Chapter 5, “Electricity”, and Chapter 9, “Renewable Energy”).

Table 6.2 Ownership of Swiss nuclear power reactors, 2017

NPP	Ownership
Beznau-1	100% Axpo
Beznau-2	100% Axpo
Gösgen	40% Alpiq, 25% Axpo, 15% EWZ (utility of city of Zurich), 12.5% Centralschweizerische Kraftwerke, 7.5% Energie Wasser Bern
Leibstadt	27.4% Alpiq, 22.8% Axpo Power, 16.3% Axpo Trading, 13.6% Centralschweizerische Kraftwerke, 9.5% BKW, 5.4% AEW, 5% Alpiq Suisse SA
Mühleberg	100% BKW

Source: IEA and NEA based on information provided by the Swiss Federal Office for Energy.

Institutions

The Federal Nuclear Safety Inspectorate (ENSI) is an independent national regulatory authority responsible for the supervision of Swiss nuclear facilities (i.e. nuclear plants, interim storage facilities for radioactive waste and nuclear research facilities). Its regulatory remit covers the entire life of a facility, from initial planning, through operation to final decommissioning including the disposal of radioactive waste. The remit also covers research activities and the transportation of nuclear and radioactive materials. ENSI is supervised by an independent management board elected by the federal government, to whom it reports.

The Federal Nuclear Safety Commission is a permanent advisory body that advises the federal government, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) and ENSI on issues relating to the safety of nuclear facilities.

It comprises five to seven part-time technical specialists who provide independent advice and opinion on safety-related science and technology issues.

The National Cooperative for the Disposal of Radioactive Waste (Nagra) is a co-operative formed by nuclear reactor operators and the federal state, and is the Swiss technical competence centre in the field of deep geological disposal of radioactive waste. It is responsible for disposing of radioactive waste from industry, medicine and research. Its mission includes finding, siting, preparing and operating disposal facilities, as well as waste package qualification.

The SFOE is an office within DETEC with responsibility for energy supply and energy use. This includes federal policies on nuclear energy and responsibility for site selection procedures for deep geological repositories.

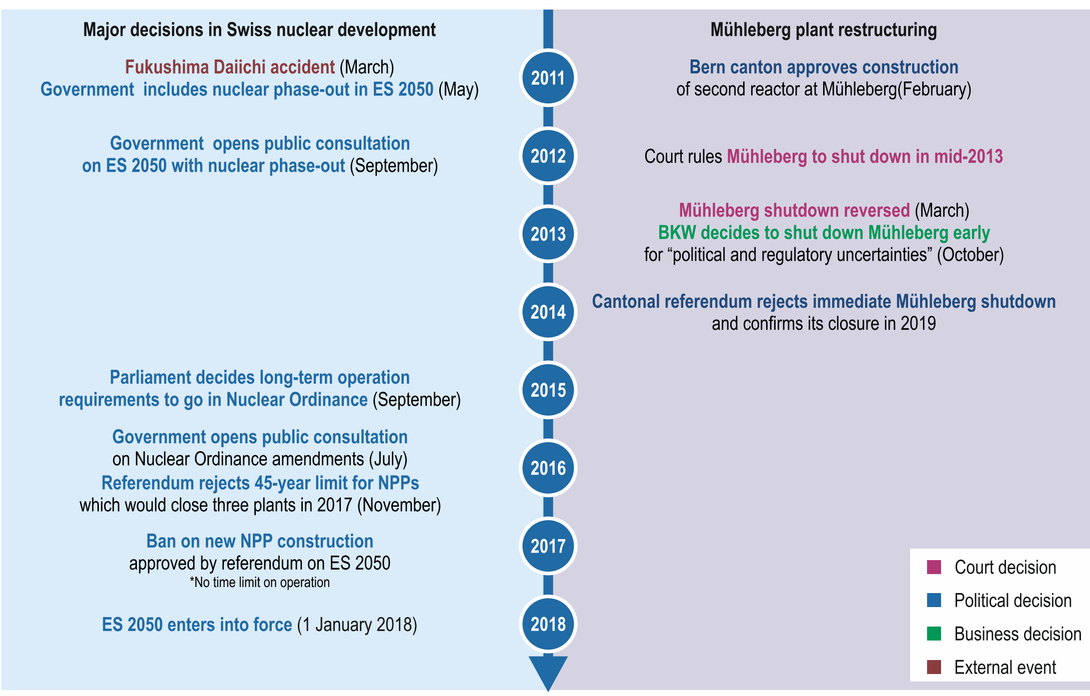
The Decommissioning Fund for Nuclear Facilities and Waste Disposal Fund for Nuclear Power Plants is the administrative management body responsible for collecting and overseeing two nuclear funds: one for the costs related to decommissioning and dismantling nuclear facilities, and one for the disposal of radioactive waste and spent fuel from nuclear reactors, medicine and research.

Policies and regulations

Nuclear power

Swiss policy on nuclear power has changed several times, particularly regarding construction of new plants and recycling of used nuclear fuel (see Figure 6.4).

Figure 6.4 Timeline of major Swiss nuclear policy events



Source: IEA based on information provided by the Swiss Federal Office for Energy.

A ten-year moratorium on building new nuclear plants and other nuclear facilities was introduced following a referendum in 1990. A new Nuclear Energy Act entered into force in 2005, and, after two public votes that rejected a proposed nuclear phase-out, new nuclear plants again became an option. The three largest Swiss utilities (Axpo, Alpiq and BKW) started projecting new plants to replace the Beznau and Mühleberg NPPs, which are expected to be decommissioned around 2020. Before the Fukushima Daiichi nuclear accident, public opinion was approximately split 50:50 over new NPPs.

Following the Fukushima Daiichi nuclear accident, the Swiss government decided not to allow the replacement of decommissioned reactors in anticipation of public opposition. By September 2011, both Chambers of Parliament had endorsed the government's decision to gradually phase out nuclear power. However, parliament voted against an outright ban of nuclear technology and mandated that Switzerland continue research into all energy sources, including nuclear. These positions are enshrined in the ES 2050.

The ES 2050 has several nuclear-specific implications, either directly in the legislation, or as amendments to the Nuclear Energy Act, or the Nuclear Ordinance. These include:

- prohibiting licences for new NPPs
- requiring existing plants to undergo a periodic safety review every ten years for long-term operation beyond 40 years
- explicitly banning the reprocessing of used nuclear fuel that had already been in effect in one form or another since 2006.

Specific safety requirements for a long-term operation concept were discussed as part of the ES 2050 debate. However, parliament did not enshrine them as an amendment to the Nuclear Energy Act. Instead, they were introduced in the amended Nuclear Ordinance, which entered into force in June 2017 (Federal Council of Switzerland, 2017). The new requirements are:

- an NPP operator has to submit proof of safety for long-term operation to ENSI, before the expiry of 40 years of operation.
- the proof of safety for long-term operation includes 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, as well as the planned backfitting, and measures intended to guarantee sufficient numbers of staff with the required expertise for the planned period of operation
- the operator may submit a renewed concept for a further ten years, before the expiry of another ten years.

Compliance with the legal requirements on nuclear safety is verified and enforced by ENSI. Operating licences are granted on a permanent basis in Switzerland. The ES 2050 and the Nuclear Ordinance do not limit the number of additional ten-year operational periods that may be granted, provided that ENSI deems it to safe to do so. If, at any time, ENSI determines that safety cannot be guaranteed, the operating licence can be withdrawn.

The circumstances surrounding the Mühleberg reactor and the BKW decision to shut it down early, even after receiving a licence to operate an additional ten years, may provide some hints of the challenges and considerations faced by Switzerland's nuclear operators. Mühleberg was the only Swiss plant with a limited-duration operating licence until 2009, when ENSI granted an unlimited-duration licence, requiring that the reactor meet the same requirements as other reactors for ten year operation periods beyond 40 years.

The Federal Administrative Court, which stayed this licence change in March 2012, ruled that the plant could operate until mid-2013. BKW appealed this ruling to the Federal Court in Lausanne and won its case in March 2013, allowing it to operate until at least 2022. However, in October 2013, BKW announced that it would instead shut down the plant in 2019, citing market conditions and uncertainty surrounding political and regulatory trends (World Nuclear News, 2013). BKW had committed investments of CHF 200 million (Swiss francs) to operate until 2019, but decided that the more significant investments to operate beyond that date carried too much risk. It is not clear whether other plant owners will view these risks and investments similarly.

European stress tests

After the Fukushima Daiichi nuclear accident, ENSI ordered Swiss operators to take part in the EU stress tests, to verify the level of safety at Swiss NPPs. The safety reassessments focused on plant design with respect to earthquakes, external flooding and a combination of both events, as well as on the coolant supply for the safety and auxiliary systems and the spent fuel pool cooling.

Some immediate measures were ordered, including setting up an external storage facility for emergency equipment, and plant-specific connections and backfitting of feed lines for the external supply of spent fuel pools. The external storage facility is a former bunkered munitions depot of the Swiss Army at Reitnau. The equipment stored here is transportable by helicopter to any location in Switzerland.

ENSI concluded that Swiss NPPs demonstrate a high level of protection against natural hazards, as well as against loss of electrical power and ultimate heat sink, based on the reviews conducted so far. ENSI and the utilities developed a list of "open points" from the reviews to increase the safety of Swiss NPPs, and they have been working to address them.

Nuclear waste

Under Swiss law, producers of radioactive waste are responsible for its safe management and disposal and have to bear the costs. Funds are collected in advance, and are held to cover the costs of managing the waste, anticipated from generation to final disposal, like in most countries. The responsibility for conditioning and interim storage of radioactive waste from NPPs remains with the NPP operators. The federal state assumes responsibility for the collection, conditioning, storage and disposal of radioactive waste generated by the use of radioisotopes in medicine, industry and research. The producers of this radioactive waste are charged a service fee.

Nuclear waste is generated as a by-product of nuclear power, as well as medical and other industrial activities, and is classified into levels or categories. These may differ among countries, according to the form or radioactivity. High-level waste in Switzerland includes used nuclear fuel after it is taken out of the reactor. It represents approximately 8% of the total volume and 99.5% of the radioactivity of all radioactive waste. Low and intermediate-level waste comprises 92% of the total waste, and can be disposed of in a different manner to high-level waste due to the lower potential risk posed. Switzerland plans to dispose of all this waste in two deep geological repositories.

Some waste is generated during the dismantling and remediation of nuclear and radiological facilities – a process referred to as "decommissioning". Mühleberg, the first light-water power reactor to undergo decommissioning, will begin the process immediately after it ceases operation and is to complete the nuclear-related work by 2031.

Nuclear energy legislation and corresponding regulations require raw waste to be minimised and conditioned as soon as possible. All radioactive waste has to undergo final disposal in repositories placed in suitable geological formations; surface and near-surface disposal is excluded. Switzerland plans to build two repositories – one for high-level waste, and one for low and intermediate-level waste.

The producers of radioactive waste (i.e. NPP operators and the federal state [for waste from medicine, industry and research]) formed Nagra, which is responsible for preparing and implementing solutions for the disposal of all radioactive waste categories. Nagra also has to assess and attest the suitability for disposal of each type of waste package to be produced. Each conditioning process needs approval by ENSI prior to its application.

All radioactive waste is stored in interim storage facilities because there are no repositories yet in operation. Each NPP has conditioning facilities and interim storage capacity for its own waste. Additional storage capacity is available in the Central Interim Storage Facility (Zwilag). Spent fuel that has been returned from reprocessing abroad is also stored at Zwilag. The radioactive waste from medicine, industry and research is conditioned and stored at the Paul Scherrer Institute.

Funding

Two funds, referred to as the Decommissioning Fund and Waste Disposal Fund (STENFO), are independent legal entities managed by a federally appointed management board. They are routinely re-evaluated to ensure that the annual contributions and investment returns will be sufficient to cover future costs. NPP operators are required to recalculate the anticipated costs every five years, overseen by STENFO. Nuclear operators in Switzerland are collectively responsible for covering the costs of waste disposal, such that, if one operator were unable to cover all of its costs, the other operators would be forced to cover any deficiencies.

A more rigorous cost-estimation method was used starting with the 2016 cost estimate (previous estimate in 2011). This replaced the best-estimate method used in the past. The 2016 estimate was reviewed by ENSI and independent experts in 2017. The projected costs were increased due to the inclusion of additional contingencies to cover risks and uncertainties, from CHF 21.8 billion to CHF 23.5 billion. Even with this increase, the provisional annual payments for 2017-21 (based on the 2016 estimate) dropped due to positive performance of the funds, modified cost calculations and a delay in the projected operation date for the repository.

However, DETEC, taking into account additional cost factors, decreed total decommissioning and waste disposal costs to be CHF 24.6 billion (CHF 3.8 billion for decommissioning and CHF 20.8 billion for waste management) in April 2018. This was CHF 1.1. billion higher than that requested by STENFO based on the 2016 estimate. The definitive costs and annual payments for 2017-21 will be determined after the entry into force (in mid-2019) of another revision of the Ordinance on the Decommissioning and Waste Funds, which will adjust some cost calculation factors. Assets in the funds totalled CHF 6.96 billion at the end of 2016.

A 2015 revision of the Ordinance on the Decommissioning and Waste Funds required an additional 30% supplement to the waste and decommissioning cost estimates to cover uncertainties in the 2011 estimate. Operators appealed this supplement, claiming that the 2016 estimate used a revised cost estimation method that took these risks and uncertainties into account.

STENFO considers the funds to be “on track”, as evidenced by the reduced annual contributions, and is closely monitoring developments and making adjustments as needed.

Site selection process

Switzerland has been executing a robust, three-stage procedure to identify and license two deep geological repositories: one for low and intermediate-level waste, and one for high-level nuclear waste (including spent nuclear fuel). The possibility of constructing a facility for all waste categories at the same site is also an option. In 2008, the rules for conducting the site selection search were developed through public consultation, and were adopted by the Federal Council.

The Federal Council agreed to the six siting regions that Nagra proposed in stage 1, at the end of 2011. Nagra narrowed the siting process in stage 2 to two geological regions (Jura Ost and Zürich Nordost), to be further investigated in stage 3. In its review, ENSI concluded that a third siting region (Nördlich Lägern) also had to be investigated in stage 3. Nagra will propose the final sites by 2022.

The site selection process is envisioned to end in 2029-31 after a general licence application is prepared, with Federal Council and Parliament approvals of the site selection and general licence. It is highly likely that this decision will be followed by a nationwide referendum. It is envisioned that waste would begin to be placed in the repositories by 2050 for the low and intermediate-level repository and by 2060 for the high-level waste repository.

The government and Nagra have made significant efforts to involve stakeholders, especially those close to potential repository locations, to educate them on what is being contemplated and to encourage them to participate in the process. Nagra, in compliance with legislation, has made it clear that safety is the foremost criteria for site selection. It has also shown willingness to work with stakeholders on other issues such as spatial planning. For example, the locations of the surface facilities, as suggested by Nagra in the sectoral plan, were adjusted through meetings and interactions with stakeholders.

Assessment

Five operating nuclear reactors account for 35-40% of Switzerland’s electricity generation. With high capacity factors, historically around 90%, these reactors have been important for Switzerland’s electricity supply, especially in winter months when low hydro reservoirs must be carefully managed and provide less flexibility than at other times of the year. The Swiss public generally seems to recognise the benefits of nuclear power, having repeatedly rejected proposals to legislatively limit operational lifetimes.

However, the government and the public have also committed to eventually phasing out Switzerland's nuclear capacity through a ban on new construction, instituted in the ES 2050 that became effective on 1 January 2018.

The first plant retirement, of the Mühleberg reactor, is envisioned for 2019. If a 50-year operating life is assumed, one-third of the nuclear capacity will be retired by the early 2020s, with the remainder retiring by 2031. Operation beyond 50 years is certainly possible; most plants in the United States have received licence extensions to 60 years, and requirements for 80 years are being finalised. However, the current planning basis in the government's energy transition analysis appears to be up to 60 years.

This creates a gap of at least 20 TWh per year to be replaced with other generation technologies, assuming stable electricity demand. Non-hydropower renewable generation was 4.6 TWh in 2017. While electricity generation in Switzerland is almost entirely carbon free, the phase-out of nuclear plants will require consideration of all options including possibly new fossil fuel capacity, such as combined-cycle gas turbine technology. This would require additional emissions reductions in other sectors to compensate for possible higher fossil fuel power generation if Switzerland wants to achieve its climate targets.

A combination of high fixed operational costs, low European wholesale electricity prices and a partially opened electricity market in Switzerland appear to be straining the profitability of the country's nuclear power fleet, and also its hydropower plants. Axpo and Alpiq highlighted their diversified portfolio in recent shareholder communications, noting that positive performance outside Switzerland has been important in offsetting financial losses from nuclear and hydropower operations.

Policy changes and other uncertainties significantly affect issues beyond just operational and decommissioning plans for the nuclear fleet. They also affect the ability to attract a qualified workforce – engineers, scientists, operators, etc. With Switzerland's plan for continued operation of nuclear reactors until at least 2030 and waste management activities that stretch for decades beyond that, it will be important to attract, train and retain qualified technical personnel.

Switzerland's STENFO is well managed to ensure that funds are collected to cover future costs of decommissioning and disposing of all waste.

The efforts of the SFOE and Nagra to involve stakeholders throughout the entire process of developing waste disposal options have been significant. They are often cited among industry best practices, and Switzerland should be congratulated for this. However, it is a long process as currently defined and continued progress through decisions and implementation will be the real measure of success. So far, Switzerland has taken measures to ensure that it can manage a solvable technical issue.

Nuclear power can be a controversial topic, particularly in Europe where several countries made decisions to phase out, speed up their phasing out or abandon plans for new plants. However, NPPs in Switzerland are a valued part of its extremely low-carbon electricity mix and can remain so if plant operators continue to demonstrate safe operation. Additional renewable capacity may not be brought on line in time to fully replace the phasing out of nuclear plants after some 50 years of operation.

It will be necessary to give clear policy signals on whether nuclear operators should plan to continue operating beyond 50 years, because of the investments and lead times required to refurbish nuclear plants and receive approval to operate for additional ten-year periods. Therefore, it is important to have open, candid discussion with the public and other stakeholders about the options available and the means for developing other sources in realistic time frames.

Recommendations

The government of Switzerland should:

- Continue its strong efforts to engage stakeholders on waste repository selection and siting activities, to ensure public confidence in the process and eventual licence applications.
- Continue to invest in nuclear research and education to maintain a qualified workforce and technology solutions for the continued safe operation of the nuclear fleet, design and construction of the deep geological repositories, and the safe regulation of both of these.
- Continue robust monitoring of decommissioning and waste disposal costs and accruing of the Decommissioning and Waste Disposal Funds.

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7. Energy and climate

Key data

(2016)

GHG emissions without LULUCF*: 48.2 $MtCO_2$-eq, -9.4% since 1990

GHG emissions with LULUCF*: 46.3 $MtCO_2$-eq, -11.7% since 1990

CO_2 emissions from fuel combustion: 37.9 $MtCO_2$, -6.9% since 1990

CO_2 emissions by fuel: coal 1.3%, oil 70.2%, natural gas 18.7%, other 9.9%

CO_2 emissions by sector: transport 42.3%, residential 23.1%, industry 13.8%, commercial 12.7%, power and heat generation 7.2%, other energy industries 1.0%

CO_2 (energy-related) intensity per GDP: 83 gCO_2/USD GDP PPP (IEA average 237)

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

*Land use, land-use change and forestry. Source UNFCCC (2018), *Switzerland NIR 2018*, https://unfccc.int/documents/65678.

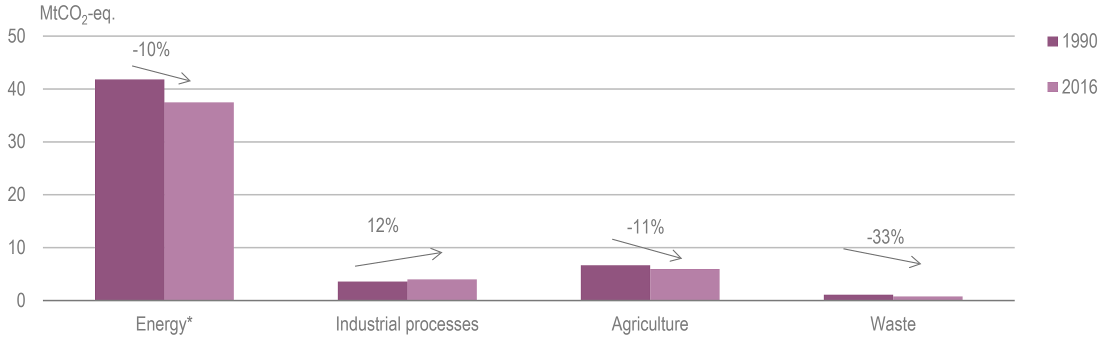
Overview

Switzerland has legislated short- and medium-term climate targets agreed to under the Kyoto Protocol and also its nationally determined contributions (NDCs) under the Paris Agreement. It is committed to reducing its greenhouse gas (GHG) emissions by 20% by 2020 and by 50% by 2030, below the 1990 base year level. Switzerland has also set indicative targets for the period to 2050 in line with its commitment to gradually shift away from fossil fuels and contribute to maintaining the increase in global temperature to well below 2°C.

In 2016, Switzerland emitted 48 million tonnes of carbon dioxide equivalent ($MtCO_2$-eq), excluding emissions and abatements of GHGs from land use, land-use change and forestry. Energy-related emissions, including from the transport sector, accounted for 78% of the total GHG emissions, followed by agriculture (12%), industrial process (8%) and waste (2%). Between 1990 and 2016, energy-related emissions declined by 10% (see Figure 7.1). Switzerland's carbon intensity is the lowest among International Energy Agency (IEA) member countries.

Switzerland has implemented extensive policy measures. However, more-stringent measures are required to ensure that the country stays on track to achieve its targets towards 2020 and the medium to long-term targets under the NDCs and the Energy Strategy 2050 (ES 2050), especially in the transport sector.

Figure 7.1 GHG emissions by sector, 1990 and 2016



* Energy related emissions include emissions from combustion processes in transport, industry and buildings.

Source: UNFCCC (2018), *Switzerland NIR 2018*, https://unfccc.int/documents/65678.

Energy-related CO_2 emissions

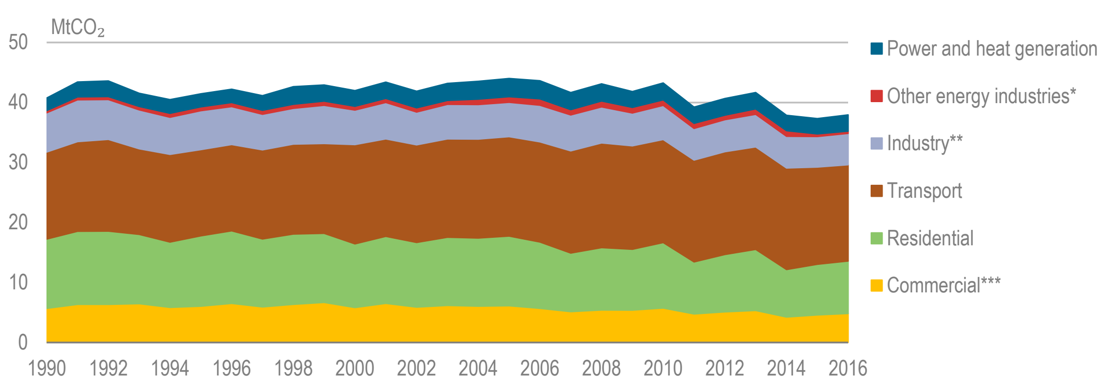
In 2016, the energy sector was responsible for 78% of the total GHG emissions, of which CO_2 accounted for 99% of energy-related emissions. The following sections specifically look at energy-related CO_2 emissions.

Emissions by sector and fuel

In 2016, the total fuel combustion from different sectors resulted in 37.9 million tonnes (Mt) of energy-related CO_2 emissions, a reduction of 7% from 1990 and 14% from 2005.

The largest energy-related CO_2 emitting sector is transport, with 42.3% of the total share in 2016; road transport accounted for 98.3% of the entire transport emissions, mainly due to combustion of diesel and gasoline. Other emitting sectors are residential (23.1%), industry (13.8%), commercial (12.7%), power and heat generation (7.2%) and other energy industries (1%) (see Figure 7.2).

Figure 7.2 Energy-related CO_2 emissions by sector, 1990-2016



* *Other energy industries* includes emissions from blast furnaces, oil refineries, coke oven, oil and gas extraction, and coal mines.

** *Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

*** *Commercial* includes commercial and public services, agriculture/forestry and fishing.

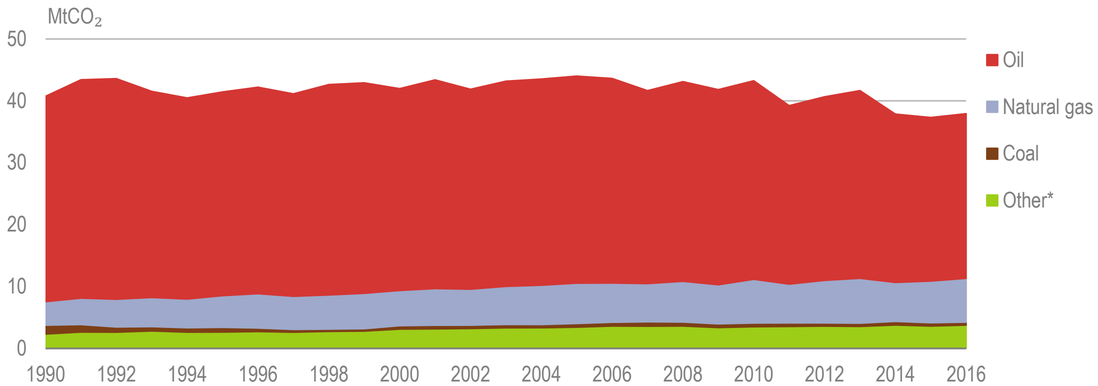
Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

All sectors have shown decreasing trends in the past decade, although rates have varied. From 2006 to 2016, significant reductions came from the commercial (15.1%) and residential (20.9%) sectors, followed by industry (14.3%), other energy industries (64.7%), transport (3.9%), and power and heat generation (10.1%).

However, when looking at the period 1990-2016, the sectoral variance was higher. The commercial sector showed a decrease of 15.1%, the residential sector a decrease of 24.3% and the industry sector a decrease of 20.0%. The power and heat generation sector showed a 29.6% increase, the transport sector a 10.6% increase and the other energy industries sector a 0.6% increase.

Oil is the predominant source of energy-related CO_2 emissions, in terms of fuels. It was responsible for 70.2% of the total share in 2016, followed by natural gas (18.7%), others (9.9%) and coal (1.3%) (see Figure 7.3). Oil combustion is mostly used for road transport and natural gas combustion in the residential sector. Coal is only used in the cement industry, which is actively exploring other, low-carbon feedstock options. Small shares of coal are also used in the residential sector for heating, but account for a miniscule share.

Figure 7.3 Energy-related CO_2 emissions by fuel, 1990-2016



* *Other* includes emissions from non-renewable waste combustion.

Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Emissions drivers and carbon intensity

Total CO_2 emissions in a country are related to size of the population, economic development, energy intensity of the economy and carbon intensity of the energy supply:

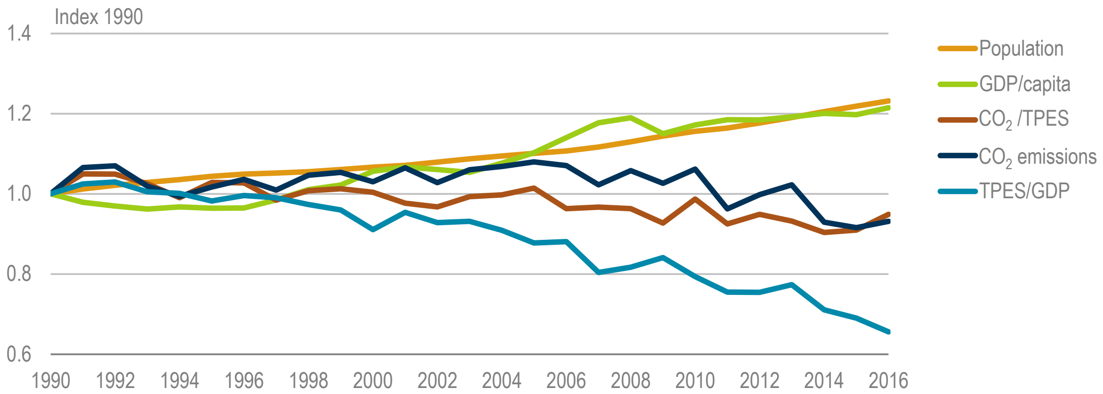
$$CO_2 = \text{population} \times \text{GDP/capita} \times \text{TPES/GDP} \times CO_2\text{/TPES},$$

where GDP is the gross domestic product and TPES is the total primary energy supply.

Since 1990, Switzerland has demonstrated a clear decoupling between economic growth and CO_2 emissions (see Figure 7.4). The energy intensity of the Swiss economy has declined considerably; by 34% between 1990 and 2016. In the same period, the carbon intensity of energy supply was reduced by 5%, from an already low level. Such achievement is particularly remarkable considering the country's significant population growth over the same period (see Chapter 2, "General Energy Policy").

In 2016, the country's carbon intensity was 0.08 CO_2 per GDP PPP (kilogrammes of CO_2 per 2010 United States dollar) the lowest among the 30 IEA member countries (see Figure 7.5). There are two major reasons for Switzerland's low-carbon intensity. The first is the country's low-carbon TPES, supported by 26% of renewable sources of energy (renewable energy), with 13% hydro and 23% nuclear. The second is an economy dominated by the service sector, with about a quarter share of GDP from industry where the manufacturing sector and energy-intensive process industries play a miniscule role.

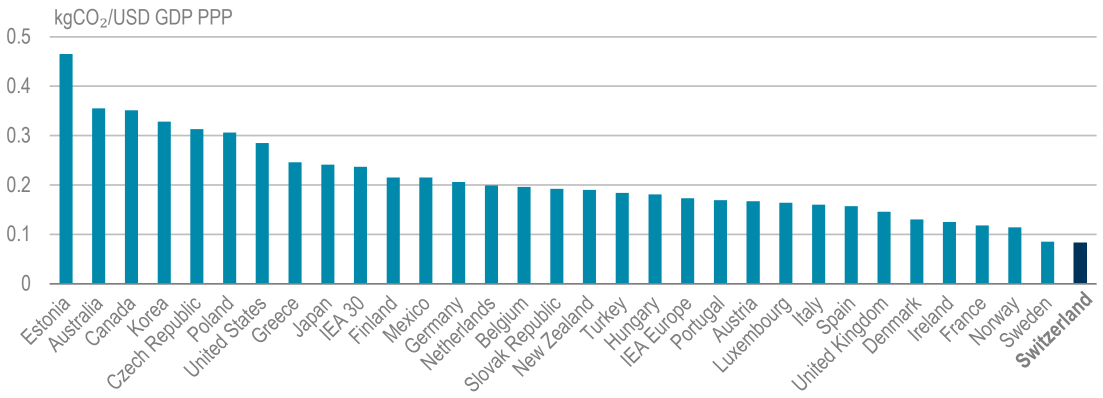
Figure 7.4 Energy-related CO_2 emissions and main drivers, 1990-2016



Notes: Real GDP in 2010 United States dollar prices and purchasing power parity (PPP). CO_2 emission data for 2017 are estimated.

Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Figure 7.5 Energy-related CO_2 emissions per unit of GDP in IEA member countries, 2016



Note: IEA Europe = average of European IEA member countries; IEA 30 = average of all IEA member countries.

Source: IEA (2018), *CO_2 Emissions from Fuel Combustion 2018*, www.iea.org/statistics/.

Institutions, policies and targets

Switzerland's comprehensive climate policies and measures are centred around its law on the reduction of CO_2 (CO_2 Law). Switzerland committed to reducing its total GHG emissions by 20% by 2020 compared to the 1990 base year level, under the Kyoto Protocol. The CO_2 Law is the main policy instrument for implementation of this target.

Institutions

The Federal Office for the Environment (FOEN), under the Department of the Environment, Transport, Energy and Communications, is responsible for environmental and climate policy at the federal level, thereby ensuring the consistency of climate and environmental policy. Other government offices involved are those for energy, transport, agriculture, economic affairs, foreign affairs, development and co-operation. Cantons play an important role in practical implementation, and are also involved in decision making through non-binding consultations on proposed laws, ordinances and strategies. The FOEN also consults extensively with civil society and academia.

CO_2 Law for the period 2008-12

First enacted on 1 May 2000, the CO_2 Law set a target to reduce total CO_2 emissions from heating and transport by 10% below the 1990 level for 2008-12, with a 15% reduction of heating and process fuels emissions and an 8% reduction of transport emissions. This is equivalent to the 8% reduction target set for the Kyoto Protocol's first commitment period 2008-12. The use of foreign offset certificates was permitted. Switzerland met its Kyoto Protocol target, but not all sector sub-targets. Transport sector emissions were 10% above the 1990 level in 2012, while the emissions reduction target for the building sector exceeded its sub-target with a 16% reduction.

Targets were originally to be met by voluntary measures, but the law included a provision to introduce a CO_2 tax on stationary fuels (including oil, gas and coal), if the interim targets for emissions reduction were not met. The CO_2 levy is an incentive tax on stationary fossil combustible fuels, such as heating oil, natural gas and coal. Making fossil fuels more expensive creates an incentive to use them more economically and choose more carbon-neutral or low-carbon energy sources. Transport fuels are excluded. An evaluation showed that the voluntary measures were not obtaining expected results, and the CO_2 levy came into effect on 1 January 2008.

CO_2 Law of 2013 towards 2020

A revised CO_2 Law entered into force on 1 January 2013 and covers the period up to 2020, equivalent to the second commitment period under the Kyoto Protocol. Switzerland is committed to reducing total GHG emissions by 15.8% on average over the period 2013-20 compared to 1990 (corresponding to a 20% decrease by 2020). The scope of the new law was broadened. It now includes all GHG emissions and carbon sinks from forestry and harvested wood products, not just energy-related CO_2 emissions as under the earlier law. It also introduced different measures for heating and transport fuels. The law prescribed that all reduction targets had to be met through domestic measures alone. However, under the Kyoto Protocol flexibility mechanism, the difference between reductions in the first and second commitment periods can also be balanced through the purchase of foreign offset credits.

Measures and instruments to 2020

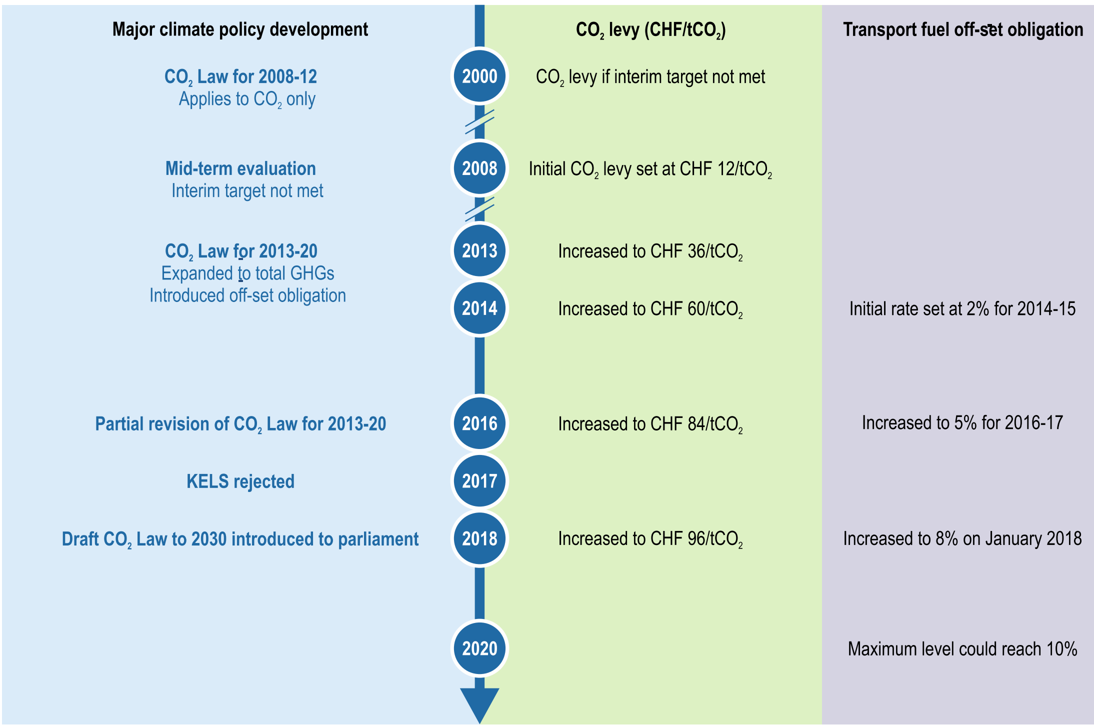
The revised CO_2 Law of 2013 maintained most of the measures of the earlier law but modified them. It also introduced additional measures based on experiences under the first law (see Figure 7.7). A partial change to the CO_2 Law of 2013 was made in 2016, which entered into force on 1 January 2018, to strengthen several measures of the ES 2050.

CO_2 levy on heating and process fuels

The law stipulates an automatic increase of the levy if CO_2 emissions reductions lag behind the target trajectory. The interim targets are calculated on the basis of CO_2 emissions adjusted for weather conditions (outside temperature and solar irradiation), because these have a strong influence on the number of heating days and heating temperature in Switzerland. The CO_2 levy has been increased in four steps from its initial level of CHF 12 (Swiss francs) per tonne of carbon dioxide (tCO_2) in 2008; to CHF 96/tCO_2 on 1 January 2018 because emissions did not meet the interim targets (see Figure 7.6).

The maximum level the CO_2 levy could reach by 2020 was set at CHF 120/tCO_2. However, in light of progress made towards meeting the interim emissions reduction targets, this level will not be reached by 2020 when the 2013 law ends.

Figure 7.6 Climate policy and measures to 2020



Source: IEA based on information provided by the Swiss Federal Office for Energy.

CO_2 levy exemption

GHG-intensive companies are exempt from the CO_2 levy under certain conditions. High emitters are obliged to take part in the Swiss emissions trading system (ETS); low and medium emitters can apply for an exemption by entering into legally binding emissions reduction commitments (target agreements) with the government (non-ETS). The CO_2 levy applies to 51% of stationary emissions, while 33% are under the Swiss ETS (see below) and 16% fall under companies with target agreements.

Small and medium-sized enterprises (SMEs) that are not under the Swiss ETS but are large carbon producers and exposed to international competitiveness can enter into binding and verifiable agreements with the government to lower their emissions. The sectors that are eligible for these target agreements are listed in Annex 7 of the CO_2 Ordinance and include mainly processing industries. They are exempt from the CO_2 levy if they meet their targets, but they have to pay a penalty of CHF 125/tCO_2 if they do not meet their targets.

There are different possibilities for each of the eligible companies to define their mandatory targets under the agreements. Independently from the measures chosen, companies commit to reducing their GHG emissions without interruption by 2020. A final assessment at the end of the commitment period will show if the targets are met. This gives companies some flexibility to smooth out annual production fluctuations. Monitoring and auditing are the joint responsibilities of the FOEN and the Swiss Federal Office of Energy.

Companies that are medium emitters may also opt into the Swiss ETS. However, only 3 of the 54 participants in the ETS were such companies. Companies that participate in the ETS are also exempt from the CO_2 levy. Companies with target agreements had reduced their annual emissions by 400 000 tCO_2 by the end of 2016 (see Chapter 8, "Energy Efficiency").

Companies operating in industries that are not listed in Annex 7 of the ordinance, primarily service companies, have the option to undertake voluntary emissions reduction measures for which they gain certificates, if they exceed their reduction targets. This also applies to companies that are exempt from the CO_2 tax and which overachieve their target agreements. These certificates can be sold, for example, to fuel importers under the compensation programme (see below "Offset obligation on transport fuels").

With the implementation of the Energy Strategy 2050 (ES 2050) on 1 January 2018, the eligibility criteria in the CO_2 Law for exemption have widened. Operators of co-generation[1] plants based on fossil fuels may be partly exempt from the CO_2 levy on fossil fuels that they use for electricity production. This rule applies to plants that are not in the ETS and that have a rated thermal input of 0.5-20 megawatts. Fossil fuel co-generation has not been considered a suitable supply or energy efficiency option, as the Swiss electricity supply is almost carbon free. However, with the need to replace nuclear capacity, co-generation is now eligible for the levy exemption.

The CO_2 levy is therefore a key policy instrument for emissions reductions in Switzerland, directly by making fossil fuels more expensive and also by persuading users to take corrective actions in anticipation of further increases. One-third of the proceeds from the CO_2 levy are re-injected into measures to reduce emissions and enhance energy efficiency through the building refurbishment programme.

Building refurbishment programme

The building refurbishment programme was launched in 2010 as a joint initiative between the federal government and the cantons (see Box 7.1). The programme finances investments in upgrading the building envelope, renewable heat supply and building systems. Funding for the programme comes from the CO_2 levy (federal level) and co-financing from the cantons. It has disbursed over CHF 1.3 billion in total subsidies from 2010 to 2016, which have resulted in savings of 21.5 million tonnes of carbon dioxide (MtCO_2) over the supported projects' lifetime (Das Gebäudeprogramm, 2016).

With the entry into force of the ES 2050 on 1 January 2018, the upper limit of the designated cap was raised to CHF 450 million annually, in line with the increase in the CO_2 levy because the interim emissions targets were not met, and the co-financing

[1] *Co-generation* refers to the combined production of heat and power.

mechanism has been optimised. Moreover, CHF 25 million is allocated annually to a technology fund. The ES 2050 also extended the programme from its original expiration date of end of 2019 to 2025.

Box 7.1 Impact assessment of the building refurbishment programme

The building refurbishment programme comprises two parts: Part A: Building envelope, and Part B: Switch to renewable heating systems. The target was to save 1.5-2.2 $MtCO_2$ annually of building sector emissions from 2010 to 2020.

An evaluation of the first five years of the programme (2010-14) made the following findings:

Direct impacts of the programme by 2014

- evaluated at 0.6 $MtCO_2$ annually
- the efficiency of the programme, measured in CHF per tonne of reduced CO_2, was better than expected at CHF 65 on average
- Part A of the programme was more successful than Part B, which met half the expected annual reductions (due to several reasons including insufficient counterpart funding by cantons).

Secondary (indirect) impacts of the programme

- a positive impact on employment and positive contribution to the economy
- induced changes to technology solutions in the building sector; for example, triple-glazed windows have become the norm
- a partly negative impact in the rental market as rent increases following investments are not fully recovered by tenants through lower energy costs.

The evaluation concluded that the mix of Swiss CO_2 policies and changes in the market has created sufficient momentum for investments. The move to market-based measures as proposed by the government under the Climate and Energy Fiscal Steering System (KELS) should replace existing subsidies. Consequently, the building refurbishment programme could be phased out after 2025. The evaluation made suggestions of how to modify the programme to increase its efficiency and reach. These have been reflected in the partial revision of the CO_2 Law in 2016 (in force since 2018) as part of the ES 2050.

Source: Bundesrat (2016): *Wirksamkeit der Finanzhilfen zur Verminderung der CO_2-Emissionen bei Gebäuden gemäss Artikel 34 CO_2-Gesetz*, Bern.

Swiss ETS

The Swiss ETS was introduced in 2008. It covers 54 emission-intensive companies and 5 $MtCO_2$-eq, or around 11% of total Swiss CO_2 emissions, for the second commitment period from 2013 to 2020. The Swiss ETS is the smallest globally in terms of coverage and trading volumes.

Swiss ETS participants are carbon-intensive and frequently also electricity-intensive companies. They can therefore be exempt from the grid surcharge (see Chapter 8, “Energy Efficiency”)” if they enter into target agreements with the government to enhance their energy efficiency. These target agreements usually include measures that contribute to a reduction of stationary fuel use and consequently also of emissions. Of the 54 companies covered under the ETS, 18 had signed target agreements for grid surcharge exemption by 2015.

An evaluation of the Swiss ETS for the years 2013-15 concluded that the ETS has not functioned well. The high number of emission allowances allocated free of charge, and consequently the low emission allowance prices during the period under review, did not create sufficient reduction incentives for ETS participants.

The problems were compounded by the suspension of operations at the Collombey refinery in 2015, the country's third-largest emitter, which made additional emission allowances available. Unexpected production fluctuations can have a severe impact on the efficacy of small ETS markets such as the Swiss one. The 2015 auction price of certificates was equivalent to 10% of the CO_2 levy (see Table 7.1).

Table 7.1 Swiss ETS auction prices, 2014-17

Date	Price (CHF)
March 2018	8.00
November 2017	7.50
March 2017	6.50
November 2016	7.15
March 2016	9.00
November 2015	11.00
March 2015	12.00
November 2014	20.00
May 2014	40.25

Source: IEA based on information provided by the Swiss Federal Office for Energy.

This situation was exacerbated by the eligibility of foreign emission certificates. Even if no additional emission allowances were to be auctioned after 2015, the number already allocated is sufficient for requirements up to 2020. Hence, the Swiss ETS did not set the expected incentives for its participants to reduce CO_2 levels.

Against this backdrop and in recognition that most of the Swiss ETS companies are exposed to international competition, Switzerland explored options to link its ETS with the European Union Emissions Trading System (EU-ETS). Switzerland and the European Union signed an agreement on 23 November 2017 to link their ETSs, starting in 2020. This is the first agreement linking the EU-ETS with a third party. The link will allow participants in the Swiss ETS to use allowances from the EU-ETS and vice versa. Many elements of the Swiss ETS were already designed to match provisions of the EU-ETS in anticipation of an eventual link. The Swiss parliament needs to adopt the agreement so that it can be ratified and enter into force in 2020.

Offset obligation on transport fuels

Transport fuels are not covered by the CO_2 levy. The 2013 law introduced an offset obligation for motor fuel importers to compensate for an increasing share of emissions from transport fuel use. The obligation is only applicable to those transport fuels, which are also subject to the mineral oil tax. However, emissions from the exempted share are miniscule.

The introduction of the offset obligation has been a key driver for the off-take of biofuels in Switzerland, although they still account for a tiny share of total consumption (see Chapter 3, “Oil”, and Chapter 9, “Renewable Energy”). Most biofuels are imported, including all bioethanol. This is due to strict sustainability criteria, the so-called “Swiss finish”, which extends far beyond the comparable obligation for European Union (EU) countries. Only biofuels from waste biomass are exempt from the mineral oil tax of about 75 Swiss cents per litre. However, the government aims to change this strict requirement as part of its post-2020 climate policy. This would allow advanced biofuels to enter the Swiss market under the same conditions as stipulated by the EU Renewable Energy Directive.

The share of emissions to be compensated is increased every two years. Initially set at 2% for 2014-15, it increased to 5% for 2016-17 and to 8% on 1 January 2018. The maximum level will reach 10% by 2020. This corresponds to a reduction of 6.5 $MtCO_2$ over the period 2013-19, financed with approximately CHF 1 billion by a surcharge on transport fuels levied by the mineral oil industry (see Chapter 3 “Oil”).

The Swiss Oil Association created the KliK Foundation, and mandated it with securing certificates from domestic compensation projects and programmes. By the end of 2017, 5.7 $MtCO_2$ of reductions had been credited to KliK by the government. Abatement costs averaged CHF 79/tCO_2 until 2017. The average certificate price in 2017 was CHF 99/tCO_2. KliK expects to secure another 5.4 $MtCO_2$ by 2019 (Klik Foundation (2017). For the year 2020, when only certificates of the same year may be accounted for, the reduction of around 1.5 $MtCO_2$ may be difficult to attain, and KliK is preparing to pay a fine of about CHF 64 million.

All offset obligations have to be met with domestic measures, excluding the purchase of international emission certificates. The competition for suitable domestic offset projects is large. The scope of eligible compensation projects is limited by the CO_2 Ordinance, which excludes, for example, the use of nuclear energy, sinks from forests and marshland, and fuel switching to other fossil energies. Hence, there is a risk that future compensation projects will have higher abatement costs and result in lower CO_2 reductions.

The offset obligation replaced a voluntary initiative by the Swiss Oil Association, the Climate Cent Foundation, which operated from 2005 to 2012. At the beginning of 2013, the Climate Cent Foundation still had CHF 150 million in undisbursed funds. These will be invested until the end of 2020 in climate protection measures abroad. The foundation expects to fund the reduction of more than 20 $MtCO_2$ in the period 2013-20, thereby offsetting over 5% of Swiss GHG emissions over that period. The foundation committed to handing over all resulting certificates to the government at no charge.

In addition to the offset obligation, Switzerland pursues a long-standing transport policy to shift traffic, especially freight, from road to rail, which it considers an indirect climate policy. Switzerland has made substantial investment in this through a dedicated fund, which is financed by two-thirds of the receipts of the distance-related heavy-vehicle fee (HVF) and receipts from the mineral oil tax (see Chapter 8, “Energy Efficiency”).

This dedicated fund was transformed into the Rail Infrastructure Fund in 2016. Its funding will continue to be derived from the HVF, the mineral oil tax and other means as necessary, including contributions from the federal and cantonal budgets.

Focus area II: Climate policy post-2020

Paris Agreement and Switzerland's NDCs

Switzerland ratified the Paris Agreement on 6 October 2017, which officially entered into force on 5 November 2017 in Switzerland. Under this agreement, Switzerland commits to halve emissions by 2030 against its 1990 baseline level (NDCs). The Paris Agreement sets out that emissions reduction targets should be met primarily through domestic measures, but it includes the possibility for achieving emissions reductions abroad with the use of market mechanisms.

ES 2050

The first phase of the ES 2050 was originally intended to consist of two parts. The first package, focusing on policies and measures to enhance energy efficiency and stimulate growth of renewable energy, entered into force on 1 January 2018 (see Chapter 2, "General Energy Policy", Chapter 8, "Energy Efficiency", and Chapter 9, "Renewable Energy").

The second package, KELS, was supposed to implement the change from subsidies to pricing signals from around 2025, to promote energy efficiency and renewable energy and hence contribute to reducing emissions. The purpose of the proposed steering levy was to increase the cost of emissions and energy to influence, or steer, demand. KELS would have been levied on stationary and transport fuels (after 2030), a change from the current system to 2020, which excludes transport fuels and electricity.

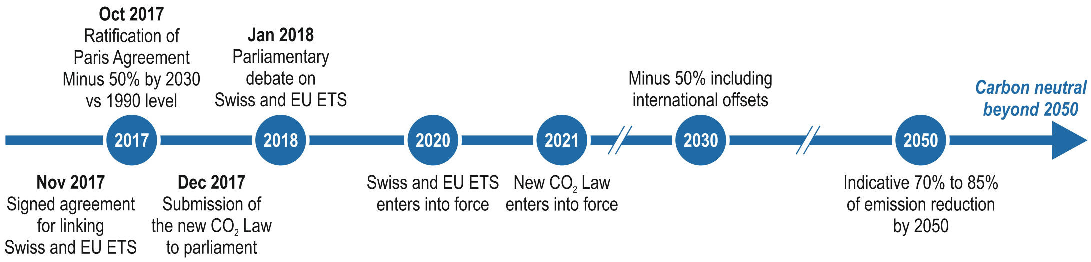
The government thus submitted a proposal for KELS to parliament in October 2015. Parliament rejected KELS in spring 2017, and the government will no longer pursue the idea of extending a steering levy beyond its current coverage. The first package of measures of the ES 2050 is not sufficient to reach the Paris Agreement targets to 2030. Neither is it sufficient to reach the indicative targets of the ES 2050 for about 1.0-1.5 tCO_2 per capita by 2050. It will provide around half of the expected CO_2 outcome. The government will now need to fill the lacuna of climate instruments due to the rejection of KELS.

New CO_2 Law post-2020

The current Swiss CO_2 Law from 2013 comes to an end in 2020. The Swiss parliament is in the process of adopting a new law for the period 2021-30. The key purpose of the new CO_2 legislation is to provide sector-specific targets and measures towards the achievement of Switzerland's NDC commitment to 2030.

The government proposed that of the total 50% emissions reductions, at least 30% are to be achieved domestically and 20% internationally against the 1990 baseline. The new law is expected to enter into force in time to ensure seamless continuation of the climate policy after 2020. It was introduced into parliament in December 2017, and discussions are ongoing (see Figure 7.7).

Figure 7.7 Switzerland's climate policy post-2020



Source: IEA based on information provided by the Swiss Federal Office for Energy.

Targets and measures under the draft CO_2 Law post-2020

The draft CO_2 Law builds on the successful measures in the current CO_2 Law, and includes provisions to strengthen them. Interim targets to facilitate monitoring of the emissions trajectory and to initiate corrective measures, if needed, are also included. The draft law covers measures for all GHG-emitting sectors. It also covers adaptation measures, because the average temperature in Switzerland is increasing twice as fast as the global average. The draft law includes provisions to develop and implement the established national adaptation strategy to promote climate resilience.

Switzerland is committed to reducing GHG emissions by 20% by 2020 against the 1990 baseline under the current CO_2 Law and its commitments under the Kyoto Protocol. To achieve its Paris Agreement commitment to reduce emissions by half by 2030 against the 1990 baseline, it needs to achieve an additional 30% reduction between 2020 and 2030. It also potentially has to make up for unmet targets to 2020. The 30% reduction is equivalent to 17.4 $MtCO_2$-eq. Existing measures will not be sufficient to reach the target, and the gap would be 7.7 $MtCO_2$. Hence, the government will need to refine existing measures and also implement additional ones (see Table 7.2).

The ES 2050 already reinforces some of these measures, and they will have an impact beyond 2020. Other measures will be developed in the draft CO_2 Law under parliamentary debate. Table 7.3 shows how the 2030 emissions reduction targets are to be achieved through additional measures.

Table 7.2 Sectoral emissions reductions, 1990 and to 2020 and 2030

Sectoral emissions ($MtCO_2$-eq)	1990	2020	2030 (business as usual)	2030 (additional policies)
Buildings	17.1	12.0	10.6	6.9
Industry	13.0	10.7	10.4	8.7
Transport	14.9	15.7	14.9	13.6
Agriculture	7.3	6.5	6.5	5.7
Others	1.4	2.2	1.6	1.4
Total	53.7	47.1	44.0	36.3
Total (%)	100	87.7	81.8	69.5

Source: Information provided by the Swiss Federal Office for Energy.

Table 7.3 Emissions reductions to 2030 from additional measures under the proposed new CO_2 Law

Measures	Emissions reduction ($MtCO_2$-eq)
Domestic emissions for 2030 reference scenario	**41.8**
Additional reductions in the building sector	**3.5**
including CO_2 levy up to a maximum of CHF 210/tCO_2	1.0
including building refurbishment programme*	1.5
including additional cantonal measures**	1.0
Additional reductions in the industry sector	**1.5**
including CO_2 levy up to a maximum of CHF 210/tCO_2	0.3
including qualifying more SMEs for reduction covenants***	0.2
including ETS	1.0
Additional reductions in the transport sector	**0.93**
including standards for passenger and light-duty vehicles	0.3
including increasing compensation obligation for fuel importers to 15-20%	0.6
Additional reductions in agriculture	**0.5**
Additional reductions in synthetic GHGs	**0.2**
Domestic emissions	**35.2** (-35% vs. 1990 level)
International offsets	8.5
Domestic emissions minus international offsets	**26.7** (-50% vs. 1990 level)

* CO_2 levy designated up to CHF 450 million in 2018, implemented with ES 2050.

**For example, if buildings emissions reductions in 2026/27 fail to reach -51% of the 1990 level, CO_2 standards can be introduced in 2029 on a subsidiary basis.

*** With levy exemptions and simplifying procedures.

Source: Bundesrat (2017), *Botschaft zur Totalrevision des CO2-Gesetzes nach 2020.*

CO_2 levy

The CO_2 levy has proven to be an effective instrument since its introduction in 2008, as shown by three methodologically different evaluations (see Box 7.2). Therefore, the CO_2 levy, and its automatic adjustment if interim targets are missed, are maintained in the draft new climate legislation. To enhance its effectiveness, the government proposes to increase the maximum rate for the levy to CHF 210/tCO_2, up from the current maximum of CHF 120/tCO_2. The allocation of the proceeds of the CO_2 levy remains as before, with one-third being allocated to the building refurbishment programme and two-thirds being reallocated to the Swiss population. The criteria for reallocation to the Swiss population on a per capita basis will be maintained. It benefits large families and families with lower incomes who pay an over-proportional part of their income for heating purposes.

Buildings

The building refurbishment programme, which is mainly funded by the CO_2 levy, will end in 2025. Extending the programme to 2030 is under consideration by parliament. Moreover, if the building sector misses its interim CO_2 reduction targets of a 50% reduction by 2027, the draft law includes a provision for the introduction of a CO_2 emissions standard for buildings.

The CO_2 emissions standards would be introduced by 2029. Existing residential and service buildings would need to meet a standard of 6 kilogrammes of carbon dioxide per square metre ($kgCO_2/m^2$), while buildings used for commercial purposes have to comply with a stricter standard of 4 $kgCO_2/m^2$. Any type of new buildings would need to meet the zero emissions standards.

Box 7.2 Impact assessment of the CO_2 levy

The CO_2 levy on stationary fuels was introduced in 2008 as a market-based instrument to influence the consumption behaviour of the industry and residential sectors. The levy increases automatically every two years if the interim CO_2 reduction targets are not met.

The CO_2 Law requires regular evaluation of the impact of the CO_2 levy. Three methodologically different evaluations were carried out and came to the same key findings as follows:

- The CO_2 levy has a marked impact in the industry and residential sectors; unsurprisingly, there is a correlation between the level of the levy and CO_2 reductions, even when differentiating short and long-term effects.
- A typical example of a short-term impact is the behaviour of households when buying heating oil, when they fill their tanks shortly before the increased CO_2 levy becomes effective. A typical example of a long-term impact is a modified investment behaviour in anticipation of future levy increases. Fossil fuel heating systems in residential buildings are typically replaced with either fuels that are less carbon intensive (e.g. natural gas) or with renewable fuels. The substitution is primarily focused on production processes in the industry sector.
- Three-quarters of effects were in the residential sector. This is partly explained by the limited avoidance strategy of the residential sector, which cannot seek exemption from the levy as is possible for industry.
- There is still sufficient potential for reductions in both sectors.
- Emission-intensive industries embarked on investments independent from their levy exemption or voluntary agreements; instead, they resulted from a systematic analysis of emissions reduction and energy efficiency potential, frequently due to announcements and public discussions of the CO_2 levy.
- Small enterprises need a higher levy before embarking on investments. However, many undertook energy efficiency diagnostics of their production processes to be prepared for increases. The willingness to invest increased over time, in all industry segments.

However, the most important finding of the three evaluations was that the impact of the CO_2 levy exceeded that of the building refurbishment programme and of the target agreements with industry.

Source: Bundesrat (2016), Wirksamkeit der Finanzhilfen zur Verminderung der CO2-Emissionen bei Gebäuden gemäss Artikel 34 CO_2-Gesetz, Bern.

Industry

Industry meets emissions reduction targets either by participating in the Swiss ETS or by signing binding target agreements with the government. Both measures will be modified by the new CO_2 Law, to increase emissions reduction incentives for industry.

The cap in the Swiss ETS will be reduced annually by 2.2% between 2021 and 2030. The level in 2021 is 4.91 $MtCO_2$-eq. Moreover, the expected link of the Swiss ETS and the EU-ETS by 2020 will expand to cover emissions from the aviation sector, which are not part of the Swiss ETS.

The option to be exempt from the CO_2 levy by signing binding target agreements with the government will be broadened to include all industries that pay more than CHF 15 000 for the CO_2 levy. Only carbon-intensive companies, as defined by the current CO_2 Law, are entitled for a levy exemption until 2020. Industry will be obliged to meet the targets through in-house measures only.

Transport

The offset obligation for emissions from transport fuels will be kept, but the maximum share that needs to be compensated is set at 90%. Some 15% of CO_2 emissions from transport will need compensation with domestic measures, and 75% can be compensated for internationally. However, a minimum of 5% of transport emissions have to be compensated through renewable fuels and can be counted towards meeting the domestic offset obligation share. The international compensation measures related to the offset obligation will likely account for the largest share of the 20% international emissions reductions to 2030.

Assessment

Switzerland has demonstrated a clear decoupling between economic growth and CO_2 emissions since 1990, with a 10% reduction in its carbon intensity. It has the lowest carbon intensity among IEA countries. Making progress against such a low-carbon baseline is challenging, yet the country has committed to short- and medium-term climate targets and has even set indicative targets towards 2050, marking the ratification of the Paris Agreement.

The CO_2 Law (2013) sets a 2020 target to reduce GHG emissions by 20% below the 1990 level, in line with Switzerland's commitments under the Kyoto Protocol. Switzerland's NDCs commit the country to a 35% reduction by 2025 and 50% reduction by 2030 of GHG emissions below the 1990 level. At least 30% reduction is to be achieved domestically and 20% internationally for the 2030 target. The first phase of the ES 2050 includes ambitious indicative long-term climate goals of reducing CO_2 emissions by 70-85% by 2050, or 1.0-1.5 tCO_2 per capita, from 5.8 tCO_2 per capita in 2015. The government expects population growth to continue to 2050.

Switzerland's GHG emissions declined from 53.7 $MtCO_2$-eq in 1990 to 48.3 $MtCO_2$-eq in 2016, but progress is mixed across sectors. Reductions in building and industry sectors outperformed intermediate sectoral guideline targets of a 22% reduction in building-related emissions and a 7% reduction in industrial and waste disposal sectors in 2015. Hence, emissions in these two sectors have the potential to reach their sector-specific 2020 targets. In contrast, emissions in the transport sector increased by 4% in 2015 compared to an interim target of maintaining the 1990 level.

Reaching the 2020 and 2030 targets

The reduction of 5.4 $MtCO_2$-eq from 1990 to 2016 implies that the country has to reduce emissions by another 5.3 $MtCO_2$-eq in the remaining years to 2020 in order to reach the 20% reduction target of 10.7 $MtCO_2$-eq. Therefore, Switzerland is unlikely to meet its 2020 climate target by domestic emissions reductions alone since it would require a rate of decarbonisation twice as fast as that of the past decade. Achieving the 2020 target is possible only if emissions evolve along the lower end of the range of Switzerland's projections. Moreover, the CO_2 Law, in line with the Kyoto Protocol, allows sinks from forests and wood products to be taken into account.

Moving beyond the 2020 targets to the 50% emissions reduction target by 2030 will be even more challenging. It would imply an additional 16.1 $MtCO_2$-eq of emissions reduction compared to 2020. It is evident that this is possible only with a mixture of domestic and foreign offsets.

Policies and measures

Switzerland needs to outline its strategy and plans for additional measures, to put the country on a pathway to achieving its medium and long-term targets. The first phase of the ES 2050 has implemented a package of measures promoting greater energy efficiency and renewables with effect from 1 January 2018. But the phasing out of nuclear energy, as mandated under the ES 2050, presents new challenges to maintaining the low-carbon intensity in the electricity sector.

KELS was rejected by parliament in 2017. KELS was building on the positive impact of the CO_2 levy and planned to be extended to the transport and electricity sectors. Therefore, the revised CO_2 Law for the years 2012-30 needs to include additional measures. The draft CO_2 Law was introduced to parliament in early January 2018 for parliamentary debate. Approval of the CO_2 Law is critical for ensuring continuity and certainty on Switzerland's medium-term climate policy.

Transport is Switzerland's largest emitting and energy-consuming sector, accounting for 15.29 Mt or 42% of the total energy-related CO_2 emissions in 2016. Transport emissions are decreasing slowly after their peak in 2008. Switzerland missed its 2015 sectoral guideline target, such that the 10% reduction by 2020 is also highly unlikely to be attained.

Federal-level transport policies include CO_2 emissions standards for passenger vehicles and an offset programme, both of which are facing challenges. Emissions standards that required average new passenger cars to reach 130 gCO_2/km by 2015 were not met. This reflects a trend towards sport utility vehicles in Switzerland. It also questions if the fines levied on importers for missing the target are having the desired impact. Standards have been tightened under the ES 2050 to align with EU regulations, reducing the emissions standard to 95 gCO_2/km by 2021. However, based on experiences so far, it is difficult to judge if these will put transport sector emissions on a more sustainable path.

Transport fuel importers have been required to offset transport sector emissions with domestic measures since 2013. The share was 5% in 2016-17 and will increase to 10% by 2020. To date, 28% of domestic offsets have come from abatement opportunities from other sectors, and around half is from biofuels. The offset obligation has stimulated the biofuel sector in Switzerland. This sector has seen strong growth rates, and has substantial additional potential to be exploited. But strict sustainability criteria prevent an even faster off-take of biofuels. Hence, the aim to bring the sustainability criteria in line with EU guidelines should have a positive impact on the growth of biofuels by making them more affordable.

Requirements that only certificates of the same year can be counted will make the 2020 offset reduction of 10% (approximately 1.5 Mt) challenging, and it is unlikely to be achieved. Proposals under the revised CO_2 Law are also considering allowing the use of international credits post-2020, with a minimum 15% domestic requirement. If domestic transport emissions do not decline, and given challenges in other sectors (such as agriculture), it would not be possible to achieve the 2030 target.

Electric vehicles (EVs) are slowly gaining popularity in Switzerland, and there are plans to introduce EVs other than passenger cars. Reorganisation of the electricity market under the ES 2050 and possibilities provided by digitalisation offer an opportunity for a more substantial introduction of EVs in line with climate goals. Establishing a comprehensive, cross-sectoral sustainable long-term decarbonisation strategy for transport is critical if Switzerland wants to meet its climate goals.

Building-related emissions declined to 13.8 Mt in 2016, a 23% reduction below the 1990 level. They now account for 27.3% of total emissions, largely from the use of oil for heating. While there is annual volatility caused by fluctuating winter temperatures, emissions have been on a significant downward trajectory, overachieving against interim guidelines of a 22% reduction by 2015 below the 1990 level. Responsibility for the building sector is with the cantons, which are entrusted with building regulations, increasing energy efficiency and use of renewables. Template building codes are harmonised, and with the new CO_2 Law, beyond 2020, emissions standards for existing buildings are set if cantonal regulation fails to reduce the emissions set by sectoral targets.

A key federal measure in the building sector is the CO_2 levy on heating oil and gas, to directly incentivise economic use of fuels and switching to lower carbon sources (or indirectly through exemptions for business following target agreements). Evaluation findings attributed emissions reductions of 2.5 $MtCO_2$ over the period 2008-13 to the direct incentives created by the levy. Emissions reductions in the building and industry sectors have been shown to be reactive to the CO_2 levy, and an evaluation demonstrated a clear impact on investment behaviour. However, this does not affect transport emissions for motor fuels because they are exempt from the levy.

A defining characteristic of the levy is its automatic adjustment should emissions fail to reach their target. Automatic adjustment characteristics may be useful to provide flexibility in other policy areas, and should be considered in the future. The proposed more than doubling of the maximum CO_2 levy to CHF 210/tCO_2 compared to 2018 under the draft CO_2 Law is a welcome measure.

One-third of the levy revenues are designated for the building refurbishment programme until 2025 (capped at a maximum of CHF 450 million per year), as of 2018. Together with co-financing and implementation by the cantons, this supports building refurbishment and switching to renewable heating systems. Funds have not yet been fully utilised, although the funding level is significant, and not all cantons draw on these funds. The impact of the programme has also been limited to 1% of the total buildings stock per year, which is a coverage rate that is insufficient to meet long-term decarbonisation.

Given that 60% of households are in the rented sector, financial incentives from the CO_2 levy and the refurbishment programme may not be sufficiently strong to overcome barriers to taking up measures. Greater policy intervention is likely to be required to improve uptake of building refurbishment in segments with high barriers such as the rental sector.

Switzerland's electricity production is low carbon, given its large shares of hydro and nuclear power. It is uncertain what the generation mix will be in the future, with the phase-out of nuclear, potentially creating additional challenges for meeting Switzerland's climate goal. The draft CO_2 Law to 2030 does not foresee any electricity taxation.

Power sector emissions are envisaged to be covered by the ETS once the Swiss programme is linked to the EU-ETS, expected for 2020. However, should this link-up be delayed beyond the target date, it will be necessary to examine alternatives. These could be either to modify the system to reflect the peculiarities of the small Swiss market, or to consider a different approach. Aviation emissions are excluded from the Swiss ETS, but will be covered once it is joined with the EU-ETS.

Over 80% of non-transport energy emissions are covered by a form of carbon price. This is either the CO_2 levy, where prices are projected to increase substantially, or the ETS. Switzerland should strengthen complementary policies to overcome non-financial barriers and improve the effectiveness of financial incentives, thus recognising the potential limitations of financial incentives and response to higher future prices.

Switzerland's carbon price and abatement costs range significantly across sectors. The government is encouraged to consider the balance of abatement costs and allocation of sectoral targets. The government is also encouraged to consider the implication of offset programmes on market signals and incentives for longer-term decarbonisation pathways.

The ES 2050 requires detailed monitoring of the implementation of the ES 2050 and reporting to parliament every five years. Progress in meeting climate targets is assessed annually based on GHG emissions data, and short-term emissions projections are updated every year. Switzerland is encouraged to keep its package of measures under continual review and to identify means of reinforcing and strengthening measures should progress fail to follow projections.

Recommendations

The government of Switzerland should:

- Ensure timely entry into force of the revised CO_2 Law, to support continued climate policy post-2020 and help Switzerland achieve its 2030 climate goals.
- Develop a long-term strategy for transport to 2050 that contributes to domestic decarbonisation pathways by providing stronger market signals.
- Regularly monitor progress towards climate goals, review sectoral guideline targets and provide flexibility to strengthen policies and measures to best manage meeting short- and medium-term targets.

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8. Energy efficiency

Key data

(2016)

TFC: 19.2 Mtoe (oil 47.1%, electricity 26.1%, natural gas 14.5%, biofuels and waste 6.9%, heat 2.5%, geothermal 2.0%, coal 0.6%, solar 0.3%), -5.5% since 2006

Consumption by sector: residential 30.0%, transport 29.6%, industry 21.0%, commercial and public services including agriculture, forestry and fishing 19.4%

Energy consumption (TFC) per capita: 2.3 toe (IEA average*: 2.9 toe), -15% since 2006

Energy intensity: 42.0 toe/USD million PPP (IEA average*: 76.3), -20% since 2006

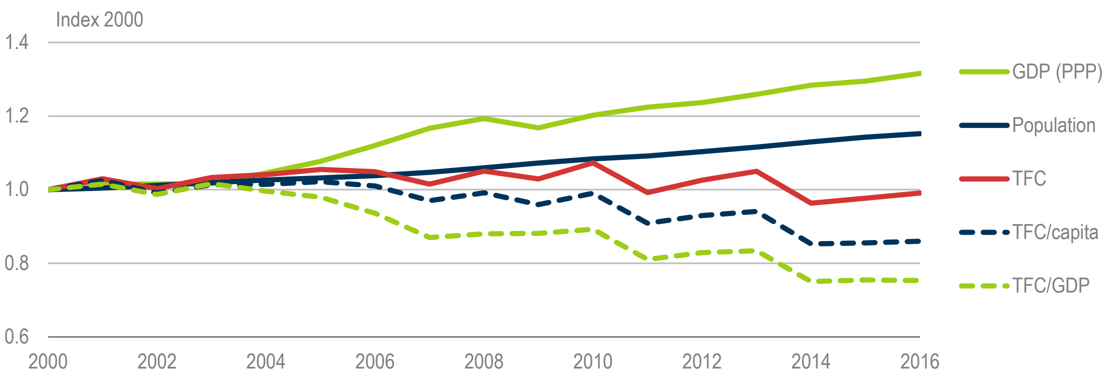
Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

*IEA averages from 2015.

Overview

Switzerland has made continuous improvements to its energy efficiency, and has the second-lowest energy intensity in International Energy Agency (IEA) member countries. The total final consumption (TFC) of energy was at the same level in 2016 as in 2000, despite a population growth of 15% and a gross domestic product (GDP) growth of 32% (see Figure 8.1). As a result, in the period 2000-16, energy consumption per capita decreased by 14% and energy intensity in terms of TFC/GDP fell by 25%, showing continuous decoupling trends.

Figure 8.1 Energy demand and drivers, 2000-16



Note: PPP = purchasing power parity.

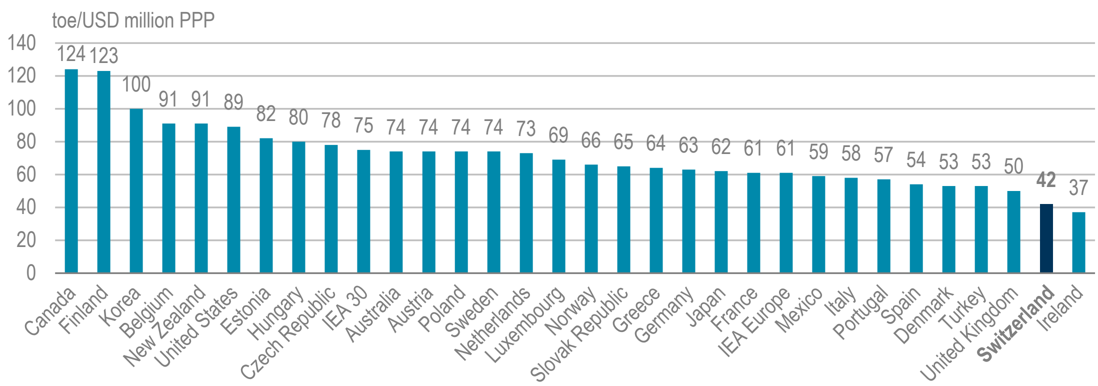
Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Improvements to energy efficiency have been cross sectoral, resulting in slightly falling demand in residential and commercial buildings, as well as in transport and industry. However, efficiency improvements can be made, especially in buildings and transport. Switzerland requires these improvements to meet its ambitious targets for energy efficiency set in the Energy Strategy 2050 (ES 2050).

Energy intensity

In 2016, Switzerland had the second-lowest energy-intensive economy out of IEA member countries, in terms of energy consumption per unit of GDP, after Ireland (see Figure 8.2). Switzerland's energy intensity has historically been low, but it continues to improve significantly.

Figure 8.2 Energy intensity (TFC/GDP) in IEA member countries, 2016

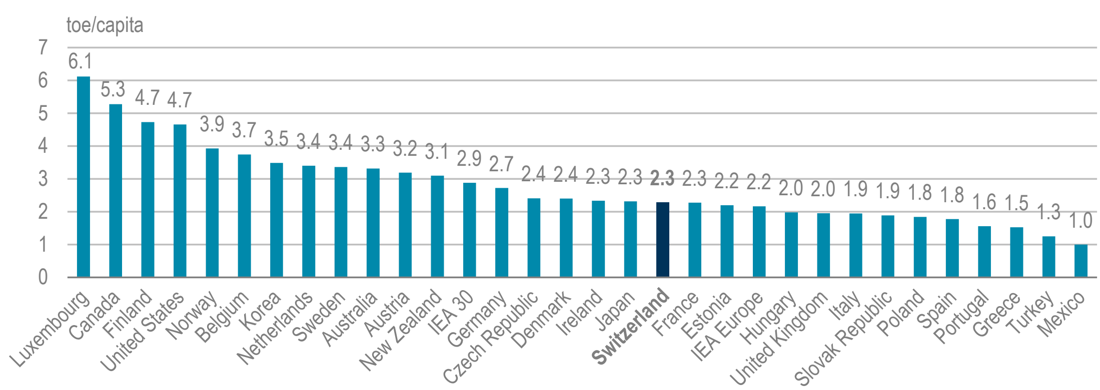


Notes: IEA Europe = average of European IEA member countries; IEA 30 = average of all IEA member countries; toe/USD million PPP = tonne of oil equivalent per United States dollar purchasing power parity.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

Switzerland's population consumed, on average, 2.3 tonnes of oil equivalent (toe) per capita in 2016, which was 20% below the IEA average but above the average among European IEA countries (see Figure 8.3).

Figure 8.3 Energy consumption (TFC) per capita in IEA member countries, 2016



Note: IEA Europe = average of European IEA member countries; IEA 30 = average of all IEA member countries; toe = tonne of oil equivalent.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

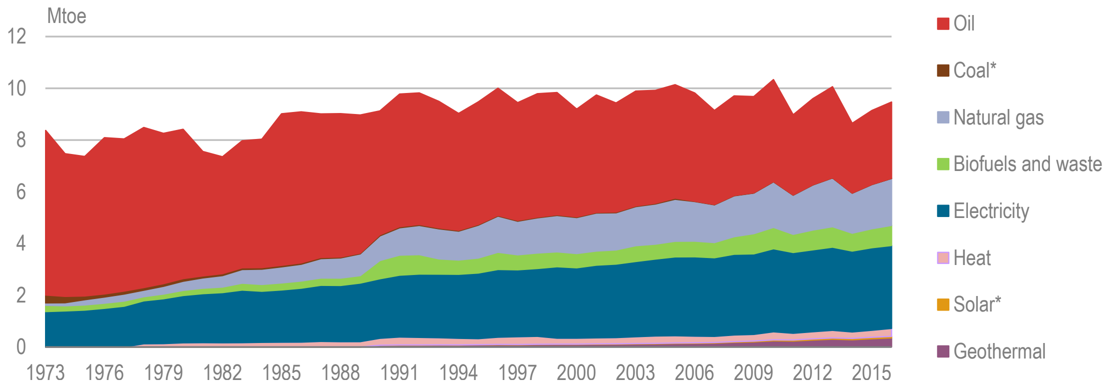
Energy consumption by sector

Switzerland's energy consumption has been stable in the decade 2006-2016, with the biggest share consumed in residential and commercial buildings. The residential, commercial, public service and agriculture sectors together account for nearly half of the TFC; followed by the transport and industry sectors, which consume the other half.

Residential and commercial

In 2016, the residential and commercial sectors consumed 9.5 million tonnes of oil equivalent (Mtoe (see Figure 8.4). The residential sector accounted for 61% of this, commercial and public services (including non-specified consumption) for 38% and agriculture for the remaining 1%. Consumption has been around 9-10 Mtoe for three decades, with annual variations due to the weather, with different numbers of heating days. Electricity and oil are the largest energy sources, each accounting for about one-third of the TFC in the sectors, with remaining shares from natural gas, biofuels and waste, geothermal energy and district heating, and minor shares of solar thermal installations and coal.

Figure 8.4 TFC in residential and commercial sectors by source, 1973-2016



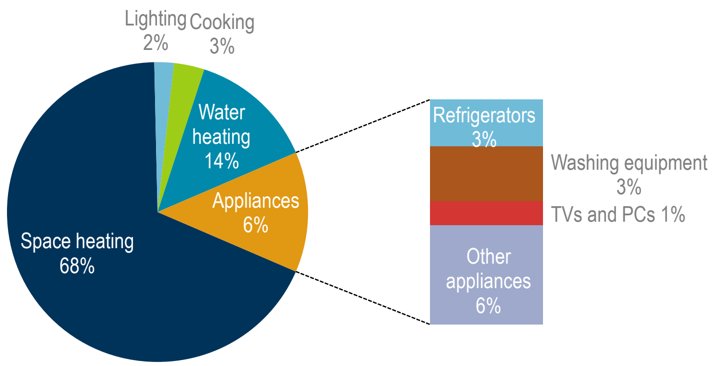
* Negligible.

Note: The commercial sector includes commercial and public services, agriculture, forestry and fishing.

Source: IEA (2018a), *World Energy Balances 2018*, www.iea.org/statistics/.

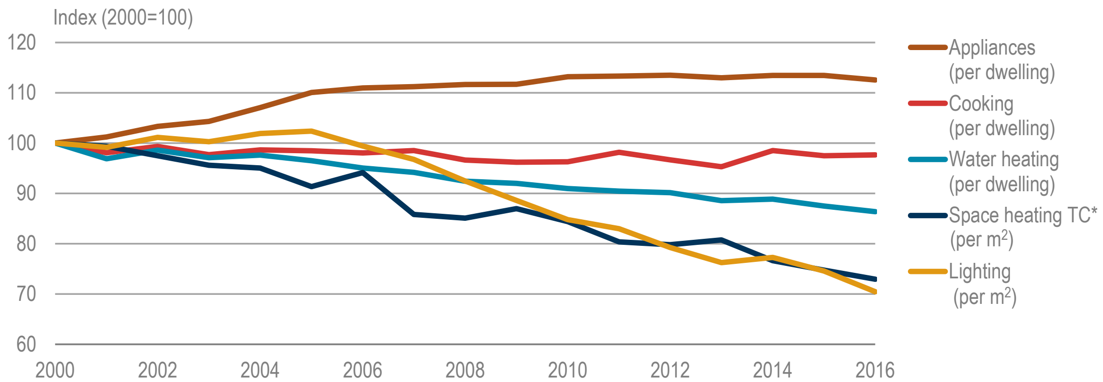
Space heating accounted for 68% of the TFC and water heating represented another 14% in the residential sector in 2016 (see Figure 8.5). Household appliances, cooking and lighting accounted for the remaining shares. Energy intensity per building area and dwelling has been reduced the most in residential energy consumption (see Figure 8.6). Energy intensity for space heating decreased by 27%, water heating by 14% and lighting by 31%, between 2000 and 2016. Household appliances became more energy intensive, due to the increase in home electronics.

Figure 8.5 Residential energy consumption by end use, 2016



Notes: PC = personal computer; TV = television. Data are preliminary.
Source: IEA (2018b), *Energy Efficiency Indicators Highlights 2018 (preliminary)*, www.iea.org/statistics/.

Figure 8.6 Residential energy intensity, 2000-16



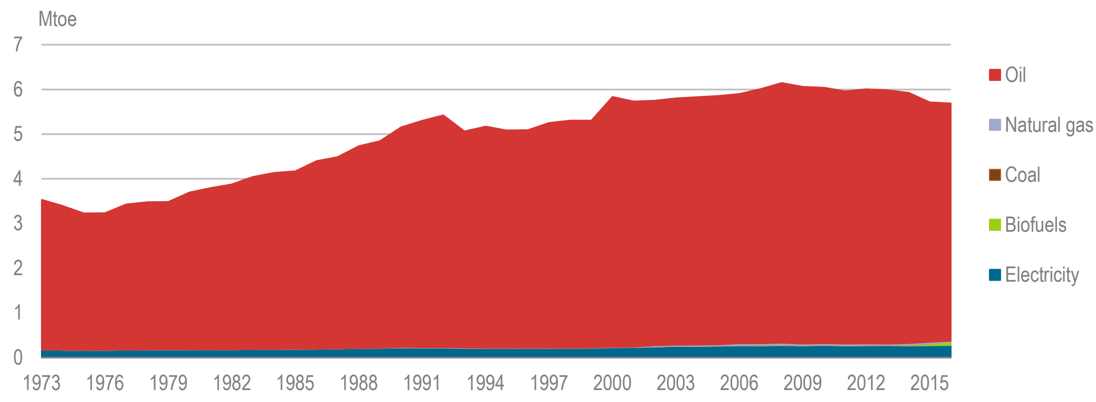
*TC = temperature correction.
Source: IEA (2018b), *Energy Efficiency Indicators Highlights 2018 (preliminary)*, www.iea.org/statistics/.

Transport

The transport sector consumed 5.7 Mtoe in 2016, which represented 30% of the TFC in Switzerland. Transport consumption has increased steadily for decades, but has declined by 7% since its 2008 peak at 6.1 Mtoe. Oil represents over 90% of transport energy demand, most of which is used for road transport (see Figure 8.7). Diesel and gasoline account for the largest shares of total transport fuels, with approximately the same amounts (see Figure 8.8). Electricity used in rail transport accounts for 5% of the TFC in transport, which is the highest share in IEA member countries. The supply of transport biofuels, mainly biodiesels, quadrupled in the two years from 2014 to 2016, but still accounts for just over 1% of the TFC in the sector.

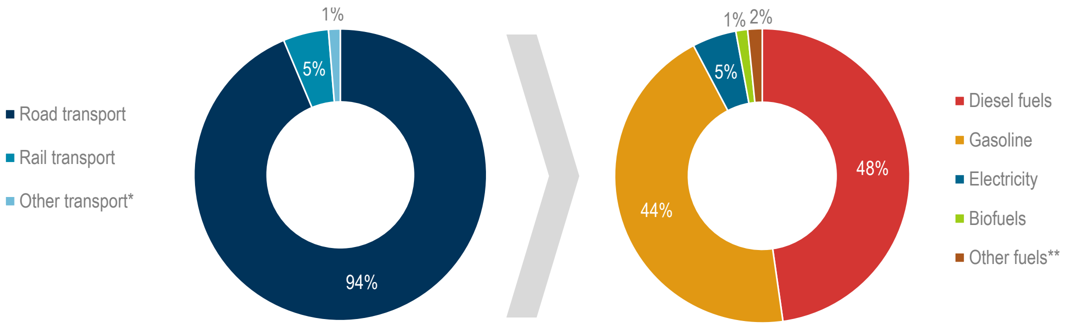
Fuel intensity of passenger cars has improved with a 13% drop in fuel consumption per kilometre (km) over the last decade (IEA, 2017). Electric vehicles (EVs) represent a small share of the total car fleet in Switzerland, with around 15 000 EVs out of 4.6 million passenger cars in 2017.

Figure 8.7 TFC in transport by source, 1973-2016



Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 8.8 Transport energy demand by transport mode and fuel, 2016



* *Other transport* includes domestic aviation and domestic navigation.

***Other fuels* includes natural gas, kerosene and other aviation fuels and liquefied petroleum gases.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

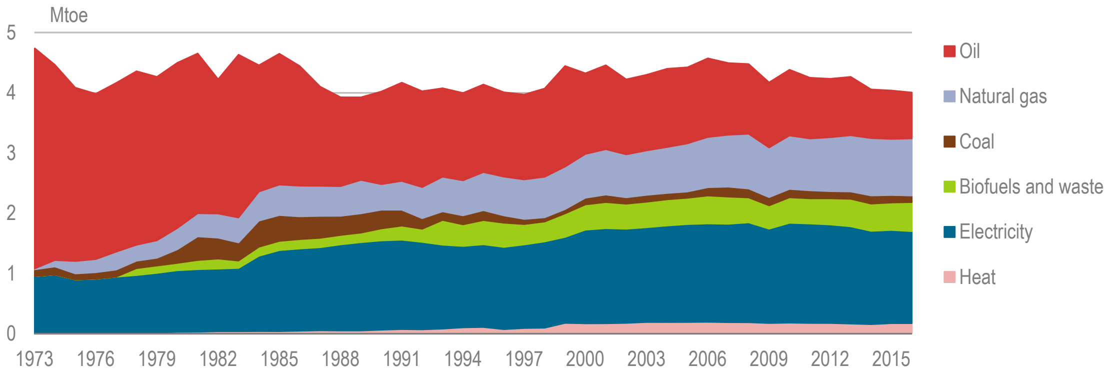
Industry

Switzerland's industry sector consumed 4.0 Mtoe in 2016, which accounted for 21% of the TFC. This included fuels that were used for non-energy purposes, in particular, bitumen used in construction projects and oil-based feedstock used in the chemical and petrochemical industries. Non-energy consumption accounted for 10% of the total industrial consumption. Industrial energy consumption declined by 12% over the decade 2006-16.

In 2016, electricity accounted for 38% of the TFC in industry, whereas oil, natural gas and coal together represented 45% of energy demand (see Figure 8.9). Biofuels and waste accounted for 12%, and the remaining share was supplied by district heating and geothermal energy. The cement industry is the only sector in Switzerland using coal. Coal accounted for 3% of the TFC in industry. The cement industry seeks to increasingly substitute coal by old tyres, combustible renewable sources of waste and wood.

Switzerland's industrial energy consumption is spread out over several sectors (see Figure 8.10). Chemical and petrochemical industries are the largest consumers of energy (including for non-energy-related purposes), representing one-fifth of the TFC in industry, ahead of machinery, food and tobacco, minerals and construction industries. Industrial oil consumption fell by 41% across multiple industry sectors in the period 2006-16, which was partly offset by a 14% increase in natural gas, mainly in the chemical industry sector.

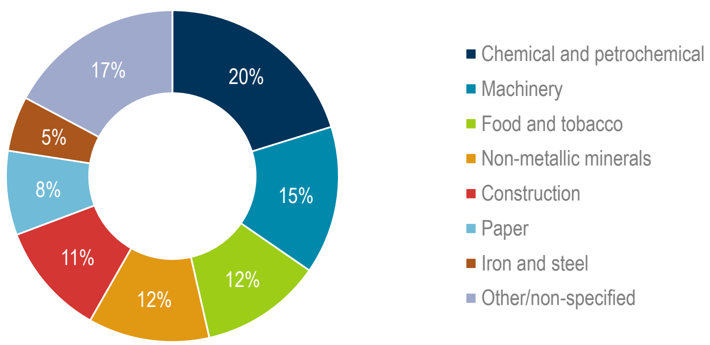
Figure 8.9 TFC in industry by source, 1973-2016



Note: Includes non-energy consumption.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 8.10 TFC in industry by sector, 2016



Note: Includes non-energy consumption.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Institutions

Switzerland is a highly decentralised federal state that upholds the principle of subsidiarity. State regulation is the last resort if private self-regulation fails to provide policy results. Policy making and enforcement are devolved to the lowest possible state level. Hence, the federal government, the 26 cantons, municipalities, industry and consumers carry out energy efficiency measures in close co-operation.

The main institutions for energy efficiency at the federal level are the Swiss Federal Office of Energy (SFOE) through the SwissEnergy Programme, the Federal Office for the Environment (FOEN), the Federal Office for Spatial Development, which is responsible for transport planning, and the Federal Offices of Public Transportation and of Roads, which are responsible for implementing transport policies.

Given the importance of the cantons under the Swiss constitution, the cantonal Energy Offices, overseen by the Conference of Cantonal Energy Directors (EnDK), play an important role in implementing energy policies in the building sector, which is a cantonal remit under the Swiss constitution. Private-sector agencies are closely involved in policy implementation, by virtue of the subsidiarity principle. These include the Energy Agency of the Economy (EnAW), Agence Cleantech (ACT) and the KliK Foundation.

Policy targets and measures

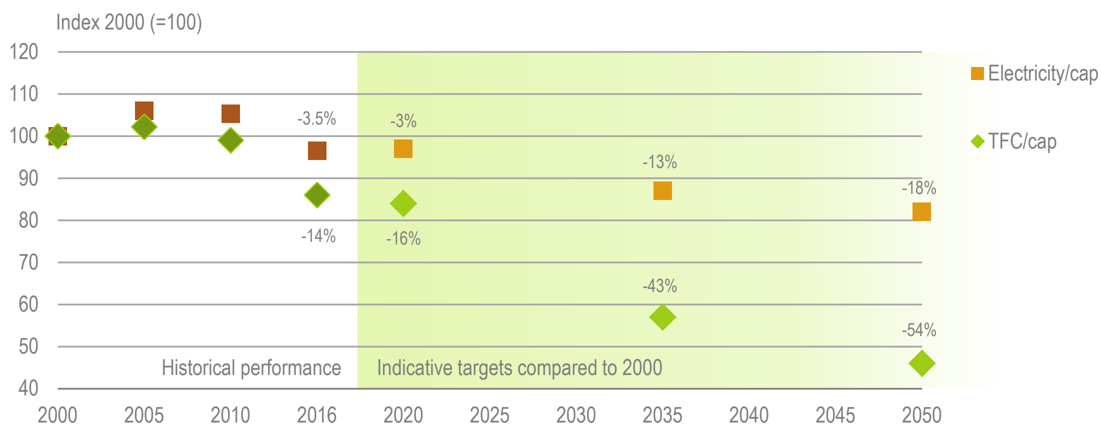
Energy efficiency is one of the three pillars of the ES 2050. It is of particular significance in meeting Switzerland's long-term climate ambitions and in light of the planned nuclear phase-out. The ES 2050 sets indicative targets for annual per capita energy and electricity consumption for 2020 and 2035.

The target to 2020 envisions a reduction of annual per capita energy consumption of 16%, and a medium-term target to 2035 of 43%, compared to the year 2000. Electricity consumption is targeted to be 3% lower by 2020 per person per year and 13% lower by 2035, also against the baseline of year 2000. The electricity consumption target by 2020 is stricter than the 2008 energy efficiency action plan, which aimed to cap demand growth at 5% from 2010 to 2020.

The government set aspirational annual energy and electricity savings per person to 2050 based on the Scenario *New Energy Policy* of the Energy Perspectives 2050 at 54% (energy) and 18% (electricity) against the baseline of year 2000 (see Chapter 2, "General Energy Policy"). Meeting the long-term indicative targets will be challenging and will require close monitoring and timely adjustment.

Consumption per capita fell by 14% during the period 2000-16, and the country is well set to meet its target of a 16% decrease by 2020 compared to the year 2000 (see Figure 8.11). In 2016, Switzerland was already below the 2020 target of a 3% decrease in electricity consumption per person per year compared to the year 2000.

Figure 8.11 ES 2050 targets on TFC and electricity consumption per capita, 2000-50



Sources: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/; Country submission.

Priority policy areas for energy efficiency are building refurbishment, efficient appliances and motors, rational use of energy and waste heat in industry, and efficient and low-emission mobility. The impact of the measures towards meeting the indicative targets will be reviewed every five years. Corrective action will be taken if the target pathway is not met.

The federal government is responsible for energy labelling, and it sets minimum energy performance standards for vehicles, systems and appliances. The Energy Law allows the cantons to be entrusted with building regulations. The federal government finances research and development, and promotes professional training in energy efficiency.

Switzerland has instruments to improve energy efficiency and reduce emissions. The government introduced the carbon dioxide (CO_2) levy on stationary fuels in 2008, in response to the failure of the private sector to provide the expected outcomes under the subsidiarity principle. The levy has since become a key policy and finance measure for reaching the country's climate and energy efficiency targets.

Other measures include the compensation obligation for transport fossil fuel importers, the grid surcharge reimbursement based on binding efficiency targets, the building refurbishment programme and the energy efficiency tenders. These measures partly compete for viable energy efficiency and climate projects in the limited Swiss market.

The SwissEnergy Programme (a unit of SFOE) plays a crucial role in providing information, professional training and capacity building on energy efficiency. SwissEnergy supports energy efficiency measures jointly with the two agencies EnAW and ACT. Activities include the development and dissemination of methods for process optimisation and the promotion of measures for the use of efficient motors and equipment. In addition, SFOE supports the cantons in introducing and implementing cantonal measures for large energy consumers. SwissEnergy's yearly budget has increased from about CHF 30 million (Swiss francs) in 2012 to about CHF 50 million per year up to 2020, to support the ES 2050.

Sectoral policies and measures

Buildings

Cantonal model prescriptions

Building regulations are a cantonal prerogative, and each of the 26 cantons applies its own building law. Cantonal model prescriptions, the so-called "Mustervorschriften der Kantone im Energiebereich" (MuKEn), were tightened in 2014 and entered into force in 2015, replacing the earlier versions of 2008. The purpose of the MuKEn is to facilitate implementation and harmonisation of building codes in Switzerland while maintaining flexibility to address specific cantonal conditions.

The MuKEn do not have the status of a law, but are recommendations to be enforced by cantonal ordinances. The basic module of the 2014 MuKEn is to be transposed into cantonal legislation by 2018 and to become effective by 2020.

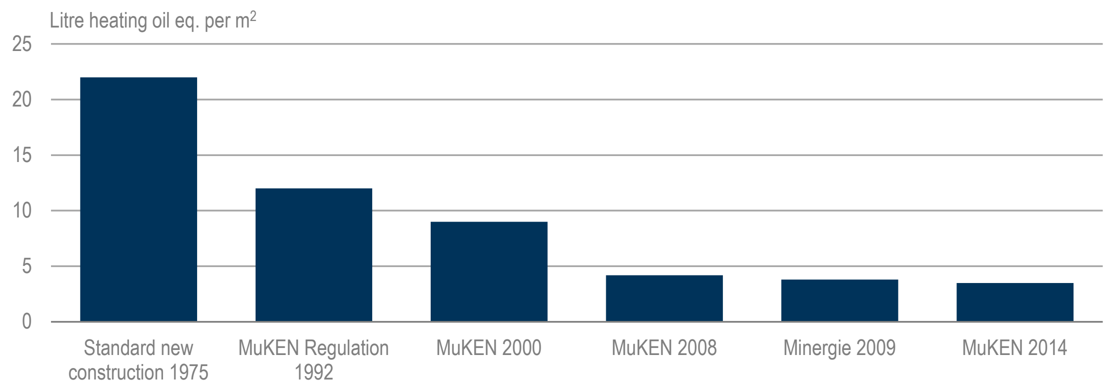
The 2014 MuKEn sets standards for nearly zero energy buildings in line with European Union (EU) recommendations. Space heating and water heating in new residential buildings should consume a maximum of 3.5 litres of oil equivalent per square metre (m^2) per year, or 35 kilowatt hours (kWh) per m^2 per year. This is a 10-15% improvement compared to the 2008 MuKEn (see Figure 8.12). While the code sets a goal for energy use per floor area, it allows designers and builders to decide how to reach the goal.

The 2014 MuKEn kept the target value for full refurbishment of existing buildings at 7.5 litres of oil equivalent per m^2 per year, but introduced a requirement for a minimum share of 10% of sources of renewable energy (renewable energy) when the heating system is replaced (see Chapter 9, “Renewable Energy”). The installation of new direct electric space heating systems was already banned in the 2008 MuKEn, and the 2014 version now requires the replacement of all remaining direct electric heating systems within 15 years.

Other measures in the 2014 MuKEn include:

- A minimum share of electricity to be autoproduced in new buildings.
- A ban on electric water heating after 2020.
- Non-renewable heating to account for a maximum of 90% when replacing the heating system.
- All public buildings to install heating that is totally free of fossil fuels by 2050.

Figure 8.12 Space heating requirements in new buildings since 1975



Source: Country submission.

Building refurbishment programme

To accelerate the improvement of building efficiency, the federal government and the cantons jointly launched the building refurbishment programme in 2010, which is a key instrument of the Swiss energy efficiency policy. The subsidies disbursed from 2010 to 2016 will result in cumulative savings of 115 terawatt hours of energy over the supported projects’ lifetime (see Chapter 7, “Energy and Climate”).

Not all available funds have been called upon during the period 2010 to 2016. In the early years of the programme, the total amount of applications exceeded the available funds. However, this has changed over time, and the number of applications has fallen continuously. Nearly 30 000 applications were received in the first year of the programme. This fell to about 10 000 in 2013 and has stabilised at around 8 500 since 2014.

The programme was managed separately until 2016 at the federal level and the cantonal level. In 2017, the programme was merged under cantonal management, to increase its effectiveness. The federal funding portion is now made available so that cantons have the flexibility to allocate funding to either the building envelope or renewable heating system and other measures based on their own policies and applications received. The ratio between funding from earmarked CO_2 levy proceeds and cantonal financing is fixed at 2:1.

The ES 2050 also introduced new requirements on the cantons. Cantons that offer their own support programme for the building envelope based on the cantonal harmonised funding model “Harmonisiertes Fördermodell der Kantone” (HFM) are eligible to receive the federal funding share. Cantons and the SFOE revised the HFM in 2015, and it became effective in 2017.

The 2015 HFM provides guidance for disbursement of the designated CO_2 levy proceeds and the cantonal co-funding for building refurbishment. It specifies minimum financial support and standard energy savings/CO_2 reductions for measures to allow for a comparable evaluation of funded measures and to limit free-riding (investments that would have been undertaken even without subsidies). The 2015 HFM reflects the climate and efficiency measures and targets for buildings of the ES 2050 and the 2014 MuKEn. Yet, it gives flexibility to the cantons to select their own focus and ease the co-financing obligation in recognition of the tight finances in some cantons.

Energy efficiency renovation in the building sector is proceeding slowly, despite the extensive support system. The rate of annual energy efficiency refurbishment is about 1% of the total building stock of 1.8 million buildings. Rental dwellings are of particular concern, as about 60% of the population are tenants. Setting the right incentives for owners to invest in refurbishment of rental properties is a key challenge to meeting the energy efficiency and climate targets of the ES 2050. It will be important to design measures that address the principal-agent problem (i.e. the missing incentive of the CO_2 tax for refurbishment as the heating costs are passed on to the tenants).

The ES 2050 introduced new tax incentives to encourage investments. Starting in 2020, tax deductions for efficiency investments can be spread over two consecutive fiscal 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 had been more attractive in fiscal terms, but which is less effective from an energy efficiency point of view.

Building labels and energy building passes

Switzerland has its own voluntary labelling system for buildings, called Minergie, which is supported by the cantons, federal government and the private sector. The labelling is applicable for new and renovated buildings and it comes with three levels of standards: Minergie, Minergie-P and Minergie-A. Requirements for the Minergie labels were revised in 2017 and already comply with the new energy legislation in the cantons in accordance with the 2014 MuKEn. By the end of 2017, over 46 000 buildings with a total floor area above 53 million m^2 were certified with the Minergie label.

The cantons established a unified and standardised energy building pass for single and multi-occupant residential buildings, the “Gebäudeausweis der Kantone” (GEAK), in 2009. The 2014 MuKEn foresees the introduction of the GEAK in all cantons and links the payment of subsidies for building shell investments above CHF 10 000 to the issuance of an energy building pass. The pass provides information about the energy efficiency and typical energy consumption of a building. Based on a thorough assessment, buildings are classified into energy-efficient categories from A to G, with A having the highest efficiency. Category B is equivalent to the current MuKEn standard for new buildings and C for buildings with extensive renovation.

The Swiss Sustainable Building Standard establishes a comprehensive concept for sustainable construction by taking into account the building, life-cycle parameters and building location (e.g. distance to public transportation). The "2000-Watt site" certificate was developed by the SwissEnergy Programme to promote low-carbon neighbourhoods.

Appliances, lighting, equipment and motors

In 2012, Switzerland introduced the first efficiency requirements for electrical appliances and refrigerators, together with energy labels for the most important household appliances and electric lamps. General efficiency requirements now apply to all electrical appliances, concerning consumption in standby and off modes. Switzerland has also introduced comprehensive provisions governing the electricity consumption of various household appliances, commercial and electronic devices, and electric lighting. Swiss regulation is mostly in line with EU regulation. The European Union is Switzerland's largest trading partner.

The legislative package of the ES 2050 has replaced the old Energy Ordinance with several specific ordinances, one of which is dedicated to energy-efficient appliances and labelling. Most regulations are set at EU standards, but the new Energy Ordinance also introduces some standards that are stricter than comparable EU ones (see Table 8.1).

Table 8.1 Comparison of Swiss and EU regulations

Product group	Swiss regulation	EU regulation
Refrigerators/freezers (10-1 500 litres)	EEI < 33 (class A++) Non-compressor appliances < 60l: EEI < 110 Wine refrigerators: EEI < 55	EEI < 42 (class A+) Non-compressor appliances: EEI < 110
Household tumble-driers	EEI < 42 (class A+)	EEI < 76 (class B)
Combined automatic household washing machines/tumble-driers	Maximum 0.93 kWh per kilogramme content for the entire washing-spinning-drying cycle (class C)	No regulations
Electric ovens	EEI < 107 (class A)	EEI < 121 (class B) From January 2019: EEI < 96 (class A)
Water heating tanks and heat storage devices (up to 500 litres)*	Efficiency class B	Efficiency class C
Complex set-top boxes**	Reference to voluntary industry agreement Requirements on standby consumption	No regulations/agreements Classified as network equipment
Coffee machines	Mandatory energy label	No regulations

* For water heaters, water heating tanks and heat storage up to 400 kilowatts or 2 000 litres, Swiss regulations are in line with EU regulations.

** For simple set-top boxes, Swiss regulations are in line with EU regulations.

Note: EEI = energy efficiency index.

Source: SFOE (2018), *Factsheet Energy Efficiency Regulations for Electric Appliances as of 1 January 2018*, Bern..

Transport

Travel by passenger vehicle remains the dominant form of transport in Switzerland. Yet, Switzerland has an excellent public transportation system. It has the highest share of public transportation in IEA countries, the second-highest share for rail (after Japan) and the highest rail share in Europe, with 17% in 2015 (in passenger-kilometres) (EC,2018).

The total number of passenger cars increased by 29% from 2000 to 2017, reaching 4.57 million. The country's car density increased from 493 vehicles in 2000 to 535 vehicles, per 1 000 inhabitants in 2015, which is higher than the EU-28 average of 498 in the same year. Although car density increased, car ownership by households reduced by 1% from 2010 to 2015, and this trend is expected to continue.

Vehicle emissions standards

Switzerland introduced mandatory passenger vehicle emissions standards in January 2012 based on those applicable in the European Union. A target of 130 grams of carbon dioxide per kilometre (gCO_2/km) was gradually phased in and became applicable to all newly registered vehicles in 2015. The 2013 CO_2 law also introduced a penalty for car importers in the event of non-compliance. The ES 2050 tightened passenger car emissions standards in line with EU regulation to 95 gCO_2/km by 2020.

The ES 2050 introduced emissions standards for light commercial vehicles and light semi-trailers (light-duty trucks). They are set at 147 gCO_2/km and will become effective by 2020. Light-duty trucks have been showing disproportionate growth rates since 2000, with close to 60% in 2016, mainly due to the performance-related heavy-vehicle fee (HVF) for heavy trucks.

The CO_2 regulations apply to all car importers, with a distinction between large-scale importers (registration of 50 or more new vehicles per year) and small importers (registration of fewer than 50 new vehicles per year). The target relates to the average emissions value of the importer's entire fleet of newly registered vehicles for large importers. Hence, large importers can offset the emissions values against each other so that they do not exceed the target value. Small importers have to apply the emissions target to each car.

In 2016, the average value of emissions of newly registered cars in Switzerland was 134 gCO_2/km. This was 1.2% lower than in 2015, but still higher than the required level of 130 gCO_2/km. Since the target was missed in 2016, car importers had to pay a penalty of CHF 2.4 million. This flows into the National Road and Agglomeration Fund (NAF), as the penalty is designated for road transportation. In comparison, car importers paid CHF 12.6 million of fines in 2015.

The emissions reduction in 2016 was the lowest annual rate since 2006, because the 2015 target had lapsed and the 2020 target had not yet been put in place. Also, the increasing share of EVs among newly registered vehicles contributed to an average CO_2 reduction of the entire new vehicle fleet of more than 2 gCO_2/km. The average fuel consumption for newly registered cars in 2016 was 5.79 litres of petrol equivalent per 100 km – a reduction of 1% compared to 2015.

Energy labels for motor vehicles and tyres

Passenger vehicles have been issued with energy labels in Switzerland since 2003. These assign all new passenger vehicles to seven efficiency categories from A to G. The labels also contain information about fuel consumption and CO_2 emissions of vehicles. The energy efficiency criteria are tightened annually, to reflect technological advancements and to ensure that one-seventh of all newly registered vehicles qualify for the highest efficiency category (A).

Energy labels for tyres became mandatory on 1 August 2014, following voluntary introduction in November 2012. The labels are based on the EU energy labels that indicate the energy efficiency (rolling resistance) rating and classify the degree of grip on wet roads, as well as the noise level.

Freight transport

Switzerland is a key transit country for European freight traffic, which is expected to continuously increase over the next decades. The Swiss government's main policy in freight transport is therefore a modal shift from road to rail, in particular for transalpine transport.

The policy measures deployed, mainly the HVF and substantial investment in infrastructure development, succeeded, in 2016, to reduce alpine lorry transit to below 1 million trucks for the first time in 20 years. This was 3.4% less than in 2015, and down from 1.4 million vehicles in 2014. Swiss research estimated that without the policy to shift freight from road to rail, around 700 000 more trucks would be using the Swiss road network each year.

The target is to reduce the transit number to 650 000 in 2018. However, it is evident that this target will not be met. The opening of the Gotthard Base tunnel (the longest railway tunnel in the world at 57 km in length) in late 2016 provided a key piece of infrastructure to progress towards the goal. It is also the first flat, low-level route through the Alps. This will allow transit freight to avoid the older, higher-altitude tunnels and will thereby induce considerable energy efficiency gains. Switzerland expects to inaugurate the Ceneri Base railway tunnel in 2020, facilitating a modal shift from road to rail.

However, Switzerland's significant investment in new infrastructure is not replicated in neighbouring countries. Key related infrastructure, such as multimodal terminals, is lagging, which is impeding a swifter shift from road to rail. In Switzerland, 71% of the net tonnes traversing the Alps were transported by rail in 2016; the corresponding share in France was 8% and in Austria it was 30%.

Switzerland introduced a distance-related HVF in 2001, which is applicable to all heavy-goods vehicles above 3.5 tonnes. Since 2008, 2.7 Swiss cents has been charged per tonne per km, and the total HVF has varied depending on the pollutant emissions level of the vehicle. One-third of the HVF revenue is designated for infrastructure projects in the cantons, and two-thirds of the revenue goes to the federal government for public transport projects, including new transalpine rail routes and rail infrastructure modernisation. The cantons use their allocation to meet their share of uncovered road transport costs.

The HVF is a policy instrument that internalises all road freight transport costs and is calculated for each heavy-goods vehicle (domestic and foreign) that uses Swiss roads. It reflects road infrastructure costs by including the number of km covered on Swiss territory and the vehicle weight, for each vehicle. It applies the “polluter pays” principle to vehicle emissions. Its purpose is to limit the increase in heavy vehicles on the road, encourage a modal shift from road to rail and relieve strain on the environment.

EVs

EVs are entering the Swiss vehicle market, and had a market share of 2.5% in new car registrations in 2017. A total of 14 539 EVs were registered in 2017, an increase of 35.6% compared to 2016. However, their share remains small, accounting for 0.3% of the total passenger vehicles in 2017. Hybrid cars accounted for 67 661, or 1.5% of the total passenger cars, an increase of 17.8% from 2016 (Bundesamt für Statistik, 2018). In May 2018, car importers committed to a voluntary target of a share of 15% of EVs in total sales by 2022.

The Swiss government considers the deployment of a charging network and other related infrastructure to be chiefly a task for the private sector under the subsidiarity principle. This reflects the finding of a government study of 2015 that existing and planned measures under the ES 2050 do not require a specific master plan.

Hence, the ES 2050 does not provide any specific EV support measures. Instead, it foresees the introduction of taxes (mineral oil tax equivalent) on EVs from 2020 under the new NAF. The EV tax is likely to be a flat rate. The NAF also includes provisions for the opening of fast charging stations at highway service areas, but does not include any specific financial support for this.

The reorganisation of the electricity market under the ES 2050 (including provisions for stimulating prosumers and solar photovoltaics, and new possibilities provided by digital technologies) offers an opportunity for an increased introduction of EVs. The transport sector lags substantially behind the climate goals set by the government (see Chapter 2, “General Energy Policy”, and Chapter 7, “Energy and Climate”).

Motor vehicle registration

Cantons levy a motor vehicle registration fee based on criteria such as vehicle weight or cubic capacity. Cantons have increasingly introduced bonus systems for efficient vehicles such as electric, hybrid, fuel cell, natural gas and vehicles in the A and B efficiency categories. The federal government supports a differentiation of cantonal vehicle taxes and recommends using the energy efficiency label as a reference for fees and rebates.

Industry and other business

The federal government has established two distinct but complementary policy measures to promote energy efficiency and emissions reductions in the industry sector. The first is the exemption from the CO_2 levy on all fossil heating and process fuels (see Chapter 7, “Energy and Climate”), and the second is the exemption from the electricity grid surcharge. Companies have to enter into legally binding target agreements to reduce a pre-agreed amount of energy use and emissions, so that they benefit from the exemptions. Target agreements are tailored for the specific needs of each company through the implementation of economically viable measures. They are designed to save about 15-20% of energy in a ten year period.

Grid surcharge exemption

Since 2014, energy-intensive companies with an electricity bill exceeding 10% of their gross value added have been fully exempt from the grid surcharge. Those with an electricity bill between 5% and 10% of their gross value added are partially exempt from the grid usage surcharge, if they commit to a binding energy efficiency target. This target covers total energy use and electricity consumption.

Additional eligibility conditions are an annual refund larger than CHF 20 000 per year and a minimum off-take of 1 333 megawatt hours (MWh) annually from the electricity grid. Companies must pay the surcharge first and can then file for re-imbursement in the following fiscal year. Measures under the target agreement usually have a payback period of a maximum of four years for process improvements and up to eight years for infrastructure investment.

The federal government monitors and audits the target agreements. If the targets are not met for more than two consecutive years, the company is obliged to take corrective measures. If targets are not met for five out of the ten years of the target agreement period, the company can be required to re-pay the reimbursement already received and to pay an additional penalty.

The new Energy Law (effective as of 1 January 2018) has altered the terms of the programme by changing eligibility and obligations. Public or private end users that undertake public interest activities based on a legal or contractual obligation are no longer eligible for the exemption, except for large research centres. In addition, the cost of the grid surcharge now counts towards annual electricity spending, therefore potentially widening the number of eligible businesses.

The most significant change under the new Energy Law is elimination of the previous obligation to re-invest 20% of the reimbursement of the grid surcharge in energy efficiency measures. These additional measures had to be "uneconomical" (defined as having a payback period longer than 4 years and up to 8 years for process investments, and longer than 8 years and up to 12 years for infrastructure investments).

Industries that are eligible for both exemptions (CO_2 levy and grid surcharge) have the option to conclude either one (universal) or more target agreements for specific measures. However, the sum of the savings of all target agreements has to be equivalent to the total energy efficiency target established for the reimbursement of the grid surcharge.

The federal government has mandated EnAW and ACT to offer their services to the relevant industries and accompany them in the design and implementation of the measures throughout the period of the agreement. Annual audits are undertaken by the SFOE and FOEN.

EnAW was set up by various industry confederations in 2001. Companies that were supported by EnAW in their target agreements had reduced their annual electricity demand by 700 gigawatt hours (GWh) by the end of 2016. ACT has been active since 2016 and is expanding its participants rapidly.

Cantonal requirements

The cantons have created their own measures to support energy efficiency improvements in industry, the so-called "cantonal model" that is targeting large energy-consuming industries subject to regular environmental reporting to the cantons. Those companies may conclude a binding efficiency target agreement instead of complying with environmental reporting. The SFOE considers these measures complementary to its own, and supports canton efforts to introduce and implement them.

Large energy-consuming companies are defined as using more than 5 GWh of heat or 500 MWh of electricity annually. Industries can choose between three models:

- A universal target agreement with either EnAW or ACT to improve energy efficiency over a ten-year period with about 2% of annual improvements.
- A cantonal target agreement with the cantonal authority. The energy efficiency targets are the same as those under the universal target agreement. However, not all cantons offer this possibility.
- An energy consumption audit, which is the minimum requirement in the case where no target agreement has been signed. Companies choosing this option are responsible for meeting the required efficiency improvements within three years.

Electricity efficiency tenders

The SFOE has run competitive tenders since 2009 for the efficient use of electricity in industry, services and households operated by the ProKilowatt agency. Financial support is awarded by auctions. This ensures that projects (undertaken by and for a single entity) and programmes (measures implemented by an organisation in several small entities) are selected with the best cost-benefit ratio. This is defined as the highest number of kWh saved per financial support unit. Eligible projects and programmes must have a payback period of more than five years. Financing has been opened under the ES 2050 for reducing transformation losses in electricity generation and distribution.

ProKilowatt supported 473 programmes and projects with CHF 157 million, which was funded through the grid surcharge from 2010 to 2016 (see Chapter 9, "Renewable Energy"). The support resulted in annual savings of 470 GWh. The Energy Law of 2018 increased the annual funding for the efficiency tenders to about CHF 50 million. It also broadened eligibility to include energy efficiency improvements in electricity production and distribution, specifically targeting electricity production from waste heat. The subsidies for competitive tenders are available until 2030 at the latest.

Assessment

Switzerland's energy intensity in terms of TFC/GDP (purchasing power parity) decreased by 20% from 2006 to 2016. It was the second lowest among IEA countries in 2016, at 42 toe per million United States dollars of GDP. Achieving improvements from such a low level will be challenging, but potential for greater efficiency exists in the building and transport sectors. The IEA commends the ambitious indicative energy efficiency targets set in the ES 2050, aiming to reduce energy consumption per capita by 43% by 2035, and electricity consumption per capita by 13%, both compared to the year 2000.

Switzerland has taken significant steps to implement the recommendations made in the 2012 in-depth review report. It has brought its minimum performance standards for appliances and equipment in line with EU regulations, and is now even exceeding EU standards for certain products. A tightened cantonal model prescription entered into force in the building sector in 2015, further harmonising building codes across the country and setting standards for new buildings.

The building sector holds potential for energy efficiency improvements. Oil accounts for 34% of residential energy consumption and natural gas for another 20%. In addition, about 10% of peak electricity demand in winter, when Switzerland relies on imports, results from direct electric heating.

Available funds for the building refurbishment programme have not yet been fully disbursed. This is a reflection of the Swiss policy system, which places the responsibility for buildings at the cantonal level. Under the programme in place up to 2016, cantons were required to offer co-funding of about 25%, but not all have implemented such a programme. The new programme gives cantons more flexibility in allocating federal funds.

The current building refurbishment programme is foreseen to end in 2025. It is important to avoid uncertainty for the period thereafter. This may be done by ensuring that new incentives in the rental sector will be in place by then, to correct for the missing incentive of the CO_2 tax (principal-agent problem).

The transport sector also has significant potential for efficiency improvements. The key instrument towards increasing transport efficiency is the continuation of the alignment of emissions regulations on vehicle fuel consumption with EU standards.

Switzerland pursues decarbonisation of the transport sector through expansion and optimisation of the public transport network and through a modal shift for freight, including transit, from road to rail. However, passenger vehicles are the dominant form of transport in the country. It is unlikely that current measures will be sufficient to reach expected efficiency and climate targets in the transport sector, based on experience so far. Reaching such targets in the transport sector is a challenge for all IEA countries.

Switzerland is not pursuing a government-led strategy for the larger-scale introduction of EVs and related infrastructure. Instead, it is relying on measures such as emissions standards for cars, as well as the subsidiarity principle, which places the deployment of charging infrastructure on the private sector. The government’s decision not to actively support the roll-out of EVs should be revisited, given the prospects for EV cost reductions, their multiple benefits (including use for public transport) and the government’s own vision for a growing share of EVs, which is embedded in its recent proposal for regulating the fuel consumption of cars and light commercial vehicles.

The implementation of the ES 2050, the introduction of smart metering and technology advances for EVs allow consideration of the preparation of a longer-term strategy. The possible opening of the retail electricity market and the new framework for prosumers offer an opportunity to integrate the potential of EVs, and their storage potential and flexibility for demand response, into electricity market design.

The energy savings potential in industry is estimated at around 15%. Binding target agreements contracts capture about 50% of CO_2 emissions of Swiss industry and small and medium-sized enterprises, which have lowered their emissions by 20-25% under the contracts. The target agreements to lower emissions and improve energy efficiency appear to have provided results, and the instrument should be maintained in the future.

Recommendations

The government of Switzerland should:

- ☐ Review incentives faced by all actors to make the building refurbishment programme more effective, taking into account the principal-agent problem. Ensure a new building refurbishment programme seamlessly continues beyond 2025.
- ☐ Prepare a strategic vision for the roll-out of EVs (including vehicles, infrastructure and grid integration) that is linked to the new electricity market design and which considers the potential for EVs to contribute to demand response.
- ☐ Provide certainty to business and industry on future energy efficiency promotion and maintain the momentum of efficiency improvements beyond 2020.
- ☐ Roll out linking of the Swiss emissions trading system with the EU Emissions Trading System by 2020.

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9. Renewable energy

Key data

(2017 provisional)

Total supply*: 5.4 Mtoe (22.4% of TPES) and 37.5 TWh (62.5% of electricity generation)

IEA total*: 10.0% of TPES and 24.7% of electricity generation

Hydro: 2.9 Mtoe (12.2% of TPES) and 34.0 TWh (56.8% of electricity generation)

Biofuels and waste:** 2.7 Mtoe (11.2% of TPES) and 2.9 TWh (4.8% of electricity generation)

Geothermal: 0.4 Mtoe (1.7% of TPES)

Solar: 0.2 Mtoe (0.8% of TPES) and 1.6 TWh (2.7% of electricity generation)

Wind: 0.01 Mtoe (0.05% of TPES) and 0.1 TWh (0.2% of electricity generation)

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

*Not including non-renewable waste.

**Including 0.8 Mtoe non-renewable municipal and industrial waste, which accounts for 31% of total biofuel supply.

Overview

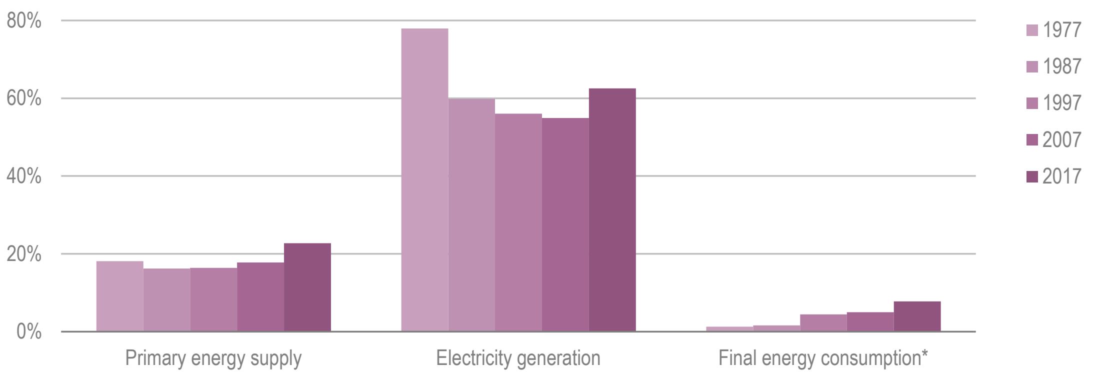
Hydropower accounts for over half of Switzerland's electricity generation and is the dominant source of renewable energy in the country. Waste, used in power generation, and biofuels (primary solid biofuels, i.e. wood fuels), used for building heat purposes, have increased in recent decades, resulting in higher shares of renewable energy in the total primary energy supply (TPES) as well as in the total final energy consumption (TFC). In 2017, renewables accounted for 22% of the TPES, compared to 18% in 2007, and the renewable share in the TFC increased from 6% to 9% over the same period (see Figure 9.1).

Hydropower is challenged by low electricity market prices in Switzerland and Europe, despite its large and stable production. The Swiss hydropower industry is under pressure from having to pay high water royalties. A temporary market premium has been introduced for large hydropower plants so that operators can cover their costs. Furthermore, the government has proposed to reform water royalties to better follow the evolution of market prices.

Feed-in tariffs (FiTs) and investment aids for small photovoltaics (PVs), financed by a network surcharge, have supported renewable power generation. The government introduced a shift from FiTs to feed-in premiums (FiPs) and expanded the use of investment aids in the Energy Strategy 2050 (ES 2050) legislative package (see

Chapter 2, "General Energy Policy"). This was to provide more incentives for market integration of renewable electricity production. Switzerland now needs to ensure that the new support programmes will allow the indicative targets for renewable energy in the ES 2050 to be met.

Figure 9.1 Share of renewable energy in different energy supplies, 1977-2017



Notes: Excluding non-renewable waste. Data are provisional for 2017. Latest consumption data are 2016.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

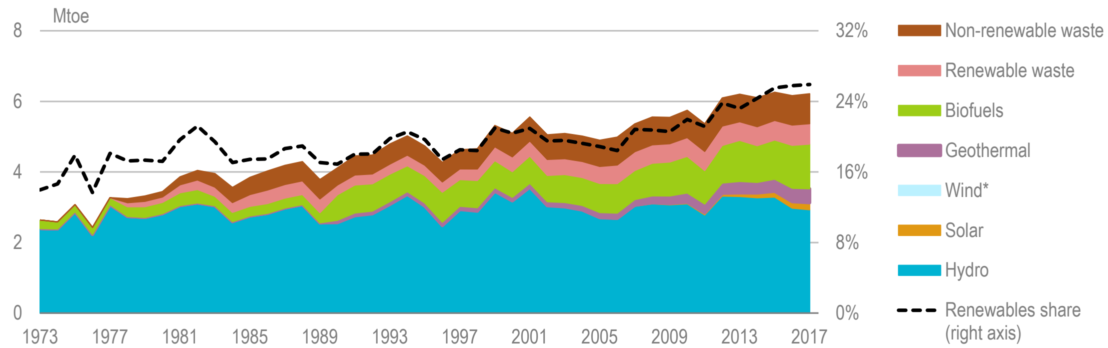
Supply and demand

Switzerland has a large share of renewable energy in electricity generation, and a growing share in the TPES.

Renewable energy and waste in the TPES

The supply of renewable energy and waste in Switzerland was 6.2 million tonnes of oil equivalent (Mtoe) in 2017, or 25.9% of the TPES, of which 3.5% was industrial and non-renewable municipal waste (see Figure 9.2). Hydro accounted for the largest share, with nearly half of the total renewables and waste in the TPES. Biofuels and waste have been increasing significantly in recent decades. The share of hydro in the total renewable energy supply has thus declined from 62% in 2000 to 54% in 2010 and 47% in 2017.

Figure 9.2 Renewable energy and waste in TPES, 1973-2017

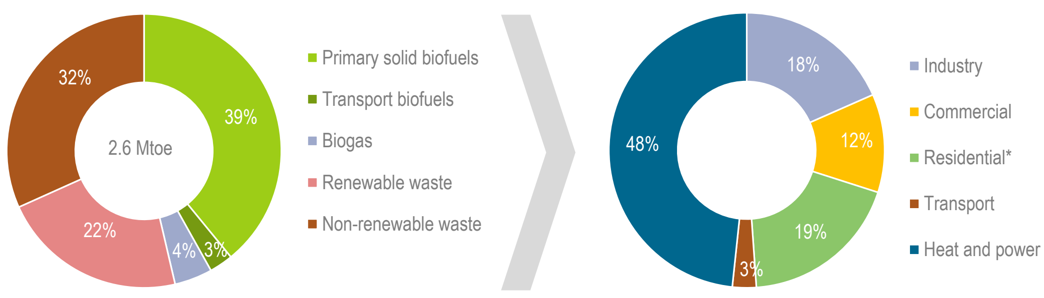


* Negligible.
Note: Data are provisional for 2017. Includes non-renewable waste.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Waste is primarily used in heat and power generation, whereas biofuels are mainly solid wood fuels used directly in industry, or residential and commercial buildings (see Figure 9.3). Biogas, primarily used in heat and power generation, and transport biofuels, mainly biodiesel, have increased significantly, but they remain a small share of the total renewable energy sources. Geothermal energy (heat pumps) and installations of solar thermal heaters and solar PVs have increased in recent years. Hydropower supply has remained at a high and stable level over time, with annual variations due to hydrological conditions.

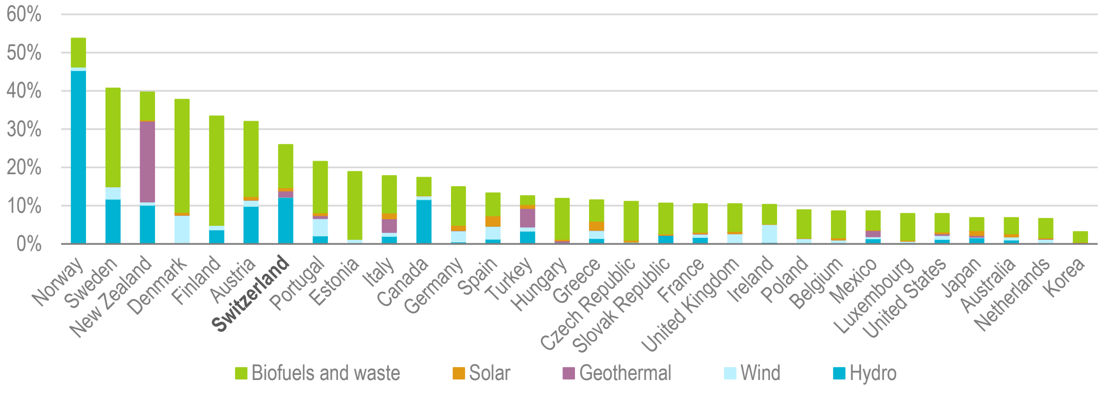
Switzerland has the seventh-highest share of renewable energy in TPES among International Energy Agency (IEA) member countries (see Figure 9.4). Its share of hydropower is the second highest, after Norway.

Figure 9.3 Biofuels and waste by fuel and consuming sector, 2016



* *Residential* includes a small share of biogas used for blending with natural gas.
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 9.4 Renewable energy and waste as a percentage of TPES in IEA member countries, 2017



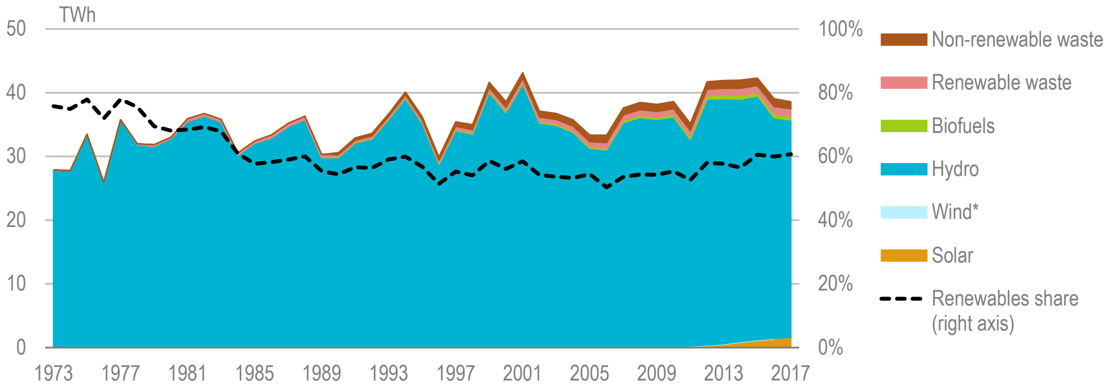
Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Electricity from renewable energy and waste

Hydropower is the largest source of power in Switzerland. In 2017, hydropower accounted for 57% of the total electricity generation and 88% of all renewable electricity (see Figure 9.5). Municipal waste incineration accounted for most of the remaining renewable electricity generation, followed by a small but growing share of solar power.

Switzerland has the seventh-highest share of renewable energy in electricity generation among IEA member countries, owing to its large hydropower generation (see Figure 9.6). Its share of hydropower is the fifth highest after Norway, Austria, Canada and New Zealand. Conversely, Switzerland's wind power production is the second-smallest share in electricity generation among IEA members.

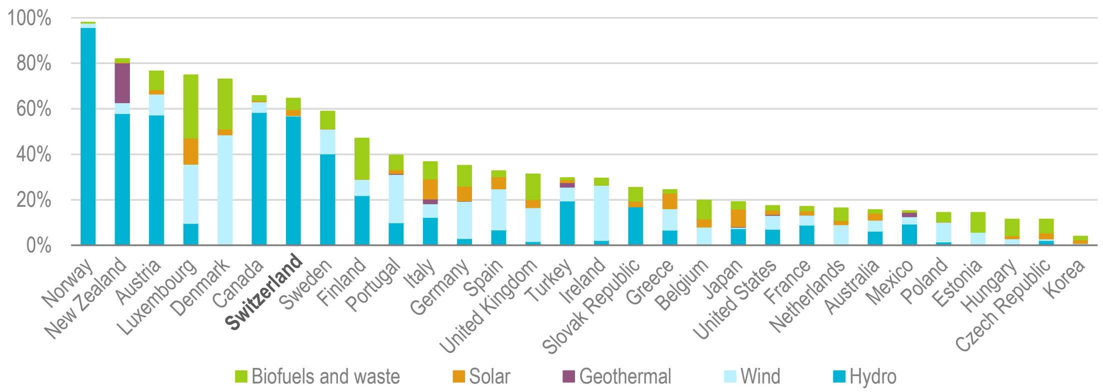
Figure 9.5 Renewable energy and waste in electricity generation, 1973-2017



* Negligible.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Figure 9.6 Renewable energy as a percentage of electricity generation in IEA member countries, 2017



Note: Data are provisional.

Source: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/.

Policies and measures

Targets

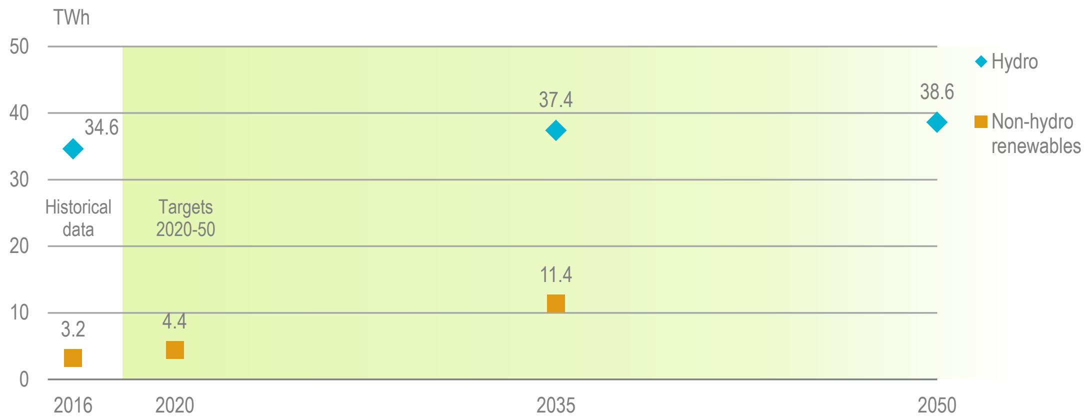
Strengthening the role of renewables in the Swiss energy sector is one of the three pillars of the ES 2050. Renewable energy will play a crucial role in filling the gap of nuclear power, which is to be phased out under the ES 2050, to maintain the low-carbon intensity of the Swiss power sector. This requires a more-effective policy framework and better targeted support programmes, resulting in higher deployment rates.

Switzerland does not have any legally binding targets for the share of renewable energy in the TPES. The SwissEnergy Programme, which is in its second phase (2010-20), aims to increase the share of renewable energy in the total energy consumption by at least 50% from 2011 to 2020, to eventually reach a share of 24% renewable energy in final consumption. The Electricity Supply Law of 2008 includes a provision that electricity generation from renewable sources should increase by 5.4 terawatt hours (TWh) by 2030.

Electricity

Switzerland has set indicative targets for renewable electricity generation in the ES 2050. Renewable sources excluding hydropower should produce 4.4 TWh by 2020 and 11.4 TWh by 2035, and yearly hydro production should average 37.4 TWh by 2035. Figure 9.7 shows the ES 2050 indicative targets to 2035 and the aspirational targets to 2050 (see Chapter 2, "General Energy Policy"), together with recent production. In 2016, the total renewable electricity generation from sources other than hydropower was 3.2 TWh, 1.2 TWh lower than the 2020 target. This represented 5.5% of the total renewable electricity generation, with hydropower accounting for the remaining 94.5%.

Figure 9.7 ES 2050 targets for renewable electricity generation, 2020-50



Sources: IEA (2018), *World Energy Balances 2018*, www.iea.org/statistics/; Country submission.

Progress under the FiT programme until 2017

Switzerland has used cost-reflective FiTs since 2009 to increase the share of renewable electricity. Solar, wind, biomass, geothermal and small hydro plants with a capacity up to 10 megawatts (MW) were eligible technologies. Large hydro plants did not qualify for the FiTs. The FiTs were signed for a period up to 25 years, depending on the technology, and adjusted downwards regularly to align renewable tariffs closer to market prices, in line with technological progress and increasing market penetration.

The FiTs are funded through a network surcharge levy, introduced in 2009, which was initially set at 0.45 Swiss cents per kilowatt hour (kWh), and which increased successively until reaching 1.5 Swiss cents per kWh in 2017. The network levy is capped to control costs and protect customers. Until 2017, there was a cap on the share that any given technology could receive from the total available subsidy. The network surcharge raised CHF 825 million (Swiss francs) in 2017, mostly for renewable support.

An extensive renewable project pipeline quickly developed in response to the financial incentives. At the end of 2017, the FiTs supported annual electricity generation of over 3.30 TWh. The largest share was small hydro (1.46 TWh per year), followed by biomass

(1.24 TWh per year) and PVs (0.53 TWh per year), while wind accounted for 0.08 TWh per year. Geothermal projects have not proven successful so far, with no project in production and three projects with a capacity of 15 MW at the exploration stage.

However, a long project waiting list formed quickly, because the funds raised through the network levy were insufficient to cover demand for the support. In 2014, the government barred small PV projects below 10 kilowatts (kW) from the FiT programme to decongest the waiting list. Instead, they were offered a one-time investment aid covering up to 30% of the investment cost of a reference plant. Of the total amount raised by the network surcharge, CHF 100 million was reserved for the PV investment aid programme. In addition, several cantons offered their own investment aid to support realisation of projects on the waiting list.

PV projects with a capacity between 10 kW and 30 kW had the option either to remain on the waiting list for the FiTs or to opt for the investment aid. The investment aid amounts to less than the accumulated FiTs over a 20-year period. However, there is no guarantee that the projects on the waiting list would eventually receive the FiTs. Many PV projects therefore opted for the investment aid instead, including some of those already approved.

At the end of 2017, the investment aid supported 0.34 TWh per year of PVs. This was up from 0.25 TWh per year just six months earlier. All PV installations above 10 kW that had applied prior to November 2011, and that had not yet opted for the investment aid, were cleared for the FiTs by the end of 2017.

However, the waiting list still comprises more than 37 000 projects with a total production capacity of almost 7 TWh, of which 96% were small PV projects. PV projects accounted for 20% of projects on the waiting list, expressed in production capacity. No projects received approval for FiT support during 2017.

New support programmes under the ES 2050

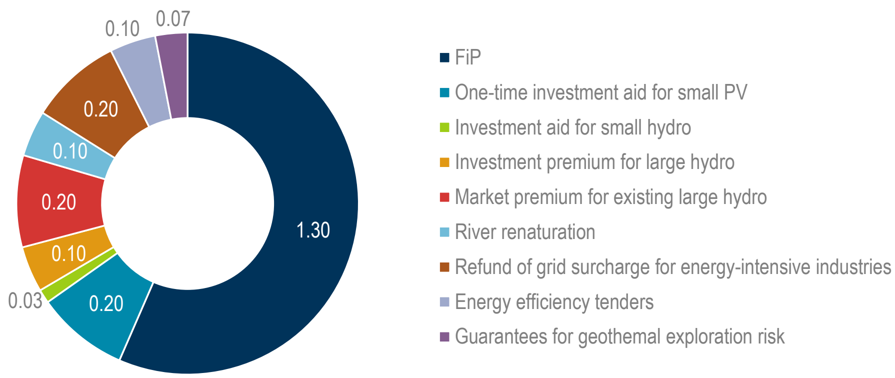
The ES 2050 legislative package has comprehensively revamped the support mechanisms for renewable electricity technologies. They were re-calibrated to address the problems encountered with earlier support programmes, to facilitate market integration of renewable power facilities and to achieve the long-term renewable generation targets. The ES 2050 also includes provisions to improve the non-financial framework conditions for renewables.

The new financial support mechanism for renewable electricity under the ES 2050 consists of three pillars, which are all financed from an increase in the network surcharge: *i*) move from FiTs to FiPs and direct marketing, *ii*) broaden eligibility criteria for the one-time investment support and *iii*) include sunset clauses for support of all new installations.

With effect from 1 January 2018, the network surcharge increased from 1.5 Swiss cents per kWh to 2.3 Swiss cents per kWh, with a fixed allocation for specific technologies and support mechanisms (see Figure 9.8). The increase of the network surcharge will generate an additional CHF 480 million per year, bringing the annual total to CHF 1 300 million, mainly for renewable support. However, the increase in network surcharge is time limited and will decrease with the expiration of renewable support under the sunset clauses. This reflects the Swiss authorities' policy goal of keeping the costs of renewables affordable and politically acceptable. The Swiss authorities do not foresee clearing the entire FiT project waiting list, despite the increase in available funds.

A small portion of the revenues continues to fund other policy measures. A 0.1 Swiss cents per kWh allocation will continue funding energy efficiency tenders (see Chapter 8, "Energy Efficiency") and the renaturation of rivers affected by hydro plants. In addition, up to 0.1 Swiss cents per kWh are designated for geothermal exploration risk guarantees and one-time investments. The refund of the network surcharge to energy-intensive industrial users under specific conditions (see Chapter 7, "Energy and Climate", and Chapter 8, "Energy Efficiency") is going to bind approximately 0.2 Swiss cents per kWh. A time-limited market premium of 0.2 Swiss cents for existing large hydropower plants is also included in the increased surcharge.

Figure 9.8 Allocation of network surcharge by funding mechanism



Source: IEA based on information provided by SFOE.

From FiTs to FiPs with direct marketing

The ES 2050 applies several changes and exclusions to the FiT programme. The payment period of the new FiPs is limited to 15 years, instead of 20 years earlier, except for biomass projects, which continue receiving support up to 20 years. Over half of the entire network surcharge, 1.2 Swiss cents per kWh, is allocated for support under the old and new feed-in remuneration programmes.

A key change under the revised Energy Law is the move from a cost-recovering FiT to a cost-oriented FiP, which no longer offers full cost recovery. Instead of a fixed FiT, plants will receive a flexible FiP, calculated as the difference between a reference market price and a technology-specific remuneration (SFOE, 2017). The market price and the technology-specific remuneration are adjusted regularly, as under the old programme. The shift to the new FiP programme will incentivise producers to feed in electricity when demand, and therefore prices, are high. Calculated over the entire payment period, support under the new FiPs is around 15-20% lower than the FiTs for installations that entered the programme during 2017. This will allow including a larger share of projects into the FiP programme.

The FiP programme continues for all technologies previously eligible under the FiT programme, but not for all plant sizes. The new eligibility criteria are applicable for all plants that have been operating since 1 January 2013 but which are still on the waiting list for FiPs.

New small hydro plants under 1 MW will not receive any support at all. There is a consensus in Switzerland that the environmental impact of small hydro projects is not proportional to their electricity generation. Certain exceptions are still possible, but under narrowly defined circumstances.

The new FiPs are available only for PV projects above 100 kW. PV projects from 2 kW up to 50 MW can apply for a one-time remuneration.

Authorities expect that hydro, wind and biomass projects that applied for the FiTs by 31 October 2015 will be included into the FiP programme by July 2018. Eligible PV projects that applied by January 2012 are going to be cleared for the FiP programme by October 2018. The waiting list for PV projects is likely to be cleared by the FiP sunset (end of 2022) for applications submitted up to June 2012. Waiting list applications for the other technologies are likely to be cleared for the FiPs if they obtained a construction permit before 2017. Authorities expressed caution that all the other projects on the waiting list, as well as any new eligible project applying for FiPs as of 1 January 2018, are unlikely to ever be included under the FiP programme due to the waiting list and limited resources.

The FiPs will be combined with direct marketing (see below) as of 2020, for all installations above 500 kW, irrespective of technology. This new provision is applicable retroactively for all installations already receiving FiTs. The same is applicable for all installations above 100 kW capacity that joined the FiP programme as of 1 January 2018. All other producers have the right to opt for direct marketing. However, the change to the new system is irrevocable.

Direct marketing means that producers of renewable power that receive an FiP will be responsible for finding buyers for the electricity generated. They continue receiving the premium at the same time. If a producer sells the electricity at a price higher than the reference market value, against which the FiP is calculated, the revenues obtained are higher than in the old system. However, if the electricity is sold at a price lower than the reference market value, revenues are lower than in the old system. The Swiss Federal Office of Energy (SFOE) expects that aggregators will handle most of the direct marketing on behalf of the producers, given the complexity of the electricity market.

The key rationale for direct marketing is to better integrate renewable power into the market and to support generation at times when it is required. This will benefit network stability and enhance security and reliability of supply. The system design incentivises and compensates reliable production forecasts, the use of storage options and the dispatching of generation.

Swissgrid, the transmission company, was responsible for collection of the network surcharge, the FiPs and one-off remuneration payments for PVs, until the entry into force of the ES 2050 legislative package on 1 January 2018. It has also been responsible for issuing guarantees of origin (GoOs) as the accredited certification body on behalf of the federal government since 2007.

With the entry into force of the new Energy Law, approved as part of the ES 2050, these responsibilities have been transferred to the newly created Pronovo AG as an independent enforcement agency. Pronovo AG is a wholly owned subsidiary of Swissgrid and will operate under the authority of the SFOE.

One-time remuneration/investment aid

The ES 2050 expands the key support mechanism for PVs, the one-time remuneration/investment aid, for PVs up to 100 kW (previously up to 30 kW). Approximately 0.2 Swiss cents per kWh of the network surcharge is designated for PVs. A total of 6 600 (around 140 MW) small PV projects of up to 100 kW will be supported under this programme during 2018.

PV projects larger than 100 kW can choose between a one-time remuneration and the FiP. For 2018, CHF 20 million is available to support around 40 MW capacities under the one-time remuneration programme for larger PV producers.

The rationale for moving PV projects mainly to a one-time remuneration is the limited availability of funds and the need to reduce the project waiting list while still allowing for the addition of a significant share of PV capacity in line with the desired future electricity mix. The SFOE estimates that the 12 400 small PV projects (below 100 kW) registered on the waiting list at the end of 2017 will receive the one-time investment aid by the end of 2019. Those projects registered after 1 January 2018 should receive their support with an approximate two-year delay.

Waste incineration plants, sewage plants and regionally significant wood-fired plants qualify for investment aid covering up to 20% of the cost of a reference plant. Small existing hydro plants with a capacity between 300 kW and 10 MW are eligible for investment support for expansion and enlargement. New small hydropower plants are no longer eligible for support due to public concerns over the protection of nature. An innovation of the ES 2050 is the provision of investment aid for project expansions, of up to 60% of the cost, and for extensive upgradation, for which up to 40% of the cost can be funded. The allocation for this is 0.03 Swiss cents per kWh of the network surcharge.

Large hydro plants can receive investment support of up to 35% of eligible investment costs for new plants and for substantial expansion of existing plants. Significant renovation projects can receive support of up to 20% of the total eligible investment costs. This will be supported through an allocation of 0.1 Swiss cents per kWh raised through the network surcharge.

Sunset clauses

New projects can be admitted to the FiPs until the end of 2022. New installations cannot benefit from the programme thereafter. Swiss authorities expect that by the end of 2022, the sunset date for the FiPs, only a few projects on the waiting list will be accommodated. This implies that many projects already on the waiting list for the FiT, or those newly applying for the FiP, would only be able to benefit from the one-time remuneration/investment aid, provided they are eligible.

Wind projects, biogas plants and new small hydropower plants are not going to be assisted by any support programme from 2023. However, the FiTs and FiPs for all projects that entered into the programme before the end of 2022 will continue receiving support until their contracts expire.

The investment aid for new projects is available until the end of 2030. No new investment contributions or one-time remunerations will be available from 2031. This longer time frame reflects the political will to establish one-time payments as the key support mechanism for renewables to bring them closer to market prices.

Market premiums for large hydro plants

Large hydro plants, defined as having capacity above 10 MW, account for around 90% of the total hydro generation. However, these plants are undergoing a period of financial difficulty. Decreasing wholesale prices and a partial opening of the electricity sector have created unequal opportunities, depending on ownership. Those plants that are part of a local utility with captive end customers can pass on their costs, while independent plants have to sell into the highly competitive wholesale market where prices are not always sufficient to cover production cost.

In addition, hydro producers are required to pay water royalties to local communities and cantons for the use of hydro resources. This questions the financial viability of hydro and threatens future investments in large hydro plants, which are expected to play a key role in the Swiss electricity sector under the ES 2050.

The new Energy Law introduced a market premium for large hydro plants that sell power below their production cost, to alleviate the financial stress. The premium became effective in 2018, and is limited to five years (up to the end of 2022). It is financed from the increase in the network surcharge as of 1 January 2018, of which 0.2 Swiss cents per kWh are reserved for this support mechanism. The maximum support for each kWh produced by large hydro is limited at 1 Swiss cent per kWh. The SFOE is in charge of administering the payouts of the market premium and the setting and verification of eligibility criteria,

Non-financial framework conditions for renewable electricity

Under the Swiss federal system, cantons and local authorities control the spatial planning and therewith the most important part of the permitting process for renewable facilities. However, the federal government elaborates, in close collaboration with the cantons and communes, spatial development concepts and sectoral plans for infrastructure of national importance, to co-ordinate and harmonise the cantonal plans. Some federal authorities are also involved, as they issue specific federal permits or advisory opinions.

An important feature of the ES 2050 is a change in the law that places the use and continued expansion of renewable energy on par with nature, landscape and heritage protection as being of national interest (see Box 9.1). This includes pumped hydro facilities. Hence, the cantons are now required to balance the different interests when giving permissions for large hydro and wind projects. However, biotopes of national importance and certain nature reserves within Switzerland continue to be excluded for the installation of new renewable facilities.

The ES 2050 also aims to streamline the licensing procedures for renewable energy. Cantons must now try to speed up licensing processes at the cantonal level, and the federal government must set up a single point of contact in charge of the co-ordination of all procedures at the federal level. Official time limits for approval procedures at the federal level were also introduced to accelerate these processes.

Box 9.1 Obstacles to accelerated hydro and wind power development

Hydropower and wind power are controversial topics in Switzerland, and public acceptance remains an issue. Small hydro projects below 1 MW capacity have now been banned by the ES 2050 from receiving public support, due to environmental impact. There are exceptions, but they are limited to specific project circumstances.

Discussion on the expansion and construction of new large hydro projects is also intense. The capacity increase of one hydro plant, which would account for 20% of the total additional hydro capacity, has been held up by several years due to public opposition. The Swiss Supreme Court eventually ruled in favour of the project in April 2017. It is likely that future constructions will face similar issues.

The potential for wind power is limited by the country's mountainous topography. There are some excellent wind sites, but they are located in only a few regions. In 2016, a total of 37 wind power plants at ten locations produced around 140 gigawatt hours (GWh) of electricity.

While the Swiss population is, in principle, supportive of wind power, there is local opposition to their construction once sites have been identified, with concerns for landscape, tourism, noise pollution and bird protection. Public opposition is well organised and has successfully prevented several large wind projects from progressing. Delays with obtaining permissions or the need to reduce the originally planned size of the installations have undermined the economic viability of some projects, which have been abandoned by project promoters.

No additional siting for new wind installations has been approved since 2012; expansion of existing facilities has been pursued instead. Just three new wind installations have become operational since 2015. There is an extensive project at the advanced planning stage, but it has been delayed due to institutional and approval issues.

Wind power is expected to increase to 1 760 GWh by 2035 and 4 300 GWh by 2050 (compared to 140 GWh in 2016) under the ES 2050. This is to be reached through the construction of 600-800 turbines. The SFOE introduced a new tool, the so-called "wind energy concept", in 2017. This tool identifies areas that may be suitable for wind developments, designates authorities to be involved in the early planning stages, specifies procedures and helps to integrate the spatial plans of the cantons. The SFOE has also established a dedicated one-stop window for wind energy questions, to serve permitting authorities and project developers.

The government will need to carefully monitor the future development of hydro and wind projects and be prepared to undertake corrective actions if it becomes evident that power installations will not meet the indicative targets set in the ES 2050.

Source: IEA based on information provided by the Swiss Federal Office for Energy.

Regulations for prosumers are being expanded to allow for aggregation of prosumers that are using the same meter point to connect with the distribution system operator. They can now form a micro-grid community and trade electricity among themselves.

Since 2013, all electricity generators of more than 30 kW have had to register in the GoO system and obtain a certificate for electricity produced. Smaller installations, mainly PVs, may also register. About 18% of electricity sold to end users remains of unknown origin. The new Energy Law mandates full disclosure on the electricity bill, prohibiting declarations of unknown origin.

Each utility or trader supplying end consumers will have to provide electricity based on the GoO, which has to be purchased on the GoO market. A substitute GoO can be produced for supply contracts from foreign plants. This is necessary because Switzerland now requires GoOs for all electricity and not only for renewables, as required under European standards. Hence, bilateral agreements on mutual recognition of GoOs have been concluded with Germany, France, Austria and Norway.

Renewable heat

Swiss cantons are leading the expansion of renewable heat in the building sector through their authority on setting buildings regulations. They agreed on “cantonal model prescriptions” in 2008. These set a target of 20% renewable heat in new residential buildings. Revised model prescriptions entered into force in 2015, extending the requirement for a renewable heating share to the replacement of existing oil and gas heating systems. Non-renewable heating may not account for more than 90% of heating demand. The residential sector is one of the largest energy consumers in Switzerland, with 30% of the TFC in the country in 2016. Oil consumption in the sector is one of the highest among IEA member countries at 34% (in 2016, Switzerland had the third-highest share after Ireland and Luxembourg).

Fossil fuel heating systems (oil and gas) accounted for 63% of total heating systems in 2015, down from 67% in 2009, while the residential building stock increased by more than 5% over the same period. The share of oil-fired heating systems declined from 52% to 47%, while gas-fired systems increased their share marginally from 15% to 16%. Continued investment in fossil fuel heating systems creates legacy assets for the next 15-30 years, as the annual turnover of existing fossil fuel heating systems is about 4%.

Among renewables, wood-based systems and heat pumps accounted for 12% each of the total stock in 2015. Heat pumps have the largest market share of newly installed heating systems (in units) at around 18 500 systems sold annually since 2014. The KliK Foundation has funded the expansion of district heating systems based on wood as part of the offset obligation programme for fossil fuel importers since 2013. While growing noticeably since then, their share remains small at 2%, as the main fuel for district heating is municipal solid waste.

Funding support for renewable heat in buildings primarily comes from the carbon dioxide (CO_2) tax on stationary fuels, with co-financing by cantons. These revenues are partly re-channelled to households under the building refurbishment programme, for the replacement of heating systems based on fossil fuels by renewable energy technologies. The funding is available according to the harmonised funding model, which requires participating cantons to supply half the funding.

A total of CHF 390 million was provided for renewable heating systems in the domestic sector from 2010 to 2014. An evaluation of the programme showed that results did not live up to expectations, achieving about half of the expected outcomes. There are multiple reasons for this, including insufficient cantonal funding to match federal funds and lack of skilled labour to undertake the work (see Chapter 7, “Energy and Climate”).

Renewable energy in transport

Switzerland has set neither a blending mandate for biofuels, nor a target for the share of renewables in transport. The country has strict legislation for sustainability criteria for biofuels, exceeding comparable European Union (EU) standards. Mineral oil tax exemption applies to biofuels from waste that qualify as second-generation biofuels, rather than from energy crops. Biofuels are therefore expensive. Their exemption from the mineral oil tax since 2008 has not resulted in a notable uptake in the transport sector.

A watershed for liquid biofuels was the introduction of a CO_2 offset obligation for transport fuel importers in 2013. They have grown substantially since then, by 380% between 2014 and 2016, albeit from a small base. The share of liquid biofuels among all transport fuels was 1.9% in 2016 (in volume terms).

The KliK Foundation, charged with implementing the offset obligation, has estimated the technical admixture potential of liquid biofuels at nearly 400 million litres (just above 6% of the total transport fuel consumption in 2016). This could reduce emissions in the transport sector annually by 1.0 million tonnes of carbon dioxide ($MtCO_2$), which is equivalent to about 6.4% of the total CO_2 emissions in the sector. KliK calculated that accumulated CO_2 savings from 2013 to the end of 2017 were about 817 000 tonnes. According to these data, the 180 million litres of biofuels sold in 2017 resulted in a CO_2 reduction of 0.45 $MtCO_2$, compared to the KliK target of 2.65 $MtCO_2$ savings for 2020 (KliK, 2018).

KliK is also preparing programmes to support biofuel uptake for heavy-duty vehicles, as well as the introduction of hybrid/electric buses, as part of compensation programmes.

The new CO_2 Law, under discussion in parliament, proposes not to extend the tax exemption for biofuels beyond 2020. However, the draft law foresees an extension of the extra charge on gasoline until 2028 and its extension to diesel. This extra charge, introduced to compensate for reduced tax revenues due to the biofuel exemption, is around 1.8 Swiss cents per litre and could possibly increase up to 7 Swiss cents per litre.

Biogas also benefits from mineral oil exemption. There is no blending mandate for biogas, like for liquid biofuels. However, a voluntary industry agreement with the government sets a minimum share of 10% biogas admixture to compressed natural gas (CNG) for vehicles. Almost 13 000 CNG vehicles were operating in Switzerland in 2016, 4% more than in 2015, and the average biogas admixture was 22.4%.

The uptake of biofuels and biogas is administratively challenging, with several different stakeholders and verification requirements. The Federal Office for the Environment (FOEN) supervises compliance of liquid biofuels with environmental and social requirements. The Directorate General of Customs, in co-operation with the FOEN and the State Secretariat for Economic Affairs, handles the mineral oil tax relief. The procedure for biogas is similarly complex. The Swiss Gas Industry Association operates the biogas registry on behalf of the Directorate General of Customs, to verify that only domestic biogas from waste is injected into the natural gas network.

At the same time, the draft CO_2 Law up to 2030 foresees to phase out the existing mineral oil exemption for biofuels after 2020. Instead, motor fuel importers would be mandated to offset 5% of CO_2 emissions from the transport sector by blending in renewable sources, including biofuels, biogas and synthetic fuels.

Assessment

The ES 2050 has set indicative targets for renewable electricity for 2035, which seem feasible with regard to the country's technical potential. Switzerland plans to produce 11 400 GWh per year from renewable sources excluding hydropower. Hydro production is to be maintained at 37 400 GWh of the annual average, to replace phased-out nuclear generation and to maintain a low-carbon electricity system. In 2016, non-hydro production was approximately 3.2 TWh (excluding non-renewable waste), and hydro produced 34.6 TWh.

The new Energy Law introduced a shift from FiTs to FiPs and increased the number of recipients of investment aid, which will give more incentives for market integration of renewable production. Market integration will be further supported by the requirement for producers to directly sell their renewable electricity generation to utilities or aggregators as of 2020.

The government has chosen not to organise competitive tenders for new capacity, given the small market size and limited number of potential bidders. Instead, it has assessed the costs of standard installations and set the level of the support programmes related to these installations. It should monitor the impact of the new programmes and ensure producers can directly market their electricity or have access to competitive aggregators.

The new Energy Law sets time limits for the new support measures. The last FiP contracts will be signed by the end of 2022, and those for investment aids by the end of 2030. These time limits could be problematic if renewable targets are not met. Some support programmes, such as the market premium for large hydro, although limited in time, may not be fully compliant with EU state aid rules. This could be an issue for the possible electricity agreement between Switzerland and the European Union.

The development of new renewable capacity will continue to be supported through a capped network surcharge. The funding will stabilise throughout the 2020s and then steeply decline once the sunset clauses for the various support measures become effective.

Hydropower is and will remain the most important renewable energy in the Swiss system. There is potential for optimising existing installations or equipping a few new sites. Investment aid will be available for capacity increases or substantial renovation, and the government will support the most efficient ones. Investment aid for renovation is granted to ensure that existing capacities needing refurbishment are not opting to close down given the low market prices. If low electricity prices were to last into the future, the government would have to develop other measures, as the subsidy cap and sunset clauses will not allow support for all existing capacities that might need it.

Hydropower has been challenged by low wholesale electricity prices in Switzerland and the rest of Europe, the current low value of flexibility and the high royalty payments for water rights. Water royalties account for an average of 22% of the total hydro production cost. The ES 2050 introduced a temporary market premium for large hydropower plants, which will last until 2022.

The government has proposed to reform water royalties in the longer term. This appears to be a suitable orientation, which could be completed by also taking into account the profitability of each concession. Setting a heavy financial burden on carbon-free power generation generally contradicts the objective of limiting CO_2 emissions cost-effectively. The authorities should ensure royalties are set at a level that encourages investment in maintaining hydropower plants.

Solar power could contribute 11 000 GWh by 2050, about 20% of the expected electricity demand by 2050. It could therefore become an important part of new renewable electricity production. Solar power development will be promoted by the new regulations for prosumers and for microgrids (collective contiguous prosumers) that were introduced under the ES 2050, and the full disclosure of end-use electricity based on GoOs, which will create more opportunities for decentralised production. It will become necessary to remunerate grid injections from distributed generation according to the value of electricity at the time and location of injection. This will ensure that deployment contributes to minimising costs to all consumers. All customers would also need to contribute to network costs according to their use of the infrastructure, particularly during periods of maximum grid usage.

Expectations for wind power development must be considered within the limited site availability. Wind could still play a role and also contribute to security of supply in winter. FiPs were set at a high level compared to those in other countries, to encourage projects. A wind potential map has been published, and a wind energy concept was adopted to facilitate location choice and permitting procedures.

However, these procedures are still long and risky, especially given the many conflicts of (national) interests and the current low, but not always insurmountable, public acceptance of wind farms. This public acceptance could be a serious obstacle for pipeline projects to be able to benefit from the support programmes before they terminate. There is a risk that wind generation targets might not be met in time, even with the new institutional support programmes under the ES 2050. The government needs to consider specific support for the repowering of existing turbines and expansion of facilities on existing sides. This would help to expand wind power generation without requiring additional sites.

Renewables have been declared of national interest, which should make their permitting easier. However, the government needs to closely monitor the effects of this change and take additional measures if necessary, to secure procedures and improve acceptance. These measures could include more local public investment in the projects and enhanced activities to include local awareness.

Biomass for heating is supported, as it is exempt from the CO_2 tax. Its contribution is expected to increase, though probably not sizeably due to the limited feedstock available. Geothermal energy continues to qualify for exploration risk guarantees, but this has not been met by success so far. Hence, geothermal energy is unlikely to be important in the near future.

The waiting list for renewable power projects for subsidies is so long that many projects are unlikely to benefit from them in light of the sunset clauses and the capped annual funding. The government needs to consider options for a post-2022 support framework while closely monitoring annual capacity growth, to be able to take corrective measures if indicative targets are not met.

Renewable heat development is supported through the building refurbishment programme and by the standards set at the cantonal level that apply to new buildings. Just three cantons have introduced standards for building refurbishments so far. The creation of district heating systems based on wood promoted by the KliK Foundation also holds potential, but not on a large scale. The government proposal for the new CO_2 Law foresees the obligation for a renewable share of energy or an energy-efficient building envelope when replacing an existing fossil fuel heating system.

In the transport sector, advanced biofuels (including biogas) are indirectly supported by the obligation of transport fuel importers to compensate for part of the CO_2 emissions, as well as an exemption from the mineral oil tax. The planned increase of the obligation would allow for further decarbonisation of the transport sector, including a continuous increase of the share of biofuels.

Recommendations

The government of Switzerland should:

- ☐ Pursue its planned reform of the water royalties to make them adjustable to evolution of electricity prices and also to the profitability of each concession.
- ☐ Monitor closely the effects of the shift towards market-based support mechanisms to avoid unintentionally creating obstacles to meeting the renewable electricity generation targets and to assess the costs of the different technologies on a regular basis, to adapt the level of the support.
- ☐ Ensure a post-2022 framework is in place to encourage continued development of renewables, particularly wind and biomass.
- ☐ Encourage the development of new and re-powered renewable energy projects where they are environmentally and economically sound, by simplifying and legally securing the permitting procedure and improving public awareness and acceptance.

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10. Energy technology research, development and demonstration

Key data

(2016)

Government energy RD&D spending: CHF 397 million

Share of GDP: 0.051% (IEA median and average*: 0.030%)

RD&D per capita: CHF 47.4

Exchange rate: CHF 1 = EUR 0.85 = USD 1.00 (16 May 2018)

* Median and average of 24 IEA member countries for which 2016 data are available.

Overview

Switzerland is one of the highest-spending countries on energy research, development and demonstration (RD&D) among International Energy Agency (IEA) countries, ranking fifth in absolute terms. The accident at Japan's Fukushima Daiichi nuclear power plant triggered a substantial increase in public spending on energy research and a change in the allocation of expenditure. The government increased spending on RD&D for energy efficiency and renewable sources of energy (renewable energy), in line with the objectives of the Energy Strategy 2050 (ES 2050). The government also created a new structure, the Swiss Competence Centers for Energy Research (SCCER), to promote synergies within RD&D communities of various energy fields by clustering public and private research around priority research areas.

Switzerland is one of the most innovative countries in the world. It has the largest share of domestic scientific documents with a high citation impact within the Organisation for Economic Co-operation and Development (OECD), the largest share of doctorates among the working age population and the highest rate of inflow of foreign researchers. Benchmarking Swiss innovation using other metrics also reveals a highly efficient innovation system. Switzerland is first in the European Union's Innovation Union Scoreboard, and ranks first globally in terms of number of patents per capita.

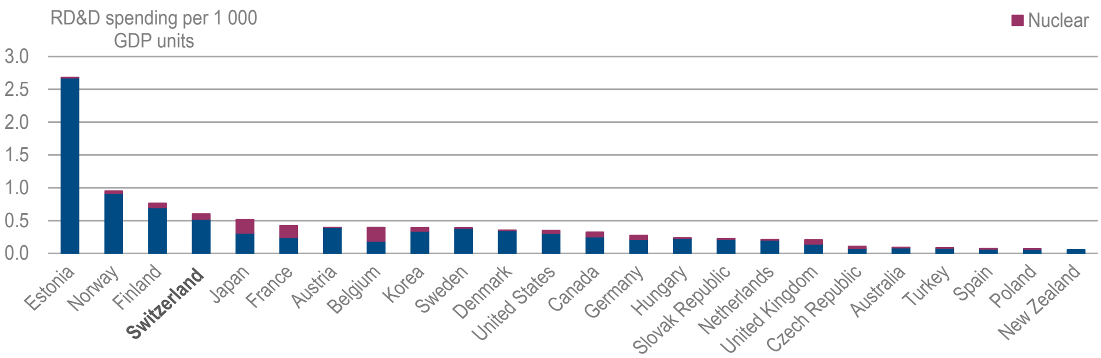
Public energy RD&D spending

Only two other OECD countries (South Korea and Israel[1]) spend more on RD&D activities across the economy per unit of gross domestic product (GDP) (OECD, 2018) than Switzerland. The country also spends one of the highest shares of GDP of energy-related RD&D among IEA member countries, albeit a significantly lower one than the top-ranking country – Estonia (see Figure 10.1). In 2017, energy RD&D in Switzerland amounted to CHF 403 million (Swiss francs), which is a similar level of spending as in 2016 (see Figure 10.2).

A key development since the 2012 in-depth review is a marked increase in public RD&D spending. Energy RD&D spending stood at CHF 234 million in 2011. Following the Fukushima Daiichi nuclear accident, an Action Plan for a Coordinated Swiss Energy Research was launched by the Swiss parliament. This allocated an increase of CHF 202 million between 2013 and 2016 and additionally CHF 139 million for the period 2017-20. It also led to the launch of other initiatives, which, on aggregate, have increased the annual RD&D budget by 65% since 2011.

Focus areas have also shifted. Spending on energy efficiency RD&D more than doubled between 2011 and 2017, and spending on renewables increased by 78%. These two areas together now account for 54.2% total RD&D spending. Nuclear energy RD&D investment has remained flat in real terms, accounting for 12.9% of the total funds in 2017. The largest increase have been electricity sector technologies such as power transmission and distribution and energy storage, which has grown more than threefold since 2011, and accounted for 14.2% of the total spending in 2017. Other cross-cutting technologies (8.8%), hydrogen and fuel cells (7.4%), and fossil fuels (2.5%) comprised the remainder of the RD&D volume in 2017 (see Figure 10.2).

Figure 10.1 Government energy RD&D spending as a ratio of GDP in IEA member countries, 2016



Note: Data are not available for Greece, Ireland, Italy, Luxembourg, Mexico and Portugal.
Source: IEA (2018), *IEA Energy Technology RD&D Budgets* (database), www.iea.org/statistics/.

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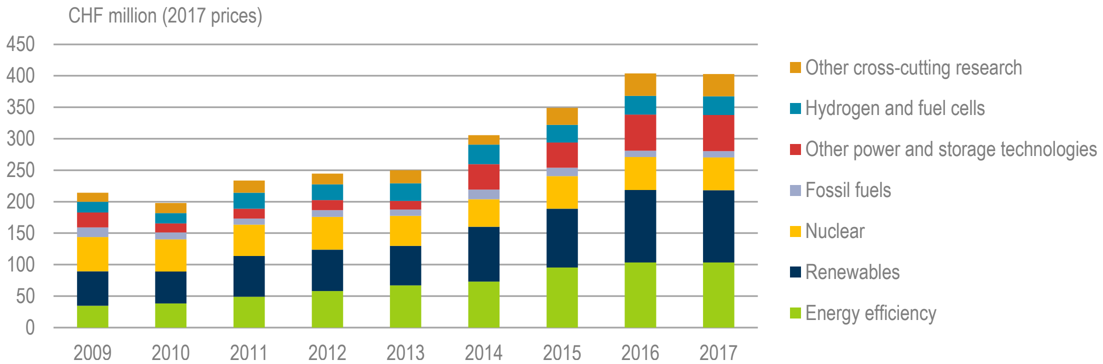
[1] *The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.*

Figure 10.2 Public energy RD&D spending by category, 2009-17



Note: 2017 data are estimates.

Source: IEA (2018), *IEA Energy Technology RD&D Budgets 2018* (database), www.iea.org/statistics/.

Energy RD&D policies and programmes

Planning for RD&D activities is carried out at the federal level in Switzerland. The Federal Energy Research Masterplan, developed by the Federal Energy Research Commission (CORE) every four years and implemented by the Swiss Federal Office of Energy (SFOE), serves as the blueprint for all public-sector RD&D activities. The masterplan includes the aims and areas of focus of public research. However, there are weak formal links between the ES 2050 and the RD&D priority-setting processes, as Swiss RD&D activities follow a strong philosophy of academic freedom of public RD&D. The Swiss Federal Institutes of Technology, which account for 42% of energy research, are not bound by the priorities in the masterplan.

CORE comprises a mix of stakeholders, including industry, small and medium-sized enterprises (SMEs), federal institutes of technology, universities of applied sciences, cantons and associations. CORE also includes observers from the Swiss National Science Foundation, the Commission for Technology and Innovation (CTI) and other federal offices (see Figure 10.3).

The shift in RD&D priority areas since the increase in funding after 2011 has largely been gradual. The allocation of this increase has led to a change in priorities since the previous in-depth review towards energy efficiency focused on residential and commercial building efficiency and renewables. Together with power grids and storage, these account for 87% of the increase in spending. While nuclear RD&D activity has remained stable, half of all activity continues to focus on fusion power, reflecting the strong Swiss capabilities in this area.

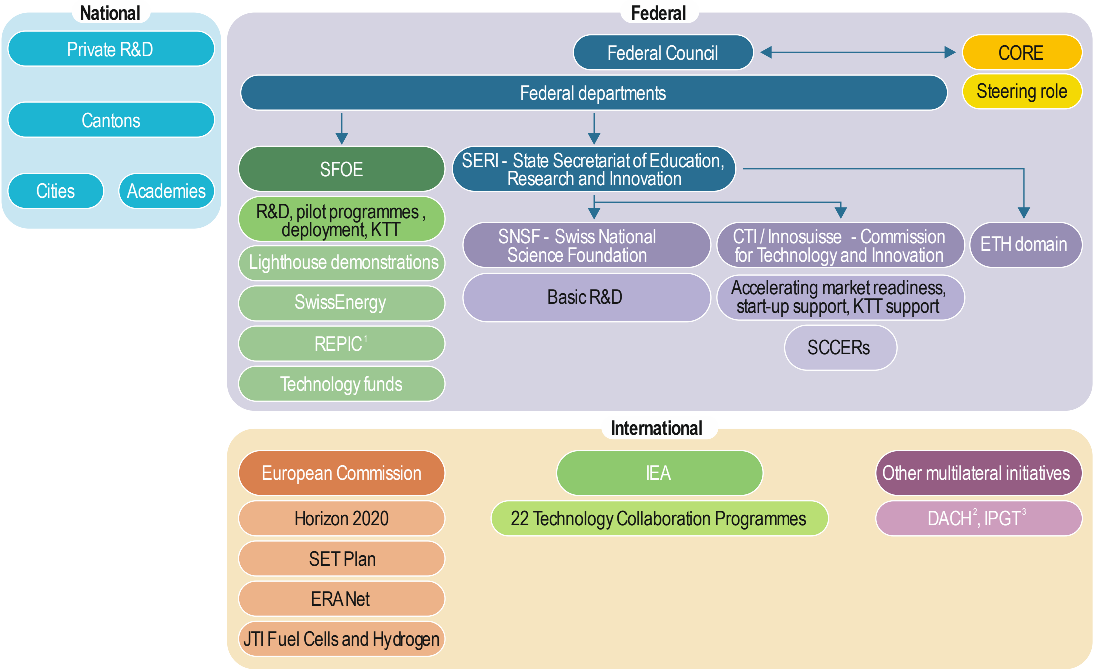
The SFOE co-ordinates RD&D activities and also runs its own RD&D programmes, amounting to 11% of RD&D spending. Two-thirds of this funding is directed towards pilot and demonstration projects and a Lighthouse programme to promote exemplary flagship projects, funding for which is allocated until 2020. The Lighthouse programme has selected key flagships in the fields of advanced building refurbishments and zero carbon buildings, smart metering infrastructure and public transport.

The CTI, superseded from 1 January 2018 by a new agency, Innosuisse, was the main actor in promoting projects closer to the final stages of the innovation chain. Innosuisse lends support to RD&D projects, to entrepreneurs in SMEs and to start-ups in collaboration with public-sector research institutions. It also helps to optimise knowledge and technology transfer using thematic and regional networks and platforms. The energy-related activities of CTI have accounted for 13% of all energy RD&D spending. The SFOE historically participated in CTI project evaluations, but there is no formal link with Innosuisse at present.

SwissEnergy is a long-standing programme supporting innovative projects that promote communication, information, counselling or training and education measures. Its purpose has been reinforced to help achieve the objectives in the ES 2050 through the adoption of a new concept for the period from 2017 to 2020, focusing on eight thematic areas including renewables, mobility, electrical appliances, industry and services, and buildings, with a strong focus on the promotion of renewable energy and energy efficiency.

The 2017-20 Federal Energy Research Masterplan establishes the main policy guidelines for federal RD&D activity, and serves as orientation for cantons and municipalities (CORE, 2015). The masterplan identifies four high-level thematic areas: living and working in the future, mobility of the future, energy systems of the future and processes of the future.

Figure 10.3 Swiss RD&D institutional framework



Note: DACH = Germany, Austria and Switzerland; ERA Net = European Research Area-Network; IPGT = International Partnership for Geothermal Technology; JTI = Joint Technology Initiative; KTT = Knowledge and Technology Transfer; REPIC = Renewable Energy and Energy Efficiency Promotion in International Cooperation ; R&D = research and development; SET = Strategic Energy Technology.

The areas of research highlighted by CORE in the masterplan reflect many of the challenges of achieving the objectives in the ES 2050. Priority setting reflects the indicative target of the ES 2050 of reaching 1.0-1.5 tonnes of carbon dioxide per capita by 2050 (see Chapter 2, “General Energy Policy”).

RD&D policy in Switzerland is underpinned by a strong “bottom-up” principle of academic independence, whereby public institutions do not readily dictate the areas and programmes that are eligible for public support. Switzerland devotes the highest financial support within the OECD to non-thematic research (OECD, 2018). Switzerland's policy framework is also unique within the OECD in that it does not offer explicit tax concessions for RD&D and innovation at the federal level. This is typically used as a tool to accelerate private-sector RD&D investment.

RD&D policy is therefore focused on project evaluation and open competition, in stark contrast with other countries. The role of public RD&D support in Swiss innovation policy is one of providing enabling and competitive conditions for firms and public agents, rather than a public RD&D strategy focused on specialised public institutes and programmes. Co-operation with the private sector is encouraged through voluntary collaboration. The bottom-up approach to RD&D also reflects a leading role given to universities, with the ETH domain[2] accounting for 42% of RD&D promotion in 2016.

The Action Plan for a Coordinated Swiss Energy Research identified seven key priority areas, which were then used as the basis for the creation of eight SCCERs funded by CTI. The eight SCCER areas of expertise are biomass, socio-economy, industrial processes, buildings and districts, grids, storage, mobility and electricity supply. Within their general area, research priorities are set by the SCCERs themselves, without overarching guidance except for high-level observation from a high-level committee. Two national research programmes were launched under the Swiss National Science Foundation, in parallel with the SCCERs: Energy Turnaround and Managing Energy Consumption.

Each SCCER has a requirement to produce an innovation roadmap detailing main activities and expected innovation timelines. These innovation roadmaps have to be approved by an evaluation panel, established by the CTI. The relevance and quality of the information in these innovation roadmaps is highly variable, and there is room for professionalising knowledge and technology transfer activities. The SCCERs, the growth in RD&D spending and capabilities, and the evaluation requirements have posed increased challenges to co-ordination of innovation activities by the SFOE since 2013.

A central function of the SCCERs was to ramp up innovation capacities in the earlier stages of the RD&D value chain. They have exceeded their targets in terms of research capacity building through sponsored research positions, according to several metrics. They have also contributed to creating strong links among actors. From 2020, universities and applied research institutes are expected to take over the capacities built up by the SCCER programme.

Beyond these initiatives, a large proportion of energy technology innovation is hosted and co-ordinated by the ETH domain on a non-thematic or non-programmatic basis. An ETH board determines the strategic direction and allocates funding. ETH Zurich and its counterpart in Lausanne, École Polytechnique fédérale de Lausanne, are consistently ranked among the top 10 and top 30 universities in the world.

Innovation towards the final stages of the RD&D chain, an area often needing strengthening in national innovation strategies, was explicitly co-ordinated in the past by

[2] The ETH domain is a national network of six technical universities and research institutions under the jurisdiction of the Federal Department of Economic Affairs, Education and Research.

the CTI and will be co-ordinated by Innosuisse in the future. Innosuisse offers extensive training and coaching for startups, as well as market evaluation and entry strategy workshops for Swiss startups looking to enter foreign markets. Beyond this area, the strong principle of Swiss subsidiary of public-sector activities within the private-sector domain has precluded further innovation policy intervention.

International co-operation

International co-operation and efficient implementation of public research findings remain high priorities of the Swiss government. The SFOE supervises participation in international RD&D activities, which remains strong. Switzerland has an important role in the European Research Area Networks Co-fund action and the European Research Area-Net initiatives. After a period where membership was suspended, Switzerland has once again been a full member of the European Horizon 2020 programme since 2017.

Switzerland is a member of 21 out of 38 IEA Technology Collaboration Programmes (TCPs), and has a steering role in the following 3: Heat Pumping Technologies, Hybrid and Electric Vehicles, and Photovoltaic Power Systems. Co-ordination of international collaboration activities is an increasing challenge for the SFOE as the number of projects and activities increases, including participation in TCPs (see Table 10.1) and other international collaborative activities.

Table 10.1 Participation of Switzerland in IEA TCPs, 2018

End-use technologies	Renewable energy and hydrogen
Buildings	Bioenergy
Buildings and Communities	Concentrated Solar Power
Energy Efficient End-use Equipment	Geothermal Energy
Energy Storage	Hydrogen
Heat Pumping Technologies	Photovoltaic Power Systems
Electricity	Solar Heating and Cooling
Demand-side Management	Wind Energy
High-Temperature Superconductivity	
Smart Grids	**Fossil fuels**
Transport	Gas and Oil
Advanced Fuel Cells	Greenhouse Gas R&D
Advanced Motor Fuels	
Clean and Efficient Combustion	**Cross-cutting**
Hybrid and Electric Vehicles	Energy Technology Systems Analysis

Assessment

The 2012 in-depth review of Switzerland recommended that the Swiss government maintain plans to double public funding of energy RD&D. The level of funding increased to CHF 397 million in 2016 from CHF 200 million in 2010, and the IEA encourages Switzerland to maintain the current level. Given the capabilities of the Swiss innovation system, the objective of doubling public RD&D budgets, in line with international efforts including Mission Innovation, should be considered.

Innovation policy in Switzerland follows the bottom-up concept of academic independence, where areas of research and projects are expected to emerge from firms and research groups competing for public funds. The concept has been an integral component of an innovation system with world-leading capacities to reap economic and societal gains from RD&D activities, although the model is not common in other countries.

However, a balance between a directive industrial policy and an innovation policy limited to creating suitable framework conditions should be found, also highlighted by CORE. There is little thematic guidance when evaluating the merits of an individual project, which could potentially lead to lower returns for the Swiss society from innovation activity occurring. This is particularly the case in areas where the rest of the innovation chain is less supported and where it may not align to the energy direction the Swiss society has set itself. Energy research should make a core contribution to implementing and achieving the objectives of the ES 2050.

Innovation roadmapping and scenario-building capabilities should therefore be strengthened. The SCCER roadmaps in their current form are not readily implementable, and there is a strong potential to improve their actionability as identified by CORE.

The research areas identified by CORE under the four themes of the masterplan are well aligned with energy policy objectives. They could benefit from an explicit association with the ES 2050 by linking the energy perspective scenarios under the ES 2050 and RD&D roadmapping work to identifying targets and metrics for technology development to 2050.

The focus on creating enabling frameworks presents enduring challenges to ensure co-ordination of research activities. The SCCERs have been an important and positive step to address this, as they explicitly promote co-operation among the ETH domain, institutes, universities of applied sciences and industry, and they support knowledge and technology transfer. Current funding is due to be phased out by 2020, and there is uncertainty over future funding streams and continuity of the SCCERs.

Clarity and expediency on the decision to continue the SCCER programme is needed to ensure built-up capacities are not rolled back. Following the current expansion plan of the SCCERs for 2017-20, continuity of the expanded capacities beyond 2020 will be necessary to give visibility to research teams and institutions and to ensure the levels of co-ordination reached are not lost.

Continuity of co-ordination should be ensured as Innosuisse replaced CTI. As the SFOE and Innosuisse are not formally linked, enhanced co-ordination within their complementary areas of activity is strongly recommended, to avoid overlap and exploitation synergies. Co-ordination of international collaboration efforts by the SFOE at the European level through Horizon 2020 and European Research Area-Net, including participation in IEA TCPs, is a related challenge that will require continued resources and staff support within the SFOE.

Funding for demonstration and pilot projects, including the Lighthouse programme, has yielded positive results and should not be curtailed. However, there is an increasing need to align thematic areas for demonstration with the targets of the ES 2050. For instance, as CORE has identified, the ES 2050 calls for strong growth in geothermal electricity generation (from no substantial capacities today), but there is a lack of corresponding innovation support for demonstration or assessment.

Nuclear energy research and development has remained stable. Innovation capacities should be maintained and realigned in this area, to support the phase-out from nuclear power. Research should be guided towards activities that facilitate the evaluation and execution of decommissioning nuclear plants and processing and storing nuclear waste.

Regional and local priorities are weakly embedded in RD&D activities. There is a cantonal representative in CORE, but no formal links for incorporating cantonal energy RD&D priorities, resources or capabilities into federal ones. Some innovations would greatly benefit from a greater co-ordination between local and federal innovation activities. These include innovations related to energy networks such as electric mobility, heat and fuel delivery and smart grids, as well as decentralised energy business models.

Adequate funding and a well-co-ordinated enabling framework for innovation are key to ensuring a technology push. However, there is an overarching need to align research priorities with regulatory frameworks for deployment of innovative technologies to facilitate market pull. For instance, the focus on shared and electric transportation in the mobility sub-areas of research in the RD&D masterplan and the ES 2050 should be followed by deployment of re-charging infrastructure and deployment strategies for electric mobility. This also includes creating favourable regulatory environments for demand-side flexibility, cross-sector coupling or decentralised energy resources, which will be necessary to ensure funding translates to positive returns on the high levels of investment in innovation.

Digitalisation of the energy sector is another area where stronger thematic guidance could be necessary. Switzerland is poised to benefit from another industrial revolution, given the innovation capacities in this area. However, the lack of a comprehensive data strategy is slowing the deployment of innovative business models that benefit from digitalisation, including forms of demand aggregation, integrated retail services or virtual power plants. Roadmapping the deployment of smart grid and digital infrastructure, and clearly articulating the roles and responsibilities in the ownership and management of energy sector data, could accelerate innovation activity in this area.

Recommendations

The government of Switzerland should:

- ☐ Maintain public RD&D financing at the current level.
- ☐ Strengthen links among RD&D activities, and establish a formal framework for monitoring these links.
- ☐ Establish a formal connection between the ES 2050 and RD&D activities and re-balance long-term strategic RD&D priorities accordingly, by continuing the SCCER model beyond 2020.
- ☐ Improve co-ordination between federal RD&D priorities and those of cantonal governments, and encourage the scalability of localised and transferable innovations that might face barriers to knowledge transfer.

References

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OECD (2018), *Gross domestic spending on R&D*, https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm.

Federal Energy Research Commission (CORE) (2015), *Federal Energy Research Masterplan for the period from 2017 to 2020*, Bern.

ANNEX A: Review team and 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 in-depth reviews conducted by the IEA. The Shared Goals are presented in Annex C.

Review team

The in-depth review team visited Switzerland from 13 to 17 November 2017. The review team met with government officials, energy suppliers, market participants, interest groups, consumer representatives, research institutions, other organisations and stakeholders. The report was drafted on the basis of the information obtained in these meetings, the team's preliminary assessment of Switzerland's energy policy, the Swiss government's response 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

Mr Stuart Richardson, Australia (team leader)

Ms Manuela Fonseca, Portugal

Mr Joseph Hajjar, France

Mr David Henderson, Nuclear Energy Agency

Ms Stephaine Ockenden, United Kingdom

Mr Colm Ó Conaill, Ireland

Mr Matti Supponen, European Union

International Energy Agency

Mr Aad van Bohemen

Mr Luis Munuera

Ms Dagmar Graczyk (senior country analyst)

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

The team expresses its gratitude to Mr Benoît Revaz, Director, Swiss Federal Office of Energy, Federal Department of Environment, Transport, Energy and Communications, for his personal engagement in the meetings and for hosting the visit. The team is also grateful to Ambassador Jean-Christoph Füg, Head, International Energy Affairs, Swiss Federal Office of Energy, and Dr Lukas Gutzwiller, Energy Policy Expert, Swiss Federal Office of Energy, for their efforts and professionalism in planning and organising the review visit and their patience and diligence in supporting the team throughout the review process. Special thanks also to Ms Brigitte Mischler and Ms Fabienne Thomann of the Swiss Federal Office of Energy for their invaluable logistical support.

The review was prepared under the guidance of Mr Aad van Bohemen, Head of the Energy Policy and Security Division, IEA. Ms Dagmar Graczyk managed the review and is the author of the report, with the exceptions of the chapters on nuclear energy and energy technology research, development and demonstration. Mr David Henderson wrote the chapter on nuclear energy. Mr Luis Munuera wrote the chapter on energy technology research, development and demonstration. Ms Selena Jihyun Lee provided substantial input for the chapter on general energy policy.

Mr Oskar Kvarnstrom and Ms Selena Jihyun Lee prepared and drafted the sections relating to energy data contained in each chapter. Helpful comments, chapter reviews and updates were provided by the following IEA staff: Mr. Sean Calvert, Mr Peter Fraser, Ms Rebecca Gaghen, Ms Diana Louis, Mr Jeremy Sung, Mr Lazlo Varro and Mr Matthew Wittenstein.

Special thanks to the IEA Secretariat with regard to the data, publication and editing. Mr Oskar Kvarnstrom, Ms Selena Jihyun Lee and Mr Bertrand Sadin ensured the preparation of the design of the report with figures, tables and maps. Ms Roberta Quadrelli and Mr Rémi Gigoux provided support on statistics. Ms Therese Walsh managed the editing process, and Ms Muriel Custodio and Ms Astrid Dumond managed the production process. Ms Merve Erdem and Mr. Jad Mouwad ensured the press launch.

Organisations visited

Agence Cleantech (ACT)

Alpiq

AXPO

BKW

Competition Commission (Comco)

CORE (Swiss Federal Energy Research Commission)

Dachverband Schweizer Verteilnetzbetreiber (Association of Small Distribution System Operators)

Economiesuisse (Confederation of Swiss Industries)

Eidgenössische Elektrizitätskommission (ElCom Energy Regulator)

EnAW (Energy Agency of the Economy)

EnDK (Conference of Cantonal Energy Directors)

Energiestiftung Schweiz

Erdölvereinigung (Swiss Oil Industry Association)

InteressenGemeinschaft Energieintensive Branchen (Association of Energy Intensive Industries)

KLiK Foundation (Stiftung Klimaschutz)

KTI (Swiss Commission for Technology and Innovation)

Landschaftsschutzverband (SL-FP)

Nagra (National Cooperative for Disposal of Radioactive Waste)

Schweizer Energiestiftung

STENFO (Decommissioning Fund for Nuclear Facilities and Waste Disposal Fund for Nuclear Power Plants)

Swiss Competence Centers for Energy Research

Swiss Federal Office of Energy

Swiss Federal Office of the Environment

Swissgrid (transmission system operator)

Swisspower

Verband der Schweizerischen Gasindustrie (Swiss Gas Industry Association)

Verband Schweizerischer Elektrizitätsunternehmen (Swiss Electricity Industry Association)

World Wide Fund for Nature

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2015	2016	2017E
TOTAL PRODUCTION		**4.28**	**10.29**	**12.02**	**12.63**	**12.22**	**11.60**	**11.41**
Coal		-	-	-	-	-	-	-
Peat		-	-	-	-	-	-	-
Oil		-	-	-	0.00	-	-	-
Natural gas		-	0.00	-	-	-	-	-
Biofuels and w aste[1]		0.24	1.48	1.82	2.33	2.38	2.52	2.53
Nuclear		1.64	6.18	6.92	6.89	6.04	5.54	5.34
Hydro		2.40	2.56	3.17	3.10	3.29	2.98	2.93
Wind		-	-	-	0.00	0.01	0.01	0.01
Geothermal		-	0.07	0.10	0.26	0.34	0.38	0.40
Solar/other[2]		-	0.00	0.02	0.05	0.16	0.18	0.20
TOTAL NET IMPORTS[3]		**14.41**	**13.95**	**12.57**	**13.53**	**11.95**	**12.37**	**12.49**
Coal	Exports	0.02	0.01	-	-	-	-	-
	Imports	0.24	0.35	0.19	0.13	0.13	0.11	0.11
	Net imports	0.22	0.34	0.19	0.13	0.13	0.11	0.11
Oil	Exports	0.23	0.16	0.64	0.40	0.42	0.47	0.37
	Imports	15.24	13.35	12.74	12.14	11.01	10.99	10.83
	Int'l marine and aviation bunkers	-0.67	-1.03	-1.55	-1.41	-1.63	-1.70	-1.73
	Net imports	14.34	12.16	10.56	10.33	8.97	8.81	8.73
Natural Gas	Exports	-	-	-	-	-	-	-
	Imports	0.15	1.63	2.43	3.01	2.85	3.00	3.01
	Net imports	0.15	1.63	2.43	3.01	2.85	3.00	3.01
Electricity	Exports	0.90	1.97	2.70	2.83	3.02	2.59	2.66
	Imports	0.60	1.79	2.09	2.87	2.93	2.93	3.14
	Net imports	-0.30	-0.18	-0.61	0.05	-0.09	0.34	0.48
TOTAL STOCK CHANGES		**0.22**	**0.11**	**0.42**	**0.04**	**0.36**	**-0.07**	**0.14**
TOTAL SUPPLY (TPES)[4]		**18.91**	**24.36**	**25.01**	**26.20**	**24.53**	**23.90**	**24.04**
Coal		0.33	0.36	0.14	0.15	0.13	0.11	0.11
Peat		-	-	-	-	-	-	-
Oil		14.45	12.26	11.03	10.35	9.33	8.75	8.87
Natural gas		0.15	1.63	2.43	3.01	2.85	3.00	3.01
Biofuels and w aste[1]		0.24	1.48	1.82	2.34	2.46	2.62	2.69
Nuclear		1.64	6.18	6.92	6.89	6.04	5.54	5.34
Hydro		2.40	2.56	3.17	3.10	3.29	2.98	2.93
Wind		-	-	-	0.00	0.01	0.01	0.01
Geothermal		-	0.07	0.10	0.26	0.34	0.38	0.40
Solar/other[2]		-	0.00	0.02	0.05	0.16	0.18	0.20
Electricity trade[5]		-0.30	-0.18	-0.61	0.05	-0.09	0.34	0.48
Shares in TPES (%)								
Coal		*1.7*	*1.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.5*
Peat		-	-	-	-	-	-	-
Oil		*76.4*	*50.3*	*44.1*	*39.5*	*38.0*	*36.6*	*36.9*
Natural gas		*0.8*	*6.7*	*9.7*	*11.5*	*11.6*	*12.5*	*12.5*
Biofuels and waste [1]		*1.3*	*6.1*	*7.3*	*8.9*	*10.0*	*11.0*	*11.2*
Nuclear		*8.7*	*25.4*	*27.7*	*26.3*	*24.6*	*23.2*	*22.2*
Hydro		*12.7*	*10.5*	*12.7*	*11.8*	*13.4*	*12.5*	*12.2*
Wind		-	-	-	-	-	-	-
Geothermal		-	*0.3*	*0.4*	*1.0*	*1.4*	*1.6*	*1.7*
Solar/other [2]		-	*0.0*	*0.1*	*0.2*	*0.6*	*0.7*	*0.8*
Electricity trade [5]		*-1.6*	*-0.7*	*-2.4*	*0.2*	*-0.4*	*1.4*	*2.0*

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
TFC	**16.67**	**18.31**	**19.37**	**20.79**	**18.93**	**19.20**	**..**
Coal	0.42	0.35	0.14	0.15	0.13	0.11	..
Peat	-	-	-	-	-	-	..
Oil	13.41	11.26	11.11	10.77	9.04	9.04	..
Natural gas	0.11	1.39	2.13	2.69	2.67	2.79	..
Biofuels and waste[1]	0.24	0.91	0.97	1.26	1.23	1.33	..
Geothermal	-	0.07	0.10	0.26	0.34	0.38	..
Solar/other[2]	-	0.00	0.01	0.04	0.06	0.06	..
Electricity	2.49	4.01	4.50	5.14	5.01	5.01	..
Heat	-	0.33	0.40	0.49	0.45	0.48	..
Shares in TFC (%)							
Coal	*2.5*	*1.9*	*0.7*	*0.7*	*0.7*	*0.6*	..
Peat	-	-	-	-	-	-	..
Oil	*80.4*	*61.5*	*57.4*	*51.8*	*47.7*	*47.1*	..
Natural gas	*0.7*	*7.6*	*11.0*	*12.9*	*14.1*	*14.5*	..
Biofuels and waste [1]	*1.5*	*4.9*	*5.0*	*6.1*	*6.5*	*6.9*	..
Geothermal	-	*0.4*	*0.5*	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	..
Electricity	*15.0*	*21.9*	*23.2*	*24.7*	*26.5*	*26.1*	..
Heat	-	*1.8*	*2.1*	*2.4*	*2.4*	*2.5*	..
TOTAL INDUSTRY[6]	**4.74**	**4.03**	**4.33**	**4.41**	**4.07**	**4.04**	**..**
Coal	0.11	0.31	0.11	0.14	0.12	0.11	..
Peat	-	-	-	-	-	-	..
Oil	3.67	1.54	1.34	1.10	0.81	0.77	..
Natural gas	0.01	0.43	0.73	0.89	0.93	0.95	..
Biofuels and waste[1]	-	0.20	0.42	0.42	0.46	0.48	..
Geothermal	-	0.01	0.01	0.02	0.03	0.03	..
Solar/other[2]	-	-	-	0.00	0.00	0.00	..
Electricity	0.95	1.48	1.56	1.66	1.55	1.53	..
Heat	-	0.06	0.17	0.18	0.17	0.17	..
Shares in total industry (%)							
Coal	*2.4*	*7.7*	*2.6*	*3.2*	*3.0*	*2.7*	..
Peat	-	-	-	-	-	-	..
Oil	*77.3*	*38.3*	*31.0*	*24.9*	*19.9*	*19.0*	..
Natural gas	*0.3*	*10.6*	*16.8*	*20.2*	*22.9*	*23.5*	..
Biofuels and waste [1]	-	*5.0*	*9.7*	*9.6*	*11.2*	*12.0*	..
Geothermal	-	*0.1*	*0.2*	*0.4*	*0.6*	*0.7*	..
Solar/other [2]	-	-	-	-	-	-	..
Electricity	*20.0*	*36.8*	*35.9*	*37.6*	*38.0*	*37.8*	..
Heat	-	*1.6*	*3.9*	*4.1*	*4.2*	*4.3*	..
TRANSPORT[4]	**3.54**	**5.16**	**5.84**	**6.04**	**5.72**	**5.69**	**..**
OTHER[7]	**8.39**	**9.13**	**9.20**	**10.34**	**9.14**	**9.47**	**..**
Coal	0.30	0.04	0.03	0.01	0.01	0.01	..
Peat	-	-	-	-	-	-	..
Oil	6.38	4.79	4.17	3.94	2.86	2.95	..
Natural gas	0.10	0.95	1.39	1.76	1.71	1.82	..
Biofuels and waste[1]	0.24	0.71	0.55	0.83	0.73	0.78	..
Geothermal	-	0.06	0.10	0.24	0.32	0.35	..
Solar/other[2]	-	0.00	0.01	0.03	0.06	0.06	..
Electricity	1.37	2.30	2.72	3.21	3.19	3.21	..
Heat	-	0.27	0.23	0.31	0.27	0.31	..
Shares in other (%)							
Coal	*3.6*	*0.5*	*0.3*	*0.1*	*0.1*	*0.1*	..
Peat	-	-	-	-	-	-	..
Oil	*76.0*	*52.5*	*45.3*	*38.1*	*31.3*	*31.1*	..
Natural gas	*1.1*	*10.4*	*15.1*	*17.1*	*18.7*	*19.2*	..
Biofuels and waste [1]	*2.9*	*7.7*	*6.0*	*8.0*	*8.0*	*8.2*	..
Geothermal	-	*0.7*	*1.0*	*0.0*	*0.0*	*0.0*	..
Solar/other [2]	-	-	*0.1*	*0.3*	*0.6*	*0.6*	..
Electricity	*16.3*	*25.2*	*29.6*	*31.1*	*34.9*	*33.8*	..
Heat	-	*3.0*	*2.5*	*3.0*	*3.0*	*3.3*	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	4.48	9.69	11.27	11.42	10.85	10.15	..
Output (Mtoe)	3.17	4.73	5.69	5.68	5.68	5.26	5.16
Output (TWh)	36.82	54.99	66.12	66.05	66.10	61.11	59.97
Output Shares (%)							
Coal	*-*	*0.1*	*-*	*-*	*-*	*-*	*-*
Peat	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Oil	*7.1*	*0.7*	*0.3*	*0.1*	*0.1*	*0.1*	*0.1*
Natural gas	*-*	*0.6*	*1.3*	*1.6*	*1.0*	*1.4*	*1.4*
Biofuels and waste [1]	*-*	*1.5*	*2.6*	*3.7*	*4.3*	*4.9*	*4.8*
Nuclear	*17.1*	*43.0*	*40.0*	*39.9*	*34.9*	*34.6*	*34.0*
Hydro	*75.8*	*54.2*	*55.7*	*54.6*	*57.9*	*56.7*	*56.8*
Wind	*-*	*-*	*-*	*0.1*	*0.2*	*0.2*	*0.2*
Geothermal	*-*	*-*	*-*	*-*	*-*	*-*	*-*
Solar/other [2]	*-*	*-*	*-*	*0.1*	*1.7*	*2.2*	*2.7*
TOTAL LOSSES	**2.26**	**5.38**	**6.07**	**6.23**	**5.54**	**5.18**	**..**
of which:							
Electricity and heat generation[9]	1.31	4.60	5.16	5.21	4.68	4.37	..
Other transformation	0.22	0.06	0.05	0.05	0.06	0.02	..
Own use and transmission/distribution losses[10]	0.73	0.73	0.86	0.97	0.81	0.79	..
Statistical Differences	**-0.02**	**0.67**	**-0.44**	**-0.82**	**0.06**	**-0.47**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2015**	**2016**	**2017E**
GDP (billion 2010 USD)	339.19	432.10	487.15	583.78	633.38	642.09	648.80
Population (millions)	6.44	6.80	7.25	7.86	8.28	8.37	8.45
TPES/GDP (toe/1000 USD)[11]	0.06	0.06	0.05	0.04	0.04	0.04	0.04
Energy production/TPES	0.23	0.42	0.48	0.48	0.50	0.49	0.47
Per capita TPES (toe/capita)	2.94	3.58	3.45	3.33	2.96	2.86	2.84
Oil supply/GDP (toe/1000 USD)[11]	0.04	0.03	0.02	0.02	0.01	0.01	0.01
TFC/GDP (toe/1000 USD)[11]	0.05	0.04	0.04	0.04	0.03	0.03	..
Per capita TFC (toe/capita)	2.59	2.69	2.67	2.65	2.29	2.29	..
CO_2 emissions from fuel combustion ($MtCO_2$)[12]	43.0	40.7	42.0	43.3	37.3	37.9	..
CO_2 emissions from bunkers ($MtCO_2$)[12]	2.0	3.1	4.6	4.2	4.9	5.1	..
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-14**	**14-15**	**15-16**	**16-17**
TPES	1.5	0.3	0.5	-1.1	-2.1	-2.5	0.6
Coal	0.5	-9.3	0.8	-1.2	-8.5	-11.6	-3.5
Peat	-	-	-	-	-	-	-
Oil	-1.0	-1.1	-0.6	-2.4	-0.8	-6.2	1.4
Natural gas	15.1	4.1	2.2	-3.0	6.8	5.1	0.4
Biofuels and waste[1]	11.3	2.0	2.6	0.6	2.7	6.5	2.6
Nuclear	8.1	1.1	-0.0	1.1	-16.2	-8.3	-3.6
Hydro	0.4	2.1	-0.2	1.3	0.6	-9.5	-1.5
Wind	-	-	-	31.6	11.1	-10.0	22.2
Geothermal	-	4.1	9.7	3.8	14.3	10.8	4.2
Solar/other[2]	-	17.5	11.6	29.4	23.0	12.9	13.7
TFC	0.6	0.6	0.7	-2.7	1.4	1.4	..
Electricity consumption	2.8	1.2	1.3	-1.0	1.4	-0.0	..
Energy production	5.3	1.6	0.5	1.2	-7.9	-5.0	-1.6
Net oil imports	-1.0	-1.4	-0.2	-2.3	-5.0	-1.7	-0.9
GDP	1.4	1.2	1.8	1.7	1.2	1.4	1.0
TPES/GDP	0.1	-0.9	-1.3	-2.8	-3.3	-3.9	-0.3
TFC/GDP	-0.9	-0.6	-1.1	-4.3	0.3	-	..

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. Other includes ambient heat used in heat pumps.
3. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels and waste and trade of electricity.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
9. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear and solar thermal and 100% for hydro, wind and solar photovoltaic.
10. Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
11. Toe per thousand US dollars at 2010 prices and exchange rates.
12. "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach from the *2006 IPCC Guidelines.* In accordance with the IPCC methodology, emissions from international marine and aviation bunkers are not included in national totals.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency and flexibility within the energy sector are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993 Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: 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

ACT	Agence Cleantech
BWR	boiling water reactor
CACM	capacity allocation and congestion management (network code)
CCGT	combined-cycle gas turbine
CHF	Swiss franc
CNG	compressed natural gas
Comco	Competition Commission
CORE	Federal Energy Research Commission
CTI	Commission for Technology and Innovation
DETEC	Department of the Environment, Transport, Energy and Communications
DSO	distribution system operator
EGZ	Erdgas Zentralschweiz
EnAW	Energy Agency of the Economy
EnDK	Conference of Cantonal Energy Directors
ENSI	Federal Nuclear Safety Inspectorate
ENTSO-E	European Network of Transmission System Operators for Electricity
ESL	Electricity Supply Law
ES 2050	Energy Strategy 2050
ETS	emissions trading system
EU	European Union
EU-ETS	European Union Emissions Trading System
EUR	euro
EV	electric vehicle
FiP	feed-in premium

FiT	feed-in tariff
FOEN	Swiss Federal Office of the Environment
FONES	Federal Office for National Economic Supply
GDP	gross domestic product
GEAK	Gebäudeausweis der Kantone
GHG	greenhouse gas
GoO	guarantee of origin
GVM	Gasverbund Mittelland AG
HFM	Harmonisiertes Fördermodell der Kantone
HVF	heavy-vehicle fee
IEA	International Energy Agency
ITO	Independent Transmission Operator
KELS	Climate and Energy Fiscal Steering System
LOL	loss of load
LULUCF	land use, land-use change and forestry
MAF	mid-term adequacy forecast
MuKEn	Mustervorschriften der Kantone im Energiebereich
NAF	National Road and Agglomeration Transport Fund
Nagra	National Cooperative for the Disposal of Radioactive Waste
NDC	nationally determined contribution
NESA	National Economic Supply Act
NPP	nuclear power plant
OECD	Organisation for Economic Co-operation and Development
PLEF	Pentalateral Electricity Forum
PPP	purchasing power parity
PV	photovoltaic
PWR	pressurised water reactor
R&D	research and development
RD&D	research, development and demonstration

SAPPRO	Société du Pipeline à produits pétroliers sur territoire Genevois
SCCER	Swiss Competence Centers for Energy Research
SFOE	Swiss Federal Office of Energy (under DETEC)
SME	small and medium-sized enterprise
SPMR	Pipeline Méditerranée-Rhône
SPSE	Société du Pipeline Sud-Européen
STENFO	Decommissioning Fund for Nuclear Facilities and Waste Disposal Fund for Nuclear Power Plants
TCP	Technology Collaboration Programme
TFC	total final consumption
TPES	total primary energy supply
TSO	transmission system operator
USD	United States dollar
WACC	weighted average cost of capital
Zwilag	Central Interim Storage Facility

Units of measurement

bcm	billion cubic metres
CO_2	carbon dioxide
gCO_2/km	gramme of carbon dioxide per kilometre
GW	gigawatt
GWh	gigawatt hour
kb/d	thousand barrels per day
$kgCO_2/m^2$	kilogramme of carbon dioxide per square metre
km	kilometre
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
m^2	square metre

m^3	cubic metre
mb	million barrels
Mm^3	million cubic metres
Mm^3/d	million cubic metres per day
Mt	million tonnes
Mtcoe	million tonnes of crude oil equivalent
$MtCO_2$	million tonnes of carbon dioxide
$MtCO_2$-eq	million tonnes of carbon dioxide equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt hour
Nm^3/h	normal cubic metres per hour
tCO_2	tonne of carbon dioxide
toe	tonne of oil equivalent
TWh	terawatt hour

IEA/OECD possible corrigenda on: www.oecd.org/about/publishing/corrigenda.htm

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ENERGY POLICIES OF IEA COUNTRIES

Switzerland

2018 Review

Switzerland has the lowest carbon intensity among all IEA countries, owing largely to the carbon free electricity sector that is dominated by nuclear and hydro generation. However, following the 2017 decision of the Swiss people to gradually phase out nuclear power, Switzerland's energy sector is now undergoing a considerable transition.

Filling the gap left by nuclear power closures while maintaining low carbon generation and high standards of supply security will be one of the challenges that Switzerland has to address in its long-term energy strategy. The country's *Energy Strategy 2050* maps the way towards a low-carbon economy in which higher energy efficiency and renewable energy sources replace nuclear energy.

In this context, the latest IEA review of Switzerland's energy policies focuses on two areas that are critical to guiding it towards a more secure and sustainable energy future: the design of the electricity market and the climate policy for the post-2020 period.

The new energy strategy will require opening the Swiss electricity market and full integration into the European electricity market to meet future energy needs. The IEA encourages the Swiss government to bring ongoing negotiations with the European Union on an electricity agreement to a successful outcome.

Switzerland's carbon dioxide levy on stationary fuels and its automatic upward adjustment have proven highly effective in shifting energy demand from oil towards gas and renewable energy sources. However, more needs to be done to limit emissions from transport.