Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

National Centre for Climate Services NCCS
Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Greenhouse gas emissions under different socio-economic and climate policy scenarios for Switzerland

Summary

IMPRINT

Project management
Lena Gubler, Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Consortium management
Quirin Oberpriller and Jürg Füssler, INFRAS

Authors
Quirin Oberpriller, Nicolas Schmid, Sophie Bogler, David Giger, Jürg Füssler (INFRAS); Andreas Kemmler, Alexander Piégsa, Sven Kreidelmeyer, Minh Phuong Vu, Andreas Brutsche, Almut Kirchner (Prognos); Johanna Zwahlen (Zoï Environment Network), Benjamin Black (ETH) and Lena Gubler (WSL)

Project partners in the consortium
Swiss Federal Institute for Forest, Snow and Landscape Research WSL, INFRAS, Prognos and Zoï Environment Network

Design
Maria Libert (Zoï Environment Network)

Editing
Stephanie Kusma, Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Translation
Text Translate AG, Zurich

This work was funded by the National Centre for Climate Services (NCCS) and carried out as part of the programme 'Decision-making bases for dealing with climate change in Switzerland: information on cross-sectoral issues (NCCS-Impacts)' within the project 'Socio-economic scenarios for Switzerland'.

More information about the programme:
www.nccs-impacts.ch

Citation
INFRAS, Prognos, WSL (2026): Greenhouse gas emissions under different socio-economic and climate policy scenarios for Switzerland. Summary. National Centre for Climate Services (NCCS) (ed.), Zurich. http://doi.org/10.55419/wsl:42762

Programme coordination for NCCS-Impacts
Andreas Fischer and Angela Michiko Hama (NCCS/MeteoSwiss)

Publisher
National Centre for Climate Services NCCS

The National Centre for Climate Services NCCS is the network of the Swiss Confederation tasked with developing actionable climate services for the environment, economy and society.

The NCCS is organised as a virtual centre and brings together eight federal offices and federal research institutions. As a national coordination and innovation body at the interface between research and practice, the NCCS supports climate-related decision-making.

Members of the NCCS

- Federal Office of Meteorology and Climatology MeteoSwiss
- Federal Office for the Environment FOEN
- Federal Office for Agriculture FOAG
- Federal Office for Civil Protection FOCP
- Federal Office of Public Health FOPH
- Federal Food Safety and Veterinary Office FSVO
- ETH Zurich
- Swiss Federal Institute for Forest, Snow and Landscape Research WSL

May 2026

The authors are responsible for the content of this publication.

This summary is also available in German, French and Italian. The original language is German.

FOREWORD

This summary of the project 'Socio-economic scenarios for Switzerland' is intended for decision-makers in administration and politics who are involved in forward-looking work such as scenarios, perspectives and strategies, as well as at researchers and consultants. It presents the Shared Socioeconomic Pathways for Switzerland (SSP-CH) and the Shared Policy Assumptions (SPA). These serve as a basis for modelling greenhouse gas emissions and changes in land use in Switzerland up to the year 2100. The summary provides an overview of the methods used, the modelling and selected results.

Detailed reports on the overall project, further scientific publications and underlying data are available on the project website:

www.nccs-impacts.ch/ssp-ch

This summary is based on the following technical report:

Oberpriller, Q., Schmid, N., Kemmler, A., Gubler, L., Bogler, S., Giger, D., Piegsa, A., Brutsche, A., Kreidelmeyer, S., Vu, M. Ph., Black, B., Kirchner, A., Füssler, J. (2026): Treibhausgasemissionen unter verschiedenen sozioökonomischen und klimapolitischen Szenarien für die Schweiz. Modellierung und Analyse. Infras, Prognos, WSL. Zürich. http://doi.org/10.55419/wsl:42766

The fundamentals of SSP-CH are described in the following report:

Gubler, L., Tschumi, P., Pütz, M., Seidl, I. (2026): SSP-CH: Sozioökonomische Szenarien für die Schweiz. Grundlagen, Methoden und Resultate. WSL Berichte 193. Birmensdorf. http://doi.org/10.55419/wsl:42764

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

National Centre for Climate Services NCCS
Swiss Federal Institute for Forest, Snow and Landscape Research WSL

CONTENTS

MODELLING FUTURE GREENHOUSE GAS EMISSIONS FOR SWITZERLAND

Tackling climate change and its consequences for society and the economy is more urgent than ever. In Switzerland, resource consumption and greenhouse gas emissions are primarily driven by the economy, energy production, transport, agriculture and consumption. Scientifically based scenarios and models demonstrate how these emissions could evolve – and be reduced – under various social, economic and political circumstances.

Exploratory socio-economic and climate policy scenarios are used to evaluate and compare potential outcomes. The future cannot be predicted with certainty, and uncertainty increases with the length of the time horizon and the complexity of the system. However, considering 'if-then' scenarios enables policy decisions to be better aligned with different possible futures.

Energy and emissions models help to visualise and compare the effects of these developments on emissions. For example, how do emissions change when technological progress advances rapidly? How do social factors and the values of the population influence resource consumption? What happens when the population grows or consumption patterns change? What is the effect of investments in renewable energy and more energy-efficient building envelopes and heat generators? How can policy instruments such as a CO_2 tax or stricter, binding building regulations contribute to reducing emissions, and what might their impact be?

Switzerland has a long tradition of scenario work to support policy-making. Examples include climate scenarios, population, GDP and industry scenarios, long-term perspectives for public finances, the Federal Chancellery's prospective work on situation and environment analysis, and transport and energy perspectives. The latter, for example, focus on energy and climate policy issues with a time horizon of up to 2050, considering a narrow range of possible socio-economic developments.

The project presented here involved developing comprehensive Shared Socioeconomic Pathways for Switzerland (SSP-CH – socioeconomic scenarios) and Shared Policy Assumptions (SPA – packages of climate policy instruments), based on the SSP framework of the Intergovernmental Panel on Climate Change (IPCC). These scenarios describe consistent and plausible developments in Switzerland without assigning probabilities to their occurrence. SSP-CH complement the existing scenarios and perspectives of the Federal Administration in several ways: they extend the time horizon to 2100. They also take into account a broader spectrum of possible, highly diverse developments. These mainly concern changes in society, the economy and technology. SPA, in turn, allow the effects of various climate policy scenarios to be analysed.

THE SSP-CH PROJECT IN THE NCCS-IMPACTS PROGRAMME

As part of the NCCS-Impacts programme, the *Shared Socioeconomic Pathways for Switzerland* (SSP-CH) project modelled the possible course of greenhouse gas emissions and land use in Switzerland up to 2100. This summary focuses on the modelling of greenhouse gas emissions. Five SSP-CH (*Shared Socioeconomic Pathways*) scenarios, which consider with different socio-economic developments, are examined (see Box 1). These are then combined with four possible Shared Policy Assumptions (SPA) (see Box 2). The modelling of land use is explained in Box 3.

This approach is based on the methodology of the IPCC's global SSP framework and enables a broad spectrum of possible future developments to be examined. Exploratory scenarios are developed in line with a 'what-if' analysis. The aim is not to extrapolate current trends or determine the most likely development, but rather to identify and compare a range of plausible, internally consistent ones. These may differ significantly from current developments: for example, they describe situations with very low or high levels of innovation, low or high economic or population growth, or low or high priority given to climate and environmental issues in society and politics.

WHO DO THE MODELS SERVE?

The results of greenhouse gas emissions modelling support decision-makers in administration, business and society in planning and implementing informed and sustainable strategies and measures. They provide a scientifically sound basis for identifying challenges and opportunities, and for making robust decisions. In addition, the SSP-CH, the SPA, the modelling results and, in particular, the methodological approach, can be utilised for forward-looking work in research and consulting. The scenario approach developed for Switzerland (Shared Socioeconomic Pathways (SSP-CH) combined with Shared Policy Assumptions (SPA)) and its quantitative translation thus make an important methodological contribution to international research in this field.

All scenarios examined in the project are so-called exploratory scenarios. In the form of 'if-then' statements, they describe the impact of assumptions regarding framework conditions, interactions and, where applicable, changes in social preferences and dynamics on future greenhouse gas emissions. These are explicitly not target scenarios that would be used to examine how specified aims can be achieved at a given point in time.

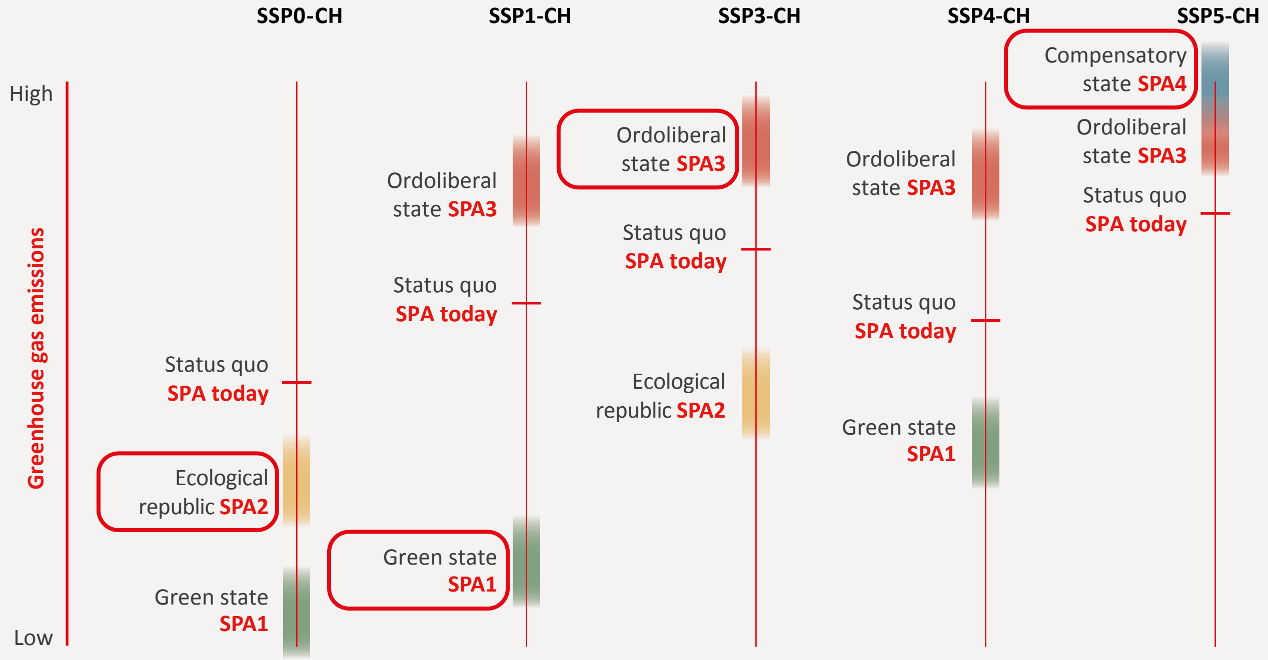
HOW WERE THE MODELLING RESULTS DETERMINED?

DEVELOPMENT OF THE SCENARIOS

In the first step, five socio-economic scenarios for Switzerland (SSP-CH) were developed in reference to the global *Shared Socioeconomic Pathways* (SSP). These scenarios describe different developments for population, economy, technology and lifestyle up to 2100 and are explained in more detail in Box 1. However, the SSP-CH do not take climate policy developments into account by design. To address this, four different Shared Policy Assumptions (SPA – *packages of climate policy instruments*) were developed in the second step, as described in Box 2.

Finally, the SSP-CH were combined with the SPA whilst ensuring consistency with the SSP-CH logic: the SPA must not contradict the SSP-CH social developments, and the SPA climate policy instruments must be politically feasible within the SSP-CH social development context. To keep the presentation clear, this summary focuses on four such combinations as examples (see Figure 1). These were chosen to represent as broad a spectrum of developments as possible. Three further combinations, bringing the total to seven, are analysed in the technical report 'Greenhouse gas emissions under different socio-economic and climate policy scenarios for Switzerland. Modelling and analysis' (see imprint).

Figure 1: Effect of SPA on SSP-CH



The status quo refers to the level of greenhouse gas emissions in the SSP-CH without additional SPA. Emissions with additional SPA are then above or below this level.
The combinations described in this summary are outlined in red: SSP0-CH & SPA2: Frugal Switzerland with participatory climate policy; SSP1-CH & SPA1: Efficient Switzerland with proactive climate policy; SSP3-CH & SPA3: Conflict-Prone Switzerland with minimal climate policy; SSP5-CH & SPA4: Resource-Intensive Switzerland without climate policy.

BOX 1 | SHARED SOCIOECONOMIC PATHWAYS FOR SWITZERLAND (SSP-CH)

The *Shared Socioeconomic Pathways for Switzerland* (SSP-CH) describe five plausible, internally consistent scenarios for Switzerland up to the end of the 21st century. They highlight possible technical, institutional, economic and cultural developments and their interactions. They are open-ended, i.e. they do not assume a specific future goal, and thus cover a broad spectrum of possible futures. Such scenarios should not be confused with visions or ideal scenarios. They include both positive and negative developments.

The SSP-CH were developed with the involvement of 59 experts from 20 scientific institutions in Switzerland and were expanded and validated in five workshops in German-speaking and French-speaking Switzerland with a total of 85 participants. The five scenarios (SSP-CH) are described in detail in a publication[1] by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. Table 1 gives an overview of selected parameters with characteristics that define the five SSP-CH scenarios.

The SSP1-CH, SSP3-CH and SSP4-CH scenarios are comparable to the corresponding global SSPs. SSP0-CH does not yet have a global counterpart. The SSP5-CH scenario differs from the global SSP5 scenario because the experts surveyed considered it implausible that a highly innovative, technologically advanced society such as that described in the global SSP5 scenario

1 Link to the WSL report: https://ssp-ch-szenarien.wsl.ch

Table 1: Overview of the selected parameters and their characteristics that define the five SSP-CH scenarios

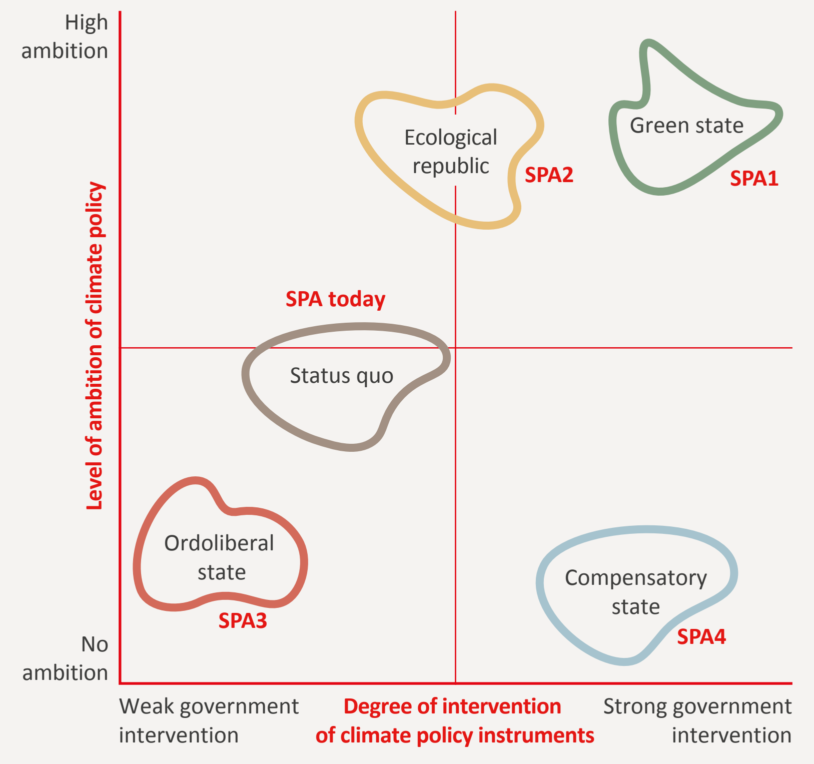
SSP-CH scenario parameters	SSP0-CH *Frugal Switzerland*	SSP1-CH *Efficient Switzerland*	SSP3-CH *Conflict-Prone Switzerland*	SSP4-CH *Unequal Switzerland*	SSP5-CH *Resource-Intensive Switzerland*
Population and public welfare					
Permanent resident population	low	high	low	medium	high
Social cohesion	high	medium	high in groups, low in society as a whole	low	medium
Economy and consumption					
Economic growth	low	high	low	high	medium
Distribution of wealth and income	even	even	medium	uneven	medium
Consumption	low	medium	low	shared	high
Politics and government					
Focus of the state	common good	economy, common good	security	economy, security	economy
International political integration of Switzerland	medium	high	low	high	low
Technology					
Technological development and innovation	slow	fast	slow	fast	slow
Environment and natural resources					
Environmental awareness	high	high	low	low	low
Resource efficiency	medium	high	low	high	low

would continue to rely on fossil fuels until the end of the century. SSP5-CH therefore assumes a non-innovative society. There is also a global SSP2 'middle of the road' scenario, which describes the average development of the relevant socio-economic parameters. However, the SSP-CH do not include a scenario like this because the methodological approach selected for developing qualitative scenarios in this project does not allow for the generation of a scenario in which all developments are average. Since a middle scenario is often considered to be the most likely and is used exclusively, it was decided not to construct an SSP2-CH retrospectively. The use of a single scenario would contradict the scenario method, which is designed to compare several possible developments without assigning probabilities to their occurrence.

BOX 2 | SHARED POLICY ASSUMPTIONS FOR SWITZERLAND (SPA)

The *Shared Policy Assumptions* (SPA) describe four future climate policy instrument packages (SPA1 to SPA4). 'SPA today' also summarises the status quo of the climate policy instruments in place in 2023. Based on political science literature, the SPA were developed along two central dimensions – the level of ambition of climate policy and the degree of intervention of the policy instruments (see Figure 2). The SPA cover a broad spectrum of possible climate policies:

Figure 2: The Shared Policy Assumptions are arranged according to the level of ambition of the policy goals and the degree of intervention of the policy measures.



- SPA today – Status quo: climate policy currently being implemented (as of 2023)
- SPA1 – Green state: ambitious climate policy, strong state intervention –proactive climate policy
- SPA2 – Ecological republic: ambitious climate policy, relatively low level of state intervention (e.g. voluntary measures by civil society and the economy) – participatory climate policy
- SPA3 – Ordoliberal state (in other publications also referred to as Market-liberal state): low-level targets, minimal government intervention – limited climate policy
- SPA4 – Compensatory state (in other publications also referred to as Conserving state): high government intervention, but aimed at other policy goals (e.g. reducing energy costs) rather than climate policy – no climate policy

The SPA were developed for the energy, transport, industry, buildings, agriculture and imports sectors. Combining the Shared Policy Assumptions (SPA) with the various Shared Socioeconomic Pathways (SSP-CH) makes it possible to analyse a comprehensive spectrum of possible future development pathways for Swiss society and climate policy.

MODELLING ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS

The main task of this project was to use quantitative modelling to translate the qualitative developments in the various combinations of SSP-CH and SPA into greenhouse gas emissions. This modelling is based on a bottom-up approach and the GHG (greenhouse gas) inventory. It is divided into the sectors of transport, buildings, agriculture, industry, energy and negative emission technologies (NETs). A broader perspective also considers emissions from imports and exports as well as those from international aviation. Energy consumption was also modelled as a precursor to greenhouse gas emissions.

In the first step, a series of scenario parameters were defined. These parameters represent the most important characteristics of SSP-CH in simplified form, describing both common variables (e.g. resident population, GDP per capita or livestock per capita) and variables such as environmental awareness or individual consumption levels. The development of these parameters under the different SSP-CH scenarios was quantified with input from experts.

In the second step, the developments of the scenario parameters were translated into changes in model parameters. These are the core building blocks of the model (e.g. building floor area or energy source mix in the building sector). In order to systematically model the many scenarios in this project, a fixed impact matrix including elasticities was defined for each sector. This specifies exactly how the scenario parameters influence the model parameters. Different results in terms of greenhouse gas emissions in the scenarios are therefore exclusively due to various developments in the scenario parameters. No separate scenario parameters were developed for the impact of climate policy instruments. Instead, the impact of the various climate policies (SPA) on the model parameters was estimated as a sum in each case. Figure 3 illustrates the steps just described, from the scenario parameters to the model results, using an example.

Models of reduced complexity developed specifically for this project are used for each sector. These are based on the results and findings from more complex models (e.g. those for modelling Energy Perspectives 2050+). This enables the crucial links between scenario parameters and model parameters to be tailored and the impact pathways to be presented in a comprehensible manner.

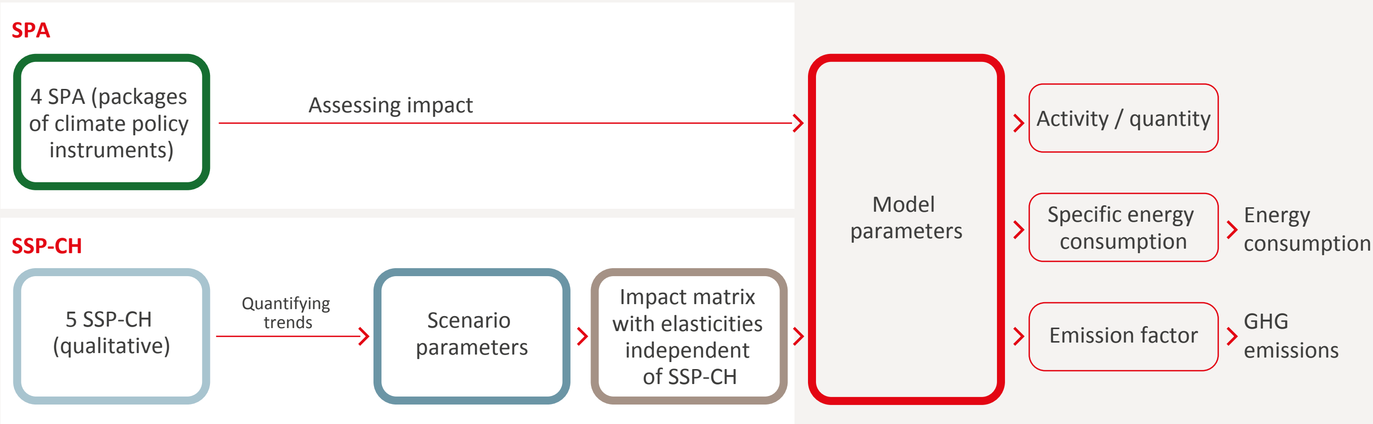
2023 is the starting point for the modelling. 2035, 2060, 2085 and 2100 were modelled. The intervening years are interpolated.[2]

In an international context the socio-economic SSP scenarios are closely linked to the RCP (Representative Concentration Pathways)[3] scenarios, which describe various developments in global greenhouse gas emissions. For example, the emission pathways of the RCP scenarios were used as targets when modelling the global SSP. However, no such link exists between the SSP-CH and the global emissions scenarios or the Swiss climate scenarios derived from them, as the SSP-CH are not target scenarios. Furthermore, as Switzerland accounts for only a small proportion of global emissions, Swiss emissions scenarios have no direct impact on the global emissions scenarios.

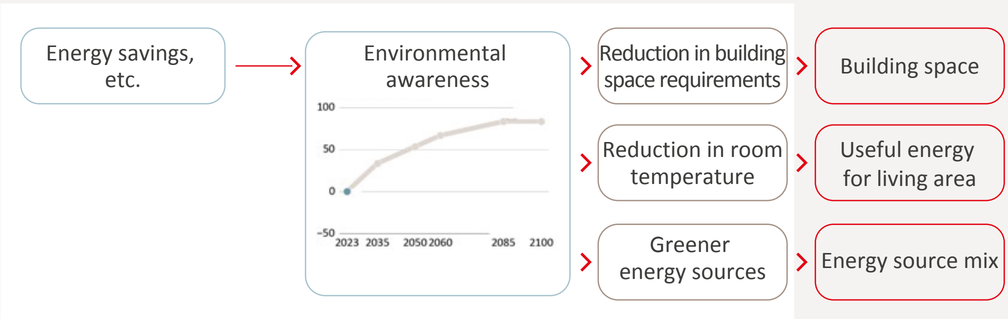
2 In addition, 2050 is shown in the figures because it is an important year for climate policy and is partly relevant for SPA modelling.
3 RCP scenarios (Representative Concentration Pathways) are greenhouse gas emissions scenarios used by the Intergovernmental Panel on Climate Change (IPCC).

Figure 3: Approach to modelling energy consumption and greenhouse gas emissions

Generic model structure



Example: SSP0-CH modelling in the building sector



Example: if environmental awareness increases by 50 per cent, demand for building space decreases by 25 per cent if the elasticity for this impact pathway is -0.5.

For the modelling in this report, all scenarios use the same average RCP scenario.[4] This is because different assumptions have little influence on the modelling presented here. From a methodological point of view, it is also advantageous to keep the impact of climate change constant so that different final energy consumption and emissions only reflect the effects of SSP-CH and SPA.

4 The RCP4.5 scenario is used. This results in a temperature increase of +2.9°C (range: 2.1°C to 4.0°C) by 2100 compared to pre-industrial levels (see Table 4.2; IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report).

FINAL ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS FOR FOUR SELECTED FUTURE SCENARIOS UP TO 2100

The following chapters present four combinations of Shared Socioeconomic Pathways (SSP-CH) and Shared Policy Assumptions (SPA).[5] Each chapter begins with a brief introduction to the relevant SSP-CH and SPA. These form the basis for the modelling. This is followed by the results for final energy consumption and direct greenhouse gas emissions in Switzerland. Final energy consumption refers to the amount of energy used in the end-use sectors of industry, buildings (including households and services) and transport.

A detailed description of all the basic principles and assumptions can be found in the technical report 'Greenhouse gas emissions under different socio-economic and climate policy scenarios for Switzerland. Modelling and analysis'.

In general, modelling results over the long period up to 2100 should be interpreted with caution. While the model can quantitatively capture possible relationships within an overall system, the underlying data, the SSP-CH and SPA, as well as energy, emissions and land use modelling are naturally subject to considerable uncertainty and limitations over such a long period. Nevertheless, modelling can help to systematically examine various possible and consistent developments in the future.

EFFICIENT SWITZERLAND WITH PROACTIVE CLIMATE POLICY SSP1-CH & SPA1

Socio-economic and climate policy assumptions

Scenario SSP1-CH – Efficient Switzerland: Switzerland is highly technological and has developed into an efficient circular economy with considerable international integration. The population benefits from the value created by a growing economy. Constant immigration leads to high urban density. Land use is increasing moderately and environmental awareness among the population is very high. The renewable energy supply is secure, largely domestic and partly imported. Food is largely imported; Switzerland maintains close international political and economic relations, particularly with the EU. Political institutions function reliably and efficiently.

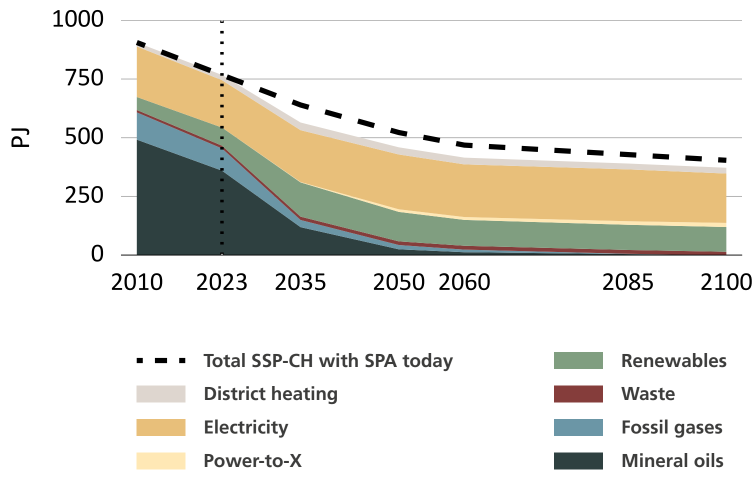
Shared Policy Assumption SPA1– Proactive climate policy: in order to achieve ambitious climate protection goals, the state intervenes in economic affairs and private consumption and has introduced a variety of new regulatory and financial instruments.

5 The technical report combines all five Shared Socioeconomic Pathways (SSP-CH) with various compatible Shared Policy Assumptions (SPA). Four typical combinations were selected for this summary, which adequately represent the range of characteristics.

Modelling results: final energy consumption

Figure 4 shows the final energy consumption for this scenario.

Figure 4: Final energy consumption in the Efficient Switzerland with proactive climate policy scenario (SSP1-CH & SPA1)



The figure shows final energy consumption broken down into different energy sources, of which mineral oils (and fossil gases), renewables and electricity are the most relevant. Mineral oils are heating fuels and transport fuels. Renewables here include all biomass, solar thermal energy and environmental heat (which is used in heat pumps). In principle, electricity can be produced using hydropower, nuclear power, fossil fuel power plants, photovoltaics and wind turbines. Renewable electricity generation therefore falls under the electricity category in the figure. District heating, power-to-X (synthetic energy sources or hydrocarbons produced from electricity, particularly hydrogen) and waste (from fossil or biogenic sources, incinerated in waste-to-energy plants) are of lesser importance. The dotted line represents the sum of all energy sources for the socio-economic scenario (SSP1-CH) if current climate policy instruments (SPA today) are continued, i.e. without the climate policies from SPA1. This line allows shows the influence of the climate policy instruments from SPA1 compared to SPA today, when considering all energy sources in total.

The figure shows the actual consumption data for the period 2010 to 2023 (to the left of the dotted line). These data indicate a decrease of around 15 per cent and this trend persists in the future scenario. In particular, mineral oil consumption continues to decline. The main reasons for this are increasing electrification (including heat pumps, electric vehicles and electric heating in industrial and commercial processes) and improved energy efficiency, which takes effect in all sectors (as assumed in SSP1-CH). In the industrial sector alone, certain high-temperature processes still rely on fossil fuels, which could only be replaced through technological change.

Even though electrification increases in SSP1-CH, electricity consumption rises only slightly. In addition, new consumers (e.g. data centres) are emerging that consume large amounts of electricity. Without this factor, electricity consumption would actually decline slightly. The main reason for this is the increased energy efficiency in SSP1-CH. In the building sector, for example, electricity consumption is rising in the short term due to heat pumps, as they heat an ever-increasing proportion of living spaces. However, less efficient conventional electric heating systems and water heaters are being replaced and the efficiency of heat pumps is increasing. Furthermore, climate warming and the associated decline in heating demand are reducing consumption. However, demand for cooling is increasing, so the net effect in the building sector is fairly small.

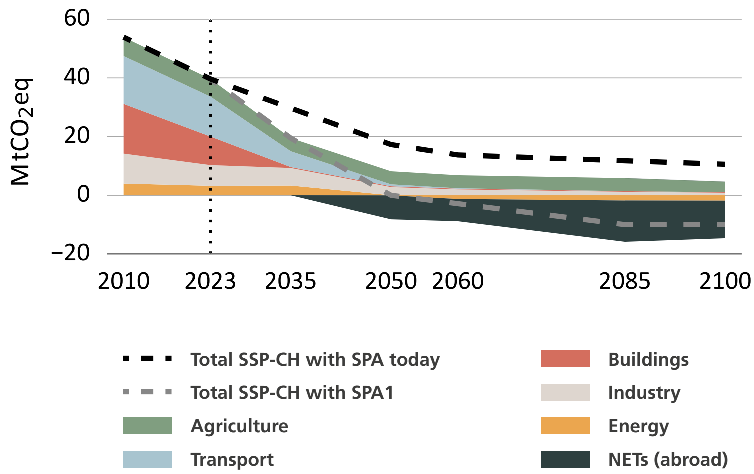
The use of renewable energy for heat generation is expected to double in the SSP1-CH scenario by 2035. This is primarily due to the increased use of heat pumps, since the environmental heat they utilise is classified as renewable. Thanks to continuous efficiency improvements, energy consumption from renewable sources will decline again from 2035 onwards. The modelling revealed no significant changes for biomass-based renewables, given the limited availability of biomass. Note that renewable electricity production is not included in this category but in the electricity category (where it is not shown separately).

Comparing this with final energy consumption if current climate policy instruments continue to be applied (the total for SSP-CH and SPA today is indicated by the black dotted line) shows that the long-term impact of SPA1's climate policy instruments is fairly small in this socio-economic scenario. This is mainly due to greater energy efficiency and lower demand resulting from social developments in SSP1-CH. Climate policy instruments aimed at moving away from fossil fuels (substitution) also have a greater impact on greenhouse gas emissions than on final energy consumption (even though battery electric vehicles, for example, are much more efficient than fossil fuel-powered vehicles). It is also apparent that the effect of SPA1 weakens towards the end of the century because socio-economic developments (e.g. high environmental awareness) anticipate this effect. Therefore, the climate policy of SPA1 accelerates and reinforces a development that is already inherent in the assumptions of the socio-economic scenario under consideration (SSP1-CH).

Modelling results: greenhouse gas emissions

Figure 5 shows the greenhouse gas emissions of various modelled sectors in Switzerland.

Figure 5: Greenhouse gas emissions in the Efficient Switzerland with proactive climate policy scenario (SSP1-CH & SPA1)



This figure follows the established sector classification used for the greenhouse gas inventory. These sectors are agriculture, transport, buildings, industry and energy. The energy sector includes emissions from electricity production, even if the electricity demand originates from battery electric vehicles in the transport sector, for example. According to the greenhouse gas inventory, these direct Swiss emissions only take into account territorial emissions (results based on an extended system boundary are shown at the end of this summary).

A rapid decline in emissions is evident in almost all sectors. The fastest decline is in the buildings sector, where technical trends and strict climate policy instruments (in particular a ban on the use of fossil fuel heating systems from 2035, as stipulated by SPA1) will result in emissions falling to zero shortly after 2035. A similar trend is evident in the transport sector, albeit slower. In this sector, emissions will fall to almost zero from 2050 onwards, primarily due to the increased use of battery electric vehicles.

The industrial sector will continue to generate emissions in the second half of the century, due to difficult-to-avoid emissions from industrial processes (e.g. cement production or high-temperature processes). These emissions will be reduced using carbon capture and storage (CCS) in line with climate policy requirements (SPA1). However, a small amount of emissions will remain because there are no plans for the widespread CCS implementation. It will be prioritised for use in cement production and, to a lesser extent, in the chemical and steel industries (as specified in SPA1).

In the energy sector, emissions mainly originate from the fossil fuel component of waste in waste incineration plants (WIPs). Waste consists of roughly equal proportions of fossil fuel and biogenic components. CCS is also used here in accordance with the SPA. As capturing biogenic components results in negative emissions (whereas biogenic emissions are climate-neutral without capture), this sector will show slightly negative emissions in the second half of the century.

According to the SPA1, additional negative emissions will be generated through the use of negative emission technologies (NETs) abroad. However, the model does not include energy consumption (abroad) and the costs of purchasing negative emissions (no costs are modelled).

Residual emissions are primarily generated by the agriculture sector, as SSP1-CH specifies that there will be no technologies to significantly reduce its emissions. Also, this future scenario does not assume a significant reduction in meat consumption, which is responsible for a large proportion of emissions. Unlike in other sectors, however, methane is the dominant greenhouse gas in agriculture, rather than CO_2.

Overall, this scenario achieves net zero in 2050 and subsequently becomes net negative. This is achieved through robust domestic emission reductions combined with the purchase of negative emissions (NETs) from abroad.

A comparison with total emissions in SSP1-CH without additional climate policy instruments (SPA today) shows how significantly the policy instruments of SPA1 reduce emissions. This is due to the described reduction in energy consumption and the extensive substitution of fossil fuels with renewables in all sectors. On the other hand, the climate policy instruments of SPA1 enable the use of both CCS and NETs in the first place.

RESOURCE-INTENSIVE SWITZERLAND WITHOUT CLIMATE POLICY
SSP5-CH & SPA4

Socio-economic and climate policy assumptions

SSP5-CH – Resource-Intensive Switzerland: the country initially experiences strong economic growth and high immigration. Increasing consumption of fossil fuels, combined with resource-intensive lifestyles, put a heavy strain on the environment. Towards the end of the century, rising resource prices and the costs of environmental degradation lead to a decline in economic performance and a loss of prosperity. Social benefits are reduced. Emigration increases and social cohesion weakens. The state has to intervene more and more to deal with environmental and social crises and their consequences.

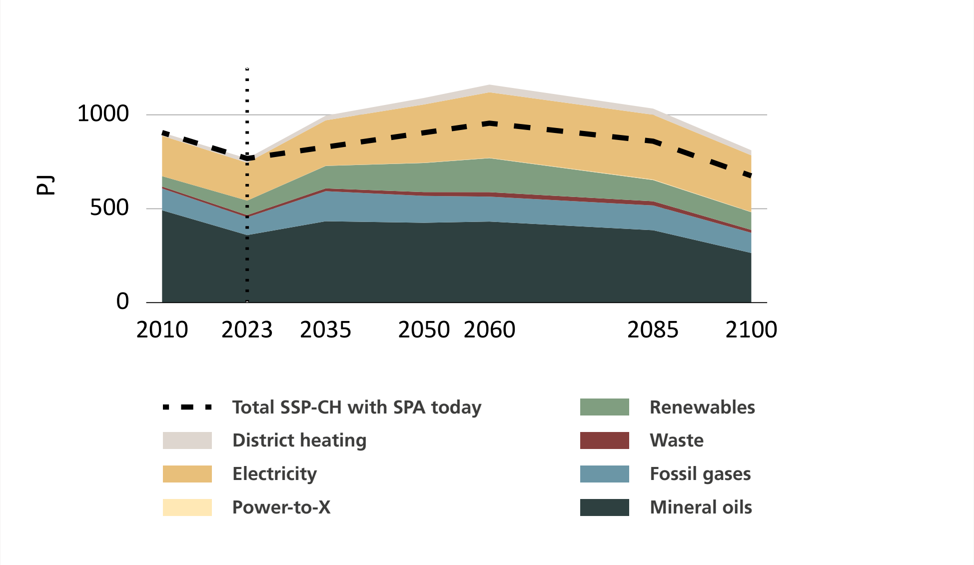
SPA4 – No climate policy: many climate policy instruments are abolished, and subsidies for fossil fuels and other support instruments are increased.

Modelling results: final energy consumption

In this future scenario, consumption of fossil fuels in particular differs significantly from that in the first scenario (Efficient Switzerland with proactive climate policy; SSP1-CH & SPA1). This consumption initially increases, but then declines due to falling economic output at the end of the century (see Figure 6). The share of fossil gases is much higher because greater use is made of them for electricity generation and industry. Compared to the first scenario, electricity consumption is around 50 per cent higher because lifestyles are more energy-intensive (as assumed in SSP5-CH). Electrification is progressing, albeit at a slower pace. New electricity consumers also emerge. The same applies to other energy sources. For example, renewable energy consumption is even higher because many heat pumps are used in buildings in this scenario, and the demand for heat is also significantly higher due to larger living spaces and fewer building renovations.

In this case, the SPA4 policy instruments lead to higher energy consumption because they abolish or scale back most of the current climate and energy policy instruments (e.g. promotion of building renovations, CO_2 tax, emissions trading system). In contrast, the use of fossil fuels is increasingly subsidised.

Figure 6: Final energy consumption in the Resource-Intensive Switzerland scenario without climate policy (SSP5-CH & SPA4)

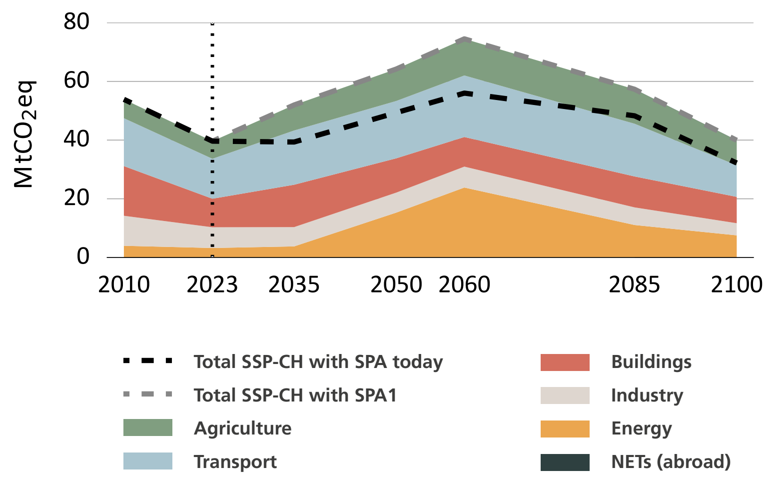


Modelling results: greenhouse gas emissions

In this scenario, greenhouse gas emissions reflect the heavy use of fossil fuels. As shown in Figure 7, emissions from the energy sector increase sharply until the middle of the century due to greater use of gas-fired power plants. Other sectors experience some technical progress, which is frequently offset by higher usage (e.g. transport performance increases). As a result, emissions from these sectors remain roughly at current levels (industry) or increase slightly (all other sectors). Total emissions therefore remain above current levels until 2100, despite an economic contraction towards the end of the century.

It is also evident that the climate policy reversal described above, as specified in SPA4, leads to increased emissions. Furthermore, neither carbon capture and storage (CCS) is used domestically nor negative emission technologies (NETs) abroad.

Figure 7: Greenhouse gas emissions in the Resource-Intensive Switzerland scenario without climate policy (SSP5-CH & SPA4)



CONFLICT-PRONE SWITZERLAND WITH MINIMAL CLIMATE POLICY SSP3-CH & SPA3

Socio-economic and climate policy assumptions

SSP3-CH – Conflict-Prone Switzerland: the country experiences political polarisation, corruption and reduced prosperity. Investment and innovation decline and the economy shrinks. Unemployment and emigration rise, companies close or relocate. The welfare state is dismantled. International relations decline sharply, Switzerland becomes increasingly isolated and basic services more difficult to provide. Many people resort to self-sufficiency. The state prioritises allocating its limited resources towards maintaining internal security.

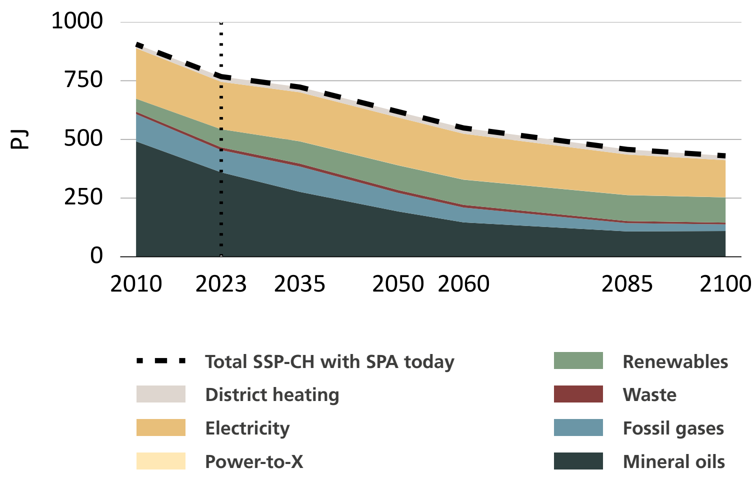
SPA3 – Minimal climate policy: climate policy instruments are dismantled.

Modelling results: final energy consumption

In this future scenario, total final energy consumption develops similarly to that in the first scenario, in which it decreases significantly (Efficient Switzerland with proactive climate policy; SSP1-CH & SPA1). However, the reasons are different: in this case, the decline in economic output and growing poverty among much of the population mean that people can afford less and less energy. This is why final energy consumption falls (see Figure 8). The share of fossil fuels in the total energy mix declines because existing climate policy instruments (e.g. in the building and transport sectors) and current consumer trends (e.g. towards battery electric vehicles or heat pumps) continue.

Minimal climate policy has no effect on total energy consumption.

Figure 8: Final energy consumption in the Conflict-Prone Switzerland with minimal climate policy scenario (SSP3-CH & SPA3)

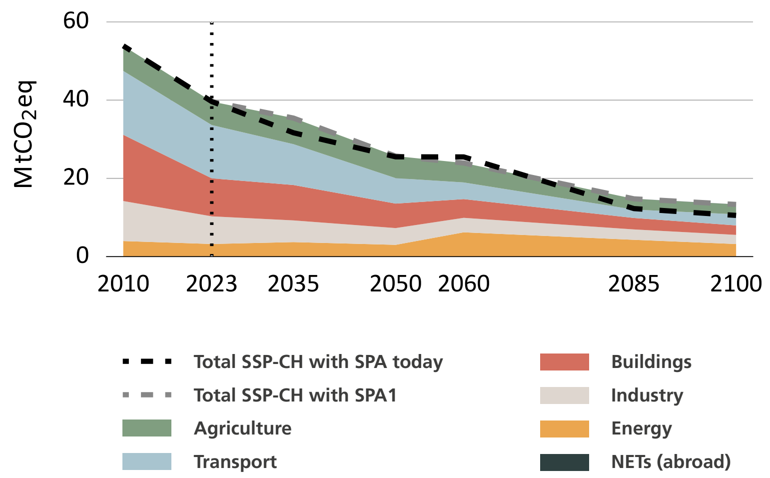


Modelling results: greenhouse gas emissions

Emissions from the energy sector are rising because more natural gas is being used (see Figure 9). Emissions from other sectors are gradually declining for the aforementioned reasons, but will remain significant even in 2100. However, compared with Resource-Intensive Switzerland (SSP5-CH & SPA4), emissions are still lower.

Minimal climate policy and the sporadic scaling back of existing instruments result in high emissions. There are few carbon capture and storage (CCS) facilities in Switzerland, and their impact is limited. Negative emissions are not purchased from abroad.

Figure 9: Greenhouse gas emissions in the Conflict-Prone Switzerland with minimal climate policy scenario (SSP3-CH & SPA3)



FRUGAL SWITZERLAND WITH PARTICIPATORY CLIMATE POLICY SSP0-CH & SPA2

Socio-economic and climate policy assumptions

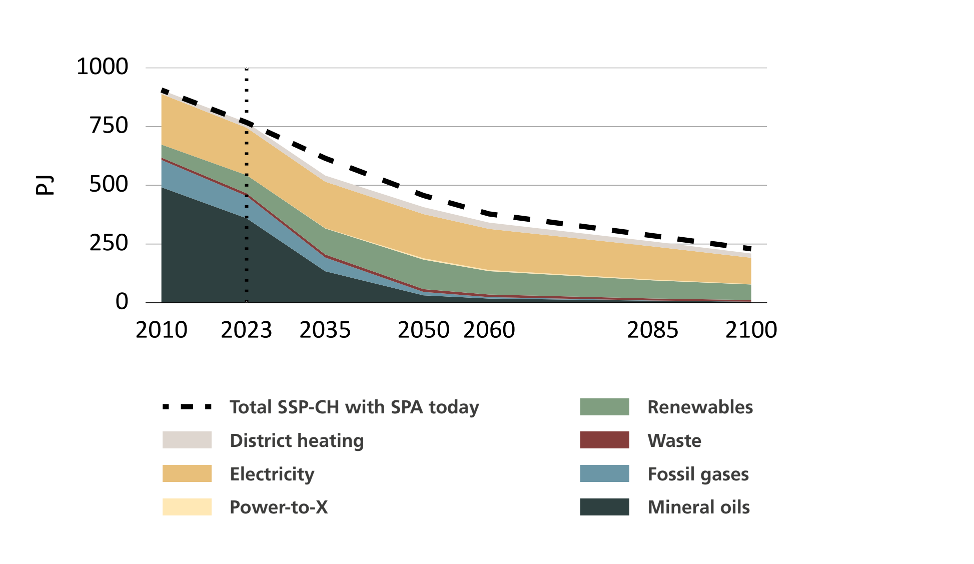
SSP0-CH – Frugal Switzerland: the Swiss population values the concept of the common good. Trust in political institutions is also high. The population consciously chooses low levels of consumption. The financial standard of living declines. Income and wealth are distributed evenly throughout society. Regional centres and urban districts offer good basic local services. The degree of self-sufficiency in terms of energy and food is high. Consumption, mobility and energy use all decline sharply, and the population's environmental awareness is very high.

SPA2 – Participatory climate policy: the state pursues ambitious climate policy goals but avoids strong state intervention. Political instruments focus on incentive-led and information-based approaches. The achievement of ambitious climate goals largely depends on civil society.

Modelling results: energy consumption

In this future scenario, energy consumption falls most rapidly. As shown in Figure 10, fossil fuels will only be consumed in minimal quantities from 2050 onwards. Demand for other energy sources will also decline due to lower economic output and more frugal lifestyles. The influence of politics beyond this is minimal. Its influence is strongest in 2035, after which it declines again as socio-economic trends move in the same direction.

Figure 10: Energy consumption in the Frugal Switzerland with participatory climate policy scenario (SSP0-CH & SPA2)

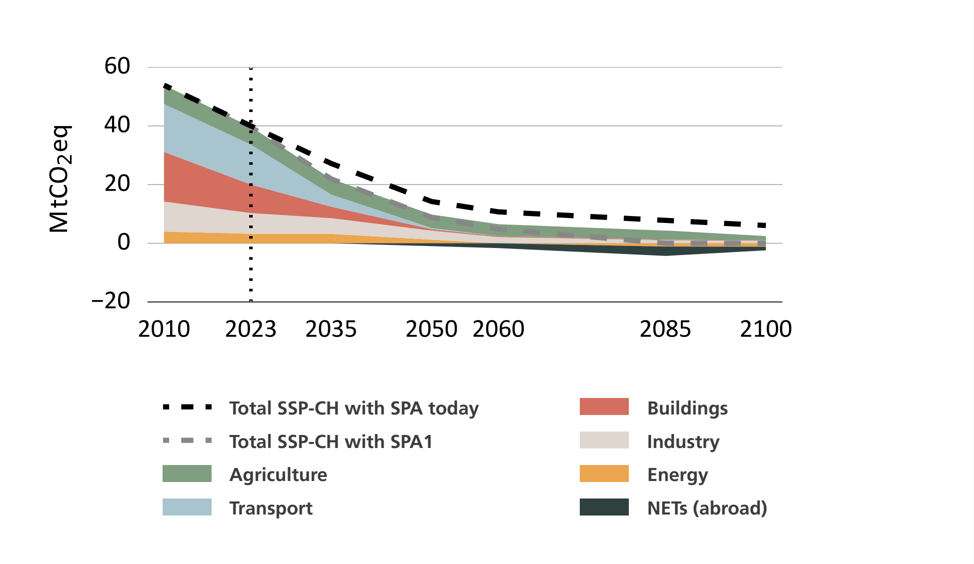


Modelling results: greenhouse gas emissions

Emissions decline at roughly the same rate in all sectors (see Figure 11). However, the reduction is slower than in the first scenario (Efficient Switzerland with proactive climate policy; SSP1-CH & SPA1) because technical progress is slower and SPA2 does not include any strongly interventionist policy instruments.

Carbon capture and storage (CCS) and negative emission technologies (NETs) are used domestically with NETs being purchased from abroad, but due to the high costs involved, this is on a much smaller scale than in the first scenario. Emissions are low in 2050, but net zero will not be achieved until around 2085.

Figure 11: Greenhouse gas emissions in the Frugal Switzerland with participatory climate policy scenario (SSP0-CH & SPA2)



OVERVIEW AND COMPARISON OF THE FOUR SCENARIOS

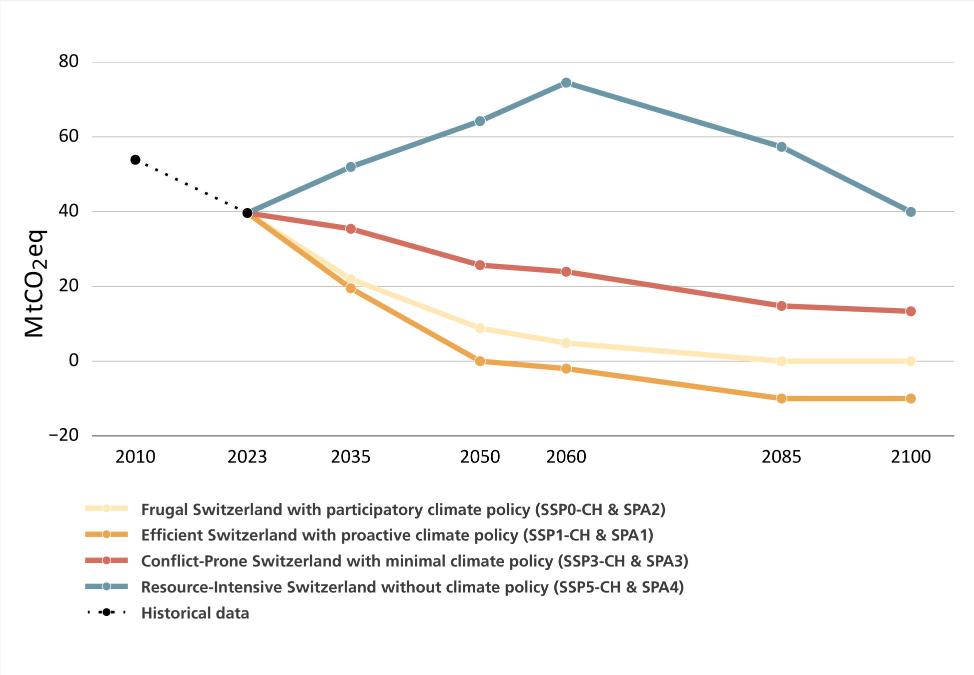
Figure 12 provides an overview of total greenhouse gas emissions across the four future scenarios. Three of the four scenarios show lower emissions. The most significant decrease occurs in the Efficient Switzerland with proactive climate policy scenario, as efficiency is combined with ambitious and effective climate policy. Strong economic performance provides the necessary resources for extensive investment in carbon capture and storage (CCS) and negative emission technologies (NETs), enabling net zero to be achieved by around 2050, with emissions continuing to fall thereafter.

In contrast, in the Resource-Intensive Switzerland without climate policy scenario, emissions rise sharply until 2060. This is due to the resource-intensive lifestyles coupled with a policy that actively promotes the use of fossil fuels. However, due to declining economic performance and a shrinking population, emissions fall back to their 2023 starting level by the end of the century.

In the Conflict-Prone Switzerland with minimal climate policy scenario, emissions are primarily reduced due to lower economic performance and (involuntary) reductions in private consumption. However, the climate-related elements of the policy tend to lead to an increase in emissions because existing instruments are scaled back. Although emissions are falling, they will remain at around 50 per cent of current levels until the end of the century.

The Frugal Switzerland with participatory climate policy scenario leads to a rapid reduction in emissions due to a modest and climate-friendly lifestyle. However, this decline is less pronounced than in the Efficient Switzerland with proactive climate policy scenario due to slower technological progress, a less interventionist climate policy and lower investment in CCS and NETs, so that emissions never become negative.

Figure 12: Greenhouse gas emissions in the four scenarios



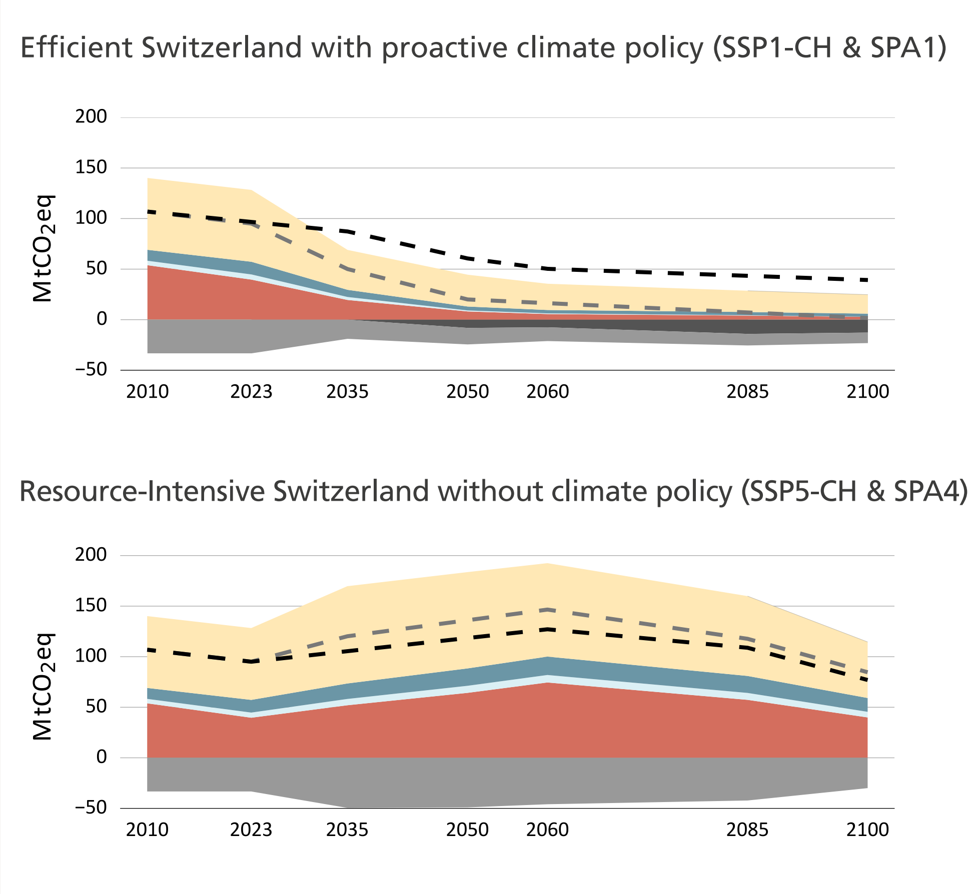
EXTENDED SYSTEM BOUNDARY: AVIATION EMISSIONS AND FOREIGN TRADE

The modelling results presented so far show the direct greenhouse gas emissions generated in Switzerland itself for the four future scenarios under consideration. This is consistent with Switzerland's greenhouse gas reporting in accordance with international requirements (greenhouse gas inventory). However, it makes sense to extend the system boundary to include the following components:

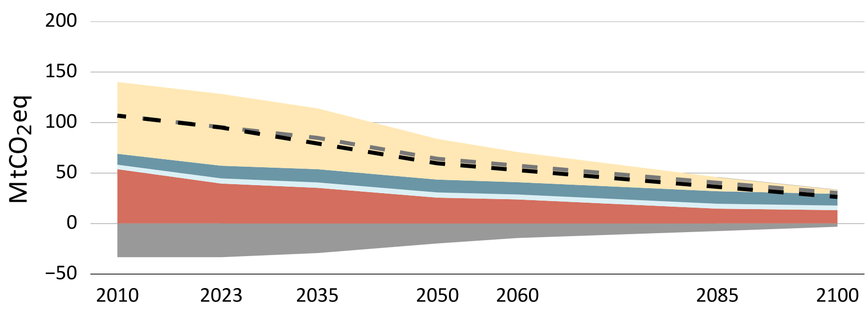
- International aviation emissions: these are included in the national greenhouse gas inventory for information purposes only and are not incorporated into the target assessment. In addition to the direct CO_2 emissions resulting from the combustion of kerosene, the climate impact of non-CO_2 emissions is also reported here. In line with current practice, CO_2 emissions are multiplied by a fixed factor that lies roughly in the middle of the range specified in the relevant literature.
- Emissions from the import and export of goods: Switzerland is credited with emissions generated abroad in the production of goods imported into the country. Conversely, the emissions generated in Switzerland for the production of goods that are exported are deducted.

Figure 13 shows modelled greenhouse gas emissions, taking into account international aviation and emissions from Swiss import and export activities. Modelling these emissions is subject to greater uncertainty than modelling direct emissions in Switzerland, mainly due to poor data on imported and exported emissions and the simple methodological approach used. Therefore, the results should be understood as rough estimates to supplement the picture of direct emissions.

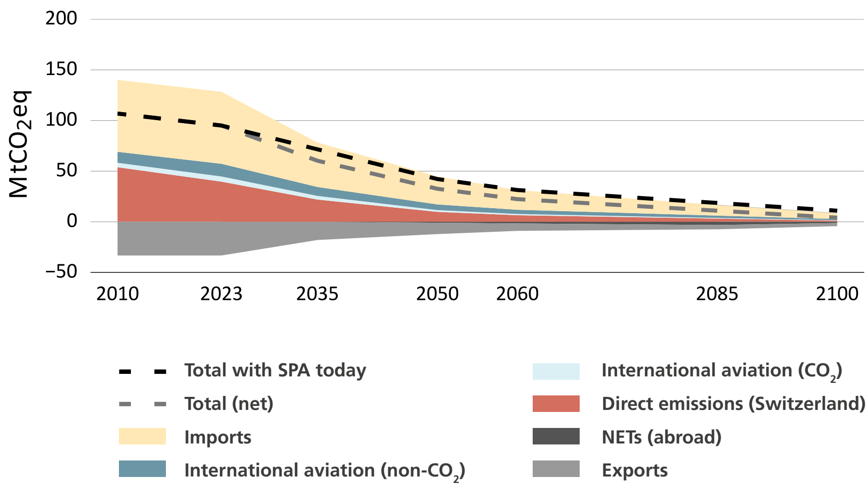
Figure 13: Greenhouse gas emissions for the four scenarios in the extended system boundary



Conflict-Prone Switzerland with minimal climate policy (SSP3-CH & SPA3)



Frugal Switzerland with participatory climate policy (SSP0-CH & SPA2)



'Total (net)' is the sum of positive and negative emissions. The emissions from the sectors considered to date according to the greenhouse gas inventory are summarised for clarity: direct emissions (Switzerland). Only negative emissions NETs (abroad) continue to be shown separately.

In every scenario, emissions from imports are higher than direct emissions in Switzerland. However, imported emissions decline over time, as the modelling in all scenarios assumes that there will be a similar, albeit slower, reduction in greenhouse gas emissions from the production of goods abroad as in Switzerland. In addition, in certain scenarios (notably, Frugal Switzerland with participatory climate policy), the quantity of imported goods decreases. Overall, the trend in imported emissions is similar to that in direct emissions. However, their relative share of total emissions increases with the extended system boundary. This is because the volume of imports and emissions from producing these goods abroad decline more slowly than total direct Swiss emissions. This is clearly evident in the Efficient Switzerland with proactive climate policy scenario, for example, in which imported emissions dominate greenhouse gas emissions in the second half of the century.

Exported emissions are also significant. However, their volume is smaller than that of imported emissions in all scenarios. This is because Switzerland imports more goods than it exports and, on average, produces goods more efficiently in terms of greenhouse gas emissions than other countries. The modelling assumes that there will be no fundamental change in this situation.

Although emissions from aviation are lower than those from other sectors, they are still significant. In addition, their relative importance is increasing over time, as the importance of international aviation is declining more slowly than that of other sectors. According to the model assumptions, aircraft will also continue to use a significant proportion of fossil fuels for a long time to come. Furthermore, the non-CO_2 effects are independent of whether the energy source burned in aircraft is fossil or renewable (biogenic or synthetic).

In the models with extended system boundary, total emissions are higher than Switzerland's direct emissions. This applies in every scenario and in all years. Furthermore, no scenario with extended system boundary achieves the net-zero target, partly because the negative emissions purchased from abroad are not sufficient to do so. However, the Frugal Switzerland with participatory climate policy scenario achieves almost zero emissions by the end of the century. In addition, Switzerland causes fewer emissions in this scenario with extended system boundary than in the Efficient Switzerland with proactive climate policy scenario. This is because in the latter scenario, emissions from the extended view do not decline as sharply.

BOX 3 | CHANGE IN LAND USE

In a supplementary analysis, land distribution by land use class was examined in relation to SSP-CH. The Evoland Model, developed at ETH Zurich, was used for this purpose.[6] In this model, land use in Switzerland is represented as cells within a grid with a resolution of 100 m x 100 m. The model distinguishes between ten higher-level land use classes: arable land, alpine farming areas, permanent crops, closed forest, open forest, settlement areas, pastures and meadows, scrubland, glaciers and other areas. Water bodies (lakes and rivers) are not explicitly modelled, as the model assumes that these areas will not change significantly over time.

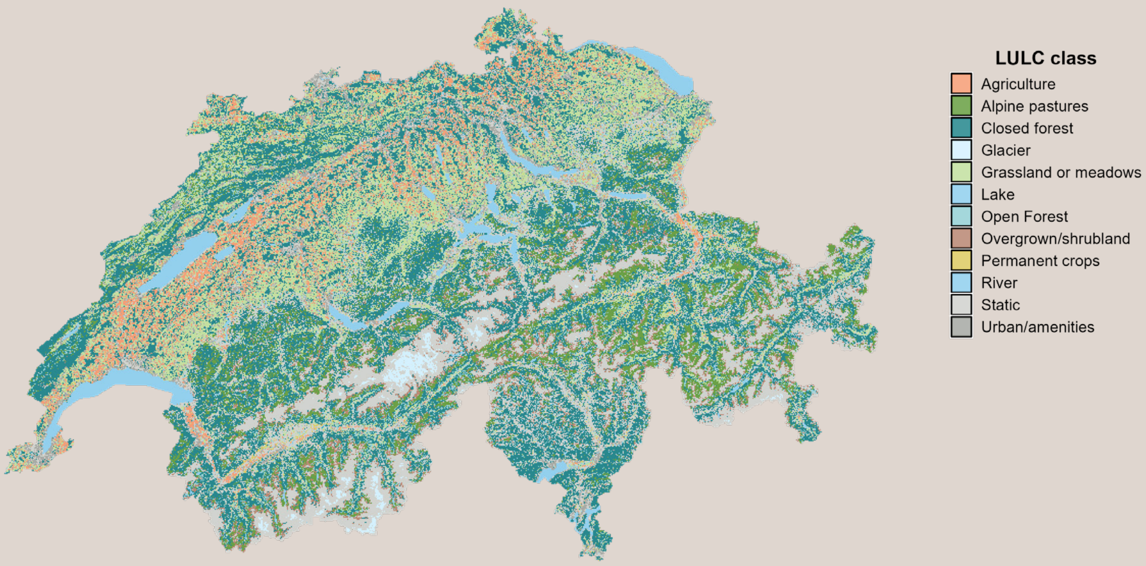
The model calculates the transition probabilities from one land use class to another for different time steps. First, the area proportions of each land use class in the last year of the simulation are determined based on the scenario parameters (target scenario) and then calculated backwards. Taking spatial restrictions into account (including environmental factors, infrastructure, regional conditions and regulations), the local interactions between the cells and the resulting type of state changes are then calculated.

The modelling shows the change in land use from 2020 to 2100, including in the form of raster maps (see example map below), Sankey diagrams and change maps (raster maps showing the addition or subtraction of individual land use classes) in 5-year increments.[7]

6 The developer of the Evoland Model, Benjamin Black, performed the model calculations as part of the NCCS project on socio-economic scenarios (SSP-CH).

7 A detailed description of the inputs used and the complete results can be found on the project page and at https://doi.org/10.5281/zenodo.17108008.

Figure 14: SSP1-CH – Distribution of land use classes in Switzerland in 2100



KEY FINDINGS AND POSSIBLE APPLICATIONS

The Shared Socioeconomic Pathways for Switzerland (SSP-CH) and the Shared Policy Assumptions (SPA) are developed in reference to the global SSP framework established by the Intergovernmental Panel on Climate Change (IPCC). They describe consistent and plausible socio-economic developments in Switzerland up to the year 2100, without assigning probabilities to their occurrence. The scenarios cover a broad spectrum of social, economic and technological changes, thus complementing the existing prospective work of the Federal Administration. The SPAs enable the effects of climate policies to be analysed against the backdrop of various socio-economic developments. All of the examined scenarios are exploratory: they describe 'if-then relationships' and are not intended to achieve predetermined target values.

CONCLUSION: THE COMBINATION OF SOCIO-ECONOMIC DEVELOPMENTS AND CLIMATE POLICY INSTRUMENTS IS CRUCIAL FOR GREENHOUSE GAS EMISSIONS

The modelling results illustrate the effects of very different assumptions about future socio-economic developments and climate policies on final energy consumption and greenhouse gas emissions:

- Previous developments in environmental awareness, technology and efficiency, as well as climate policy to date, act as robust drivers for reducing emissions this century. Under the assumptions of SSP1-CH *Efficient Switzerland* and SSP0-CH *Frugal Switzerland* scenarios, emissions will fall significantly over time, even without further political intervention. This is primarily due to high environmental awareness among the population, coupled with increased efficiency (SSP1-CH) or consciously reduced consumption (SSP0-CH). However, the net-zero target will only be achieved in both SSP-CH scenarios with additional climate policy instruments.
- Negative economic development, reduced international relations and a loss of prosperity, as assumed in SSP3-CH *Conflict-Prone Switzerland*, also lead to a reduction in greenhouse gas emissions in Switzerland in the long term.
- In the SSP5-CH scenario, *Resource-Intensive Switzerland*, emissions rise sharply due to strong, resource-intensive growth and the extensive removal of climate policy instruments. In the long term, they return to current levels due to economic contraction.

Fundamentally, the 'societal climate' depicted in the Shared Socioeconomic Pathways (SSP-CH) has a significant impact on emissions development: it encompasses the continuation of the existing climate policy framework, as well as societal developments and policies that do not directly pursue climate protection goals.[8] These can indirectly influence emissions, for example by triggering societal advances in areas such as environmental awareness and technical innovation, which impact the climate.

8 Therefore, these must be taken into account in the SSP-CH, but not in the additional climate policy instruments (SPA).

In all SSP-CH scenarios, ambitious and proactive climate policy is necessary to achieve the net-zero target, or even to become net negative in some cases, as required by the Paris Agreement. Net-zero emissions can only be achieved if emissions that are difficult to avoid (e.g. from industry and agriculture) are captured and stored using carbon capture (CCS) or offset using negative emission technologies (NETs). This requires additional Shared Policy Assumptions (SPA) in all scenarios (SSP-CH).

POSSIBLE APPLICATIONS OF THE FRAMEWORK FOR SCENARIOS AND MODELLING DEVELOPED IN THE PROJECT

The framework of Shared Socioeconomic Pathways for Switzerland (SSP-CH), Shared Policy Assumptions (SPA) and a simplified emissions model developed in the project can be used for further applications:

- **Extended scenario work:** SSP-CH and SPA can also be used for other scenario work that considers long time periods and broader spectra of possible future developments. Examples of possible applications include integrated risk analyses, scenario work within the context of the SWEET programme, extended energy perspectives or climate adaptation scenarios.
- **Sectoral deepening:** the method presented here could also be applied in detail to specific sectors. For example, it could be used in scenario work examining the interaction between energy systems and new digital developments, such as a large-scale adoption of AI applications.
- **Further development of modelling approaches:** the model's assumptions, parameterisations, modules and results could be refined further. For instance, the emissions module relating to the import and export activities of the Swiss economy is currently highly simplified and could be expanded.
- **Broad application of emissions modelling:** the model could form the basis for other studies on possible emission trajectories. For example, it could focus more on negative emission technologies or the interaction with land use emissions (in this project, land use change is modelled separately and CO_2 flows are not taken into account).