



Axpo Energy Reports

Others



# Introduction

A secure, affordable and sustainable electricity supply is fundamental to the functioning of Swiss society and the economy. Today, Switzerland benefits from very good conditions for a reliable supply thanks to hydropower, nuclear power, new renewable energies and its central location in the European power grid.

In the coming decades, this position will come under pressure unless suitable countermeasures are taken. The electrification of mobility and heating, in addition to population growth, are likely to significantly increase the demand for electricity. Rising energy demand of data centres, cloud services and generative AI further contribute to this trend. At the same time, the planned phase-out of nuclear power will eliminate a substantial proportion of domestic electricity production in the long term.

The winter half-year are increasingly in focus. Switzerland already consumes more electricity in winter than it produces. In the darker months of the year, the demand for heat is higher and people generally spend more time indoors, which increases the power consumption of electronic devices and lighting. In addition, due to the seasonal runoff profile with a high proportion of run-of-river water, hydropower generates more electricity in the summer than in the winter. The current expansion of renewable energies in Switzerland and neighbouring countries is also largely based on solar energy, which generates most of its yield in the summer half-year. The seasonal difference between summer surpluses and winter deficits is increasing, making a secure winter supply increasingly difficult.

In addition to close cooperation with neighbouring countries and the EU, the development of reliable, affordable and sustainable domestic electricity production is needed to secure the electricity supply in the future. In

the Axpo Energy Reports, we look at four technologies that can substantially increase domestic electricity production in winter: Wind energy, new nuclear power plants, solar energy and gas-fired power plants.

A separate report deals with hydropower, which is treated in isolation due to its limited potential for future expansion.

This report considers other currently known energy sources, namely biomass, geothermal energy and seasonal thermal energy storage. Below, for each technology, it is shown what is already in use in Switzerland, what potential can be assumed for electricity production and whether there are specific projects for the use or expansion of the respective technology. It also looks at whether and if so what contribution the respective technology can make to closing the winter electricity gap; as will be shown, the corresponding potential is rather limited.

**This report deals with the other relevant energy sources, namely biomass, geothermal energy and seasonal thermal energy storage.**

<b>01 Biomass</b>	<b>4</b>	<b>03 Seasonal energy storage</b>	<b>14</b>
1.1 Technological development	5	3.1 Technological development	16
1.2 Current buildout	6	3.2 Current buildout	16
1.3 Theoretical expansion potential	7	3.3 Theoretical expansion potential	17
1.3.1 Sustainable, additionally usable potential	7	3.4 Law and regulation	18
1.3.2 Winter electricity from biomass	8	3.5 Conclusion	19
1.3.3 CDR certificates	8		
1.4 Law and regulation	9	<b>Disclaimer and bibliography</b>	<b>20</b>
1.5 Conclusion	9		
<b>02 Geothermal energy</b>	<b>10</b>		
2.1 Technological development	11		
2.2 Current buildout	11		
2.3 Geothermal energy in the winter half-year	12		
2.4 Theoretical expansion potential	12		
2.5 Law and regulation	13		
2.6 Conclusion	13		

# Table of contents



01

**Biomass**

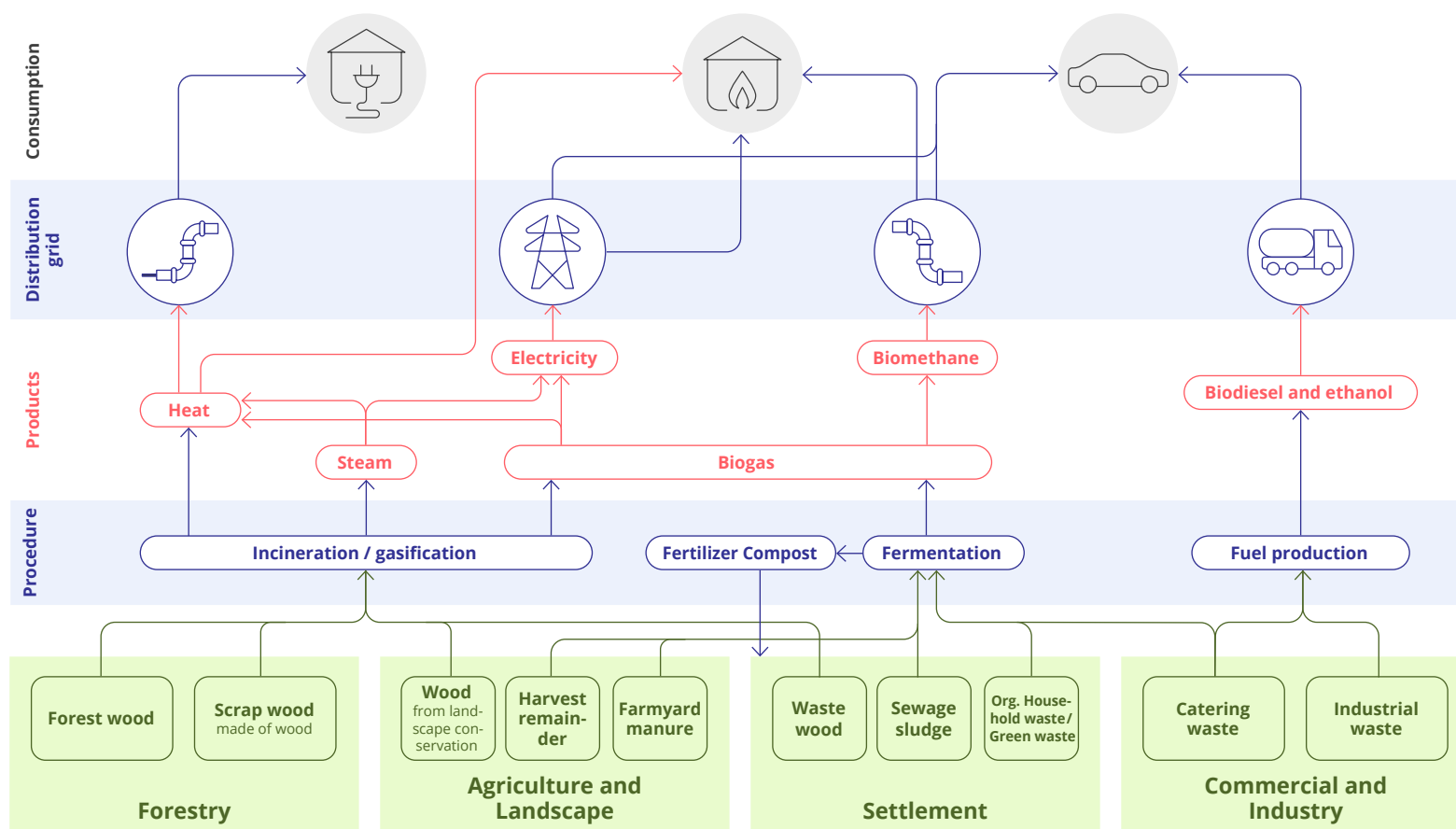
### 1.1 Technological development

Biomass resources include all resources that are obtained directly or indirectly from biogenic material. Biomass is divided into two main categories:

- Woody (dry) biomass, including forest wood, wood by-products from the wood industry and waste wood (e.g. from the construction industry),
- Non-woody (moist) biomass, which includes agricultural manure (liquid and solid manure), crop residues and biogenic waste from the food industry, gastronomy and private households.

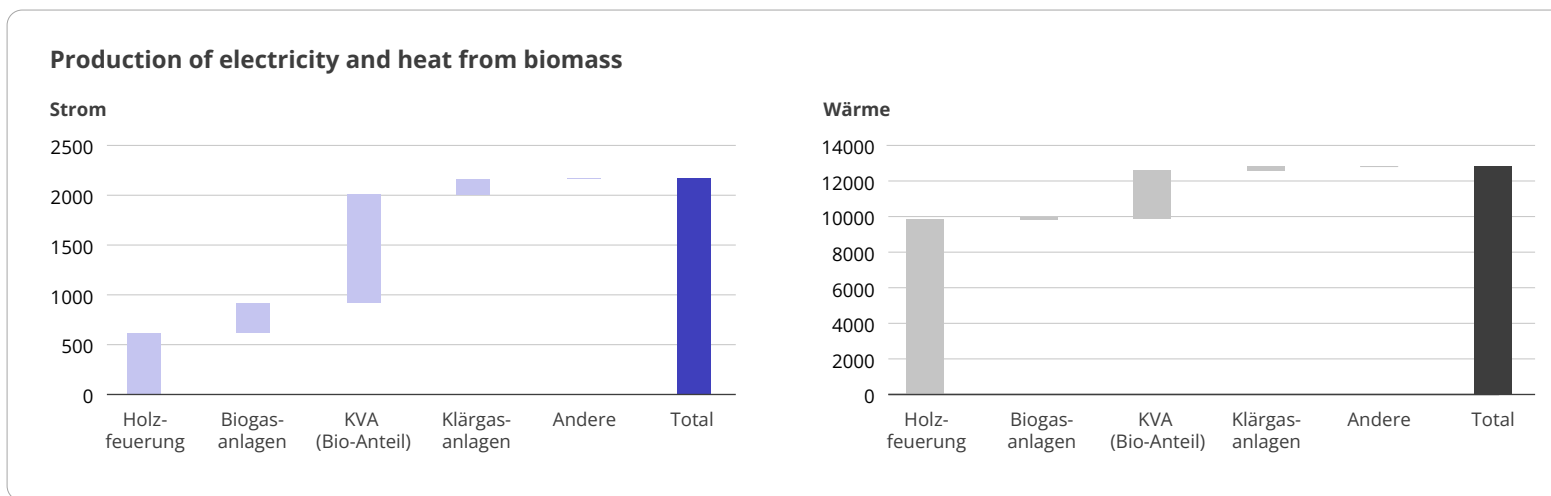
Woody biomass is typically used in combustion plants to generate heat or a combination of heat and electricity. New technologies aim to convert woody biomass by gasification into a mixture of high-energy gases that can be used to generate heat, electricity or fuels.

#### Overview of biomass resources



**Figure 1:** Overview of biomass resources<sup>1</sup>. In order to convey the topic of energy from biomass in an understandable way, the graphic greatly simplifies the complex issues. The energetic use of biomass in waste incineration plants (WIP) in Switzerland was shown in this graph deliberately excluded so as not to further increase the level of complexity.

<sup>1</sup> Swiss Federal Office of Energy SFOE, 2026, Energy from biomass



**Figure 2:** Production of electricity and heat from biomass in Switzerland (excluding biogas fed into the gas grid), 2024, GWh<sup>5</sup>

Non-wood biomass can be processed into biogas (a mixture of biomethane and biogenic CO<sub>2</sub><sup>2</sup>) through anaerobic fermentation. This biogas is then either burnt to generate heat and electricity or processed to separate biomethane from the biogenic CO<sub>2</sub>. The biom-

ethane can then be fed into the gas grid<sup>3</sup>, while the biogenic CO<sub>2</sub> is either released or separated and reused or stored.<sup>4</sup> Alternatively, biomethane can also be combined with renewable hydrogen to produce renewable liquid fuels – but this technology is still at a very

early stage of development and there are no commercial plants in Switzerland. The “Gas Energy” report in the Axpo Energy Reports takes an in-depth look at the two energy sources biomethane and biogas.

## 1.2

### Current buildout

In 2024, Switzerland generated around 2.2 TWh of electricity and 12.8 TWh of heat from biomass. Wood combustion contributed around 10 TWh to total energy production, mainly for the provision of heat. Approximately 4 TWh of this was attributable to heating systems in buildings, the rest to industrial incineration plants. Biogas plants generated 0.3 TWh of electricity and 0.1 TWh of heat. In addition, approx. 0.5 TWh of biomethane was fed into the gas grid<sup>5</sup>. The renewable share of energy from waste incineration plants (biological share of waste incineration plants) amounted to 3.8 TWh, of which 1.1 TWh was electricity.

<sup>2</sup> CO<sub>2</sub> from biomass

<sup>3</sup> Biogas produced from fermentation is a mixed gas consisting of methane (called biomethane) and CO<sub>2</sub> (called biogenic CO<sub>2</sub>).

<sup>4</sup> It is also possible to capture the biogenic CO<sub>2</sub> from the combustion of biogas, but this requires more complex CO<sub>2</sub> capture processes, which are very expensive, especially given the small size of biogas plants in Switzerland.

<sup>5</sup> Gaz Energie, 2024, LSG annual statistics

### 1.3 Theoretical expansion potential

#### 1.3.1 Sustainable, additionally usable Potential

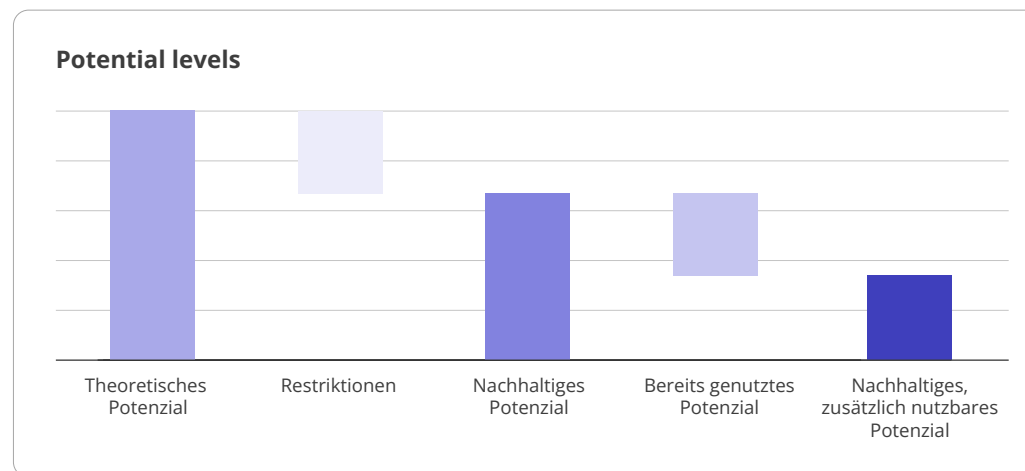
A distinction is made in biomass energy potential between domestic potential (produced in Switzerland) and import potential. The domestic potential is further divided into: the theoretical potential; the sustainable potential (which considers ecological and techno-economic framework conditions); and the additional sustainable potential (which does not account for resources already used).

In 2017, the WSL (Swiss Federal Institute for Forest, Snow and Landscape Research) estimated the sustainable primary energy potential<sup>6</sup> of biomass in Switzerland at around 26.9 TWh, of which 14.7 TWh had already been used. This results in an additional sustainable potential of approximately 12.2 TWh of primary energy.

The additional sustainable potential is made up of 8.4 TWh of non-woody biomass (of which 6.8 TWh is farmyard manure) and 3.8 TWh of woody biomass (of which 2.5 TWh is forest wood).

Assuming that woody biomass is incinerated and non-woody biomass is anaerobically digested into biogas and then incinerated, the remaining sustainable electricity potential from Swiss biomass is around 4 TWh (with a conversion rate of 30 percent from primary energy to electricity).

This potential is not currently in particular because the transport costs for the provision and distribution of the corresponding biomass resources (e.g. collection and distribution of farmyard manure from individual farms, logging in hard-to-reach forest areas) and the costs for conversion into energy are too high. For example, the production costs for biogas in Switzerland are often higher than the European benchmark, largely due to



**Figure 3:** Theoretical potential, sustainable potential and sustainable, usable potential, represented in potential levels<sup>7</sup>

the small size of Swiss farms and the often unfavourable topography.<sup>7</sup>

In addition, electricity generation from biomass competes with other possible uses of these materials. Although both woody and non-woody biomass can be used in combined heat and power plants to generate electricity and heat, many wood-fired heating systems in households and industry only gen-

erate heat. Biogas can also be processed into biomethane and fed into the existing gas grid, where it can replace fossil natural gas. In agriculture, the use of animal excrement for energy competes with its direct use as farmyard fertiliser, although the fermentation residues from anaerobic digestion can also be used as fertiliser. The use of forest wood for energy production also competes with material uses, particularly in the con-

<sup>6</sup> Primary energy is the energy content of raw materials before it is converted into final energy, such as electricity. The conversion of primary energy into final energy leads to losses that are considerable in the case of biomass for electricity generation.

<sup>7</sup> Thees O., Burg V., Erni M., Bowman G., Lemm R., 2017, Biomass Potentials of Switzerland for Energy Use

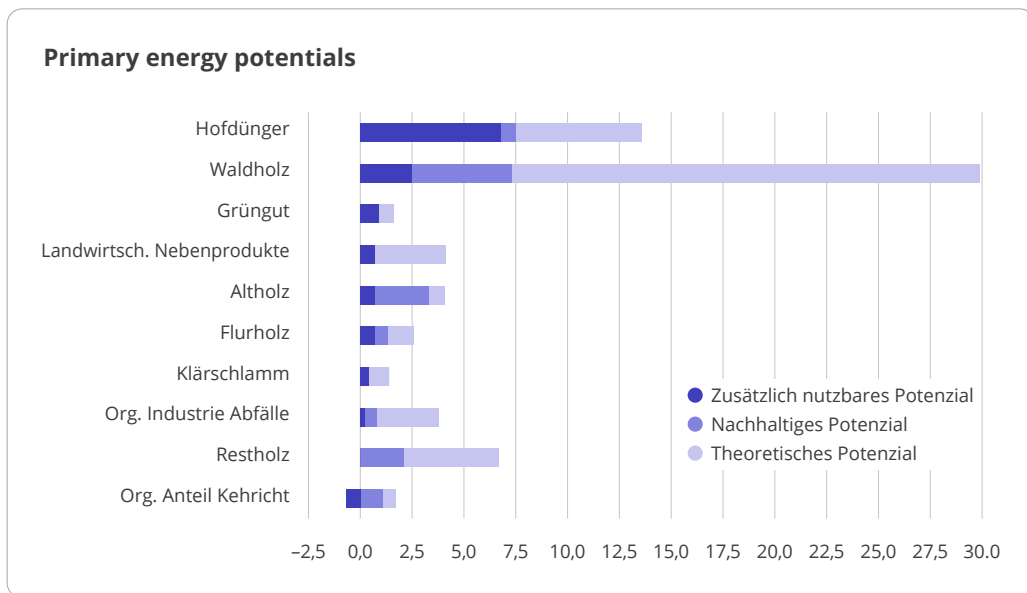


Figure 4: Primary energy potential in Switzerland, TWh<sup>8</sup>

struction industry, which are prioritised in a circular economy context. This competitive situation significantly reduces the hypothetical potential for electricity production from sustainable domestic biomass.

In addition to the domestic biomass potential, Switzerland imports biomass, particularly wood pellets, from abroad. The import potential depends heavily on international demand, the sustainable production potential of other countries, and transport costs.

### 1.3.2

#### Winter electricity from biomass

As a low-emission energy source, biomass currently contributes around 1.1 TWh to electricity generation during the winter half-year. Most biomass plants operate in base load mode throughout the year. In principle, biomass systems can be used flexibly and could therefore be operated preferentially in the winter half-year; however, in practice this is only feasible to a limited extent. Shifting annual production to winter makes it possible to store large quantities of biomass raw materials until winter, as raw material production varies according to season (e.g. base load for biowaste, seasonal differences such as the increase in biomass in spring). Since biomass is not dense in terms of energy – especially compared to fossil fuels – storage costs increase rapidly with increasing volumes. In addition, certain biomass resources (biowaste, manure) are difficult to store.<sup>8</sup>

In addition to electricity generation, biomass contributes significantly to the substitution of

other energy sources through its direct heat generation. This reduces the pressure on electricity requirements in winter and enables electricity to be substituted as an energy source for heat production.

### 1.3.3

#### CDR certificates

The utilisation of biomass for energy generation releases biogenic CO<sub>2</sub>, whether during the combustion of biomass or the processing of biogas into biomethane. This CO<sub>2</sub> can be captured and stored permanently, resulting in negative emissions. These negative emissions can be used as carbon dioxide removal (CDR) certificates to offset greenhouse gas emissions. To date, CDR certificates are only traded on voluntary markets and cannot be counted on regulated markets such as the EU Emissions Trading System (EU ETS). The “Gas Energy” report in the Axpo Energy Reports takes an in-depth look at the topic of CDR certificates and negative emission technologies.

<sup>8</sup> It is possible to ensilate the goods into silo bales or transport silos. This works in the same way as in agriculture with grass and maize. The shelf life is around one to two years. Disadvantages such as the high-volume requirement and necessary infrastructure remain.

## 1.4 Law and regulation

Unlike some other countries, Switzerland does not have a legal framework governing the cultivation of agricultural crops exclusively for energy use. Due to the specific purpose limitation of agriculture to food production (Art. 1 LwG), the permissibility of energy crops on agricultural land is likely to be questionable or, at best, to be permissible to a limited extent.

A range of subsidy instruments are available for generating energy from biomass. Under the Energy Act (EnG) and the Energy Promotion Ordinance (EnFV), biomass plants are eligible for subsidised investment cost contributions of up to 60 percent of their eligible investment costs. Biogas plants and wood-fired power plants can also choose between a sliding market premium or an investment cost contribution (Art. 29a EnG). However, the absolute maximum contribution limits for investment cost contributions (Art. 71 EnFV), prevent large and therefore more efficient biomass plants from being developed. If an in-

vestment contribution is chosen, operating cost contributions may also be granted.

The CO<sub>2</sub> Act (Art. 34a) provides a legal basis for the possible promotion of plants that produce renewable gases, particularly for feeding into the gas grid. However, this subsidy has not yet been introduced by the Federal Council and the deletion of Art. 34a is planned as part of the Federal Budget Relief Package 27 (EP 27), which is currently under discussion in Parliament. In addition, the Association of the Swiss Gas Industry (VSG) supports the development of biogas plants for feeding into the gas grid with a subsidy programme (the so-called biogas fund) (Association of the Swiss Gas Industry, 2025).

The requirements of Swiss spatial planning and, in particular, environmental law as well as cantonal planning and building laws and their implementation via spatial planning instruments (directional and usage planning) form important framework conditions for the planning and (construction) approval of biogas plants.

## 1.5 Conclusion

Biomass is a scarce and localised resource. It is particularly effective where alternatives to decarbonisation are limited and the strengths of biomass come into play: it provides a storable source of heat and combined heat and power that can be used as required, indirectly reducing the demand for winter electricity. In addition, as a domestically available energy source, biomass strengthens energy supply security by reducing dependence on imported energy and fuel imports.

Today, Switzerland already produces around 2.2 TWh of electricity from biomass. The additional sustainable biomass potential amounts to 12.2 TWh of primary energy per year. In theory, if this entire potential was used for electricity generation, around 4 TWh of additional electricity could be generated with a conversion efficiency of 30 percent.

There are many reasons why the potential is not being utilised. On the one hand, the costs of providing the corresponding biomass re-

sources are too high, particularly due to the small size of Swiss agriculture and the often unfavourable topography. On the other hand, there is a subsidy ceiling (absolute maximum contributions of the investment cost contributions), which does not promote the construction and expansion of larger plants. In addition, electricity generation from biomass competes with other recycling methods such as exclusive use for heat generation, processing into biomethane and direct use as farmyard manure.

Nevertheless, biomass is likely to continue to play a complementary role in the energy mix. These conclusions are reflected in the Power Switcher: By 2050, an increase to 4.9 TWh of annual electricity generation is expected, of which 2.7 TWh will be generated in the winter half-year.



02

Geothermal energy

## 2.1 Technological development

Geothermal energy technologies use the heat stored underground in the earth. This heat originates from hot rock located several kilometres underground and can be harnessed to generate electricity. The operation of a geothermal power plant requires locations that meet two conditions: Firstly, sufficiently high temperatures (more than 130 °C) must be found at achievable depths. Secondly, the rock must be sufficiently permeable so that water can flow through the hot rock and heat up in the process. For these reasons, geothermal energy utilisation has historically developed primarily in regions with active tectonics and volcanism – such as in Italy, Iceland and Turkey. So-called **hydrothermal technologies** use the heat directly from naturally occurring aquifers<sup>9</sup>.

The aim of new **generation of geothermal technologies** is to make geothermal heat usable even where there are no natural aquifers. Today, these technologies are evolving, drawing heavily on the technologies and expertise from the oil and gas industry. So-called “Enhanced Geothermal Systems” (EGS) aim to create reservoirs in the desired depth in the subsurface by means of fracturing. Advanced Geothermal Systems (AGS), also known as closed-loop systems, take a different approach. Here, a closed pipe system is introduced into the substrate in which water or another heat transfer medium circulates. Heat is absorbed directly from the hot rock without the water coming into contact with the ground. Both technologies therefore do not depend on naturally occurring aquifers and instead create suitable artificial reservoirs. While first large-scale commercial EGS projects are currently being implemented in

the US, AGS is still in an early commercial pilot and demonstration stage<sup>10</sup>.

New drilling technologies such as plasma/electropulse drilling and millimeter wave drilling are expected to open up additions to even deeper geothermal resources (7–10 km) with higher temperatures and supercritical fluids<sup>11</sup>, but are currently predominantly in the research and demonstration stage.

## 2.2 Current buildout

In Switzerland, geothermal energy is currently used solely to generate heat: In 2024, it was around 4 TWh, 80 percent of which was generated by near-surface geothermal heat pumps.<sup>12</sup>

The development of geothermal power generation in Switzerland has been strongly in-

fluenced by past experience. Two previous projects had to be abandoned following noticeable earthquakes: an EGS project in Basel in 2006 and a hydrothermal project in St. Gallen in 2013. These events led to increased sensitivity to earthquakes triggered by geothermal projects and continue to influence public perception to this day. As a result, the legal requirements have been tightened, and the selection of suitable locations has become much more cautious. At the same time, nearly two decades of research and development have led to important advances. Today, gentler methods for developing the subsurface as well as improved calculation and monitoring methods are available, which make it possible to better assess seismic reactions.<sup>13</sup>

The current geothermal projects in Switzerland are building on these advances<sup>14</sup>. Most of these initiatives focus on the use of hydro-

<sup>9</sup> Aquifers are water-bearing rocks or layers of sediment in the subsoil that store and conduct groundwater

<sup>10</sup> Global market leader: Eavor in Germany, first project went into operation in Geretsried in December 2025

<sup>11</sup> Supercritical fluids are substances that are neither clearly liquid nor gaseous at very high temperatures and pressures and can therefore absorb and transport heat particularly efficiently.

<sup>12</sup> EGC, 2025, Geothermal Energy Use, Country Update for Switzerland

<sup>13</sup> SED, 2020, Good Practice Guide for Managing Induced Seismicity in Deep Geothermal Energy Projects in Switzerland

<sup>14</sup> Geothermal energy Switzerland, 2026, Geothermal factsheets

thermal resources – with comparatively moderate temperatures of below 150 °C – solely for heat generation. Accordingly, prospecting and exploration campaigns<sup>15</sup> are currently underway in several regions of the country, including in the cantons of Geneva and Thurgau, to identify suitable sites. A few projects also aim to generate electricity and therefore require higher temperatures and deeper boreholes. These projects are still at an early stage and are planned, among others, in Éclépens in the canton of Vaud and in the La Broye region in the canton of Fribourg<sup>16</sup>. An electrical output of several megawatts is planned for each project.

The most significant next-generation geothermal energy project currently underway in Switzerland is the Haute-Sorne EGS pilot project in the canton of Jura, developed by Geo-Energie Suisse. The project involves two deep boreholes reaching depths of around four to five kilometres. The goal is to generate approximately 5 MW of electricity and provide additional heat for the region. After extensive preparatory measures and lengthy authorisation procedures, the first deep well was drilled in 2024 and successfully stimulated in 2025. Initial results indicate that the permeability of the rock could be improved without exceeding the seismic limit values. Geo-Energie Suisse aims to put the project into operation by 2030. There are also plans to develop further projects; several potential locations in the Swiss Plateau have already been identified.<sup>17</sup>

### 2.3 Geothermal energy in the winter half-year

Geothermal energy is a base load technology that can provide continuous output with an availability of over 80 percent, regardless of weather conditions and season. In addition, geothermal power generation is often combined with the provision of heat, which is used locally for district heating networks. This provision of thermal energy helps to reduce the electricity required for heating (heat pumps).

During the winter half-year, the lower air temperature slightly improves the production of the geothermal systems by increasing the temperature gradient to the underground heat source. Basic research to make electricity generation more flexible between summer

and winter is in its infancy. Testing in specific projects is still pending.<sup>18</sup>

### 2.4 Theoretical expansion potential

The limited knowledge of the geological properties of the subsurface in Switzerland currently makes it difficult to reliably assess the geothermal potential. For example, there are promising geothermal temperature gradients of 25 to 40 °C/km in the Swiss Molasse Basin. However, the aquifers present there are poorly explored geologically, spatially uneven and therefore come with uncertain production volumes, which means that there is a lack of reliable framework conditions for specific hydrothermal power generation projects. Therefore, the potential of conventional hydrothermal power generation is considered limited from today's perspective.<sup>19</sup>

<sup>15</sup> Prospecting and exploration campaigns include step-by-step surveys of the subsurface, from initial geological analyses to detailed surveys and drilling to assess the geothermal potential of a site

<sup>16</sup> [Swiss GeoEnergy, 2026](#)

<sup>17</sup> [Geo-Energie Suisse, 2025, Locations](#)

<sup>18</sup> [Poore, 2024, Flexible geothermal power approach combines clean energy with a built-in "battery"](#); [Ricks et al, 2024, The role of flexible geothermal power in decarbonised electricity systems](#)

<sup>19</sup> One advantage of hydrothermal power generation is that if thermal water is found, it is already heated to the temperature of the surrounding rock. In this case, the possible production rate is primarily limited by the hydraulic permeability of the reservoir rock. In EGS, on the other hand, cold water is injected, which must first absorb heat from the rock during circulation. To ensure sufficient heating, a longer dwell time is required, which limits the maximum realisable flow rate.

Next-generation technological approaches such as EGS and AGS, on the other hand, are basically independent of natural aquifers and can therefore be implemented in principle throughout the country. The crystalline basement north of the Alps is currently considered to be particularly promising for the development of EGS.

## 2.5

### Law and regulation

The requirements of Swiss spatial planning law and, in particular, environmental law, as well as cantonal planning and building legislation and their implementation via spatial planning instruments (structure and utilisation planning), form key framework conditions for the planning and structural approval of geothermal projects. Within these guidelines – and in accordance with Switzerland's federal system – the specific regulations are issued primarily by the cantons and municipalities, resulting in considerable diversity. This diversity is also reflected in the responsibilities: Depending on the canton and munic-

ipality, different authorities are responsible for spatial planning specifications (directive and use planning), for specific building and operating permits and for upstream permits such as prospecting and exploration permits.

According to the Energy Act (Art. 27b EnG), investment contributions of up to 60 percent of the eligible investment costs can be granted for the exploration and development of geothermal reservoirs as well as for new geothermal plants. In addition, a project planning contribution can be claimed for new geothermal plants up to a maximum of 40 percent of the eligible project planning costs. If the project is successful, this will be offset against the investment contribution.

The use of geothermal energy for the provision of heat is promoted by means of the CO<sub>2</sub> Act (Art. 34a) and the CO<sub>2</sub> Ordinance. However, the deletion of Art. 34a CO<sub>2</sub> Act is planned as part of the Federal Budget Relief Package 27 (EP 27), which is currently under discussion in Parliament.

## 2.6

### Conclusion

The potential of conventional hydrothermal power generation is likely to remain limited due to the limited number of naturally occurring aquifers. In contrast, next-generation geothermal energy technologies such as EGS and AGS enable the creation of suitable artificial reservoirs through stimulation, making them less dependent on natural geological conditions.

In Switzerland, previous seismic setbacks have slowed the expansion of geothermal energy. Recent advances in stimulation techniques and seismic monitoring, however, have improved the situation. Combined with the current subsidy regime, this opens up new opportunities for the implementation of new projects, such as the Haute-Sorne EGS pilot project and several hydrothermal project initiatives. These projects must now demonstrate that seismic problems can be successfully avoided and that they gain public acceptance. If successful, geothermal energy –

particularly next generation systems such as EGS and AGS – could play an important complementary role in the energy mix. These conclusions are also reflected in the scenarios in the Axpo Energy Reports: Over the course of the year, an increase to 2.1 TWh of annual electricity generation is expected by 2050, of which around 1 TWh will be accounted for in the winter half-year.



03

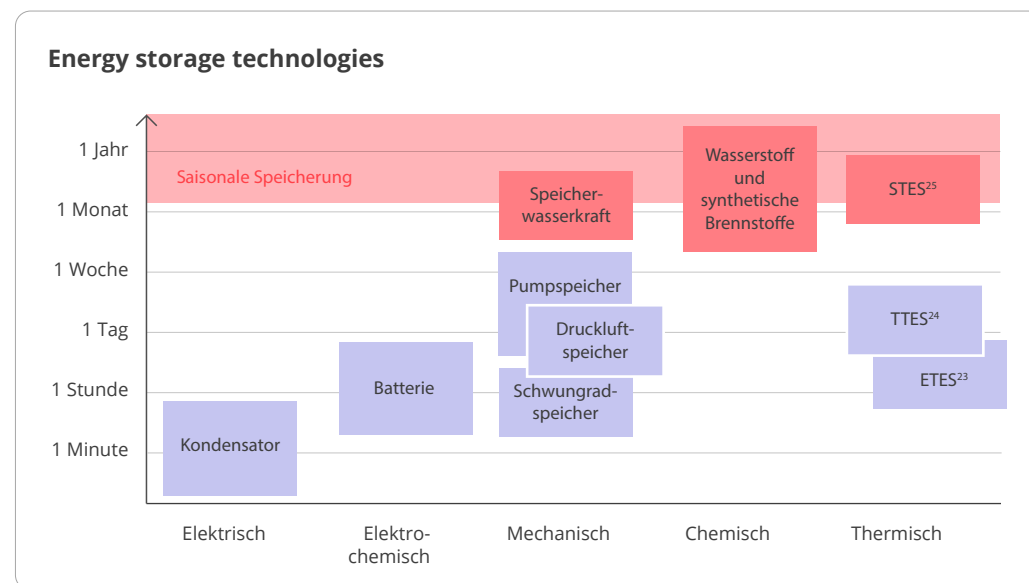
Seasonal energy storage

A seasonal energy storage system can store energy for several months and make it available for later use, enabling electricity or heat produced in summer to be used in the winter half-year.

Several technologies are available for seasonal energy storage. The most important are storage hydropower, the chemical storage of molecules in the form of hydrogen and other synthetic fuels, and seasonal thermal energy storage (STES). In Figure 5, these technologies are shown together with other common storage technologies and classified according to storage period and type of storage technology. The storage period refers to the length of time energy can be stored and later used under typical technical and economic conditions.

**Storage hydropower plants** enable the storage of energy for periods ranging from several weeks to months. In Switzerland, they currently represent the most important tech-

nology used for seasonal energy storage. Storage hydropower plants – together with pumped storage plants which are primarily designed for storage periods of a few hours – are discussed in more detail in the Hydro-power Technology Report in the Axpo Energy Reports'. An alternative seasonal storage option is chemical energy storage, where electricity is converted into **hydrogen or other synthetic fuels**. The first hydrogen production plants already exist in Switzerland, but so far only on a limited scale and not specifically for seasonal energy storage. This topic is explained in more detail in the Gas Energy Technology Report in the Axpo Energy reports series. Energy can also be stored in the form of heat over longer periods. This section focuses on **seasonal thermal energy storage (STES)** systems. Other heat storage systems such as ETES (Electrothermal Energy Storage) or TTES (Tank Thermal Energy Storage) systems, which are typically used as short-term buffer storage systems in district



**Figure 5:** Overview of different types of energy storage technologies sorted by storage period and storage technology.

heating networks, are not suitable for seasonal heat storage due to higher thermal losses.<sup>20,21,22</sup>

All seasonal energy storage systems typically only undergo one or two charging and discharging cycles per year. Compared to short-

<sup>20</sup> ETES: Electrothermal energy storage  
<sup>21</sup> TTES: Tank Thermal Energy Storage  
<sup>22</sup> STES: Seasonal Thermal Energy Storage

and medium-term storage systems, which are used much more frequently, the total costs of seasonal storage systems must therefore be correspondingly low, as they are distributed over a much smaller amount of energy stored annually.<sup>23</sup>

### 3.1 Technological development

STES makes it possible to store heat generated in summer for several months and make it available again in winter. The stored heat typically originates from processes that cannot be flexibly controlled, such as waste incineration plants, industrial plants, data centres or solar thermal plants – sources where the heat would otherwise remain unused.

In addition, STES can also store heat generated by an electric boiler or heat pump when electricity prices are low or even negative. However, this requires additional investment

in the electric boiler or heat pump. Procuring electricity also requires either a connection to the power grid – with the associated costs – or the use of electricity from a nearby plant, which imposes constraints on the possible location of the STES system.

The most important STES technologies currently in use store heat either in natural underground aquifers (aquifer thermal energy storage (ATES)), in artificially created, water-filled earth basins (pit thermal energy storage (PTES)), or directly in solid rock via boreholes (borehole thermal energy storage (BTES)). BTES systems are already used in combination with geothermal heat pumps and photovoltaic or solar thermal systems. In summer, when there is a surplus of energy on site, excess heat is selectively transferred into the substrate and stored there. This increases the underground temperature, which in turn improves the coefficient of performance (COP) of the geothermal heat pump in winter.

The efficiency of STES technologies is usually defined as the thermal recovery efficiency (i.e. the ratio of usable heat recovered after the storage period to the amount of heat stored). As the surrounding soil serves as a storage medium in BTES and ATES systems, the recovery rates are typically limited to around 65 percent. In contrast, PTES systems achieve significantly higher storage efficiencies of up to around 90 percent due to their comparatively good thermal insulation.<sup>24</sup> It is important to understand that ATES and BTES systems are usually discharged in combination with heat pumps in order to make the stored temperature level usable for the heat supply. For this reason, the focus is on increasing the COP of the connected heat pumps, which reduces the electricity required for heat generation and makes it possible to integrate surplus energy into the heating system in summer. With PTES systems, on the other hand, some of the stored heat can also be used directly without a heat pump – espe-

cially with sufficiently high storage temperatures.

Current research is investigating alternative storage media with higher energy density, for example through the use of latent<sup>25</sup> or thermochemical<sup>26</sup> energy. However, the current costs of such systems remain extremely high.

### 3.2 Current buildout

In general, STES technologies are still in the early stages of commercial development, with only a few commercially operated projects in Europe to date. An exception is the widespread use of low-temperature ATES systems in the Netherlands since the 1990s, which were favoured by very suitable subsoil conditions.

The first commercial STES systems are also in operation or in the planning stage in Switzer-

<sup>23</sup> [Energie Lexikon, 2026, RP-Energie-Lexikon](#)

<sup>24</sup> [Yang, T., Liu, W., Kramer, G., Sun, Q., 2021, Seasonal thermal energy storage: A techno-economic literature review](#)

<sup>25</sup> Latent energy refers to heat that a material can absorb or release during a phase change without changing its temperature. This means that large amounts of energy can be stored in a comparatively small volume.

<sup>26</sup> Thermochemical energy describes the storage of heat in reversible chemical reactions.



- All current STES technologies store heat at temperatures below 90 °C (previously even below 20 °C in Switzerland), which means that applications for heat consumption are largely limited to building heating.
  - Due to the low energy density of today's STES technologies and pronounced economies of scale in terms of costs, only large-scale storage systems that are connected to several buildings, entire sites or larger district heating networks are economical as a rule.
  - Because of the high costs and losses involved in heat transport, STES systems require a close proximity of the heat source, storage and consumption
  - Most mature STES technologies, especially ATES and BTES, are highly dependent on local geological conditions. ATES requires naturally existing aquifers at an accessible depth, whereas BTES requires a subsurface with little or no groundwater flow (as this can otherwise dissipate the stored heat and significantly reduce the recovery rate).
  - The use of ATES and BTES in Switzerland is limited by the current legal framework (see next section).
  - PTES require large areas and suitable sites such as pits or earth basins are currently very limited. Such areas are particularly difficult to find in densely populated regions and correspondingly expensive.
- In 2025, the ZHAW, HSLU and consentec GmbH published a study on behalf of the Swiss Federal Office of Energy (SFOE) to assess the technical and economic optimum of heat storage capacities in the Swiss energy system for the years 2035 and 2050<sup>34</sup>. The

study concludes that approximately 350 GWh of seasonal heat storage is economically viable. Achieving this capacity would require an area of roughly 70 hectares – equivalent to around 100 football pitches. According to the study, seasonal heat storage would reduce Swiss electricity demand in the winter half-year by around 90 GWh. For the conversion of saved winter heat into reduced winter electricity demand, it is assumed that the heat output from the STES systems reduces the use of heat pumps or electric boilers accordingly.

### 3.4 Law and regulation

There is no special legal framework for STES technologies in Switzerland<sup>35</sup>. Instead, the requirements of Swiss spatial planning law, environmental law, and cantonal planning and building laws – implemented via spatial planning instruments (structure and utilisation planning) – form the key framework condi-

tions for the planning and building approval of STES facilities.

From an environmental perspective, the requirements of the Water Protection Act (GSchG) are particularly important for underground STES technologies. According to the Waters Protection Ordinance (Annex 2, Section 21, Paragraph 3 WPO)<sup>36</sup>, in particular, the permissible temperature change of the groundwater due to heat input or removal is limited to a maximum of 3 °C in order to protect ecological processes and water quality. This requirement considerably limits the development of underground STES systems with higher storage temperatures and currently favours low-temperature applications in combination with heat pumps.

There are several regulatory instruments that can support the market ramp-up of STES technologies. According to Art. 21 of the Climate Protection Ordinance (based on Art. 7 of the Climate Protection Act), there is the

<sup>34</sup> ZHAW, 2025, Demand for energy storage in Switzerland

<sup>35</sup> No in-depth clarifications were made within the scope of this overview report, specifically with regard to cantons or municipalities.

<sup>36</sup> SR 814.201 – Water Protection Ordinance of 28 October 1998 (WPO)

possibility of state risk insurance for investments in public infrastructure, including thermal grids and seasonal heat storage facilities. This mechanism is intended to mitigate the risks of such projects and facilitate their implementation. These risks for long-term thermal storage systems include the elimination of dual use<sup>37</sup> and the fact that the predicted annual storage efficiency of long-term thermal storage systems is less than 15 percent lower. The specific requirements and design of this risk protection are described in the SFOE's policy: Risk protection for thermal grids and long-term thermal storage facilities (SFOE, 2025).

### 3.5

#### Conclusion

STES technologies can theoretically contribute to increasing the overall efficiency of the energy system by storing previously unused heat generated in summer for several months and making it available again in winter. However, despite their high level of technical maturity, their potential in Switzerland is clearly limited. According to the study commissioned by the SFOE, electricity demand in the winter half-year can only be reduced by 90 GWh with STES, which is significantly less than 1 percent. This assessment is also reflected in the Axpo Energy Reports' scenarios, according to which STES technologies will only make a marginal contribution to reducing winter electricity demand in Switzerland by 2050.

<sup>37</sup> Dual use in accordance with Art. 23 of the Climate Protection Ordinance: other surface use in earth reservoirs

# Disclaimer and bibliography

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aeesuisse. (2022). *Winter electricity demand and seasonal heat storage – saving electricity in winter with summer heat*. Forum Energy Storage Switzerland. From [https://speicher.aeesuisse.ch/wp-content/uploads/sites/15/2022/05/FESS\\_Saisonale\\_Waermespeicher\\_Positionspaper\\_2205.pdf](https://speicher.aeesuisse.ch/wp-content/uploads/sites/15/2022/05/FESS_Saisonale_Waermespeicher_Positionspaper_2205.pdf).

Association of the Swiss Gas Industry. (2025). *Implementing provisions for the Biogas Fund (valid from 1 January 2026)*. From [https://gazenergie.ch/fileadmin/user\\_upload/ErneuerbareGase/Ausfuhrungsbestimmungen\\_Biogasfonds\\_ab-1.1.2026-en.pdf](https://gazenergie.ch/fileadmin/user_upload/ErneuerbareGase/Ausfuhrungsbestimmungen_Biogasfonds_ab-1.1.2026-en.pdf).

EGC. (2025). *Geothermal Energy Use, Country Update for Switzerland*. Geothermal Switzerland. From [https://geothermie-schweiz.ch/wp\\_live/wp-content/uploads/2025/10/EGC-2025-Country-Update-Switzerland-final.pdf](https://geothermie-schweiz.ch/wp_live/wp-content/uploads/2025/10/EGC-2025-Country-Update-Switzerland-final.pdf).

Empa. (2026). *Borehole Thermal Energy Storage (BTES)*. From <https://www.empa.ch/web/s313/borehole-thermal-energy-storage-btes->.

*Energy Lexicon*. (2026). From RP-Energie-Lexikon: [www.energie-lexikon.info/saisonaler\\_energiespeicher.html](http://www.energie-lexikon.info/saisonaler_energiespeicher.html).

*Geo Energy Suisse locations*. (2025). From [www.geo-energie.ch/standorte/](http://www.geo-energie.ch/standorte/).

Holinger. (2025). *Innovative project: Energiezentrale Buech in the west of Bern*. From [www.holinger.com/projekte/innovatives-projekt-energiezentrale-buech-im-westen-von-bern/](http://www.holinger.com/projekte/innovatives-projekt-energiezentrale-buech-im-westen-von-bern/).

Poore, C. (2024). Flexible geothermal power approach combines clean energy with a built-in 'battery'. *Priceton Engineering, Andlinger Centre for Energy and the Environment*. From [www.engineering.princeton.edu/news/2024/02/16/flexible-geothermal-power-approach-combines-clean-energy-built-battery](http://www.engineering.princeton.edu/news/2024/02/16/flexible-geothermal-power-approach-combines-clean-energy-built-battery).

SED, E. (2020). *Good Practice Guide for Managing Induced Seismicity in Deep Geothermal Energy Projects in Switzerland*. From [www.doi.org/10.3929/ethz-b-000453228](http://www.doi.org/10.3929/ethz-b-000453228).

Swiss Federal Office of Energy, SFOE. (2025). *"Risk hedging for thermal grids and thermal long-term storage" policy*. From [www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRTaW4uY2gvZGUvcHVibGllYX/Rpb24vZG93bmxvYWQvMTE5Njk=.html](http://www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen.exturl.html/aHR0cHM6Ly9wdWJkYi5iZmUuYWRTaW4uY2gvZGUvcHVibGllYX/Rpb24vZG93bmxvYWQvMTE5Njk=.html).

Swiss Federal Office of Energy, SFOE. (2020). *Energy from biomass*. From [www.bfe.admin.ch/bfe/de/home/versorgung/erneuerbare-energien/energie-aus-biomasse.html](http://www.bfe.admin.ch/bfe/de/home/versorgung/erneuerbare-energien/energie-aus-biomasse.html).

Swiss Federal Office of Energy, SFOE. (2023). *Groundwater as a heat reservoir for heating and cooling – the Swatch-Omega example*. Energiaplus. From <https://energiaplus.com/2023/06/07/grundwasser-als-waermespeicher-zum-heizen-und-kuehlen-das-beispiel-swatch-omega/>.

Thees, O., Erni, M., Burg, V., Bowman, G., Biollaz, S., Damartzis, T., Nussbaumer. (2023). *BioSweet*. Energy wood in Switzerland: Potential, technology development, resource mobilisation and its role in the energy transition: [www.doi.org/10.55419/wsl:32789](http://www.doi.org/10.55419/wsl:32789).

ZHAW. (2025). *Demand for energy storage in Switzerland*. From <https://www.zhaw.ch/de/forschung/projekt/76261>.

Zurich Airport. (2026). *Subglacial groove – a natural heat and cold storage*. From <https://www.flughafen-zuerich.ch/en/company/flughafen-zuerich/airport-development/current-construction-projects/rinne>.