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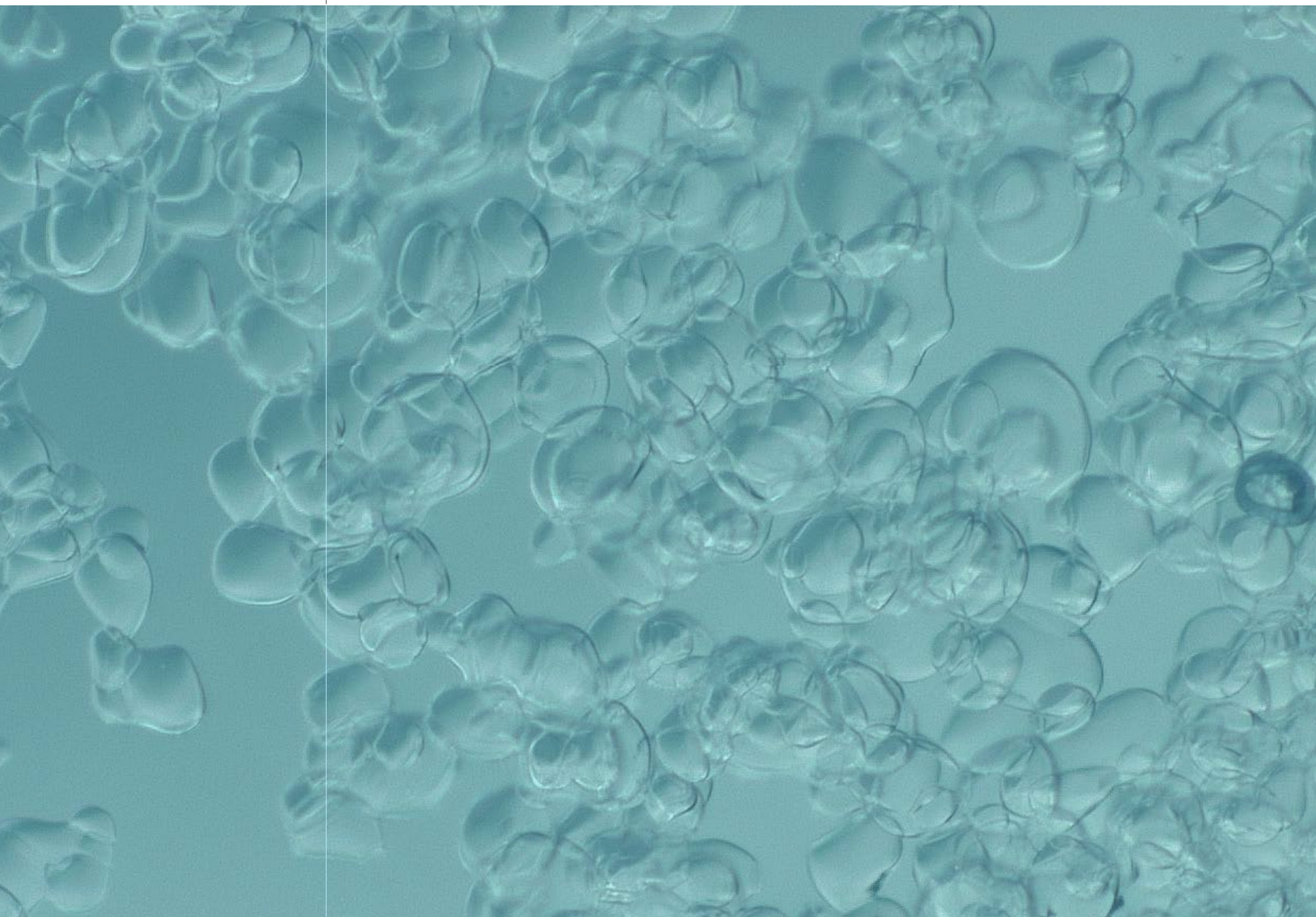
Swiss Federal Office of Energy SFOE

Energy research and innovation
Report 2024



Editorial

Energy supply security and the challenges of climate change are among the most important topics in Switzerland and worldwide. Alongside the implementation of efficiency measures and the application of renewable energy technologies, energy research plays an important role. Research helps to study the increasingly complex energy system with its various interactions between a wide range of actors and different energy sectors, and to develop technical and non-technical solutions which can be successfully implemented.

The Swiss Federal Office of Energy (SFOE) has been promoting and coordinating Swiss energy research in a programmatic approach for many years and supports application-oriented research, pilot and demonstration projects as well as larger interdisciplinary research consortia. Three different funding instruments are employed for this purpose, which complement each other. This brochure presents examples of projects that are supported and closely monitored by the SFOE, representing a large number of other research, pilot and demonstration projects. The QR codes provided will take you to detailed information.

Swiss Federal Office of Energy SFOE
Section Energy Research and Cleantech

(Cover picture) Ice storage systems have great potential for providing and storing heat and cold, which can be used in both residential buildings and industry. In order for them to be used more widely, they need to be more cost-effective and flexible. Researchers at the University of Applied Sciences in Eastern Switzerland are therefore working on a new concept that uses a fine ice slurry (seen here under a microscope) instead of solid layers of ice.

The basic principle of ice storage is based on what is known as latent heat: when water turns to ice, energy is released that can then be used. Conventional ice storage systems consist of water tanks with heat exchanger pipes. The problem with this is that the layer of ice that forms on the pipes acts as insulation and hinders heat exchange. The new concept developed by the University of Applied Sciences in Eastern Switzerland circumvents this problem with an ice slurry storage system. Instead of forming solid ice, a fine ice slurry consisting of water and ice crystals is created. This makes heat exchange more efficient.

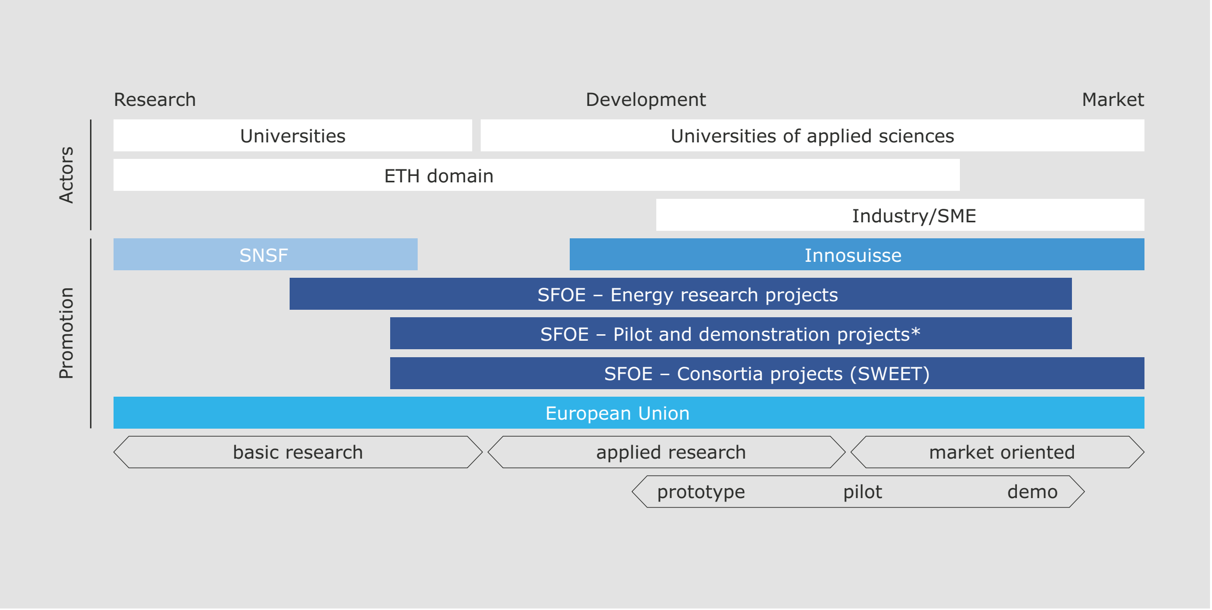
The technology is being investigated experimentally and with numerical modelling in two projects supported by the Swiss Federal Office of Energy: SlurryStore and ModIceCrys. Initial tests show promising results, some technical challenges, such as blockages in the tank, still need to be resolved (source: Slurry ice under microscope/commons.wikimedia.org/Michael Froehlich [downloaded on 16 May 2025]).

Content

Promotion of technology and innovation

With three complementary funding instruments for research and innovation in the energy sector, the Swiss Federal Office of Energy (SFOE) covers almost the entire technology spectrum. The SFOE bases its activities on the federal government's energy research strategy 2025–2028. FTechnical, social and human sciences (SSH) should work closely together right from the design stage of research projects so that research results can be geared towards later application at an early stage.

Funds from SFOE for energy research are used in a subsidising manner to close gaps in the funding landscape. It is allocated strategically in line with the concept in order to promote the national und international integration of researchers. In 2024, around 50 million Swiss francs per year are available for this and around 400 ongoing projects are closely monitored each year.



The Swiss Federal Office of Energy (SFOE) coordinates research and innovation in the energy sector across a large part of the value chain. (Innosuisse = Swiss Agency for Innovation Promotion; SNSF = Swiss National Science Foundation). *As part of the measures to relieve federal finances, the Federal Council is planning to cancel the Pilot and Demonstration Programme.

Thematic energy research programmes

With its thematically oriented energy research programmes, the Swiss Federal Office of Energy (SFOE) covers a broad spectrum of energy research. These programmes are closely linked to the SFOE's other funding instruments (Pilot and Demonstration Projects Programme and the SWEET Programme). The individual programmes are oriented along the axes of "Energy efficiency", "Renewable energy", "Humanities and social science topics", "Storage and grids". Central topics such as "digitalisation", "sector coupling" and "energy storage" are addressed across the programmes.

- Buildings and Cities (3–8)
- Mobility (4–8)
- Industrial processes (3–8)
- Electricity (3–8)
- Fuel cells (2–8)
- Batteries (2–8)
- Heat Pumps and refrigeration (4–8)

- Solar heat and heat storage (4–8)
- Photovoltaics (3–8)
- Solar energy at high temperature (CSP) (3–8)
- Hydrogen (2–8)
- Bioenergy (3–8)
- Hydropower (4–8)
- Geoenergy (3–8)
- Wind energy (4–8)
- Dams (3–8)

- Energy–Economy–Society

The SFOE's thematic energy research programmes. The numbers in brackets indicate the technology maturity level of projects funded by the corresponding programme.

Inter- and transdisciplinary energy research promotion with SWEET

The SWEET funding programme – "SWiss Energy research for the Energy Transition" – supports interdisciplinary and transdisciplinary research consortia that address key issues relating to the Energy Strategy 2050 and Switzerland's long-term climate strategy. To this end, thematic calls for proposals are launched.

In collaboration with the Federal Office for the Environment, the Swiss Federal Office of Energy launched a call for proposals on the net-zero target in 2024. The future consortium will be tasked with identifying ways in which Switzerland can deal with hard-to-abate greenhouse gas emissions from industry, waste incineration plants and agriculture to achieve the net zero target by 2050. The focus is on carbon capture and storage (CCS) and negative emission technologies (NET), but also on approaches that can further reduce hard-to-abate greenhouse gas emissions.

In 2024, the RECIPE (Resilient Infrastructures for the Swiss Energy Transition) consortium was awarded the funding for the call on "Infrastructures, climate change and resilience of the Swiss energy system". Led by ETH Zurich, the researchers will identify, among other things, the effects of climate change on the Swiss energy system. They are also investigating the impact of disruptions, such as interruptions to the energy supply or fluctuations in energy prices, on the economy, society, resources and ecosystems.

The CoSi (Co-Evolution and Coordinated Simulation of the Swiss Energy System and Swiss Society) consortium has been active since 2023. It coordinates the development of energy scenarios for the SWEET consortia and integrates findings from the social sciences and humanities. This is based on a common understanding of the models developed by the first four SWEET consortia in the CROSS activity from 2021 to 2023. The scenario definitions have been harmonised to ensure that all models use same definition of net zero. Various parameters were also harmonized: for example, the energy wood potential has now been adjusted to the latest analyses and the potential of waste for process heat production has been reduced, as this is used or is intended to be used for district heating networks in many places.

With this common basis, the researchers calculated and compared energy scenarios using a total of seven models. This revealed interesting similarities, but also major differences: for instance, the models agreed on the share of solar power to be added by 2050 and how this interacts with hydropower. However, they delivered very different results regarding the future importance of hydrogen or the supply of process heat for industry. The data needs to be refined to achieve more consistent predictions . One example: the researchers are currently collecting data on how much heat industry needs at what temperature levels.

The researchers in the CoSi consortium are currently working on the next model comparison. They are continuing to highlight technically oriented system developments but are also working on integrating more humanities and social science aspects into their analyses. This is done by examining various in-depth topics that shed light on different aspects of the energy transition. For example, agent-based models can be used to investigate how different actors make their decisions. The results provide information on whether and under what conditions the population or companies decide and act in such a way that the scenarios from the technical models can be implemented. The various analyses are expected to start in the second half of 2025, with initial results planned for 2026.

The CoSi consortium plans to conduct three such cycles of analyses by 2032. This should make the energy scenarios more meaningful and provide a better basis for decision-making in politics, business and society.

Irene Bättig, Sprachwerk GmbH

DeCarbCH

EDGE

PATHFNDR

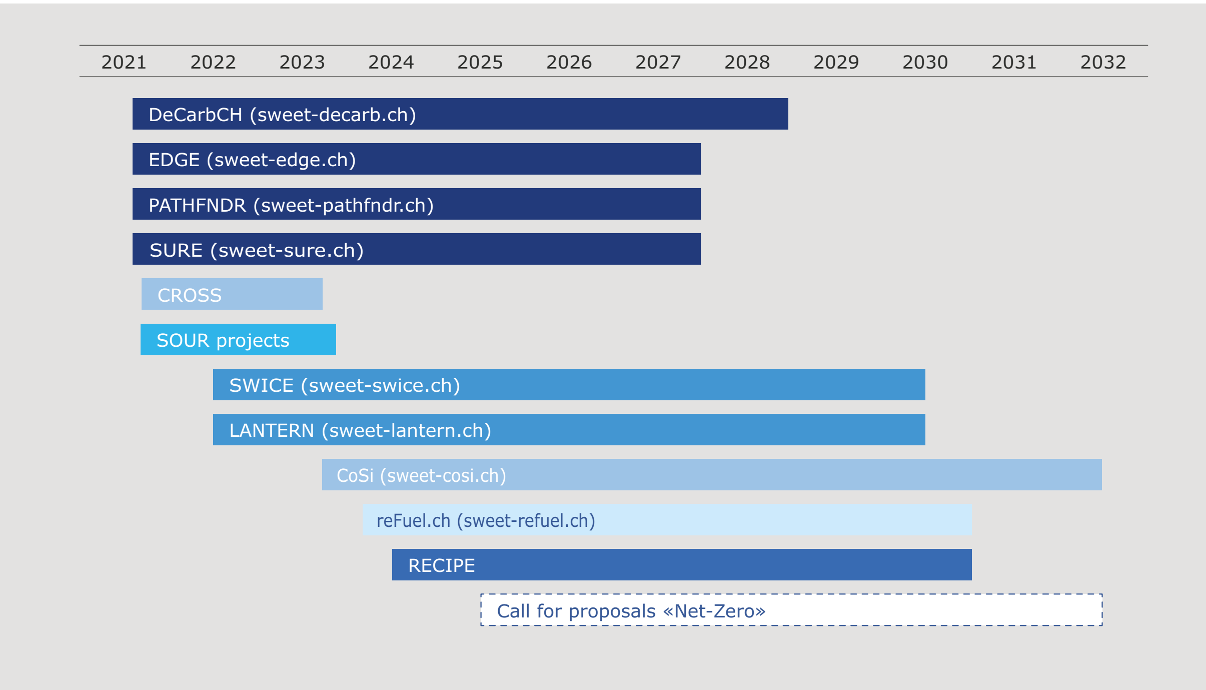
SURE

SWICE

LANTERN

CoSi

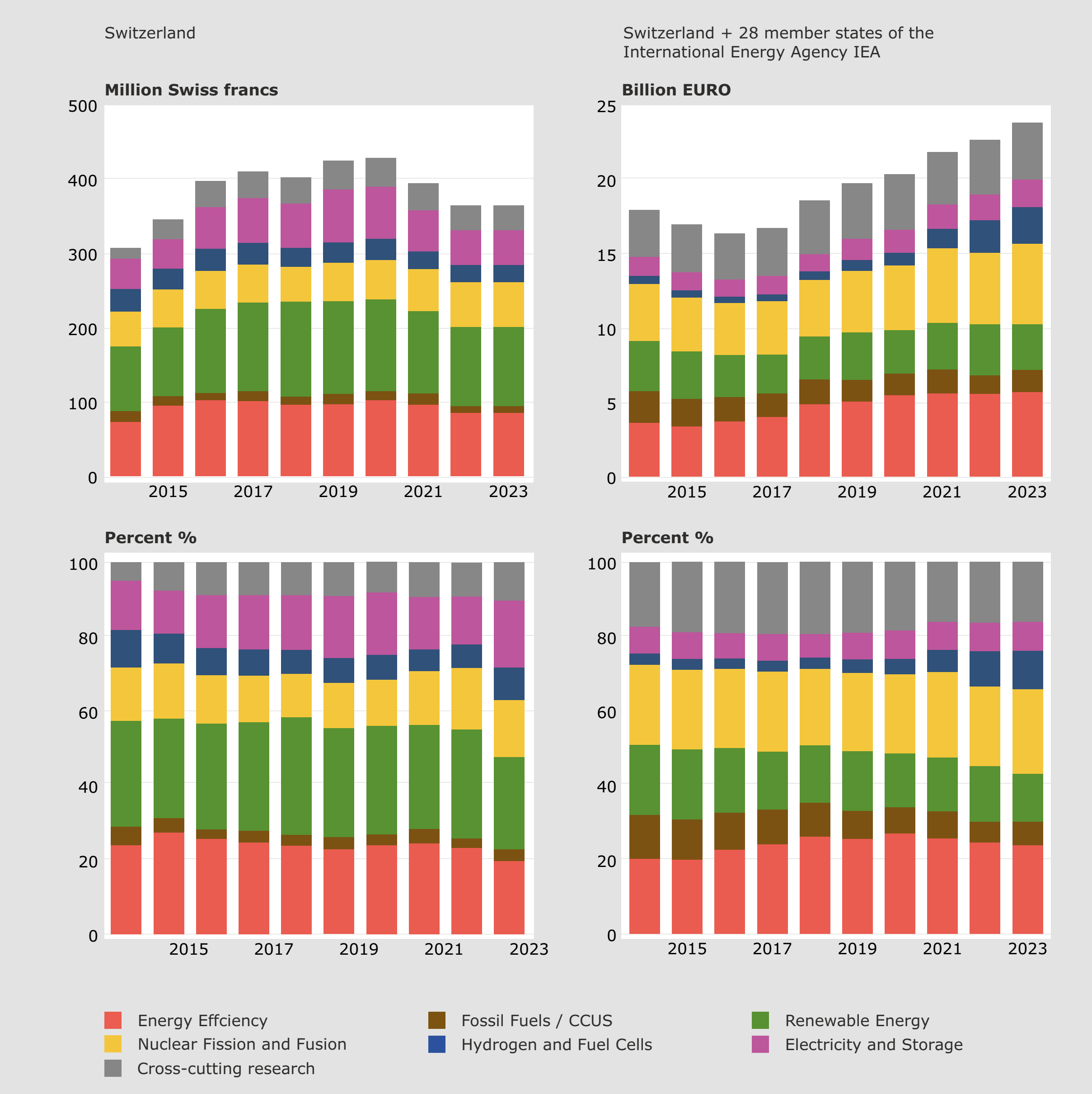
reFuel.ch



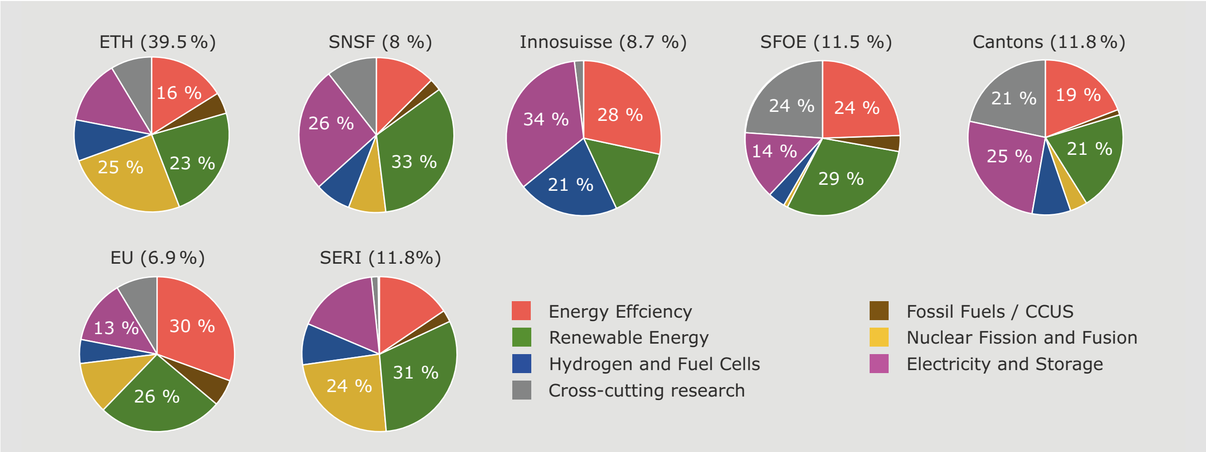
Overview of consortia of completed, ongoing and planned calls for proposals under the SWEET funding programme. The RECIPE consortium began its work in 2024. It will identify hazards and develop vulnerability storylines for the interdependent energy and communication infrastructure of Switzerland. The consortia from previous calls are still active: DeCarbCH, EDGE, PATHFNDR and SURE are working on various aspects of the future Swiss energy system, including the decarbonisation of heating and cooling, the integration of renewable energies, sector coupling, sustainability and resilience. The two consortia LANTERN and SWICE are using living labs to develop new ways of living, working and getting around, as well as solutions for a decarbonised, resource-efficient Switzerland. CoSi is looking at how the development of the Swiss energy system and Swiss society influence each other and is incorporating these findings into models and scenario analyses. ReFuel.ch focuses on sustainable fuels and platform chemicals.

Swiss energy research statistics

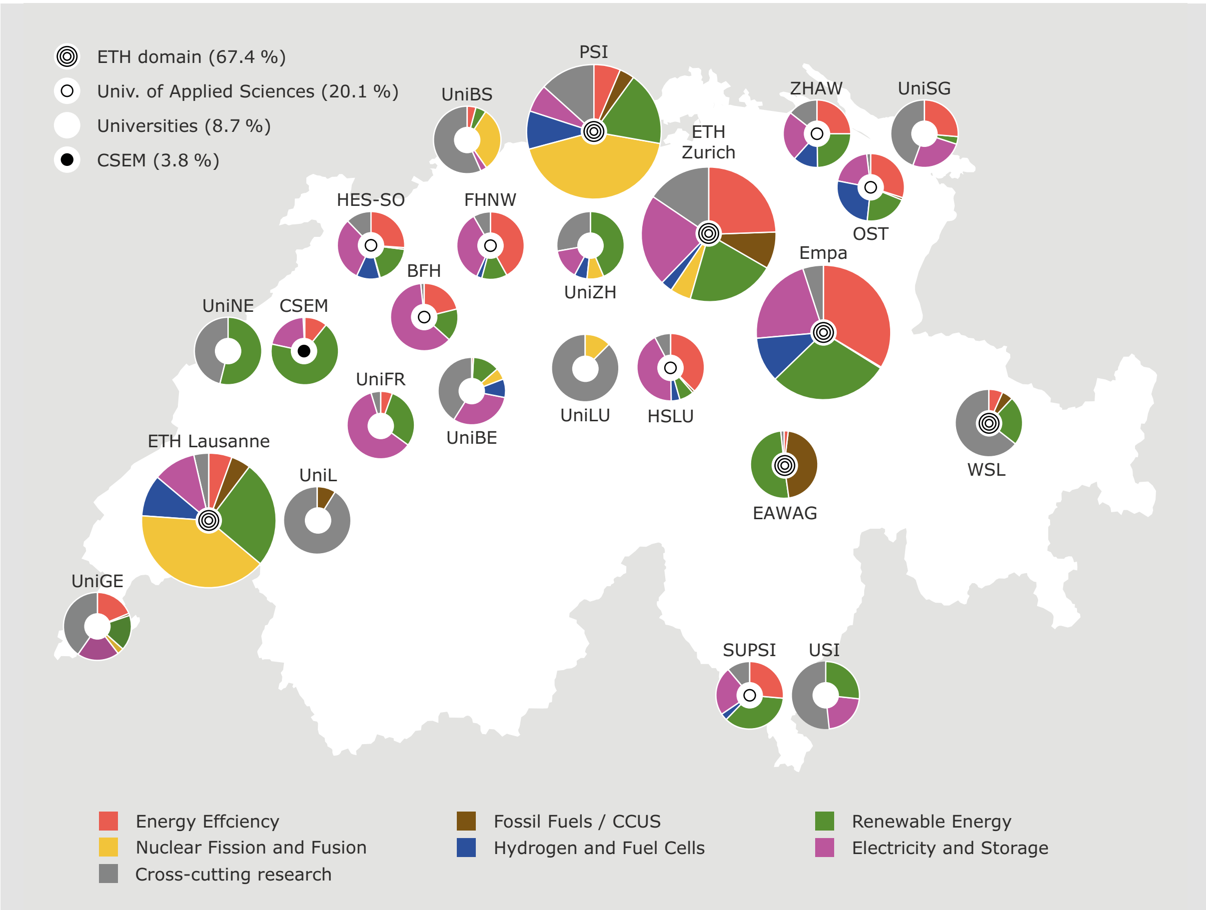
Since 1977, the Swiss Federal Office of Energy (SFOE) has been collecting data on projects that are funded in whole or in part by the public sector (Confederation and cantons), the Swiss National Science Foundation (SNSF), Innosuisse or the European Union (EU). Information on individual projects can be obtained from the publicly accessible information system of the Confederation (www.aramis.admin.ch), the SNSF (data.snsf.ch), the EU (cordis.europa.eu) and the respective websites of individual institutes. In 2023, the public sector in Switzerland spent 405.6 million Swiss francs. At around 39.5 %, the ETH domain contributed the largest share. After the cantons and the SERI (both 11.8 %), the SFOE had the fourth-largest share with 11.5 %. Of the CHF 36.6 million spent by the SFOE, around CHF 12.4 million went to projects in the field of energy efficiency, CHF 12.5 million to renewable energy projects and CHF 11.3 million to projects in the area of social sciences.



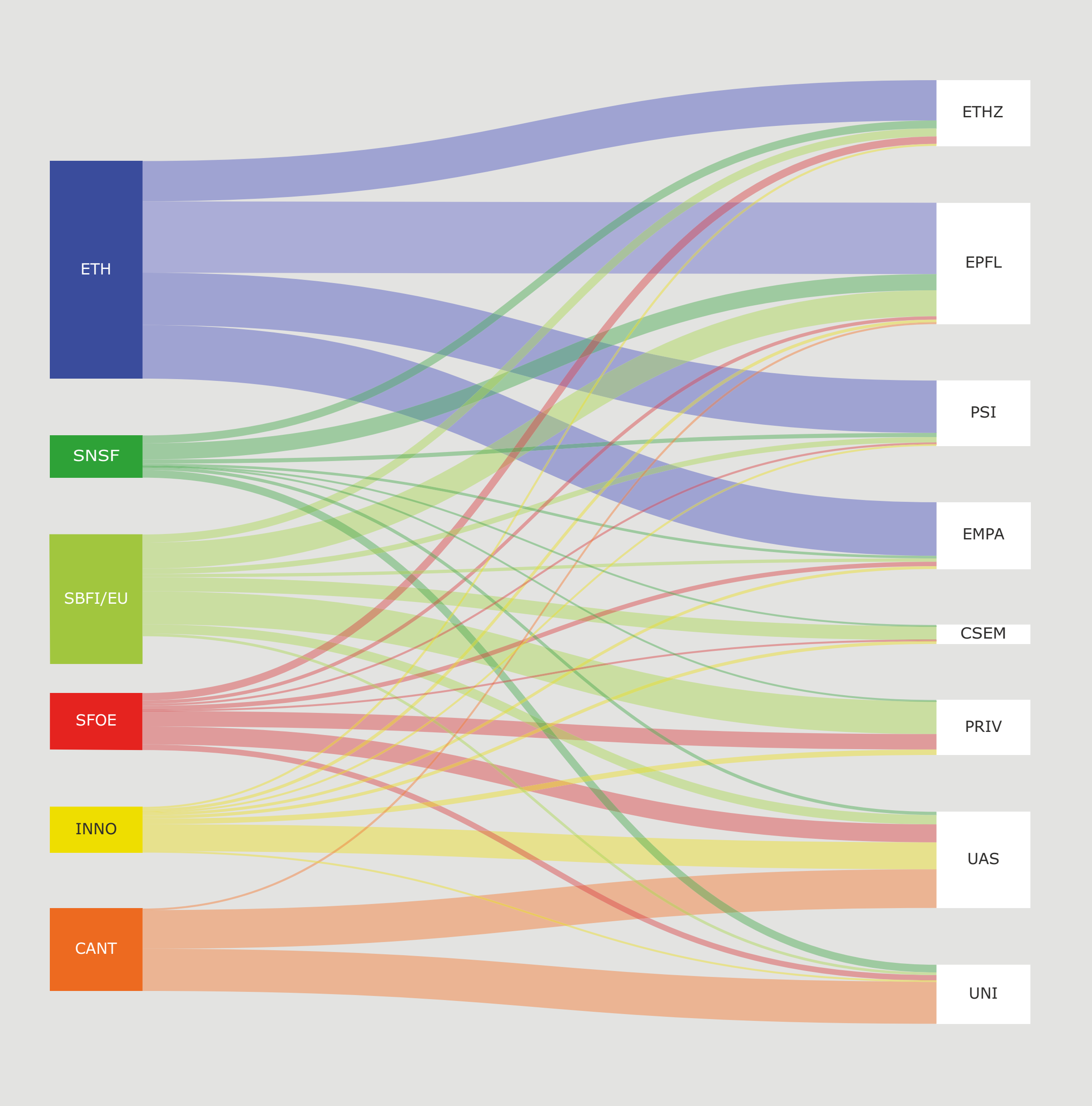
Public funds spent on energy research in Switzerland (left) and in 29 member countries of the International Energy Agency (IEA) (right). Swiss expenditure is in the range of 0.4 to 0.58 per mille of the gross domestic product. The funds are broken down according to the classification of the IEA (source: SFOE energy research statistics).



Public funding for energy research (data 2023) by funding agency and thematic area. Around 40 % of the funding for energy research in Switzerland comes directly from the ETH Domain, and around 12 % from cantonal funding for universities of applied sciences and universities. The rest is competitive funding. ETH: Council of the Swiss Federal Institutes of Technology, SNSF: Swiss National Science Foundation, Innosuisse: Swiss Agency for Innovation Promotion, SFOE: Swiss Federal Office of Energy, EU: European Union, SERI: State Secretariat for Education, Research and Innovation (source: SFOE energy research statistics).



Various energy research topics at Swiss universities (data 2023). The topics are broken down according to the classification of the International Energy Agency (IEA). Most of the public energy research (67 % of the public funds used) takes place in the ETH Domain. BFH: Bern University of Applied Sciences, CSEM: Centre suisse d'éléctronique et de microtechnique, EMPA: Swiss Federal Laboratories for Materials Testing and Research, EPFL: Swiss Federal Institute of Technology Lausanne, ETHZ: Swiss Federal Institute of Technology Zurich, FHNW: University of Applied Sciences Northwestern Switzerland, FHO: University of Applied Sciences Eastern Switzerland, FHZ: University of Applied Sciences of Central Switzerland, HES-SO: University of Applied Sciences of Western Switzerland, PSI: Paul Scherrer Institute, SUPSI: University of Applied Sciences of Italian-speaking Switzerland, UniBE: University of Bern, UniBS: University of Basel, UniFR: University of Fribourg, UniGE: University of Geneva, UniLS: University of Lausanne, UniLU: University of Lucerne, UniNE: University of Neuchâtel, UniSG: University of St. Gallen, UniZH: University of Zurich, USI: University of the Italian-speaking part of Switzerland, ZFH: Zurich University of Applied Sciences (source: SFOE energy research statistics).



Where does the public funding for energy research in Switzerland come from and where does it go? A large part comes directly from the ETH Domain. Funds from private sources, such as own contributions to Innosuisse projects or pilot and demonstration projects of the SFOE, are not included. Cash flows of less than CHF 0.2 million are not shown.

Source of funds: ETH: ETH Board, SNSF: Swiss National Science Foundation, SERI/EU: funds from European projects or from SERI (State Secretariat for Education, Research & Innovation), SFOE: Swiss Federal Office of Energy, INNO: Innosuisse, CANT: cantons.

Use of funds: PSI: Paul Scherrer Institute, EMPA: Swiss Federal Laboratories for Materials Testing and Research, ETHZ: ETH Zurich, EPFL: ETH Lausanne, PRIV: Private Sector, CSEM: Centre Suisse d'Electronique et de Microtechnique, UNI: Universities, UAS: Universities of Applied Sciences, (source: SFOE energy research statistics).

(Left) Conventional thermal recycling of this type of paper sludge only allows its energy potential to be partially utilised (source: Alex Treichler).
(Right) This is what the dewatered biochar generated from paper sludge looks like. It is easy to store and can be used, for example, on site to generate high-temperature heat (source: Alex Treichler).

Optimal utilisation of biomass residues

When wet biomass residues are thermally recycled in industry, much of their energy potential often remains unused. A newly developed three-stage process now makes it possible to utilise this potential. This reduces industrial companies' dependence on fossil fuels and thus lowers their CO_2 emissions.

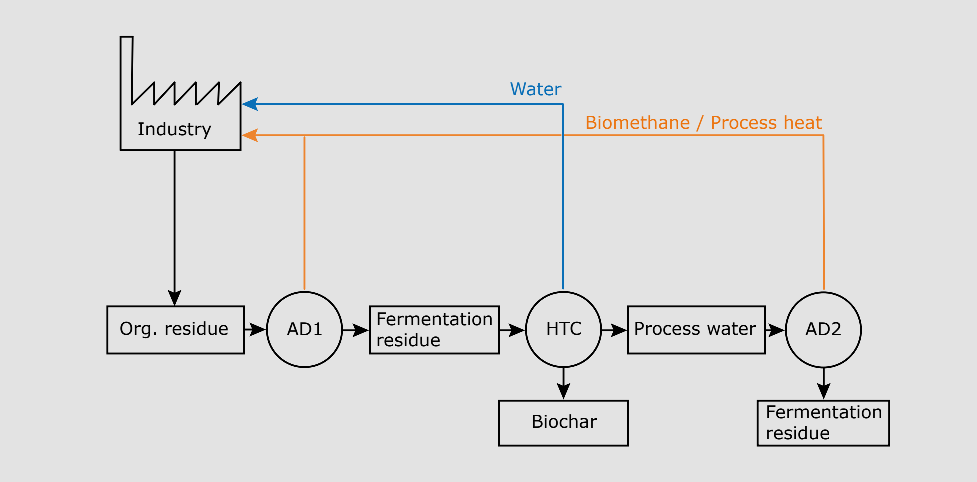
In businesses such as breweries, dairies and butcher's shops, or even in paper production, waste materials often take the form of biomass – material that has grown or been produced naturally. These waste materials, which are often mixed with water, are usually thermally recycled to generate heat for industrial processes. However, this does not make optimal use of their potential because the water content reduces the energy yield.

Cascade utilisation in three steps

As part of an international collaboration, Swiss researchers have developed a novel concept that allows wet biomass to be optimally utilised in a three-step process.

- In the first step, the residual materials are converted into biomethane through fermentation. Fermentation residues remain.
- In the second step, the fermentation residues are heated to 180 to 250 °C under increased pressure. In this process, known as "hydrothermal carbonisation" (HTC), most of the remaining carbon is converted into solid biochar. What remains is so-called process water.
- In the third step, the remaining carbon in the process water is fermented again and also converted into biomethane.

The biomethane and biochar produced in this process are CO_2-neutral energy sources that can be easily stored or used directly on site to produce process heat. Because biochar is much easier to dewater than wet residual biomass and the carbon is largely recycled, the energy yield is increased. This means that less fossil carbon (petroleum, natural gas) has to be used for heat generation, reducing CO_2 emissions.



In the newly developed three-stage process, organic residues are first fermented (AD = anaerobic digestion), producing biomethane. The fermentation residues are heated under high pressure (HTC = hydrothermal carbonisation). This produces biochar and process water. The latter is fermented again in step 3 so that biomethane can also be obtained from the remaining carbon (source: Alex Treichler).

Application example: paper factory

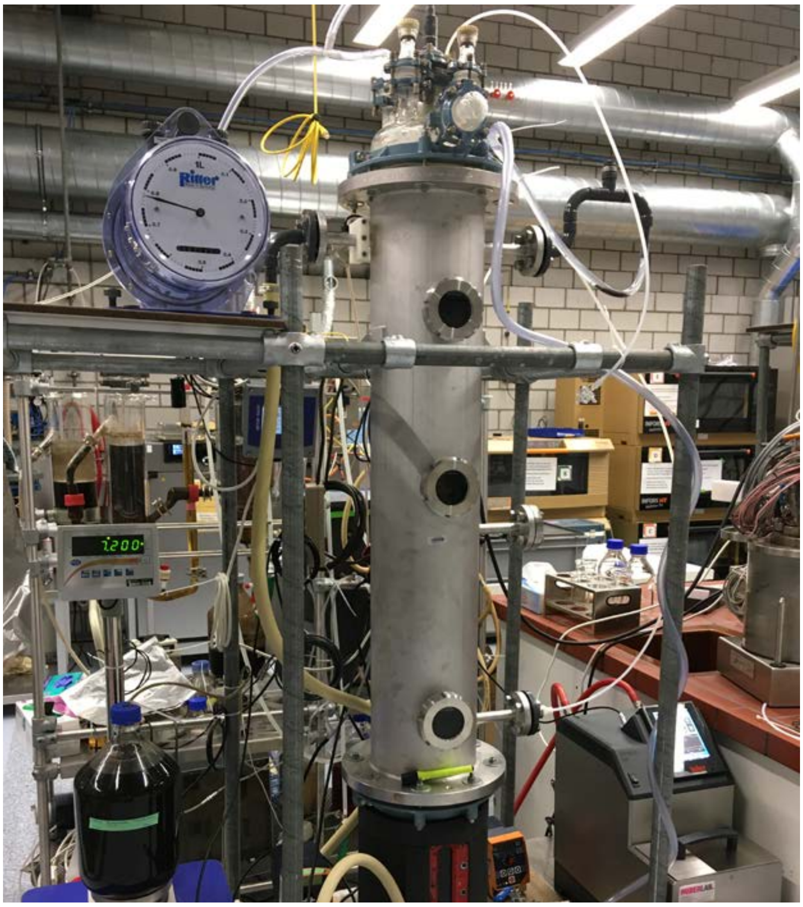
This is also the goal of TELA GmbH, a paper factory in Niederbipp, Bern. It manufactures toilet paper, kitchen towels and tissues and also operates one of Switzerland's largest waste paper processing plants. In order to make these processes more climate-friendly, the paper factory provided residual biomass and data for a research project supported by the Swiss Federal Office of Energy. This enabled the three-stage process concept to be tested in the laboratory.

The residual biomass produced in the factory includes paper sludge and sewage sludge. Until now, these have been laboriously dewatered and burned in the factory's own furnace to generate steam. However, this requires the addition of additional fuels in the form of wood energy and plastic residues from waste paper recycling.

Reducing emissions

The project tested how well the paper mill's residual biomass can be recycled using the three-stage process concept. The results are positive. They show that the concept works and that TELA GmbH can significantly reduce CO_2 emissions from fossil fuels. According to a model calculation, in the best case scenario, almost 13,000 MWh can be generated additionally per year, which corresponds to just under 7 % of the factory's total annual energy requirement. This reduces CO_2 emissions by around 3,000 tonnes per year. A study is now planned to assess the economic viability of the concept in real-world application.

Remo Bürgi, Faktor Journalisten AG



In this fermenter with a capacity of 60 litres, the process water was fermented and the carbon it contained was converted into biomethane (source: Alex Treichler).

The first exploratory drilling at Zurich Airport site was carried out in 2023. It confirmed the presence of water-bearing gravel layers at the base of the glacial channel (source: Geo Explorers AG).

Glacial channels as energy reservoir

In Switzerland, there are numerous underground channels created by glaciers that are filled with loose rock and groundwater. Heat and cold can be stored in them – for example, to supply Zurich Airport with energy in an environmentally friendly way.

The Central Plateau of Switzerland bears the scars of the glaciers that shaped the landscape during the Ice Ages. The mighty ice streams not only changed the surface but also left their mark on the subsoil. The meltwater runoff created numerous long channels in the bedrock, some of which are over 300 metres deep. After the glaciers melted, these channels filled with loose rock and groundwater. Due to the bathtub-like shape, experts assume that the groundwater in the channels is almost stagnant – it can be thought of as an underground lake that is isolated from other bodies of water.

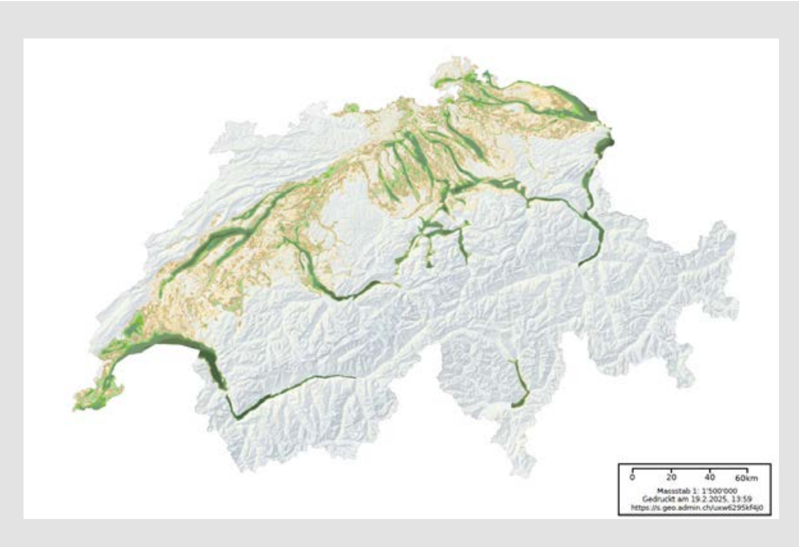
Accessible via wells

These properties make the glacial channels an ideal storage medium for heat and cold. The basic principle works like this: during the winter months, a well is used to extract the water, which has a temperature of almost 20 °C at this depth. This serves as an energy source for a heat pump that supplies various buildings or a district heating network. The slightly cooled groundwater is returned to the channel through another well. In summer, the underground water can be used to cool buildings in an environmentally friendly way. The pumped-up water absorbs excess heat from the buildings and conducts it into the depths, where it is released into the groundwater. This ensures that its temperature remains constant in the long term.

Tests give cause for optimism

It is still unclear whether the glacial channels can actually be used as storage in practice. A pilot project funded by the Swiss Federal Office of Energy on the grounds of Zurich Airport aims to change this and gain insights that can be applied to similar projects. Above all, however, the underground storage facility should enable an environmentally friendly supply of heating and cooling to the airport.

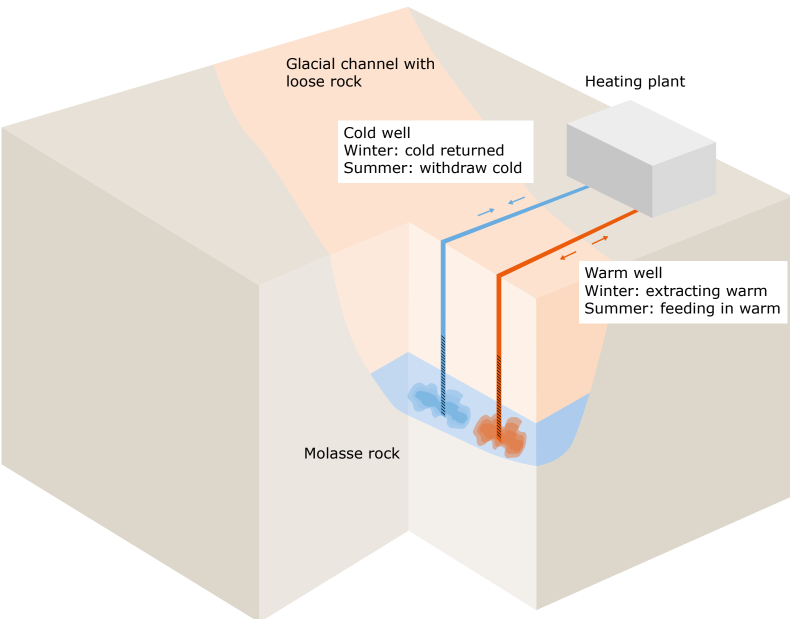
After various geophysical measurements, three exploratory drillings were carried out along the centre of the channel in the summer of 2023. These drillings to a depth of almost 350 metres were successful and allowed the next step: the drilling of a test well in the summer of 2024. This made it possible to carry out more detailed analyses and measurements of the rock and groundwater.



The dark green bands indicate the presence of massive deposits of loose rock, in other words, glacial channels. It is estimated that these reach a total length of around 900 km in Switzerland and thus hold great potential for an environmentally friendly energy supply (source: map.geo.admin.ch).

From a drilling depth of 34 metres, a flushing drill with a so-called roller bit as the drill head was used (source: Geo Explorers AG).

The results give cause for optimism that the glacial channel can be used as a heat and cold store as planned. Therefore, a second test well will be drilled in the summer of 2025 to test the complete cycle of extraction and return. The findings will provide a reliable basis for statements on yield and economic efficiency. If successful, the experts can use this information to create a specific operating concept and apply to the canton for a licence.



To use the groundwater in a glacial channel as a heat and cold storage, at least two wells are drilled. In winter, groundwater is taken from the warm well and returned slightly cooled via the cold well. In summer, the process works in reverse: groundwater from the cold well returns slightly warmed via the warm well to the ground (source: Faktor Verlag /Geo Explorers AG).

High potential

If the further investigations go as expected, several wells will be drilled into the channel in the main project to extract and return the water. Exactly how many wells are needed for optimal operation and where they should be placed is still an open question. However, the pilot project already shows that the presumed potential of glacial channels as heat and cold stores is likely to be usable in practice. Compared to other geological structures, the gullies are easier to locate and develop, which reduces costs and technical hurdles. The project at Zurich Airport is therefore likely to be not the last to use an ice-age gully as an energy store.

Remo Bürgi, Faktor Journalisten AG

The switch from analogue electricity meters to digital smart meters is an important prerequisite for avoiding peak loads (source: EWA-energieUri).

The electricity system of the future rewards flexibility

When many large consumers such as boilers, heat pumps and charging stations consume electricity at the same time, peak loads occur. These are expensive for grid operators and technically challenging. Several projects are investigating how they can be avoided with innovative incentives.

In the future, renewable electricity will power our cars and heat our homes instead of fossil fuels. This transformation will require more electricity, especially for heat pumps and charging stations. The problem is that these large consumers often run at the same time, placing a heavy load on the local power grid. This is referred to as peak loads. The more heat pumps and charging stations are built in an area, the greater the risk of peak loads. This, together with the increasing local feed-in of solar power, is costly for distribution network operators – often small electricity companies − because they have to pay higher contributions to the supraregional network operators and may have to expand their own infrastructure. Ultimately, the end customers pay the costs. The good news is that they can help to delay and reduce the expansion by changing their behaviour.

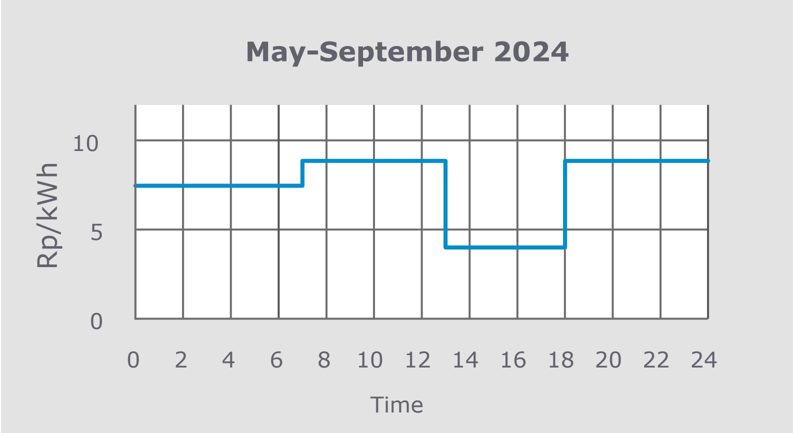
Stagger consumption

The easiest way to avoid unwanted peak loads is for large consumers to stagger their electricity consumption rather than using it all at the same time. In most cases, heat pumps and charging stations can be switched on a little earlier or later without any problems – the house will still be warm and the electric car battery will still be charged in time. However, end consumers need an incentive to grant this flexibility and behave in a “grid-friendly“ manner, as it is known in technical jargon. One option for this is dynamic grid usage tariffs (see info box). This means, for example, that the tariff depends on the current electricity generation and demand in the relevant grid area. In other words, electricity is cheap when there is a lot of it available and little is being consumed. If, on the other hand, there is little electricity available and/or consumption is high, the price rises. This price differentiation creates an incentive for end customers to run electricity-intensive appliances when the grid usage tariff is low.

Direct or indirect control

From the perspective of grid operators, this type of electricity consumption control, known as load control, can be implemented either indirectly or directly. Indirect means that end customers decide for themselves whether and when to adjust their consumption. With the help of an energy management system (EMS), they can respond automatically to dynamic tariffs. This model is likely to be more acceptable to end customers because they remain in control. The disadvantage for the grid operator is that they have no direct influence and can only predict to a limited extent how end customers will behave in a way that benefits the grid.

The alternative is for the grid operator to control large consumers directly at the end customer level. This allows peak loads to be reliably avoided. However, end customers must first be convinced to delegate the operation of their devices. In addition, direct load control requires a constant line of communication, which is technically challenging. And: customers must be compensated for providing flexibility and leaving control to the grid operator. All this makes direct load control a relatively expensive method.



The static tariff from the pilot project in Winkel remains the same for several months. It is based on hourly average grid utilisation values over several years and therefore does not respond to current developments (source: EKZ, edited).

Different forms of incentives and control are not mutually exclusive, but can be used simultaneously. This enables grid operators to meet the expectations and needs of different customer groups.

Testing tariffs

Innovative approaches are now being tested in practice in various projects supported by the Swiss Federal Office of Energy. For example, three grid usage tariffs were developed for end customers in the Zurich

- The static tariff has three fixed price levels. These are based on hourly average values of grid utilisation over several years. The lowest price level applies in the afternoon in summer, for example, because a lot of solar power is available and the load is low. The static tariff has an indirect effect; customers control their consumption themselves, also with the help of an EMS.
- The dynamic tariff is based on current demand and supply. It is communicated 15 minutes in advance for a period of 15 minutes. This tariff also has an indirect effect, with customers controlling their consumption themselves, including with the help of an EMS.
- The flat rate does not offer incentives in the form of changing prices, but in return, the grid operator can directly control end customers' consumption in exchange for a fee.

The results so far show that in summer, the dynamic tariff and the flat rate work best to avoid feed-in peaks (too much solar power). In winter, however, when the primary concern is to avoid peak loads, control and incentives are not necessary. The reason for this is that peak loads are already fairly well distributed. However, according to those responsible for the project, this could change in

The price of electricity

In Switzerland, the electricity price consists of four components: The energy tariff (median 47% of the electricity price for households in 2025), the grid usage tariff (41.5%), levies to cantons and municipalities (3.5%) and the grid surcharge (8%). If a distribution system operator wants to give its end customers price incentives to avoid peak loads, it usually does so via the grid usage tariff. This covers the costs of using the transmission and distribution network and for system services that are necessary to ensure the stability of the electricity grid. If an end customer provides flexibility, this is a system service for which they receive a discount on the grid usage tariff or a credit note.

The dynamic tariff from the Winkel pilot project is defined on the basis of current demand and supply for each quarter of an hour and communicated to end customers 15 minutes in advance (source: EKZ, edited).

the future if more electric cars are charged, as these will add to the existing loads in the evening.

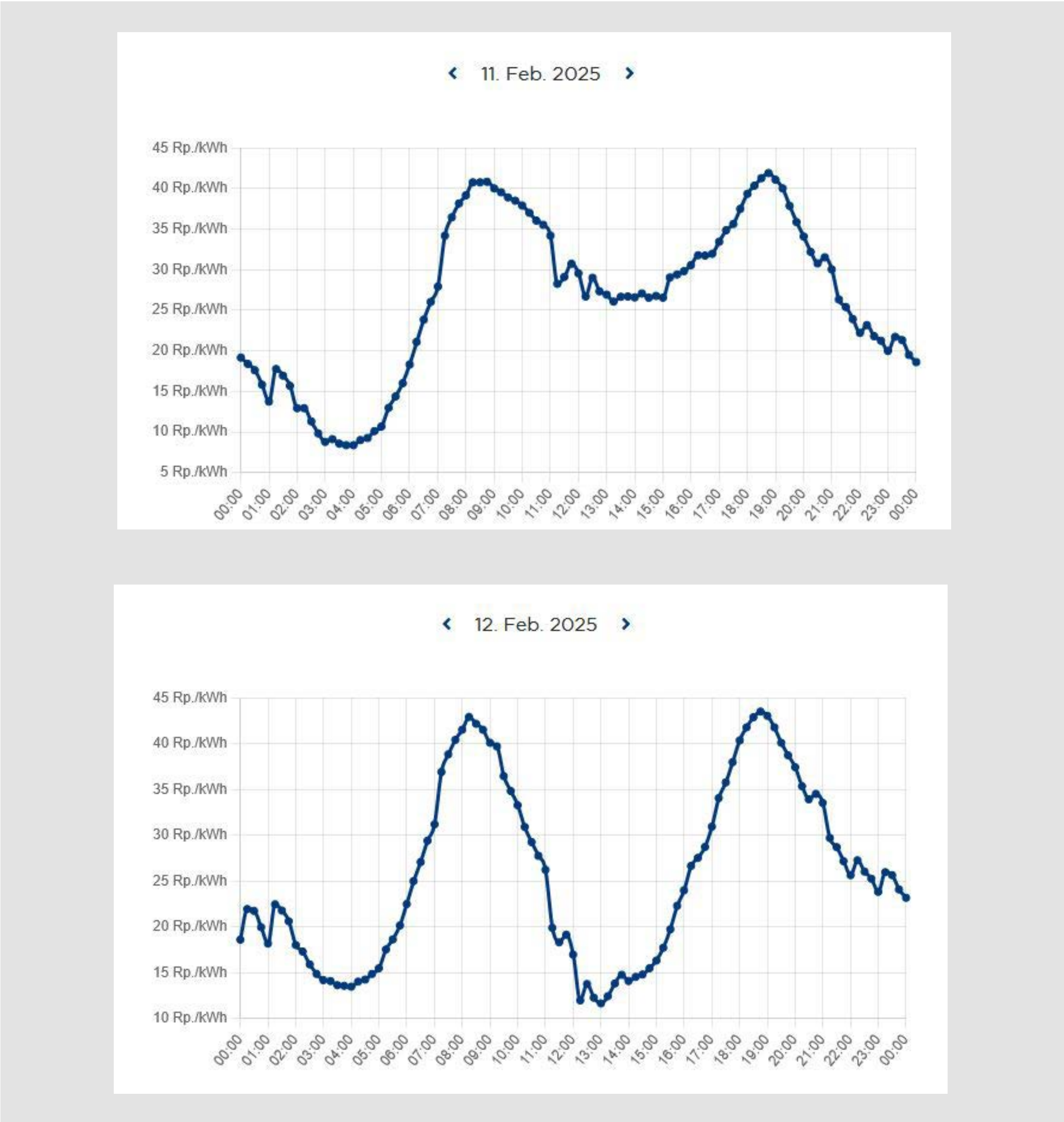
Tariff for the following day

Another project focused on the development and introduction of the so-called Vario tariff. This dynamic tariff is calculated for all 15-minute intervals of the following day. It is based on the grid load forecast for that day, which com-

Network operators can use their own power generation facilities in a targeted manner to cover peak loads in their network. The picture shows a hydroelectric power plant operated by Technische Betriebe Vilters-Wangs, which was involved in the local pilot project (source: TB Vilters-Wangs).

bines the expected demand and supply. The energy supplier transmits the Vario tariff to the participating end customers or their EMS the evening before. The EMS automatically plans the operation of large consumers so that the customer incurs the lowest overall costs. Practical implementation shows that the Vario tariff does indeed offer end customers good incentives to shift flexible consumption to time slots when the grid is less congested. Like other models, it can thus help to avoid peak loads and reduce the costs of grid expansion.

Remo Bürgi, Faktor Journalisten AG



A comparison of the Vario tariff on two consecutive winter days shows a clear difference in the early afternoon. The reason for this is the expected weather: rain was forecast for 11 February and dry weather for 12 February. Therefore, higher yields from the photovoltaic systems could be expected for 12 February, allowing lower prices to be offered (source: Screenshots www.groupe-e.ch from 12 February 2025).

With smart meter data and artificial intelligence, electricity suppliers can specifically alert their customers to potential savings (source: EKZ).

Using AI to detect inefficient heat pumps

Many heat pumps consume more energy than necessary. The target values are often set too high, with little optimisation during operation. The ETH Zurich has developed algorithms that detect inefficient heat pumps, based on smart meter data. Energy suppliers can thus make customers aware of their potential savings in a targeted manner.

One in five buildings in Switzerland has a heat pump. They replace fossil fuel-powered heat generators and make a significant contribution to decarbonising the building portfolio. At the same time, however, heat pumps increase the demand for electrical energy. Therefore, efficient operation is important. Due to the growing number of different types of heat pumps and their connection to components such as photovoltaic systems, the planning, installation and operation of these systems are becoming increasingly complex. This is often reflected in unfavourable settings that achieve heating comfort but are inefficient in terms of operation.

Incorrect settings go unnoticed

An evaluation of 410 energy consultations carried out by the Zurich Cantonal Electricity Works (EKZ) has highlighted the typical problems: in 41 % of households, the heating curve, which regulates the flow temperature depending on the outside temperature, was set too high. In 36 % of cases, the activated night setback increased energy consumption, contrary to expectations. In 26 % of cases, the heating limit at which the heating is switched on was higher than necessary. Even after energy improvements to the building envelope, the heat pump control is often not adjusted. Building operators often do not notice such incorrect settings.

Smart meter data as the key to optimisation

The project “KI in der Wärmepumpenberatung (AI in heat pump consulting)“, which was completed in spring 2024 and funded by the Swiss Federal Office of Energy (SFOE), aims to address these issues. Researchers at the Bits to Energy Lab at ETH Zurich, in collaboration with EKZ, Enerlytica (formerly BEN Energy AG) and Hoval, collected anonymised data on household electricity consumption (known as smart meter data) during three heating periods and evaluated it using artificial intelligence (AI). They developed algorithms to help identify systems with excessive electricity consumption. This makes it pos-

Problem/incorrect setting	Relative frequency*	Absolute frequency
Heating curve set too high	40.98 %	168
Night setback incorrectly activated	36.10 %	148
Heating limit set too high	25.61 %	105
Descaling of hot water necessary	17.80 %	73
Expansion system incorrectly set	13.41 %	55
Problems with air flow in air source heat pumps	11.25 %	27
Heat pump incorrectly dimensioned	10.00 %	41
Pipes not insulated well enough	9.02 %	37
Domestic hot water temperature incorrectly set	7.80 %	32
Brine pressure in geothermal heat pump not correct	7.19 %	12
Circulation pump control incorrectly set	6.34 %	26
Temperature of ground probe in geothermal heat pump too low	5.99 %	10
Installation of thermostatic valves for individual room control recommended	4.88 %	20
Dirty heat pump	3.17 %	13
Heat pump not working properly	1.46 %	6
Basic functions not working properly	1.46 %	6

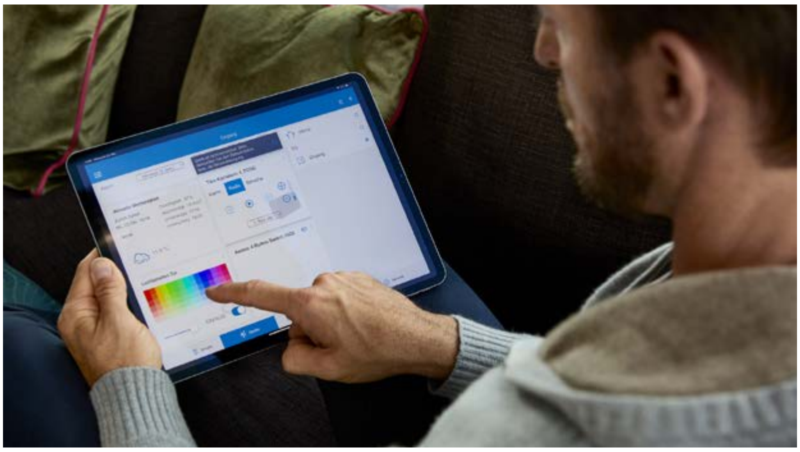
The relative frequencies refer to all 410 heat pumps inspected, except for problems where a distinction is explicitly made between heat pump types. There are 240 air source heat pumps (58.54 %) and 167 ground source heat pumps (40.73 %).

Typical problems and configurations of heat pumps based on 410 consultation reports from on-site inspections by EKZ energy consultants (source: final report KI-WP, edited).

sible to assess the electricity consumption of a heat pump without detailed knowledge of the exact operating environment, for example by evaluating the operating hours or the times when the system is switched on and off. The algorithms also detect recurring patterns of incorrect settings and report them automatically to the electricity suppliers. This enables them to estimate savings and provide targeted information to households with potential for optimisation.

Consulting pays off quickly

A comparison of smart meter data before and after optimisation showed how much electricity can be saved. Around half of the 297 households participating in an analysis were able to save an average of 1805 kWh (15.2 %) of electrical energy per year after optimisation. At an electricity price of 32.14 centimes per kilowatt hour, this corresponds to annual cost savings of 580 assuming a price of 400 Swiss francs for an energy consultation, the optimisation often pays for itself after the first heating period. The open-source algorithms developed as part of the project are also available to other users. This enables energy suppliers to make relevant information available to their customers via their customer portals with the aim of increasing the efficiency of heat pumps.



Many energy suppliers already make individual consumption data available to their customers via customer portals. This transparency is intended to help reduce energy consumption and costs (source: EKZ).

Sandra Aeberhard, Faktor Journalisten AG

Alternative power highways

Expanding the power grid is likely to meet with resistance if it affects densely populated areas or sensitive landscapes. New types of transmission technology that can be laid underground and reduce transmission losses are therefore welcome.

The electricity grid is already highly branched in order to supply end customers everywhere with energy. In future, however, it will also have to accommodate ever-increasing amounts of renewable electricity, which will not be possible without additional grid expansion. Both local distribution grids and interregional transmission grids will have to be supplemented with new lines and routes. However, while grid levels 4 to 7 in the medium and low voltage range are already primarily laid underground, there is also growing demand for underground power transmission in the extra-high and high voltage range. Not least as an alternative or replacement for overhead lines in sensitive landscapes.

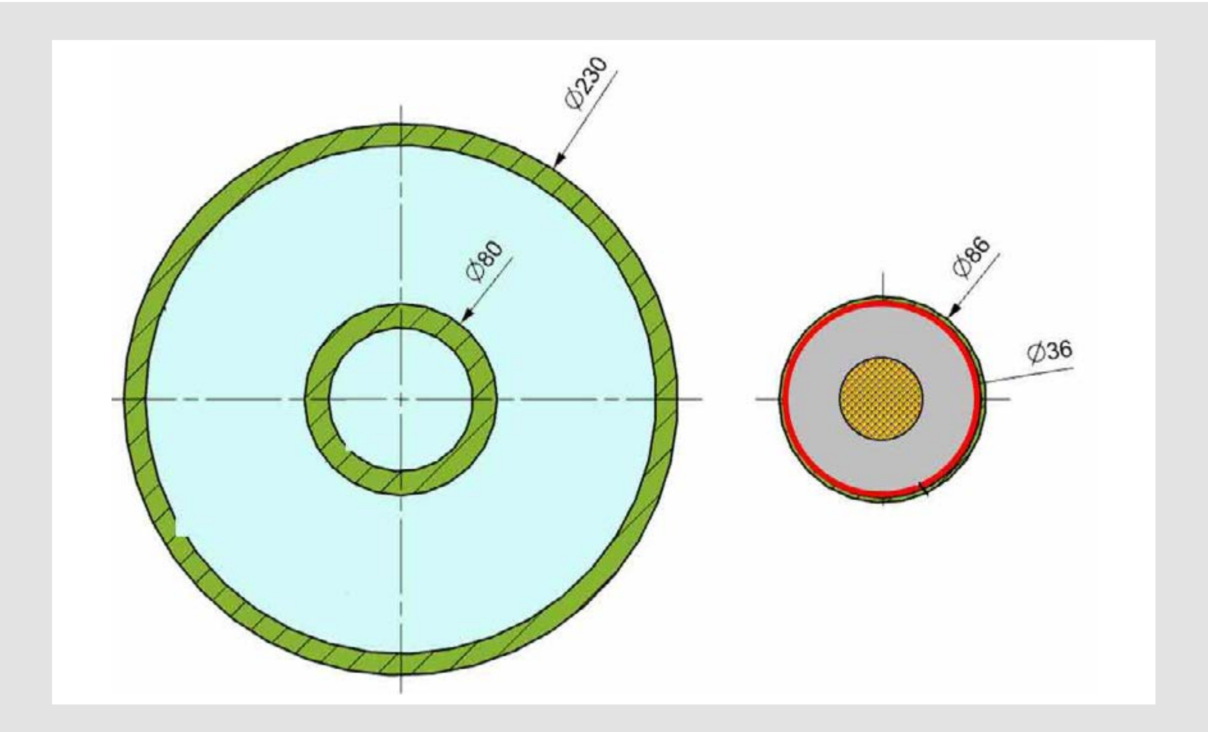
No loss of performance

A new underground cable technology is now attracting attention: Swiss start-up Hivoduct aims to expand the market for network components with compressed air-insulated cable systems. The young company was supported by the P+D programme of the Swiss Federal Office of Energy (SFOE) to test the new cable technology in continuous operation at an SBB site for one year. If an overhead line solution is not possible, compressed air cables could simplify the expansion of the medium and high-voltage grid without any loss of capacity.

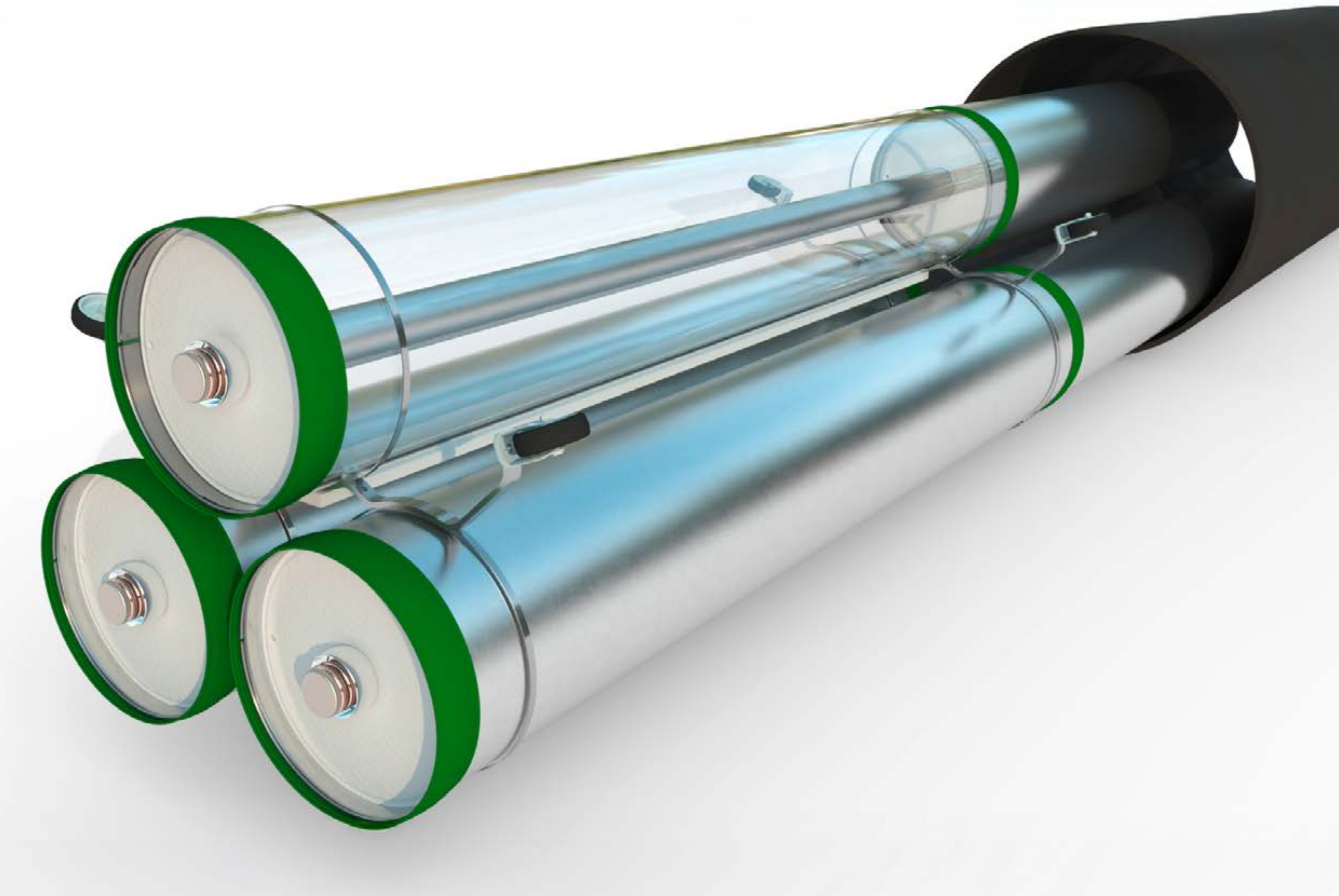
The national grid company Swissgrid is interested in the practical application of compressed air cables because they require less reactive power compensation than conventional underground cables. The hoped-for effect is that the capacity for power transmission will increase. In addition, initial orders for the new cable technology have been received from Switzerland and abroad.

Reliable test operation

The pilot plant subsidised by the SFOE, a compressed air cable line with a mains voltage of 145 kV,



Comparison of the cross-sections between a compressed air cable (left) and a conventional high-voltage cable with VPE insulation (right). The protective sheath and the inner ring (green) of the compressed air cable are made of aluminium; dimensions in mm (source: Hivoduct).



Three-phase configuration for a type-tested compressed air cable for power transmission with a voltage of 220 kV. The cables are each protected by an aluminium tube and encased in a further protective tube (source: Hivoduct).

was tested under various operating conditions. The evaluation of the accompanying investigations yielded the hoped-for success: the one-year operation was reliable and trouble-free; the cable sheathing also remained tight. The air pressure in the insulation layer is around 10 bar, which – for comparison – corresponds to the pressure of a coffee machine.

During the one-year test, the air pressure did not drop by even one percent. Nevertheless, compressed air lines are equipped with a valve to allow refilling if necessary. The housing is an aluminium tube that can withstand pressures of up to 50 bar. The current conductor inside is also made of aluminium. Compressed air cables are significantly more voluminous than conventional underground cables.

The outer aluminium shell has a diameter of over 20 centimetres. The cavity filled with compressed air insulates just as well as the millimetre-thin special plastic used to coat copper cables. A direct comparison of the two insulation methods also shows that compressed air insulators heat up less and reduce energy losses during power transmission.

Limits complied with

Another advantage of the newly developed version is that the magnetic field is smaller than with a conventional underground cable, which simplifies underground installation and means that safety requirements can be met with less additional effort. The aluminium sheath is also earthed, meaning that the tube can be touched without risk during operation.

An important test criterion for high-voltage cables is heating, because it indirectly indicates electrical resistance and is also a measure of line losses. In tests, the compressed air housing complied with the type test limit value of 65 °C, even with very high current flows and on hot days.

Thanks to the successful tests, the start-up has now received all safety certificates for the voltage range up to 145 kV, meaning that this type of compressed air cable can be launched on the market. To cover higher transmission capacities, a second pilot plant for 220 kV cables has now been successfully tested.

Adaptable mounting systems

The research work provided further insights into the design, installation and maintenance of the installations. Although a single tube is only five metres long, compressed air cable lines can be connected together over several kilometres and at different angles. A special roller system was invented specifically for this purpose so that three line phases can be laid simultaneously. This consists of mobile consoles for feeding the compressed air cables side by side or one above the other into a large protective pipe.

The final assembly has also already been partially tested: depending on the terrain and natural obstacles, the pipe system can be configured in different ways and laid in the ground. Watercourses can be crossed using a trenchless microtunnelling process. Across meadows and fields, a metre-deep trench is sufficient to stack or line up cable pipes.

Type testing for 245 kV

The installation of underground compressed air cables is even easier if an existing underground route can be used. In fact, the federal government is striving to coordinate network expansion and transport planning. Motorways, railway lines and tunnel sections are to be equipped with an additional channel for high-voltage cables, subject to certain safety requirements. Such reserve pipes are being integrated for the first time in the construction of the second Gotthard motorway tunnel.

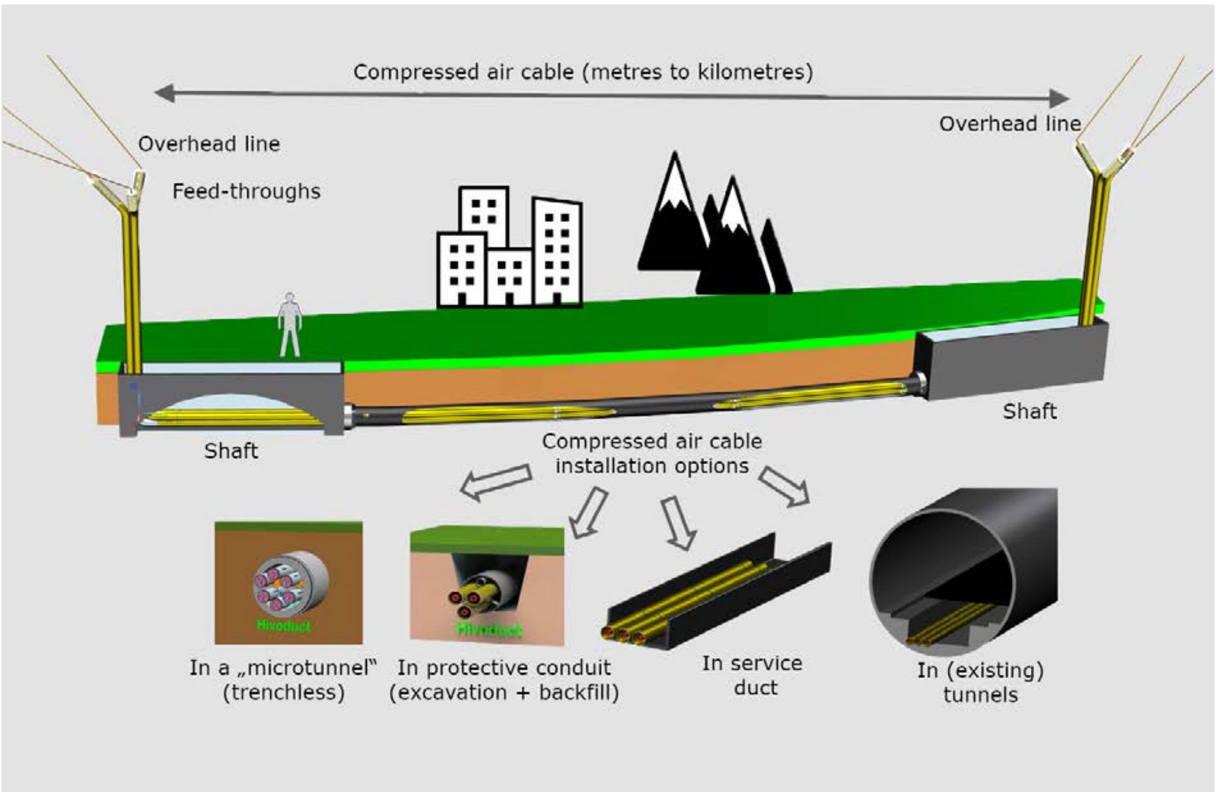


Diagram of a high-voltage line for which a compressed air underground cable is used. Various installation methods are available for underground cable routing (sourcee: Hivoduct, edited).

In order to use compressed air cables in infrastructure construction in the future, a separate type test had to be completed. Among other things, the variant was installed on a trial basis in the Uetliberg tunnel on the western bypass around Zurich. A safety certificate for Hivoduct cables in the high-voltage range (245 kV / 4,000 A) is now available.

Permanent system

However, for compressed air technology to become established on the market, it must be economically viable for network operators. Because compressed air cables are not yet mass-produced, project developers can only estimate the costs for individual applications at this stage. However, the following generally applies to the installation of underground cables: they are more expensive than overhead lines. The specific additional costs are one and a half to ten times higher.

On the other hand, general statements about the durability of the new cable technology can already be made today. Although it has only been tested for a year, a service life of 40 years is likely. Compressed air cables would thus be on a par with the underground cable systems commonly used to date in terms of quality.

Paul Knüsel, Faktor Journalisten AG

A roll system developed in-house is used for installation. The cable tubes are pulled into the protective tube using a pull rope (source: Hivoduct).

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Workshops were held to discuss ideas and examine measures for reducing CO_2 emissions in the region (source: Manu Friedrich).

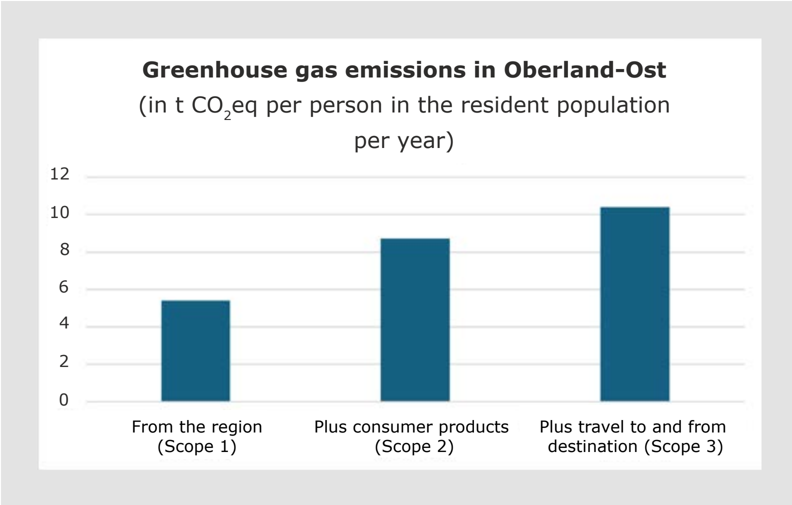
Becoming climate neutral as a region

The municipalities in the eastern Bernese Oberland have been actively supporting climate protection in the region for several years. They were inspired by a research project at the University of Bern that sought to support the transition to a climate-neutral society through a process known as “transition management“.

The “Regional Conference Oberland-Ost“ is an association of 28 municipalities east of Lake Thun. This committee coordinates inter-municipal issues such as land-use planning and regional development. Another important issue is climate change, which is clearly noticeable in this region characterised by tourism and agriculture – for example, through the retreat of permafrost, changes in vegetation periods and the increase in severe storms. The region therefore decided several years ago to actively promote climate protection and developed the “Climate-Neutral Oberland East Region“ strategy. The long-term goal is to reduce CO_2 emissions in the region to net zero by 2040. In the eastern Bernese Oberland, CO_2 emissions are caused not only by households, businesses and transport, but also by tourism and agriculture in particular. It therefore had to be clarified whether the focus should be “only“ on emissions produced locally or also on those caused by holidaymakers travelling to the Bernese Oberland. Those responsible decided to concentrate on emissions produced directly in the region because they can influence these immediately.

Based on scientific research

The region was inspired, supported and accompanied by a research project conducted by the University of Bern and the Office for the Environment and Energy of the Canton of Bern. This project sought to initiate the transition to a climate-neutral society through a “transition management process“. The approach is based on involving the relevant regional stakeholders in the planning process. This was achieved in the Bernese Oberland: they jointly developed a vision for the region, defined measures tailored to local conditions and became actively involved in their implementation. The project received financial support from the Swiss Federal Office of Energy, the Office for the Environment and Energy of the Canton of Bern and the Wyss Academy for Nature at the University of Bern. Four workshops formed the core of the process. Representatives from various sectors were invited to participate, including the public sector, tourism, energy, the private sector, the timber industry, agriculture, the housing and mobility sectors, and civil society. The 35 to 40 participants in each workshop addressed the four phases of transition management: orientation, agenda setting, activation and reflection. The project team



The regional conference is focusing its actions on reducing CO_2 emissions from Scope 1. This refers to emissions that are directly caused in the region itself. These can be reduced more effectively than those from Scopes 2 and 3 (source: B. Vogel, edited).

supported this transdisciplinary process by preparing, moderating and following up on the workshops, as well as documenting and jointly evaluating the process. Participants were able to evaluate the results of the workshops, for example. Interviews were also conducted with selected workshop participants and an online survey of the population was carried out.

First projects launched

In the workshops, participants developed broad-based ideas, projects and concepts, exchanged thoughts and created new networks. An important measure was the appointment of a specialist to advise the population, companies and authorities and support them in their projects. This role of "climate coach" has been filled for just over two years by Alina von Allmen, an agronomist who lives in the region. She discusses climate issues with different groups and helps them to network. For example, she brought the seven regional mountain railways together so that they could share experiences and coordinate climate protection measures. A number of exciting projects have already emerged from the initiative. These include the production of biogas to decarbonise Interlaken's gas network, the expansion of wind and solar power in the Axalp ski resort and an electric catamaran on Lake Brienz. The latter transports guests across the lake in a climate-friendly manner while also providing summer jobs for those employed in winter tourism. To convince even more companies to take climate action and initiate further projects, Alina von Allmen is relying on emotions. She says it is important to address issues that are important to local people. In the Bernese Oberland, for example, these include a strong connection to the landscape, the mountains and the snow.

A role model for other regions

The research team at the University of Bern is satisfied with the results of the three-year project. They say that the joint process has succeeded in anchoring the issue of climate neutrality in the region. In addition, the implementation agenda, the established network and the position of climate coach have created the basis for the change process to continue successfully. According to the researchers, the transition management approach could also trigger important processes in other regions and support the societal shift towards climate neutrality in Switzerland.

Remo Bürgi, Faktor Journalisten AG

The electric catamaran, manufactured by a local company, transports guests across Lake Brienz in the summer. This has created new jobs for employees from the winter tourism industry (source: Brienz Tourismus).

International cooperation

Switzerland attaches a great deal of importance to international cooperation in the field of energy research. At the institutional level, the Swiss Federal Office of Energy (SFOE) coordinates its research programmes with international activities in order to utilise synergies and avoid redundancies. Cooperation and exchanges of experience within the framework of the International Energy Agency (IEA) are of particular importance to Switzerland. Here, for example, the SFOE participates in various IEA "Technology Collaboration Programmes" (cf. www.iea.org/tcp), see list on following page.

At the European level, wherever possible Switzerland participates in EU research programmes. Here, at the institutional level the SFOE coordinates its energy research in alignment with the energy-reated European Partnerships, the European Research Area Networks (ERA-NET), Joint Technology Initiatives (JTI), the European technology platforms, etc. Beyond that, intensive multilateral cooperation with selected countries also exists in certain fields (smart grids, geothermal energy, hydrogen etc.).

Participation in technology cooperation programmes of the IEA

Energy Storage (iea-eces.org)

Energy Efficient End-Use Equipment (iea-4e.org)

User-Centred Energy Systems (userstcp.org)

High-Temperature Super Conductivity (ieahts.org)

Clean and Efficient Combustion (ieacombustion.com)

Electric Vehicle (ieahev.org)

Geothermal Energy (iea-gia.org)

Hydropower (ieahydro.org)

Solar Heating and Cooling (iea-shc.org)

Wind Energy Systems (iea-wind.org)

Energy Technology Systems Analysis Program (iea-etsap.org)

Energy in Buildings and Communities (iea-ebc.org)

Heat Pumping Technologies (heatpumpingtechnologies.org)

International Smart Grid Action Network (iea-isgan.org)

Advanced Fuel Cells (ieafuelcell.com)

Advanced Motor Fuels (iea-amf.org)

Bioenergy (ieabioenergy.com)

Hydrogen (ieahydrogen.org)

Photovoltaic Power Systems (iea-pvps.org)

Concentrated Solar Power (solarpaces.org)

Greenhouse Gas R&D (ieaghg.org)

Industrial Energy-Related Technologies and Systems (iea-industry.org)

Participation in European Partnerships

Accelerating CCS Technologies (act-ccs.eu)

Concentrated Solar Power (csp-eranet.eu)

Geothermica (geothermica.eu)

Smart Energy Systems (eranet-smartenergysystems.eu)

Geothermal Implementation Working Group (geothermal-iwg.eu)

Clean Energy Transition Partnerhsip (cetpartnership.eu)

Driving Urban Transitions (dutpartnership.eu)

Materials (m-era.net)

Solar (solar-era.net)

Further international cooperation

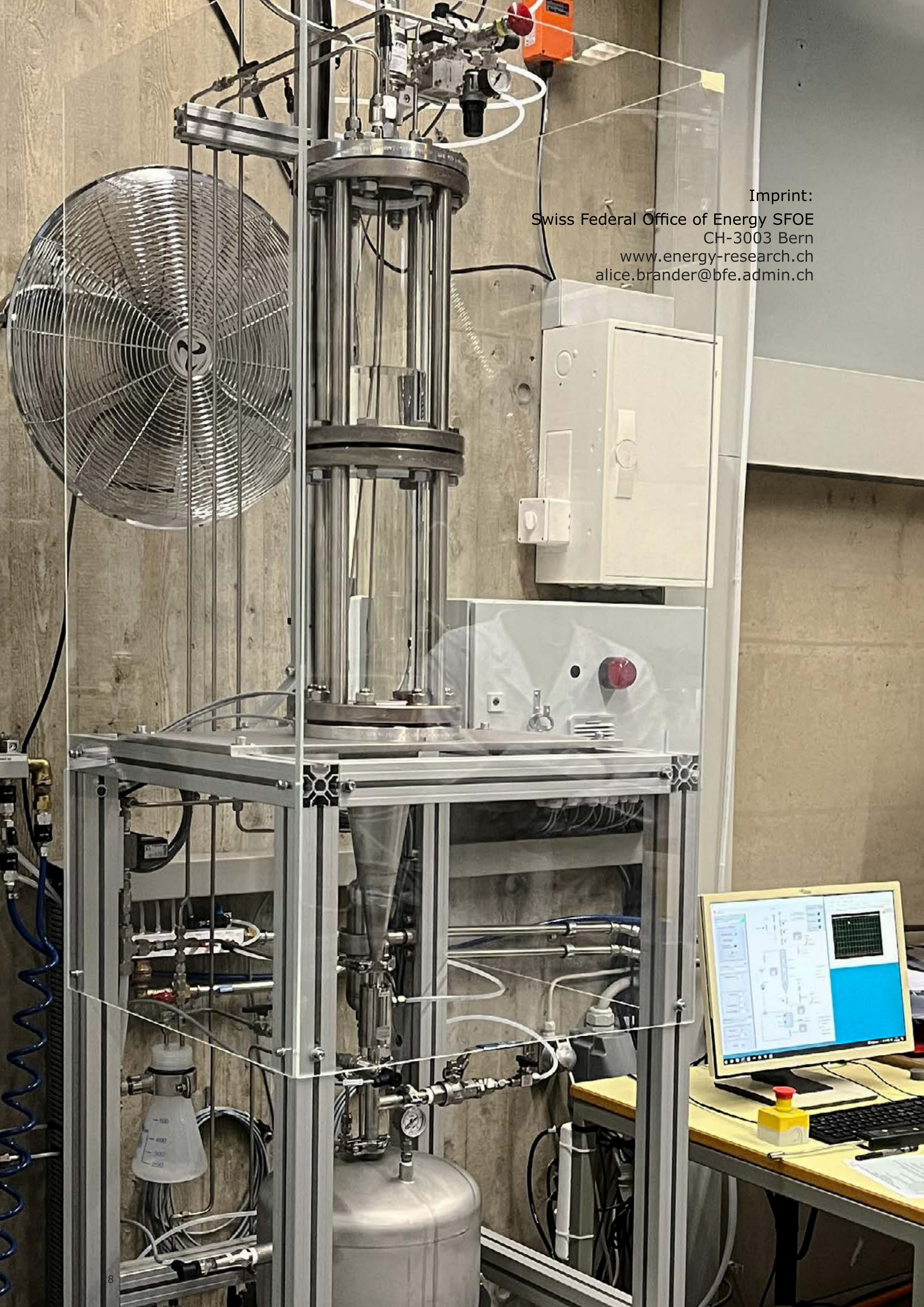
Fuel Cells and Hydrogen Joint Undertaking

International Partnership for Geothermal Technology

DACH-Kooperation Smart grids

Collective Research Networking CORNET

(Next page) When metals react with oxygen, enormous amounts of energy are released. Aluminium and other metals can therefore be used to store renewable electricity, which can then be used to generate heat and electricity in winter. As part of the project "Covering Winter Peaks of Heat and Electricity Demand by Renewable Metal Fuels" (PeakMetal), researchers at the University of Applied Sciences of Eastern Switzerland have evaluated which metals are particularly suitable for energy storage and retrieval and to what extent they could contribute to alleviating electricity shortages/energy scarcity in winter through renewable energy. Aluminium, iron and silicon are technically suitable as seasonal energy storage materials, with each material having its own advantages and disadvantages. The OST is working with aluminium. The picture shows a prototype from the OST's Institute for Solar Technology (SPF) for 2kW hydrogen output from aluminium. Based on their study, the researchers assume that marketable "metal storage cycles" made of aluminium and iron will be used in the short to medium term. Seasonal energy storage cycles could make a significant contribution to covering electricity shortages in winter (source: SPF Laboratory).



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