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Swiss Federal Office of Energy SFOE

Energy research and innovation
Report 2022

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) Photovoltaics on agricultural land, so-called agri-photovoltaics (agri-PV), can make an additional contribution to domestic electricity supply. However, according to current legislation, such installations in Switzerland must result in a benefit for agricultural production. In a pilot project supported by the SFOE, three different agri-PV systems are being tested and compared for this purpose in the berry production of the company Bioschmid GmbH, in order to thereby evaluate the effect of protection and shading with the three different systems for agronomic yield development (image source: Insolight SA).

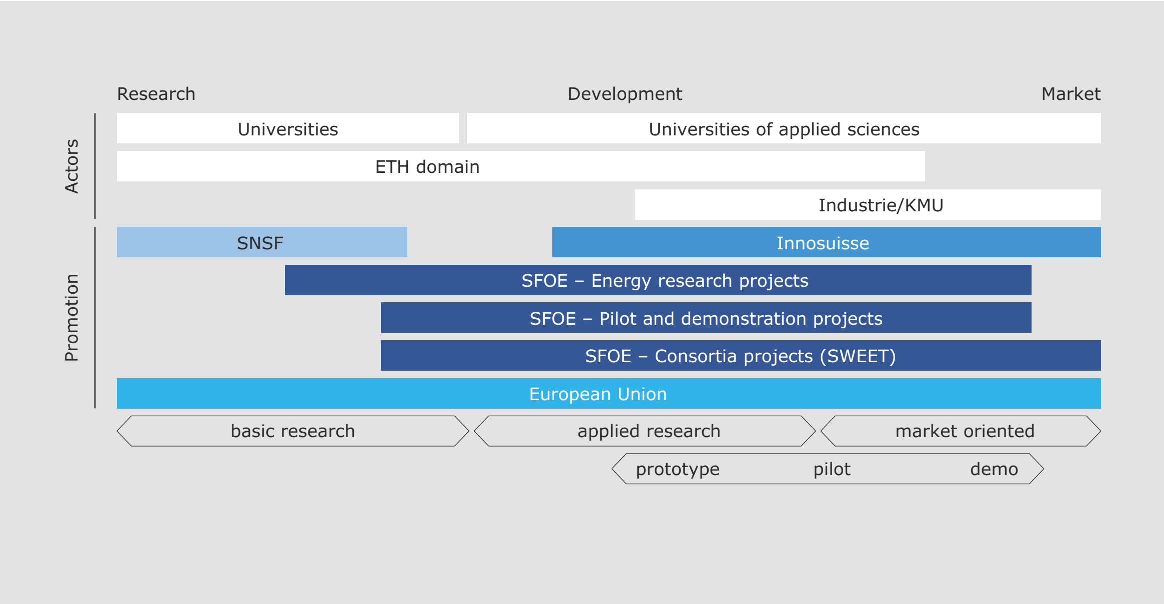
(Left) A project by the University of Applied Sciences Northwestern Switzerland, Bioburn AG and Kaskad-E explored which types of biomasses, besides wood, can be used energetically. Pyrolysis (charring) can be used to generate thermal energy and plant charcoal from biomass. 32 types of biomasses were investigated, with three of the substrates proving particularly promising: Forest wood bark, wheat bran and coffee roasting waste. They were subjected to additional measurements at two commercial pyrolysis plants in Basel and Stettlen (BE). Forest wood bark was judged to be suitable for the production of energy and charcoal (top left photo, image source: Léonard Marchand/FHNW). It has the greatest additional usable energy potential of the substrates studied. The pyrolysis plant of the energy provider IWB, which has been in operation since 2021, can be seen at the bottom left (image source: IWB). This plant generates district heating for 170 households and 550 tonnes of vegetable coal from landscape management material.

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 is guided by its own energy research concept 2021–2024, which in turn is based on the federal government's energy research strategy. For the current period 2021–2024, an even stronger focus is put on non-technical research (SSH: social sciences and humanities). Technical sciences and SSH are to work closely together as early as the conception stage of research projects in order to orient research results towards later application at an early stage.

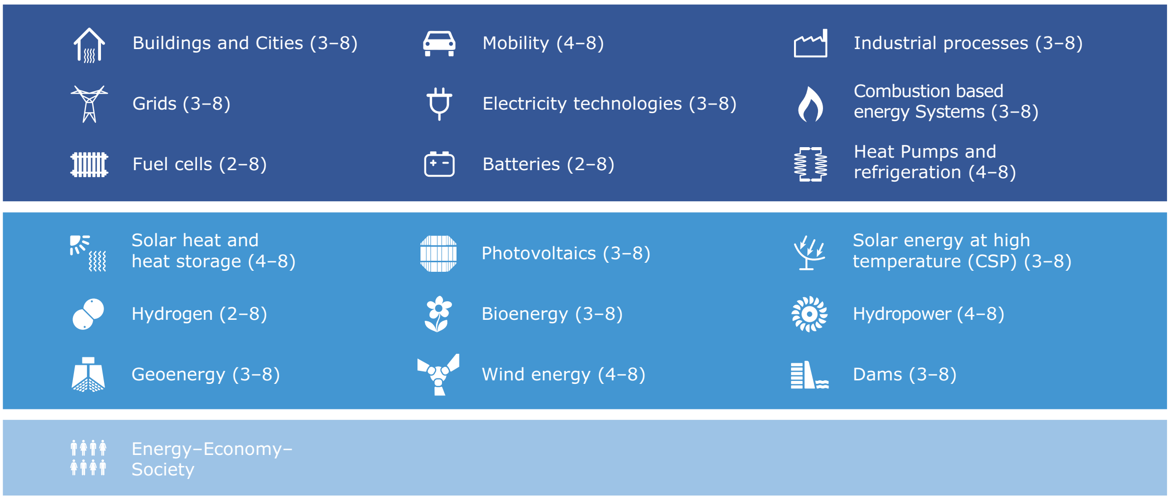
Funds from SFOE for energy research are used in a subsidising manner to close gaps in the funding landscape and thus to coordinate Swiss energy research. Currently, around 50 million Swiss francs per year are available for this and around 300 ongoing projects are closely monitored each year.



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).

Thematic energy research programmes

With its thematically oriented energy research programmes, the Swiss Federal Office of Energy (SFOE) covers the entire spectrum of energy research in the fields of “Energy Efficiency” and “Renewable Energy”. 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.



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

In September 2020, the Swiss parliament approved the funding programme SWEET - "SWiss Energy research for the Energy Transition" funding programme, which seamlessly follows the preceding programme SCCER "Swiss Competence Centers in Energy Research". Funding of 136.4 million Swiss francs is available for SWEET until 2032. In contrast to SCCER, SWEET is a competitive programme, i.e. calls for proposals are published regularly for consortia to apply. SWEET uses calls for proposals to support inter- and transdisciplinary consortia made up of various universities, higher education institutions and partners from the private and public sectors.

The four consortia DeCarbCH, EDGE, PATHFNDR and SURE of the first call for proposals on the topic of "Integration of renewables into a sustainable and resilient Swiss energy system" started their research work in 2021. The consortia address topics such as decarbonisation of heating and cooling, decentralisation of the energy system through renewable energies, sector coupling and sustainable development and resilience of the energy system.

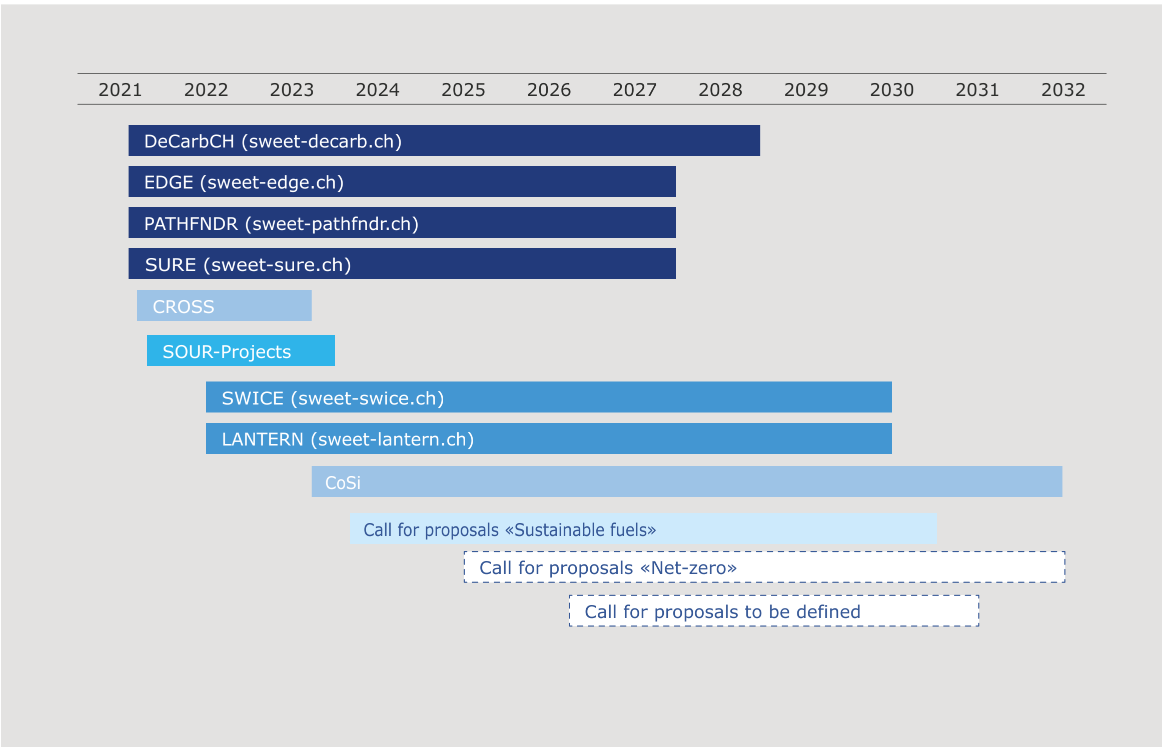
In addition to the SWEET consortia, the instrument SOUR ("SWEET OUtside-the-box Rethinking") consciously supports unconventional projects implemented by individual researchers or small teams. In the first SOUR call - on the same theme as the first SWEET call - four projects were awarded funding.

The LANTERN and SWICE consortia resulting from the "Living & Working" call started their work in 2022. Both consortia are investigating issues in the setting of so-called Living Labs. LANTERN uses these to develop, test, validate and scale measures for a decarbonised, resource-efficient Switzerland. SWICE aims to identify and quantify opportunities to save energy and to improve quality of life that could result from new ways of living, working and mobility.

The CoSi consortium was awarded the contract in the call for proposals "Co-evolution of the Swiss energy system and Swiss society and its representation in coordinated simulations". It is going to establish a platform for exchange between the natural and engineering sciences and the social sciences and humanities to develop scenarios and models that better represent the interactions between the energy system and society. To enable a sustainable set-up, the CoSi consortium will exceptionally be supported for 10 years. CoSi will continue the CROSS activity of the first four consortia.

The question of how Switzerland can meet its future needs for sustainable fuels and platform chemicals will be addressed in the "Sustainable Fuels and Platform Chemicals" call for proposals. This was launched in autumn 2022 in cooperation with the Federal Office of Civil Aviation (FOCA) and armasuisse. The aim is to further develop technologies for production, transport, distribution, storage and use. In addition, the aim is to show how the additional potential of Swiss farmyard manure can be profitably used for the production of fuels and platform chemicals.

A call for proposals in cooperation with the Federal Office for the Environment (FOEN) on the topic of "Net-zero" is planned for 2024.

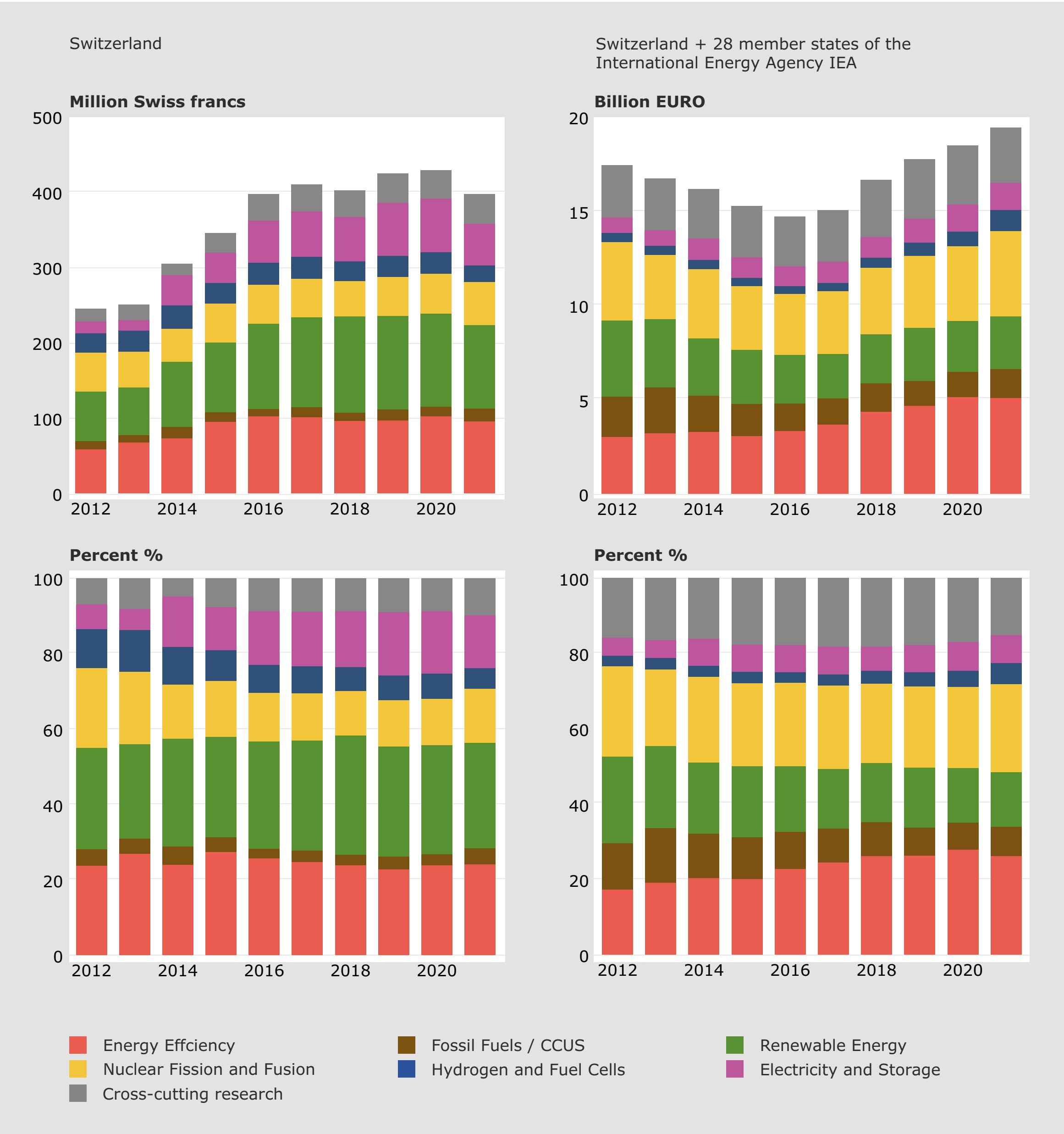


DeCarbCH
EDGE
PATHFNDR
SURE
SWICE
LANTERN

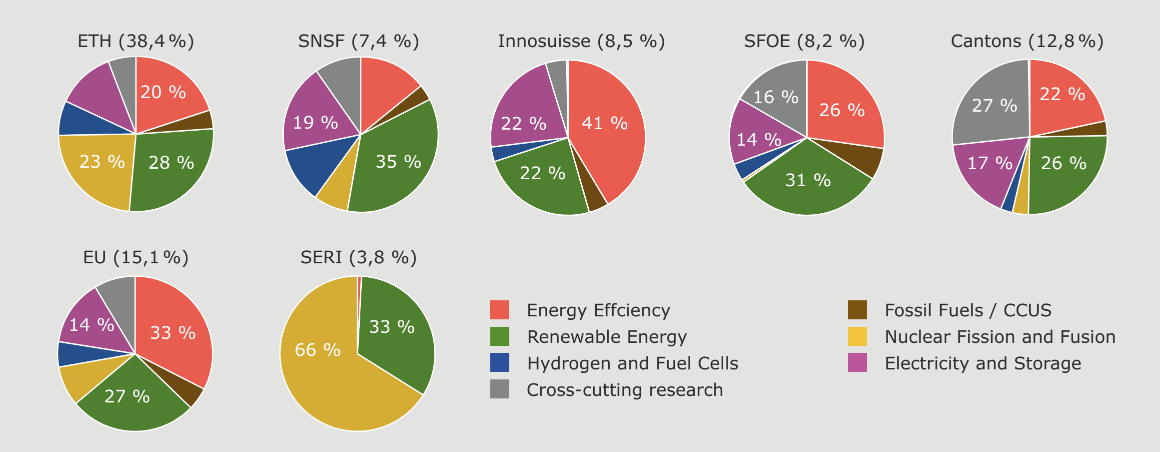
Overview of the consortia of the completed, current and planned calls for proposals of the SWEET funding programme.

Swiss energy research statistics

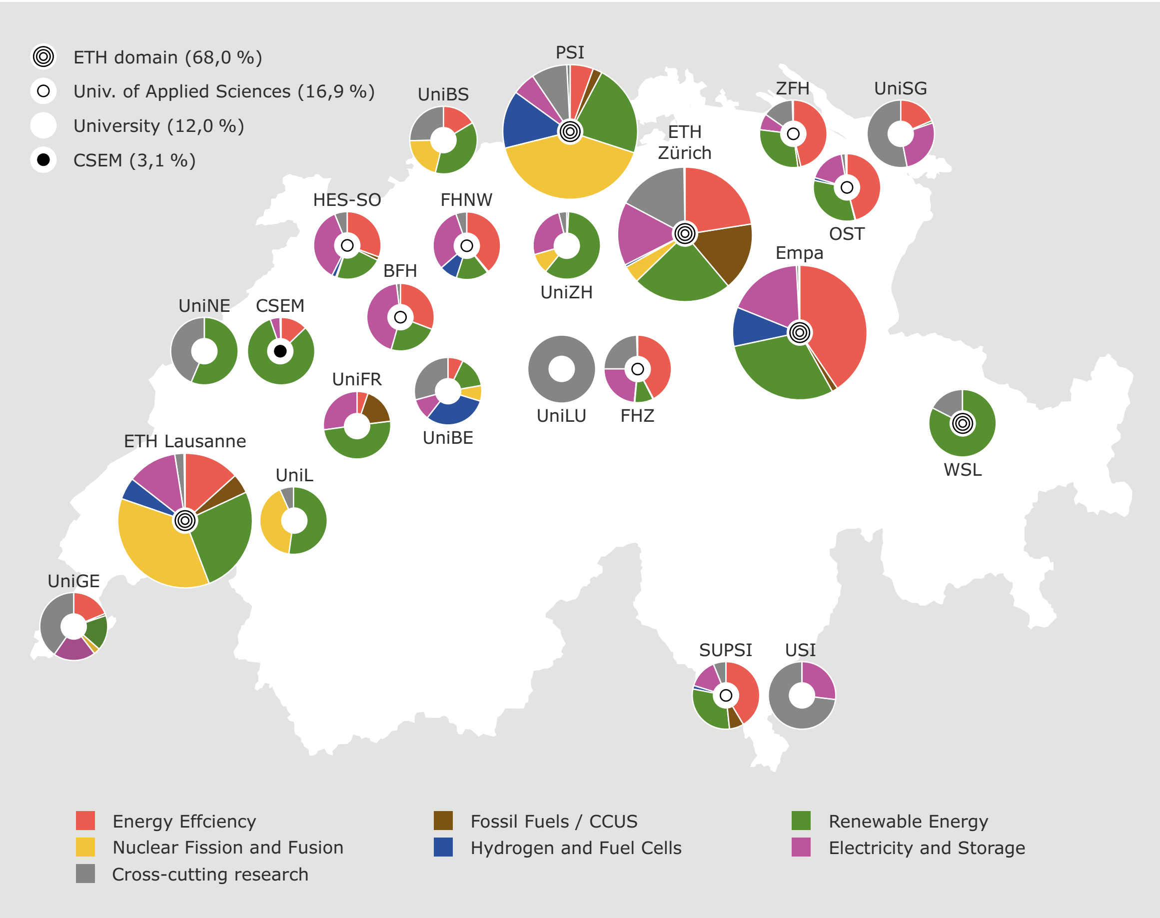
Since 1977, the Swiss Federal Office of Energy (SFOE) has been collecting data on projects that are funded in whole or in part by the public sector (Confederation and cantons), the Swiss National Science Foundation (SNSF), Innosuisse or the European Union (EU). Information on individual projects can be obtained from the publicly accessible information system of the Confederation (www.aramis.admin.ch), the SNSF (data.snf.ch), the EU (cordis.europa.eu) and the respective websites of individual institutes. In 2021, the public sector in Switzerland spent 400 million Swiss francs on energy research, which corresponds to 170 % of the expenditure in 2011. For comparison, the total expenditure of 29 member countries of the International Energy Agency (IEA) (including Switzerland) amounts to around 19 billion euros and remained more or less constant over the last 10 years.



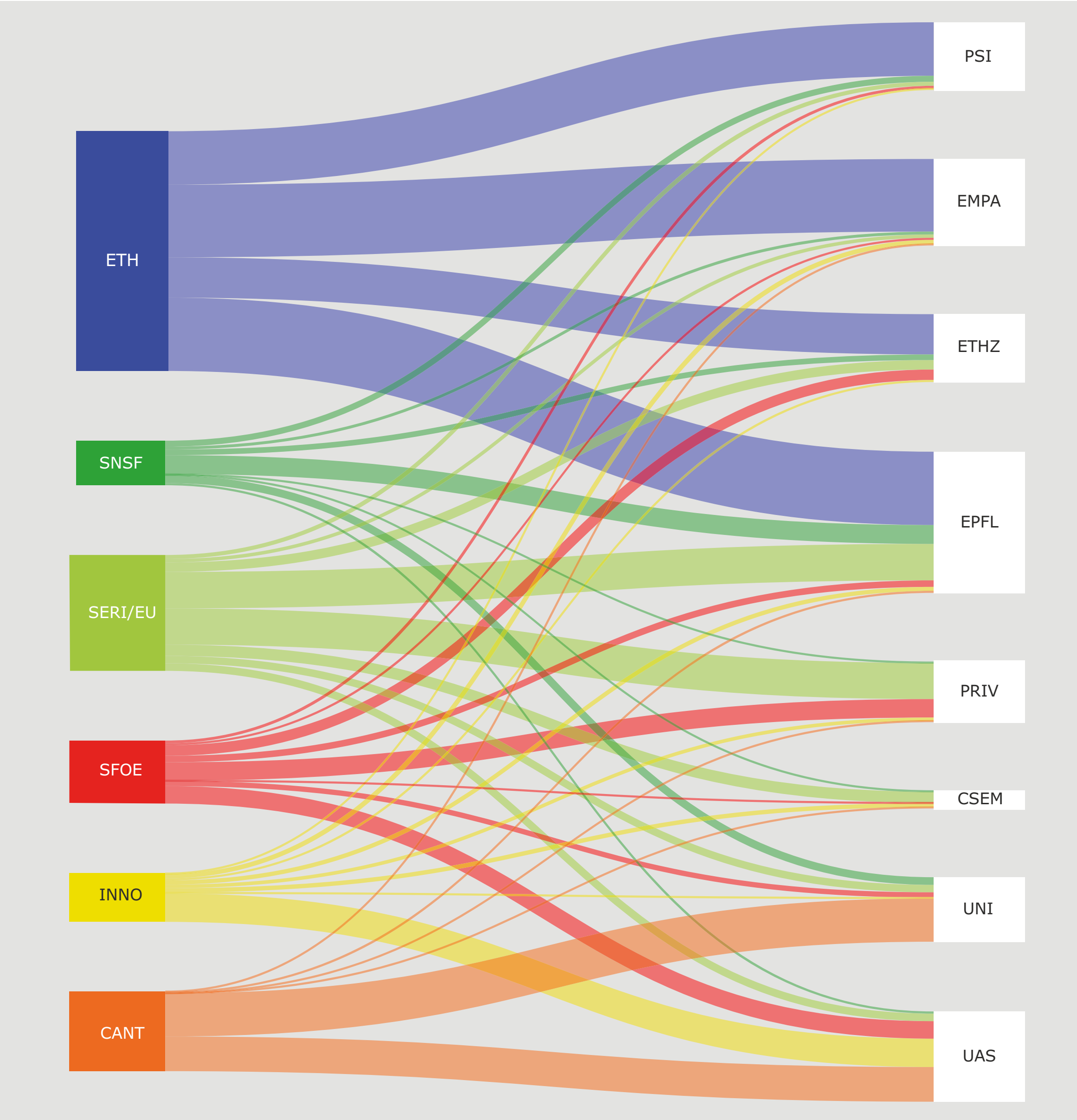
Public funds spent on energy research in Switzerland (left) and in 29 member countries of the International Energy Agency IEA (right). Swiss expenditure is in the range of 0.3 to 0.65 per mille of the gross domestic product. The funds are broken down according to the classification of the International Energy Agency (IEA) (source: SFOE energy research statistics).



Public funding for energy research (data 2021) by funding agency and thematic area. Around 38 % of the funding for energy research in Switzerland comes directly from the ETH Domain, and around 13 % 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 2021). The topics are broken down according to the classification of the International Energy Agency. Most of the public energy research (68 % 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).

(Right) Thanks to a lithium-ion battery connected to the power plant, the Ernen high-pressure run-of-river power plant in the Upper Wallis can also compensate for short-term fluctuations in the electricity grid without having to adjust the output of the turbines. This increases the service life of the mechanical components (source: FMV).

Making hydropower even more valuable

Vastly increased output, more flexibility for grid stabilisation and less environmental impact: these are the demands on hydropower in the coming years. The "HydroLEAP" project is investigating how power plant operators can meet all these requirements in the best possible way.

Hydropower is the central pillar of Switzerland's electricity supply: it makes a decisive contribution to security of supply and grid stability. Its importance is growing with the increasing use of irregularly occurring electricity from new renewable energies. In order to achieve the goals of the Energy Strategy 2050, hydropower must be expanded significantly without causing too much harm to the environment. At the same time, a number of power plants are due for renovation and modernisation work in the short to medium term as part of the concession renewal process.

In the "HydroLEAP" project, researchers from EPFL, ETHZ and the University of Applied Sciences of Western Switzerland (HES-SO) are working together with power plant operators to investigate how the necessary conversion and expansion can be achieved. They are looking for measures with which the output of the hydropower park can be expanded and at simultaneously minimise the operating costs as well as the environmental impact. To achieve this, they examine various issues in a practice-oriented manner using a representative selection of three power plants.

Pumped storage power plants are essential for the stability of the electricity grid because they can store production surpluses and compensate for production bottlenecks. This flexibility will become increasingly important in the future. In the Veytaux I and II pumped storage power plants on Lake Geneva, the researchers are now testing new operating methods to increase flexibility. Another goal is to develop a method for predictive maintenance of power plants. In doing so, algorithms analyse the relevant operating data of the plant in real time and determine when certain components need to be replaced or serviced. As a result, costly power plant shutdowns and expensive empty trips by service personnel can be avoided. Maintenance work can also be better planned and operating costs are reduced.

At the second pilot site, the high-pressure run-of-river power

The Massongex-Bex-Rhône run-of-river power plant is scheduled to go into operation in 2028 and produce around 80 GWh of electricity annually. In order to keep the impact of the dam on the Rhone bed as low as possible, various compensatory measures are planned. To protect the fish, researchers at ETH Zurich are developing a new type of fish screen. This is intended to guide downstream migrating fish into the bypass system provided for them and around the power plant (source: MBR SA).

Pumped storage power plants can compensate for fluctuations in the electricity grid. To do so, they use surplus electricity to pump water back into the reservoir or bridge bottlenecks by turbining stored water. The Veytaux power plant is now investigating how this balancing can be optimised (source: Forces Motrices Hongrin-Léman SA (FMHL)/David Picard).

plant in Ernen, the focus also lies on the flexibility of hydropower utilisation. In the case of flexible operation, the power plant has to adjust its output quickly, often within seconds. This accelerates the wear of the turbines and shortens their lifespan. Batteries can cushion this effect by compensating for short-term fluctuations in the grid. Initial trials are underway worldwide. With the battery installed in the Upper Valais, more in-depth experience is now to be gained in Switzerland.

A second sub-project in Ernen is looking for the best option for the upcoming renovation of the power plant. The replacement of a Francis turbine with a more expensive but more flexible Pelton turbine is being tested. This should provide findings for suitable retrofitting measures in other Swiss hydropower plants.

The third studied plant is the planned new construction of the river power plant in the Rhone between Massongex VS and Bex VD. Here the goal is to keep the environmental impact as small as possible. Therefore, the researchers are using laboratory simulations to find the most effective solutions for fish migration in both directions, and determining the most suitable turbine design and operating strategy with regard to fine sediments. High concentrations of such particles in the water can cause damage to the turbines. The methods developed in this project will be tested through practical trials so that they can be applied to large proportions of the Swiss power plant fleet. In this way, hydropower can make an even more sustainable contribution to the energy transition.

The cement industry is the second largest CO_2 emitter in the world after the steel industry. Around 2.2 gigatonnes of CO_2 are produced every year, particularly during the combustion of fuels, but also through the decomposition of limestone. With the oxyfuel process, which supplies pure oxygen instead of ambient air to the combustion process, less CO_2 is to be released into the atmosphere in future. The project "Accelerating Carbon Capture using Oxyfuel technology in Cement production" (AC2OCem) is investigating its effect in new and existing cement plants with the aim of decarbonising the cement industry as quickly as possible (source: Holcim).

Innovative and efficient solutions for CO_2 capture

The capture, use and storage of CO_2 plays a crucial role in decarbonising energy supply and industry. Innovative solutions are needed to achieve the global emission reduction targets. The Swiss Federal Office of Energy is supporting two pilot projects that are advancing the development of such solutions.

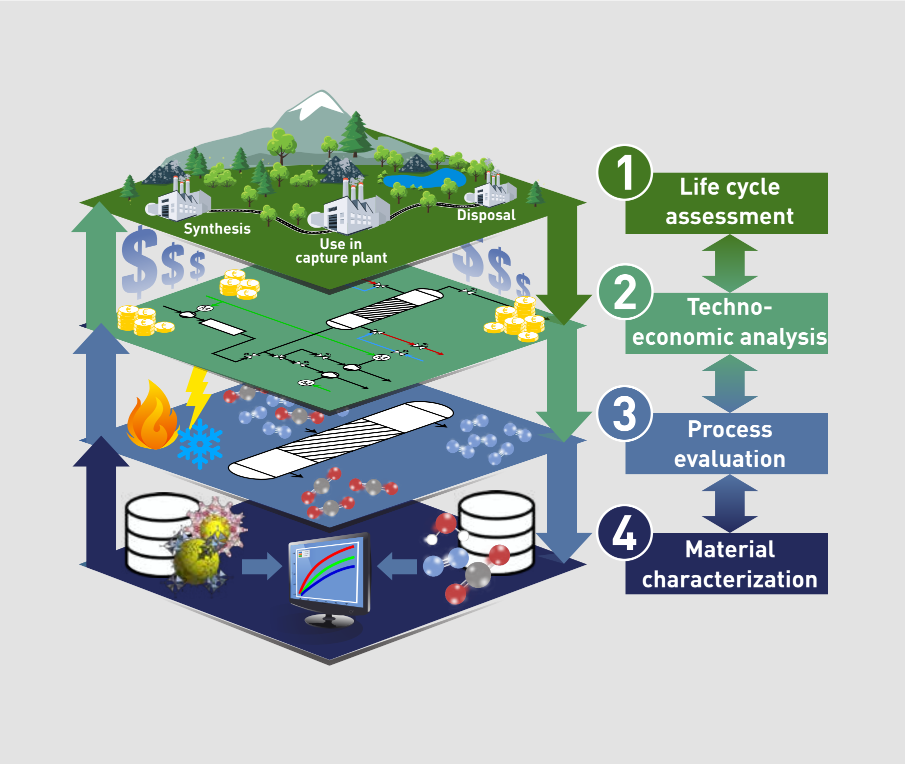
Increasing greenhouse gas emissions are one of the greatest global challenges. In order to minimise CO_2 emissions from various sources, CO_2 can either be captured and used as a resource for fuels or the chemical industry, or permanently stored. The international pilot project PrISMa ("Process-Informed design of tailor-made Sorbent Materials for energy-efficient carbon capture") is dedicated to this task. The USA, Norway, Switzerland and the United Kingdom are involved. It aims to drive the transition of the energy and industrial sectors towards a carbon neutral economy by accelerating the market introduction of competitive and environmentally friendly carbon capture, utilisation and storage (CCUS) technologies.

In order to decarbonise the various industrial sectors, there is a great need for capture technologies that are specifically tailored to the respective CO_2 source. In the future, the captured CO_2 will also be used in various applications. Against this background, world-leading research teams, in close cooperation with partners from the private sector and non-governmental organisations, are developing a technology platform that combines solutions for the capture of CO_2 from different sources as well as for its use and storage.

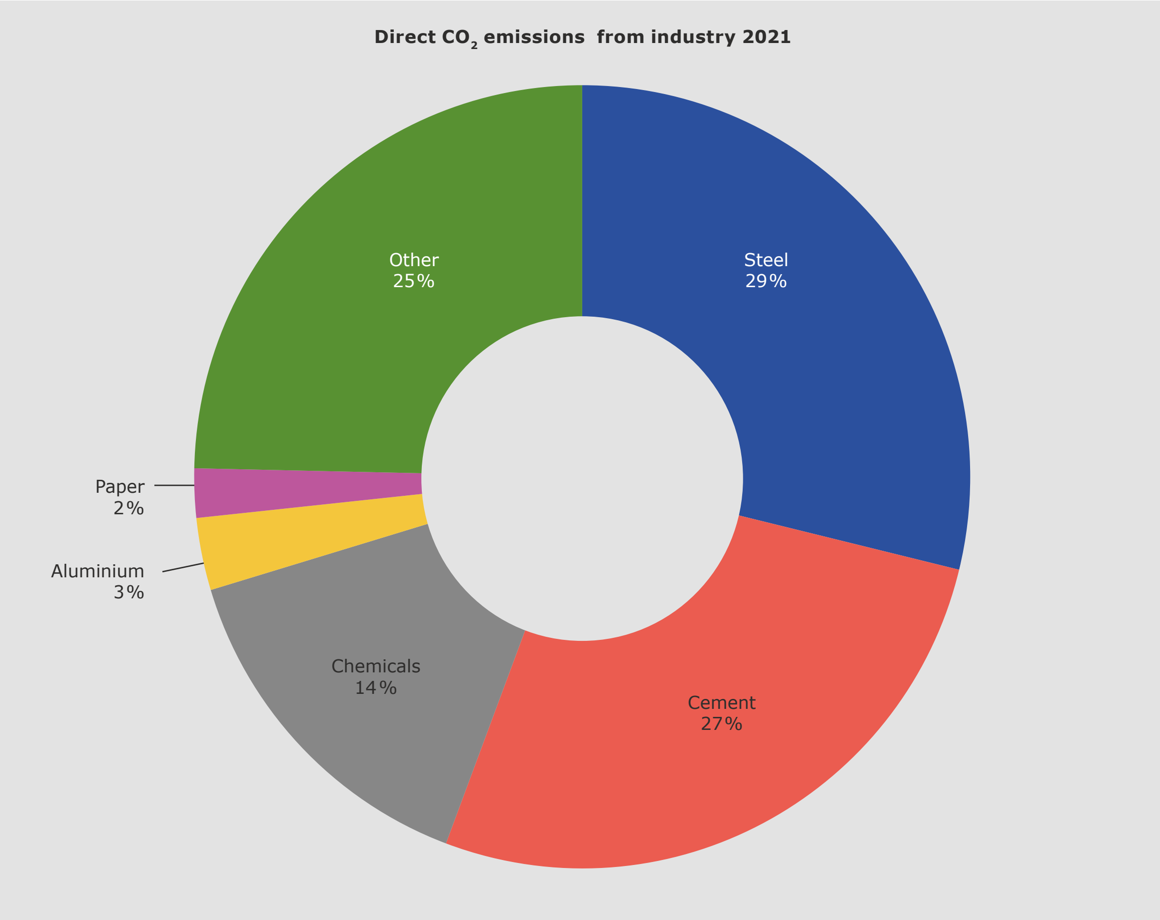
While today's CO_2 capture methods have to be developed specifically for each combination of CO_2 source and sink, PrISMa aims to develop tailor-made and economically viable solutions in an efficient workflow. In particular, the practically unlimited diversity of chemical materials is to be systematically exploited. Tailoring capture technologies to a specific combination of CO_2 source (e.g. waste incineration, coal combustion or cement production) with a sink (e.g. geological storage) allows to increase efficiency and cost-effectiveness. The PrISMa workflow is the first to systematically develop CO_2 capture methods as a key link in the overall chain from CO_2 generation to use as a raw material or final storage, in order to better utilise the potential for CO_2 reduction in the future.

The researchers have compiled over 50 case studies from the UK, the USA, China and Switzerland, with CO_2 sources covering a broad spectrum - from natural gas and coal to cement and air. In particular, the potential of novel sorbent materials that are optimally suited to a particular capture process and contribute maximally to CO_2 reduction has been investigated. Even for new materials that so far only exist in the computer, the platform allows the evaluation of both their future costs and their environmental impact through predictive models and life cycle assessments. This identifies promising materials for manufacturing and echoes the performance of existing materials.

The technology platform created during the three years of research is now operational. In the future, it will be expanded to enable researchers to better predict the CO_2-reducing effect of materials. At the same time, the focus will be on synthesising some of the best-performing



The figure on the left schematically depicts the PrISMa platform for the development of CO_2 capture technologies. This combines innovative new materials with process development and evaluates them on the basis of techno-economic and ecological criteria (graphic: ETHZ).



In 2021, industry was directly responsible for the emission of 9.4 gigatonnes of CO_2. This corresponds to a quarter of global emissions (excluding indirect emissions from electricity used for industrial processes). Cement production accounts for 27 % of this. The "net zero emissions by 2050" scenario forsees the reduction of industrial emissions to about 7 gigatonnes of CO_2 by 2030 - despite the expected growth in industrial production. Improvements have already been achieved in energy efficiency and the use of renewable energies. Important preconditions for achieving the targets are higher material and energy efficiency, faster diffusion of renewable fuels and accelerated development and introduction of low-carbon production processes as well as CO_2 capture and storage (source: IEA).

materials. The PrISMa project is an important step in advancing advanced CO_2 capture technologies and creating the conditions for a climate-friendly economy.

Another project from the CCUS area is AC2OCem ("Accelerating Carbon Capture using Oxyfuel technology in Cement production"). Its goal is to decarbonise the cement industry as quickly as possible. The cement industry is the second largest industrial source of CO_2 emissions, releasing 2.2 gigatonnes of CO_2 per year. This corresponds to 27 % of total CO_2 emissions in the industrial sector. A large amount of CO_2 is released during cement production, on the one hand through the combustion of fuels in the burning chamber, and on the other hand through the decomposition of limestone. The European pilot project is investigating the use of the oxyfuel process in both existing and new cement plants. This is considered one of the most cost-effective solutions for carbon capture in the cement production process. In the oxyfuel process, pure oxygen is fed into the combustion process instead of ambient air. This creates a CO_2 waste gas stream. The CO_2 is separated and, for example, processed into methanol by means of synthesis or made available to other industries as a feedstock for further processing.

Within the AC2OCem project, the already advanced first-generation oxyfuel technology, which is to be used in existing cement plants, was further developed. In addition, the second-generation oyxfuel technology without exhaust gas recirculation, which is to be used in new kilns in particular, was investigated analytically and experimentally. A series of tests were carried out with the prototype of a new kiln burner, in which up to 100 % oxygen was added and up to 100 % alternative fuels with a high biomass content (e.g. sewage sludge) were used. Among other things, the tests provide information on how retrofitted and new cement plants can be optimally designed.

Simulations help to further increase the efficiency of the oxyfuel concept in terms of energy consumption. Data was also collected to create a life cycle assessment over the entire life cycle of new and retrofitted cement plants, and the potential of this new technical solution for carbon capture and storage was estimated.

The successfully conducted pilot tests bring the oxyfuel technology closer to large-scale application in the cement industry and contribute significantly to the market maturity of the first generation of oxyfuel technology. Last but not least, the project aims to increase public awareness and acceptance of the use of CCUS in energy-intensive industries and to make the acquired knowledge accessible to others.

One approach to reducing CO_2 emissions in cement production is the use of alternative fuels, including biomass. This plays a key role in the decarbonisation of cement production. According to Cemsuisse, the use of biogenic fuels can already save 400'000 tonnes of CO_2 annually. In 2020, the share of alternative fuels in Switzerland was 69.1 %, of which 43.3 % was biomass. According to the Cemsuisse roadmap, the goal is to increase the share of alternative fuels to 100 % by 2050, and that of biomass to 60 % (source: University of Stuttgart).

Swiss Blue Energy has been researching the development of a thermo-magnetic engine since 2012. The company from Bad Zurzach (AG) focuses on the development of emission-free methods for power generation that use waste heat at a temperature level of 20 to 80 °C (source: Swiss Blue Energy).

How a "magnet motor" generates electricity

A Swiss company developed a thermo-magnetic motor that can produce electricity directly from waste heat at a low temperature level. The idea is not market-ready yet, but recently it was possible to prove that the concept works.

What can be done with the waste heat that accumulates in industrial plants or power stations? In the temperature range below 100 °C, it is mostly used today - if at all - for heating and hot water. The Aargau based company "Swiss Blue Energy", however, is convinced that it can make even better use of such low-temperature waste heat: It wants to generate electricity from it. Steam turbines, which are commonly used to generate electricity from waste heat, are out of the question for waste heat temperatures below 100 °C. Swiss Blue Energy therefore relies on an innovative in-house development: the Thermo-Magnetic Motor (TMM).

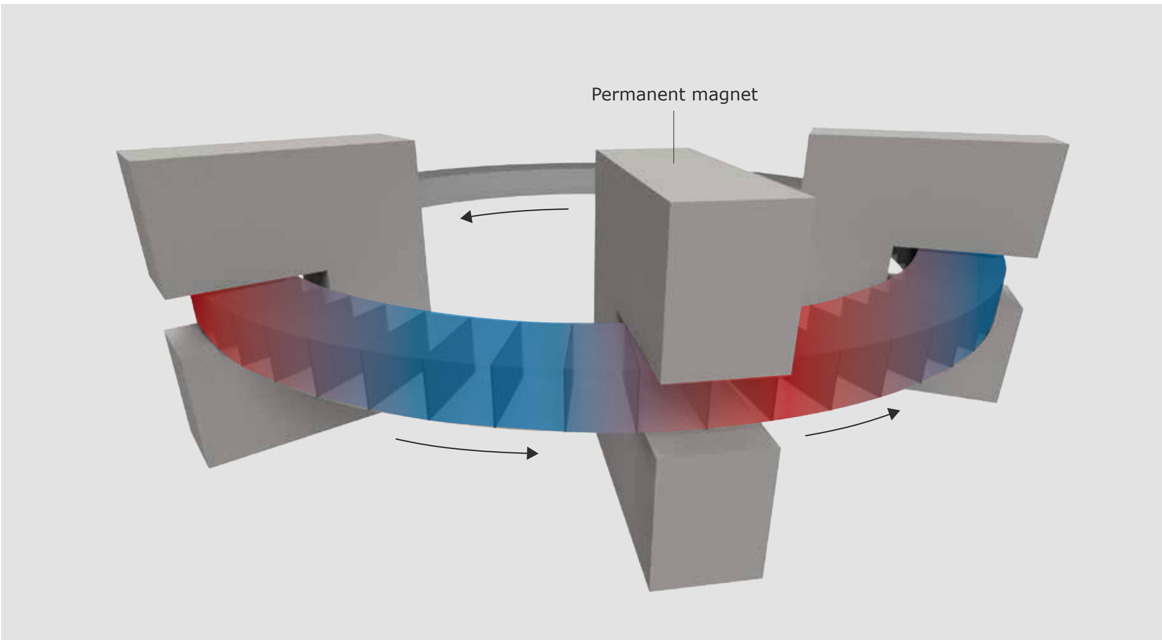
The concept of the TMM is based on the fact that certain materials are only magnetic in a certain temperature range. One of these materials is gadolinium (see picture on the right). It is magnetic as long as it is colder than 19.3 °C. If it is heated, it loses its magnetic property. The TMM makes use of this phenomenon by alternately cooling the gadolinium with cold water and heating it with hot water. The required hot water with a temperature of around 60 °C can be provided by low-temperature waste heat from industry or power plants, as such low-grade waste heat would usually remain unused. The availability of cold water can be ensured by choosing a location near a river or lake. The TMM only needs additional energy to operate the pumps that transport the cold or hot water into the system.

To generate electricity from the magnetic properties of the gadolinium, Swiss Blue Energy has mounted it on a horizontal rotor surrounded by a casing with permanent magnets. If the gadolinium is alternately cooled and reheated, a magnetic flux is created which is converted into a circular motion by the permanent magnets (see graphic below). The mechanical energy from the rotary motion of the rotor is then converted into electricity via a conventional generator. In this way, valuable electricity is generated from previously often unused low-temperature waste heat.

However, the TMM is still a long way from being ready for the market. In a two-year project, Swiss Blue Energy has succeeded in producing more electricity than the pumps and auxiliary systems themselves consume.

Gadolinium (Gd) is one of the rare earth metals. It is magnetic provided its temperature is less than 19.3 °C. This threshold is called the Curie temperature. Gadolinium is not ideal as a material for the thermo-magnetic motor, among other things because of its toxicity, so research is being carried out into suitable alternatives (source: Wikimedia Commons).

The 531 watts of electrical power generated by the generator could power an e-scooter, for example. The concept still needs to be greatly optimised for marketability. This mainly requires an alternative to gadolinium, which is not efficient enough, too expensive and not environmentally friendly enough. Such alternatives are being researched internationally; Swiss Blue Energy is working together with the Delft University of Technology (Netherlands). They are trying to develop an alloy that is more efficient, more environmentally friendly and cheaper than gadolinium. As soon as this is successful, Swiss Blue Energy wants to start optimising the TMM and develop a market-ready version.



Functionality of a thermo-magnetic motor: In the circular horizontal casing there is a rotor on which gadolinium is mounted. Permanent magnets are located in regular intervals on the casing - shown as vertical grey blocks in the diagram. Between each two of these magnets, the gadolinium on the rotor is cooled by a cold water flow (blue). This makes it magnetic and attracts it to the next permanent magnet, causing it to rotate to the right. When the gadolinium reaches the permanent magnet, it is heated with warm water (red). From 19.3 °C, it loses its magnetic property and can pass through the permanent magnet unhindered. It is then cooled again (blue), attracted by the next permanent magnet and moved further to the right (graphic: Swiss Blue Energy).

The heating system with a heart of ice

Due to the lack of alternatives, a combination of heat pump and ice storage provides the heat supply in a building complex in Bern. The concept, which at first glance seems perplexing, works and also achieves a high level of efficiency, as proven by two years of monitoring.

There are many options available in Switzerland today for supplying heat from renewable sources. Whether heat pumps, district heating or wood heating: the systems are established and economically competitive. But what can be done if none of these systems can be realised at a particular location? Such cases are rather rare - but they do exist, as the example of Weltpostpark in the east of Bern shows.

In the case of this three-building development, the client required that the total of 170 flats meet the requirements of Minergie-Eco and that the entire development meet those of the "2000-Watt Site" label. Consequently, a heat supply based on renewable sources was required. The energy planners' investigations revealed that a heat pump with a groundwater or geothermal probe was not possible for geological reasons. An air-to-water heat pump was not considered because of the high electricity demand and possible objections due to noise emissions. In addition, there was no heating network in the neighbourhood and there were no efforts to realise one in the foreseeable future. Finally, a wood-burning stove was out of the question because it would have polluted the air more than the energy plan allowed. In short, none of the current renewable heating systems could be realised at this location.

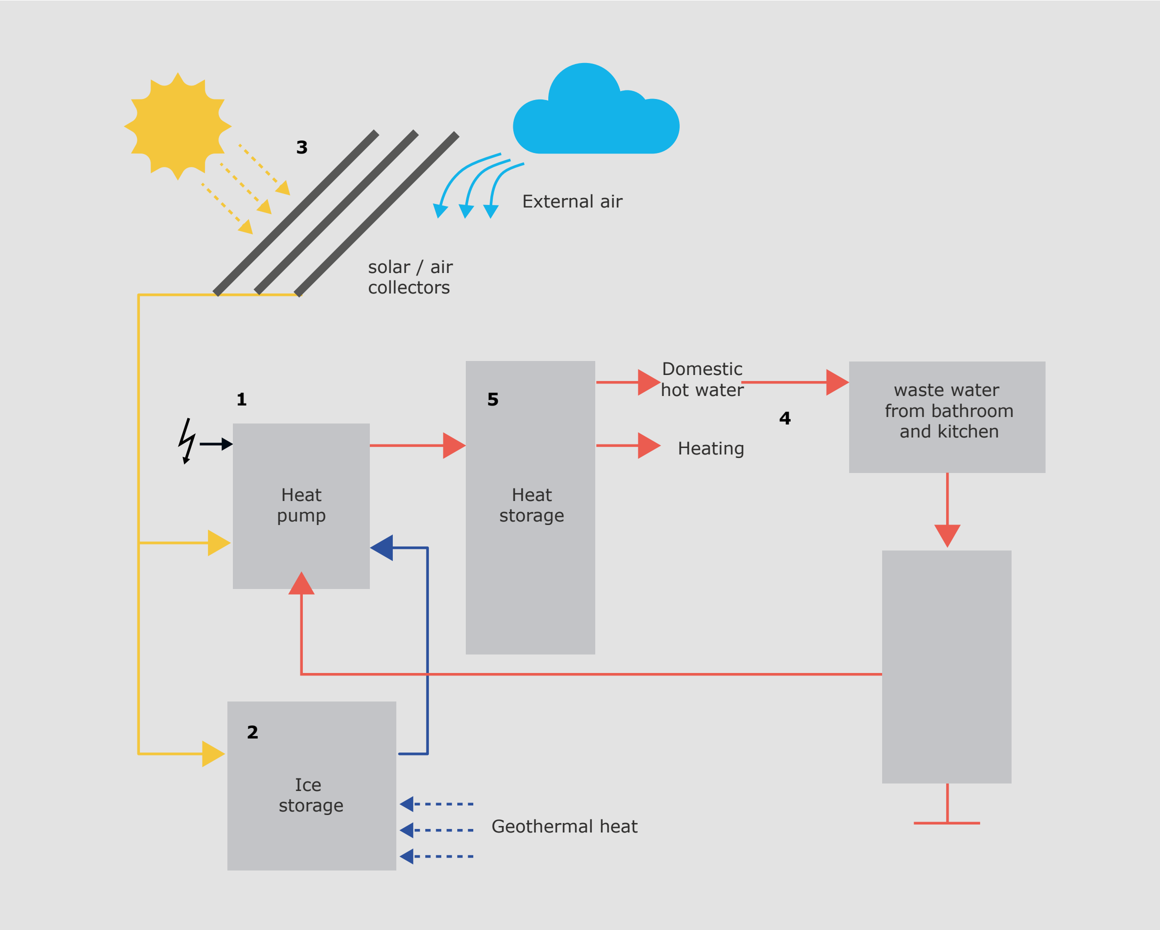
In order to still meet the client's sustainability requirements, the energy planners looked for alternatives. After evaluating various options, they finally found a suitable solution: the combination of a heat pump with an ice storage tank. Solar collectors and a wastewater heat recovery system were to serve as the heat source. But how do ice storage

The Weltpostpark in the east of the city of Bern comprises three buildings that were built according to Minergie-Eco specifications. The development as a whole also meets the criteria of the "2000-Watt Site" label (source: B. Vogel).

and heat supply fit together? The concept of the ice storage tank is based on a special property of water: when it is cooled to 0 °C, it begins to freeze. This process, known as crystallisation, releases energy - a lot of it. Example: When a litre of water freezes, the same amount of energy is produced that is needed to heat the same amount of water from 0 to 80 °C.

In an ice storage tank, a heat pump extracts the thermal energy from the water and thus ensures crystallisation. When the storage reaches a certain degree of icing, the ice is thawed again by adding heat from solar energy, which is called regeneration. The process of freezing and thawing can be repeated as often as desired and requires hardly any maintenance.

View of the inside of an ice storage tank before it was filled with water. Heat is extracted from the water during operation via the pipes arranged in a ring, which eventually causes it to start freezing from the bottom up. A free space was deliberately left on the very outside so that no ice would form there that could cause damage to the wall. The ice storage is defrosted by a second pipe system installed on the walls. The ice store therefore defrosts from the outside to the inside (source: Viessmann Schweiz AG).



This is how the heat supply of the Weltpostpark works: The heat pump (1) supplies the apartments with domestic hot water (DHW) and heating energy via a heat storage tank (5). Solar collectors (3), the ice storage tank (2) and the wastewater heat recovery system (4) serve as energy sources (graphic: Weisskopf und Partner and FEKA AG).

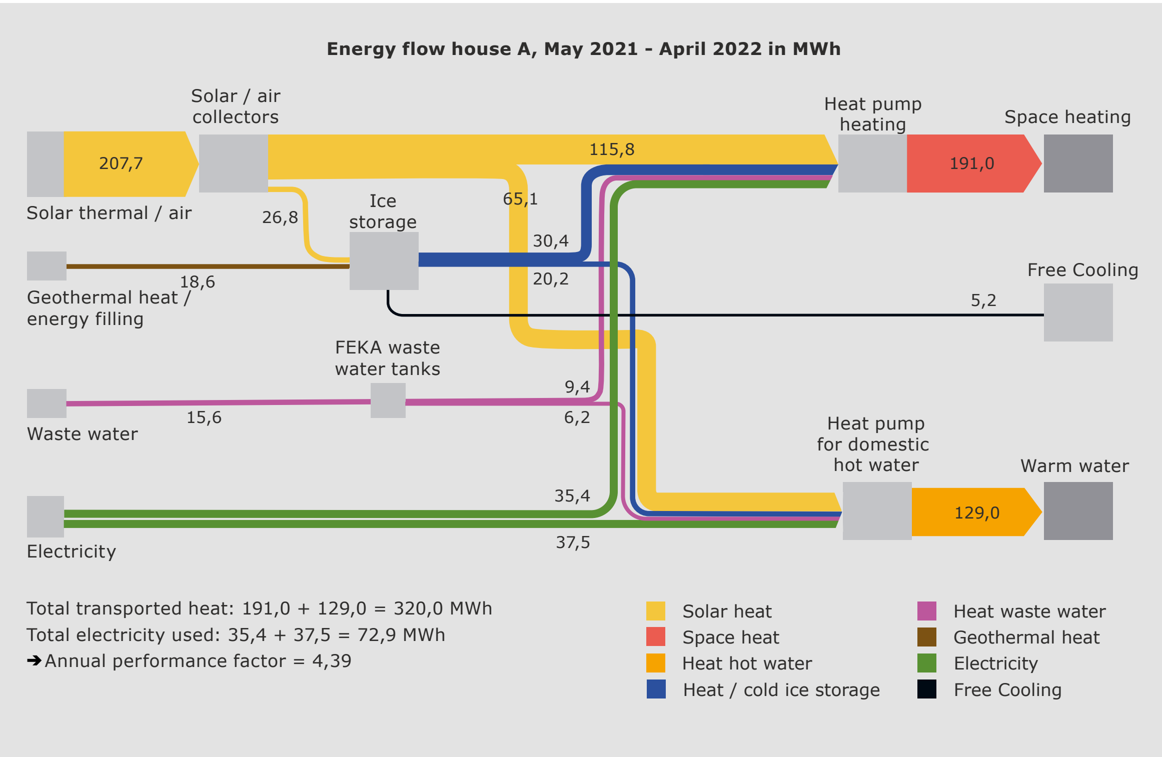
However, an ice storage tank can not only be used for heating in winter, but also for cooling in summer. To do this, a lot of ice is deliberately created in the storage tank towards the end of the heating period. On hot summer days, the stored cold is used by cooling the water from the heating circuit in the ice storage tank. When the water then flows through the pipes in the flats again, it absorbs heat there and thus cools the room. Conversely, the ice storage is heated and the ice gradually thaws. At the beginning of the heating season, the storage tank is then made of liquid water again - the cycle can start all over again.

In the Weltpostpark project, each of the three buildings received an independent energy supply: solar collectors on the roof, plus a heat pump and an ice storage tank. In addition, a system for wastewater heat recovery is used. The storage tanks were built outside the buildings in the ground - they are actually nothing more than underground tanks made of concrete. Two buildings have a round ice storage tank with a diameter of around 11 m, while the third is supplied by two smaller, rectangular tanks due to space constraints. The interior of the ice storage tanks contains two separate pipes arranged in a spiral that serve as heat exchangers. One pipe extracts heat from the reservoir and thus ensures crystallisation, the other regenerates the ice reservoir by introducing heat.

The original plan was to use only solar collectors to regenerate the ice storage. However, a simulation showed that this would not ensure the supply, because solar radiation is often insufficient in winter. So another heat source was needed. Covering peak loads with an oil or gas boiler was out of the question. So the choice finally fell on wastewater heat recovery. The concept is quite new, but it is likely to be used more often in the future. This is due to the fact that in energy-efficient buildings (e. g. buildings constructed according to the Minergie label), water heating accounts for a large share of the total energy demand. To prevent the thermal energy contained in the waste water from sinks, toilets, washbasins and showers from going to waste in the sewage system, it can be extracted with a heat exchanger. A heat pump uses the recovered heat to heat the building - or in the case of the Weltpostpark, to regenerate the ice storage tank. For heat recovery to be worthwhile, however, a sufficiently large volume of wastewater is needed. The system is therefore not suitable for single-family homes and apartment buildings, but it is ideal for large residential developments such as the Weltpostpark.

The innovative energy supply system at Weltpostpark can be an inspiration for other locations with similar starting points. The Swiss Federal Office of Energy therefore supported the monitoring of the system for two years to see if it had potential for other applications. The measurements showed that a system that combines solar thermal energy, ice storage and a heat pump can be operated efficiently. This can be proven by the heat pump's average annual performance factor (APF) of 4.5, which means that 4.5 kWh of heat were produced from 1 kWh of supplied electricity - a very good value. In terms of costs, the solution with heat pump and ice storage is roughly on the same level as a ground-source heat pump.

The results of the measurements also made it clear that wastewater heat recovery is an important part of the concept: with a time-variable main energy source such as solar energy, it is imperative to have another one that steps in when there is too little or no sun. The energy supply of the World Post Park, born out of necessity, thus turned out to be a reliable, efficient system that could well be used again in similar initial situations.



The energy flow diagram of house A for one heating period shows that only 15 % of the solar energy gained had to be used for the regeneration of the ice storage tank - 85 % went directly into the operation of the heat pump. Also exciting: An estimated 8 % of the energy absorbed by the ice storage came from the surrounding soil (graphic: eicher+pauli).

This picture of the offshore wind farm "Horns Rev 1" off the coast of Denmark shows the air circulation (wake vortices) that can occur behind a wind turbine (source: Horns Rev 1 owned by Vattenfall, photographer Christian Steiness).

More wind power through optimised models

For a wind farm to generate as much electricity as possible, local conditions and interactions between the individual wind turbines in the wind farm must be taken into account during planning. An open-source library with data from Swiss companies should help to reduce the planning effort and deliver more precise results.

Anyone planning a wind energy project in Switzerland has to overcome very different challenges. These include the complex terrain and the special weather conditions that characterise this country. The interaction between thermal effects and the terrain, for example, leads to diurnal winds. For the precise design of a wind farm, one cannot simply rely on conventional calculation methods, but must include such influencing factors. As a result, specific models are used for each wind energy project and the exchange of experience between different projects is only possible to a limited extent.

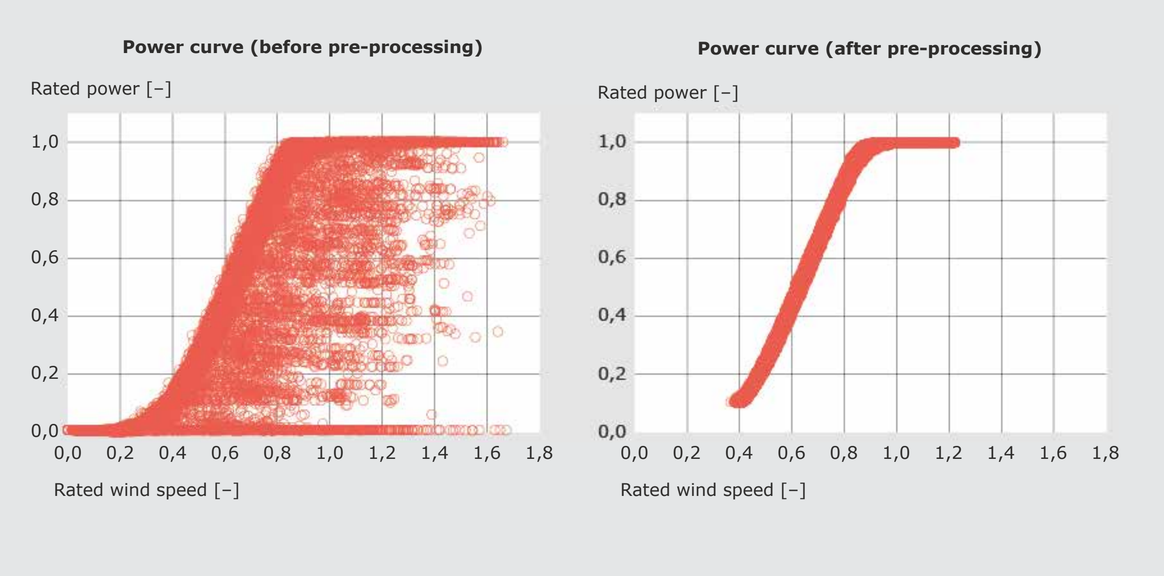
The high planning effort is contrary to the goal anchored in the Swiss energy strategy: in 2050, wind energy should achieve an annual production of around 4000 GWh of electricity. For this to succeed, about 40 wind turbines with a capacity in the megawatt range must be commissioned each year. This figure makes it clear that the effort required for planning wind energy projects must be reduced to enable faster and more cost-effective implementation.

Thanks to digitalisation, it is now possible to collect a lot of data relating to the operation of wind turbines. One of the methods for this is called "Supervisory Control and Data Acquisition" (SCADA). The data collected by SCADA includes, for example, the wind speed and direction, the speed and temperature of the generator or the position of the nacelle, i.e. the casing with the mechanical equipment. By using this extensive data with machine learning methods, the power curve of a wind turbine can be predicted more precisely. This enables the operator to better monitor and control the turbine.

At wind farm level, the individual turbines can influence each other depending on the wind direction, because air circulations occur behind them - as is the case with aircraft, by the way (see left picture). These so-called wake vortices interfere with the operation of other wind turbines. They can be steered to a certain extent by technical devices so that the overall performance of the wind farm is less affected. Today, these complex interactions are simulated by data-driven models in order to gain insights into the optimal planning and operation of wind farms.

As part of the "OpenIMPACT" project supported by the Swiss Federal Office of Energy, a Swiss research group - the "Wind Energy Innovation" department led by Dr Sarah Barber at the Eastern Switzerland University of Applied Sciences - is compiling such data-driven models in an open-source library. This will make it easier for owners and operators to optimise the energy production of their wind farms. The models are geared to the challenges of Swiss sites, as they take into account the complex terrain, weather and wake turbulence effects. The data required for this are collected on the basis of two use cases (see graphic below).

Based on the results of previous studies, the researchers assume that the use of models from their open-source library can increase the electricity production of wind farms by at least 10 %. Thus, the library would contribute significantly to achieving the goals of the Energy Strategy 2050 in the field of wind energy.



The graphic shows how the power curve of a wind turbine is processed in order to develop a forecast model. The graph on the left (a) shows the data collected between March 2020 and March 2022. Each green dot corresponds to the mean value of electricity production over a time interval of ten minutes. However, these data contain outliers, i.e. deviations from the expected ideal state, as well as partial distortions of the results due to maintenance work, defects, measurement errors, control strategies to reduce turbine load or shutdown in stormy winds. The outliers were removed in order to finally be able to determine the ideal state of a wind turbine using the adjusted power curve (b) (graphic: OST).

Regulating demand through dynamic electricity prices can reduce the need for expansion of the electricity grids. These tariff models motivate end customers to only purchase electricity for certain applications when the grid is not heavily loaded. Another possibility is that the grid operator may disconnect certain devices from the grid for a certain time in the event of power shortages (source: Eniwa AG).

How flexible tariffs stabilise the electricity system

With the decarbonisation of our energy system, the demands on the electricity grid are also changing. The increasing share of electromobility, heat pumps and irregularly occurring renewable energy puts a strain on the distribution grids and makes expansions necessary. Digitalisation can help to keep investments low. One possible solution is consumption control via various types of load control and corresponding tariff models.

The energy transition and increasing electrification result in more frequent and higher load peaks, i.e. short, strong power demands in the electricity grid. For its stable and efficient operation, it must be modernised and expanded. At the same time, solutions are being sought to break load peaks and thus reduce investment costs. One possibility is to motivate end customers with tariff incentives to make their consumption more flexible. In the project "Efficient Network Tariffs for Flexible Consumers" (NETFLEX), a research team from the Zurich University of Applied Sciences ZHAW, together with the regional energy supplier Eniwa, investigated which tariffs provide the greatest incentive and are the most effective.

To determine the costs and acceptance of different tariff models, the researchers surveyed a representative sample of private and commercial customers. The participants had to answer seven questions in which they were asked to choose one of three tariff models. The models in the individual questions differed in terms of which appliance is disconnected from the grid in the event of power shortages, how long and how often this may occur, and how high the compensation for this is. The surveys showed that both customer groups are in principle willing to make their consumption more flexible for the benefit of grid stability in return for appropriate compensation.

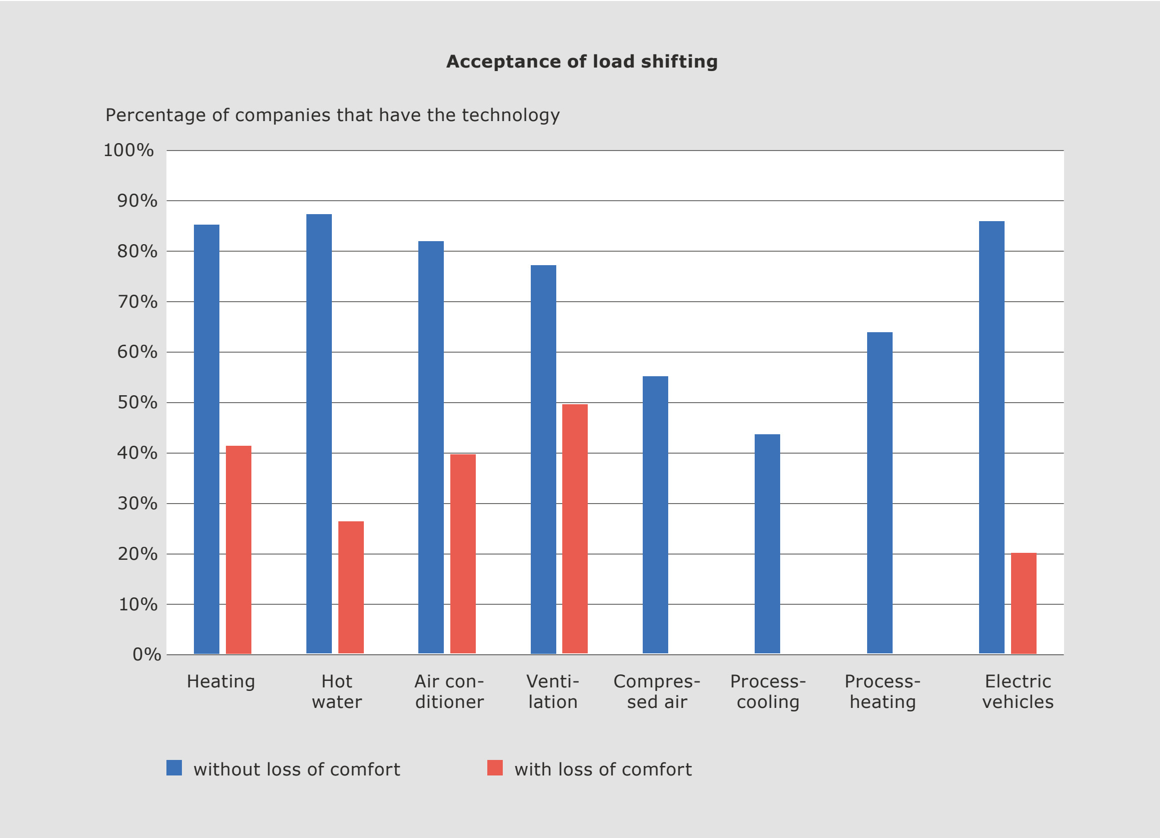
Among private customers, load shifting, i.e. the temporal shifting of electricity consumption, is best accepted for charging stations for electric vehicles, followed by heat pumps. This is also reflected in the costs: for a one-hour load shift per week, the respondents demanded an annual compensation of around 60 francs for heat pumps and 36 francs for electric car charging stations.

Further surveys revealed that the majority of household customers surveyed have a strong aversion to variable tariffs that are linked, for example, to the time of use (high and low tariff) or the utilisation of the grid. Almost 72 % of the respondents would rather opt for a uniform tariff with direct load control than for a variable tariff with or without direct load control.

Using Eniwa's supply area as an example, the researchers compared the costs of the necessary expansion with and without incentives to control certain consumers such as heat pumps, battery storage or electric vehicles. It turned out that such measures are worthwhile: Already today, the savings in grid expansion due to flexibilised consumption are similar to the compensation demanded by end customers. With the increasing spread of heat pumps and electric cars, the savings will increase even more.

Another important finding of the research project is that about two thirds of the grid costs are determined by the grid structure, i.e. the number and location of the grid connection points. One third stems from the load peaks, i.e. has to do with the dimensioning of the grid components. Therefore, the researchers recommend charging the structure-dependent costs via a regionally different basic fee per connection point. The load-dependent costs, on the other hand, should be allocated via the energy prices. In this case, energy suppliers or end customers who control their own loads are charged a variable price. End customers who have their loads controlled by the energy supplier pay a constant energy price. In addition, end customers should be able to choose different quality levels of grid service.

Control by the energy supplier instead of the grid operator has the advantage that load control can also be used for other purposes, such as reducing electricity procurement costs, during periods with sufficient grid capacity. Furthermore, in order to make even better use of the often manufacturer- and appliance-specific control options, it could be efficient if individual loads, such as charging stations, heat pumps or boilers, are supplied and controlled by separate energy suppliers specialising in this class of appliances, although this is not permitted in the current legal framework .



In the commercial sector, energy-intensive manufacturing processes are particularly suitable for load shifting. However, many companies fear a negative impact on product quality and the operational process. Therefore, they do not accept load shifting for production-relevant systems - whereas they do for building technology. More than 85 % of respondents said they would accept load shifts for space heating, hot water and electric vehicles without sacrificing comfort. The willingness is somewhat lower for ventilation (77 %) and air conditioning (82 %). With comfort restrictions, 40 % of respondents are still willing to accept load shifting for space heating, ventilation and air conditioning, while only 20 % of respondents are still willing to accept load shifting for hot water and electric vehicles. Without comfort losses, the surveyed companies expect at least 10 % of the annual electricity costs as compensation. With comfort losses, the demands rise to 20 %, which significantly reduces the potential here (source: SFOE interim report).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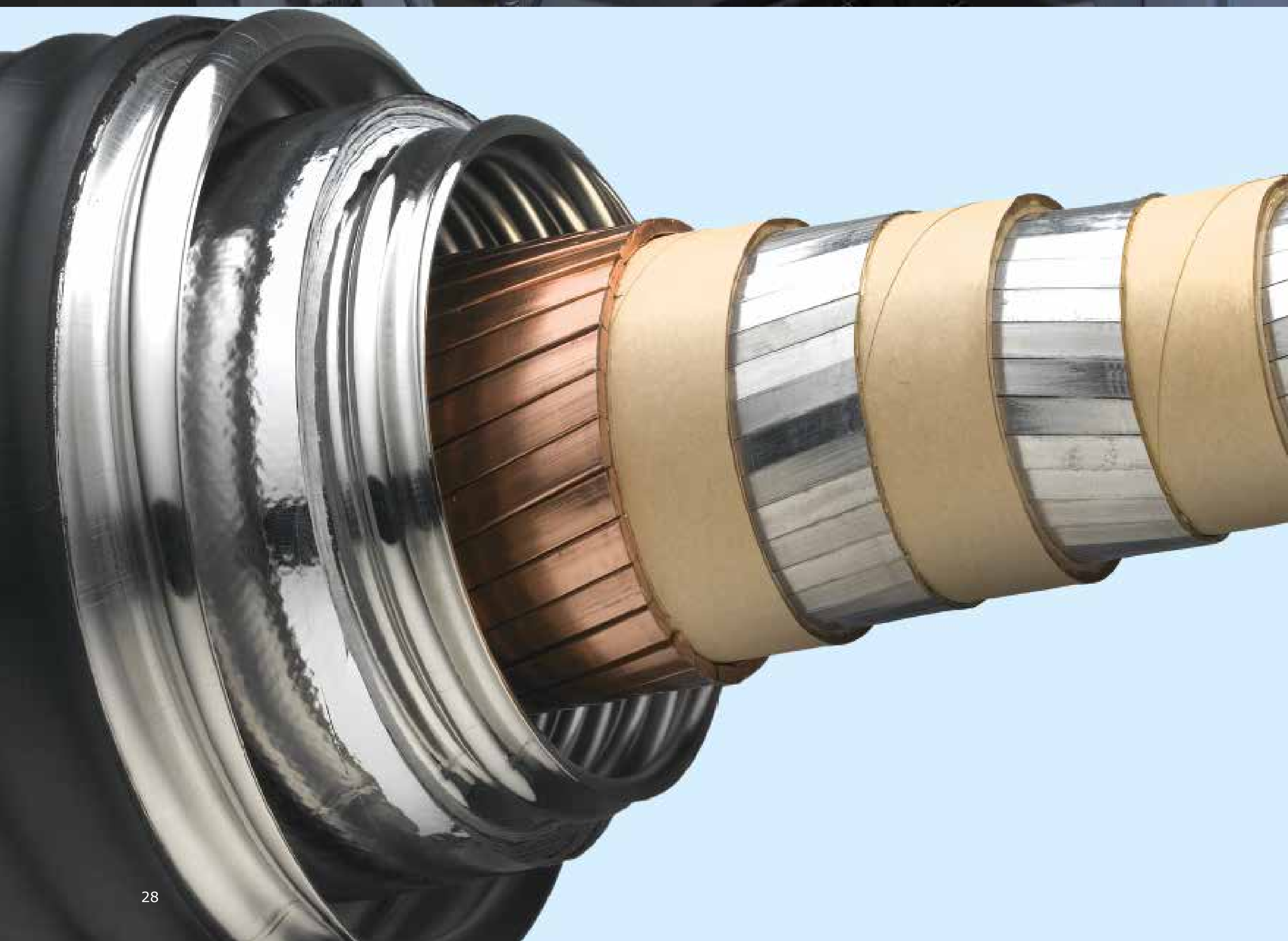

International cooperation

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" (formerly called "Implementing Agreements, cf. https:// www.iea.org/tcp), see list on following page.

At the European level, wherever possible Switzerland actively participates in EU research programmes. Here, at the institutional level the SFOE coordinates its energy research in alignment with the European Strategic Energy Technology (SET) Plan, the European Research Area Networks (ERANET), the European technology platforms, joint technology initiatives, etc. Beyond that, intensive multilateral cooperation with selected countries also exists in certain fields (smart grids, geothermal energy, hydrogen etc.).

Superconductors conduct electricity without noticeable electrical losses, but this requires strong cooling. For commercial applications, the focus lies on high-temperature superconductors (HTS). As part of the IEA's technology cooperation programme "High-Temperature Super Conductivity", in which Switzerland is also involved (see p. 30), a panel of experts has assessed the state of development of HTS applications for the power grid and compiled it in a "Application Readiness Map". The areas in which HTS technology already has a high degree of maturity include, among others, high-performance medium-voltage cables for supplying city centres, such as those used in Essen from 2014 to 2021 (top left, source: Westenergie AG). The cable of the AmpaCity project transported 39,000 MWh of electricity annually, which corresponds to just over a thousandth of the transmitted energy. The cooling required 45 MWh of energy in the same period , which is only slightly more than one thousandth of the transmitted energy.

The picture on the bottom left shows an HTS cable as it was used in Essen. The copper shielding can be seen on the left. The three silver superconducting layers are separated from each other by three brown insulations. Nitrogen flows around the inside and outside of the tube, cooling it to -200 °C (source: Westenergie AG).

Participation in technology cooperation programmes of the IEA

Energy Conservation through Energy Storage (iea-eces.org)

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

User-Centred Energy Systems (userstcp.org)

High-Temperature Super Conductivity

Clean and Efficient Combustion (ieacombustion.com)

Hybrid & Electric Vehicles Technologies (ieahev.org)

Geothermal (iea-gia.org)

Hydropower (ieahydro.org)

Solar Heating and Cooling (iea-shc.org)

Wind (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 Programme (iea-pvps.org)

Solar Power and Chemical Energy Systems (solarpaces.org)

Greenhouse Gas (ieaghg.org)

Participation in ERA-NETs – European Research Area Networks

Bioenergy (eranetbioenergy.net)

Accelerating CCS Technologies (act-ccs.eu)

Concentrated Solar Power (csp-eranet.eu)

Smart Energy Systems (eranet-smartenergysystems.eu)

Solar (Cofund1 & Cofund2) (solar-era.net)

Geothermica (geothermica.eu)

Materials (https://m-era.net/)

Further international cooperation

Fuel Cells and Hydrogen Joint Undertaking

International Partnership for Geothermal Technology

Driving Urban Transitions

DACH-Kooperation Smart grids

Clean Energy Transition Partnerhsip

To ensure that photovoltaic (PV) systems produce the maximum amount of solar power, they are equipped with so-called maximum power point (MPP) trackers. If MPP trackers are mounted decentrally on the individual PV modules, they are called "optimisers". Scientists at the Zurich University of Applied Sciences (ZHAW) in Winterthur have developed recommendations regarding the cases in which the installation of optimisers in PV systems brings an additional energy yield. If there is slight or no shading, a central MPP tracker on the inverter of the PV system is indicated. In case of medium shading, it is worthwhile to use optimisers on selected modules. In the case of heavy shading, an all-optimiser solution makes sense (source: Tigo Energy).

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