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Swiss Federal Office of Energy SFOE

Energy research and innovation
Report 2017

Strengthening the renewable energy sector, incentives to increase energy efficiency and phasing out of nuclear power: in the past year significant steps were taken to set a course toward a sustainable and secure energy supply for Switzerland. The much heralded systemic change in the energy system presents major challenges marked not only in terms of economic and technological developments but also in terms of political decisions at home and abroad. Greater decentralisation of the electricity supply will place higher demands than before on the flexibility of the electricity grid.

However, this change in the energy system consists of much more than just a list of problems and challenges: it also opens up enormous opportunities for economic development and innovation, lowers the degree of dependency on others and ultimately contributes to this country's prosperity. For this reason, since the "Energy Strategy 2050" was launched, vital research essential for innovation has been expanded in a targeted manner.

Research should in principle take place free of stipulations. Nevertheless, a certain degree of coordination and constancy can serve to retain the focus on the aims and needs of the public sector. Through its various organised research programmes the Swiss Federal Office of Energy has been playing a key role in this respect for the past 30 years.

The examples presented in this brochure are representative of numerous projects that the Swiss Federal Office of Energy supports and closely monitors.

Benoît Revaz
Director SFOE

Cover and figure left: Solar test facility of the ZHAW Wädenswil at Totalpsee in the Parsenn area close to Davos. Conventional monofacial as well as bifacial modules are installed on the system, the latter also using the radiation on the back of the module to generate electricity. The effect of the radiation reflection at the snow surface on the power production of the bifacial modules (albedo effect) is one of the questions that is addressed in this field experiment (source: ZHAW Wädenswil).

3 MW wind turbine in Haldenstein (GR)
(source: www.suisse-eole.ch)

Promotion of technology and innovation by the Swiss Federal Office of Energy

The first Swiss energy research conference was held under the aegis of the Swiss Federal Office of Energy in March 1988. The conference was organised as the result of a motion in the National Council in the wake of the Chernobyl reactor disaster calling for promotion of promising research projects in the field of energy supply and savings. Already, two years earlier, CORE, the extra-parliamentary federal energy research commission (Commission de la recherche énergétique), had been brought into existence. At regular intervals this commission draws up the Federal Government Energy Masterplan, thus setting the guidelines for targets and support measures. The Swiss Federal Office of Energy is a central hub in the Swiss energy research landscape owing to its promotional programmes and coordinating role.

The Swiss Federal Office of Energy funds and coordinates national energy research and supports the development of new markets in connection with a sustainable energy supply. To handle the task of coordination, funds are deployed in a targeted manner to further the development of innovative technologies and concepts aligned with specific research programmes. Funds deployed in a subsidiary manner aim to fill gaps in Switzerland's funding landscape (Figure 1). Grants are given to private entities, the domain of the Swiss Federal Institutes of Technology (ETH), universities of applied sciences, and universities. The Swiss Federal Office of Energy provides specialist advice to funded projects drawing on experts and representatives of other funding agencies on a case-by-case basis.

Expert knowledge from within the Swiss Federal Office of Energy is also applied to evaluating grant applications to other funding agencies. In addition, regular exchange of information between various national funding schemes is maintained and measures are supported which promote general knowledge transfer. Thus, the Swiss Federal Office of Energy is tightly integrated in the value chain and ensures steady growth of knowledge and its implementation in specific applications.

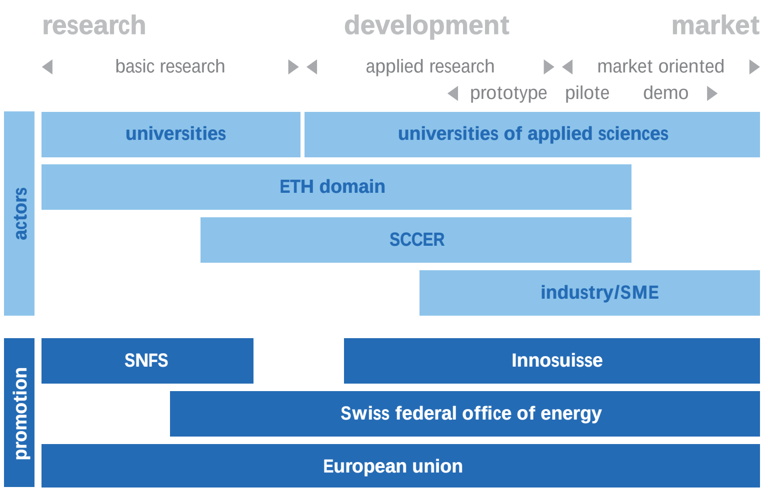


Figure 1: The Swiss Federal Office of Energy coordinates research and innovation in the energy sector along a large part of the value chain. (Innosuisse = Swiss Innovation Agency, formerly Commission for Technology and Innovation CTI; EU = European Union; SNF = Swiss National Science Foundation).

Swiss Federal Office of Energy research programmes

The main challenge for energy research is the interplay betweenlong term perspectives and visions and short-term, economic and political realities. Development of energy technologies is long-term in nature: new technological approaches and systems require long lead-in times. Long-standing research programmes coupled with support of pilot and demonstration projects aim to ensure a faster transfer of results to of market-ready technologies.

- Buildings and Cities
- Mobility
- Industrial Processes
- Grids
- Electricity Technologies
- Combustion Based Energy Systems
- Fuel cells
- Heat Pumps and Refrigeration
- Solar Heat and Heat Storage
- Photovoltaics
- Solar Energy at High Temperature (CSP)
- Hydrogen
- Bioenergy
- Hydropower
- Geoenergy
- Wind energy
- Dams
- Energy, economy, society
- Radioactive Waste

Sources and use of funds for Swiss energy research

Since 1977 the Swiss Federal Office of Energy has been compiling data on research and development projects as well as pilot and demonstration projects. Only projects are considered which – in whole or in part – are funded by the public (Confederation and cantons), the Swiss National Science Foundation (SNF), the Commission for Technology and Innovation (CTI) (as of 2018 Innosuisse), or by the European Commission (EU).

The survey of projects retrieves information from data bases maintained by the Confederation, the SNF and the EU, as well as by analyses annual reports, business reports, and summaries provided by research officers at research facilities. Information about individual research projects can be obtained from the publicly accessible system of the Confederation, ARAMIS (www.aramis.admin.ch), from the SNF (p3.snf.ch), the EU (cordis.europa.eu) and the websites of the various institutions.

Figure 2 shows the public expenditure for energy research in Switzerland since 1980 (in million Swiss Francs, adjusted for inflation) in the four main sectors according to the Swiss classification system. Swiss energy research has been expanded broadly in recent years in connection within the context of the Energy Strategy 2050 and the Swiss Coordinated Energy Research Action Plan. A major contribution has been made by: (1) the establishment of the Swiss Competence Centers for Energy Research (SCCERs) by CTI/Innosuisse in 2013 (figure 4), which entered the second phase of operation in 2017; (2) new National Research

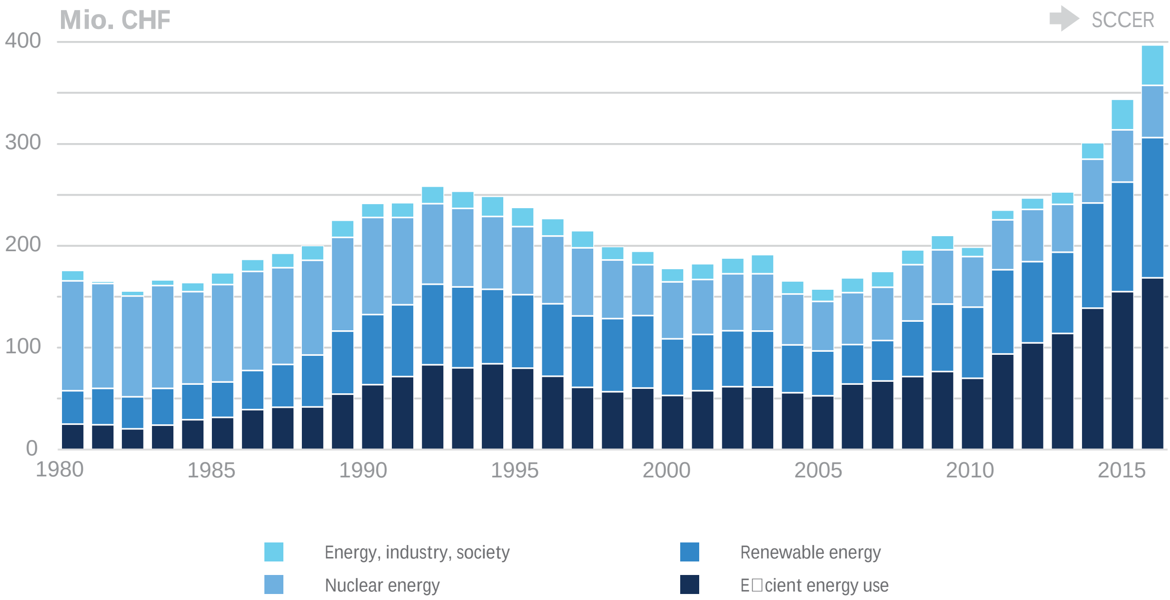


Figure 2: Long-term overview of public expenditure on energy research. Figures are shown as real data, i.e. after adjustment for inflation, and vary between 0.03 and 0.065 percent of GDP.

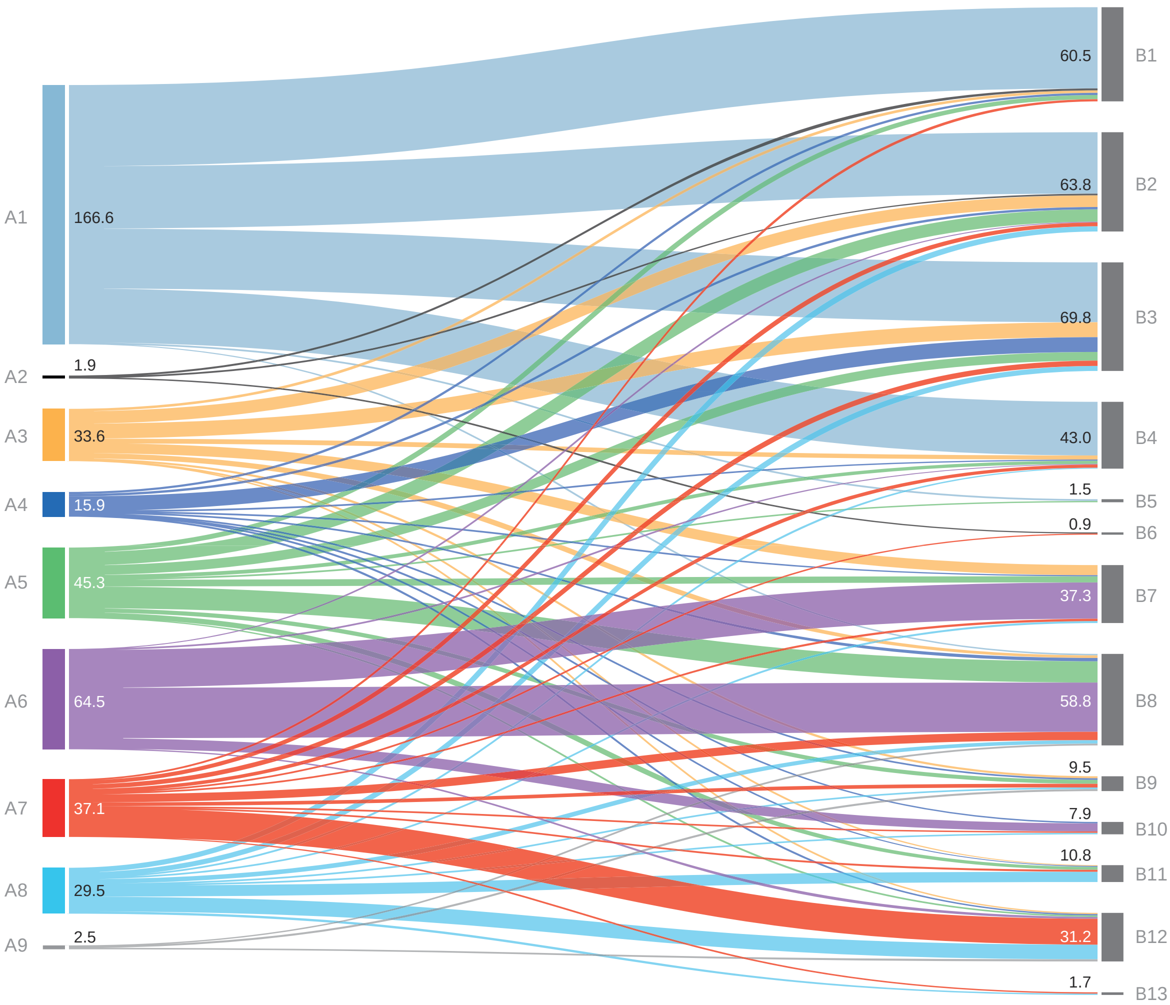
Programmes (NRP 70 and 71) in the energy sector under the direction of the Swiss National Science Foundation; (3) and targeted expansion of pilot and demonstration activities by the Swiss Federal Office of Energy. Within the ETH Board supplementary funds were available to expand infrastructure and enlarge capacity thus also contributing to growth in funds allotted to energy research. Some of the apparent increase owes to changes in data compilation, for example, by consistently taking the overhead into account; this led to an increase in the financial contributions from the ETH Domain and the universities.

As indicated in figure 3, a large proportion of the public funds invested in energy research (42 %) is a direct consequence of strategic objectives set by the ETH Board determining research priorities and funds for the Federal Institutes of Technology and the institutes in the ETH Domain. Guidelines are also set by the Energy Research Master Plan of the Federal Energy Research Commission (CORE), which contains a common vision for the Switzerland's research community and recommendations for energy research financed with public funds in Switzerland. Further substantial contributions toward energy research are made by the cantons (16 %) through financing of universities and universities of applied science.

A proportion (41 %) of funds provided by the Commission for Technology and Innovation (CTI, now Innosuisse), the Swiss National Science Foundation, the State Secretariat for Education, Research, and Innovation (SERI), the European Union (EU) and the SFOE is allocated competitively. Project funds from the EU and SERI mostly flow into European projects and SERI›s share will decline in future because Swiss partners in European projects have again been financed directly by the EU since 2017.

The Swiss Federal Office of Energy in particular encourages a relatively broad number of actors from the ETH Domain, universities, universities of applied science and from industry (figure 4). Thus the Office fulfils its coordinating role and makes substantial contributions towards implementing research results in innovations taken up by the market.

Stefan Oberholzer



Sources of funds:

A1	ETH domain
A2	Swiss Federal Nuclear Safety Inspectorate ENSI
A3	Swiss National Science Foundation SNSF
A4	European Union EU
A5	Commission for Technology and Innovation CTI
A6	Cantons
A7	Swiss Federal Office of Energy SFOE
A8	State Secretariat for Education, Research and Innovation SERI
A9	Others

Use of funds:

B1	Paul Scherrer Institute PSI
B2	ETH Zurich
B3	EPF Lausanne
B4	Empa
B5	Eawag/WSL
B6	International organisations
B7	Universities
B8	Universities of applied sciences
B9	Other federal organisations
B10	Other cantonal organisations
B11	Swiss Center for Electronics and Microtechnology CSEM
B12	Private sector
B13	Communities

Figure 3: Sources of public funds for energy research in Switzerland in 2016 and implementation of such in various institutions in the energy research sector. Private funds are not included (e.g., large in-kind contributions to CTI projects), and pilot and demonstration projects funded by the Swiss Federal Office of Energy). All figures in millions of Swiss Francs. (Empa: Swiss Federal Laboratories for Materials Science & Technology, Eawag: Swiss Federal Institute of Aquatic Science and Technology, WSL: Swiss Federal Institute for Forest, Snow and Landscape Research).

	2015	2016
1 Energy Efficiency	**94.4**	**101.8**
11 Industry	9.4	12.4
12 Residential and commercial buildings	33.7	33.9
13 Transport	40.1	39.9
14 Other energy efficiency	11.0	14.9
19 Unallocated energy efficiency	0.3	0.7
2 Fossil Fuels: Oil, Gas and Coal	**13.2**	**9.8**
21 Oil and gas	7.0	4.9
23 CO_2 capture and storage	6.2	4.9
3 Renewable Energy	**92.3**	**113.2**
31 Solar energy	45.9	53.5
311 Solar heating and cooling	5.0	4.0
312 Solar photovoltaics	32.2	37.2
313 Solar thermal power (CSP/STE)	6.4	9.8
319 Unallocated solar energy	2.2	2.4
32 Wind energy	1.9	2.8
34 Biofuels (incl. biogases)	17.7	20.8
35 Geothermal energy	14.1	20.4
36 Hydroelectricity	12.5	15.4
39 Unallocated renewable energy sources	0.2	0.3

	2015	2016
4 Nuclear Fission and Fusion	**51.2**	**51.3**
41 Nuclear fission	25.6	24.8
42 Nuclear fusion	24.3	25.4
49 Unallocated nuclear fission and fusion	1.2	1.2
5 Hydrogen and Fuel Cells	**27.9**	**29.3**
51 Hydrogen	11.3	17.4
52 Fuel cells	6.4	5.5
59 Unallocated hydrogen and fuel cells	10.2	6.3
6 Other Power and Storage Technologies	**39.6**	**56.4**
61 Electric power generation	7.6	6.9
62 Electricity transmission and distribution	23.3	38.2
63 Energy storage (non-transport)	8.7	11.4
631 Electrical storage	4.5	6.5
632 Thermal energy storage	2.3	3.0
639 Unallocated energy storage	1.9	1.9
7 Other Cross-Cutting Research	**26.5**	**35.1**
71 Energy system analysis	24.9	32.9
72 Basic energy research (not specified)	1.0	0.4
73 Other	0.6	1.8
Total	**345.1**	**396.9**

Public expenditure on applied energy research, including pilot, demonstration and lighthouse projects, in million Swiss francs in 2015 and 2016 (nominal amounts).

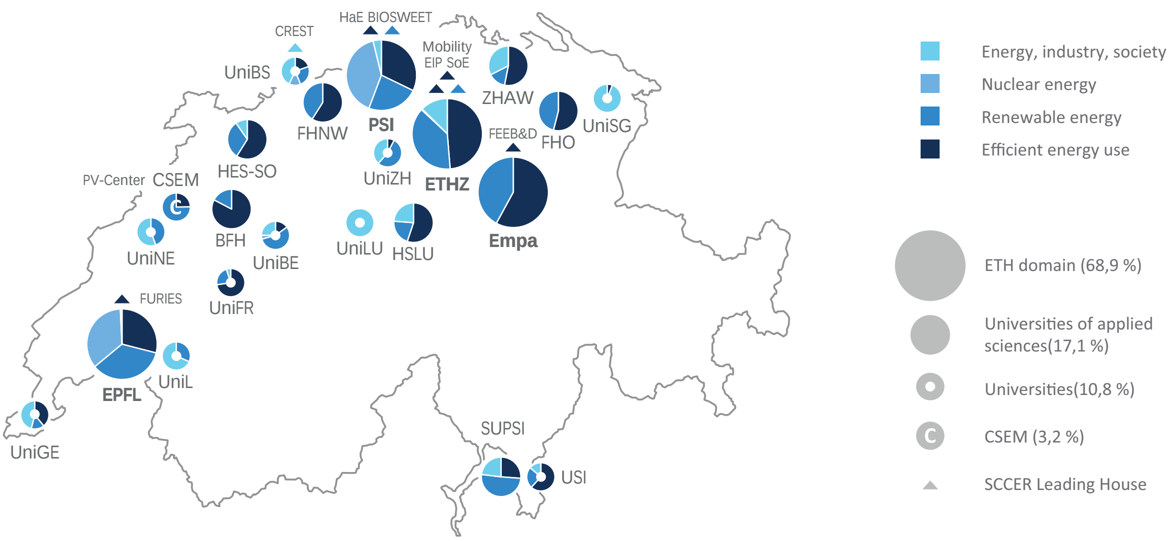
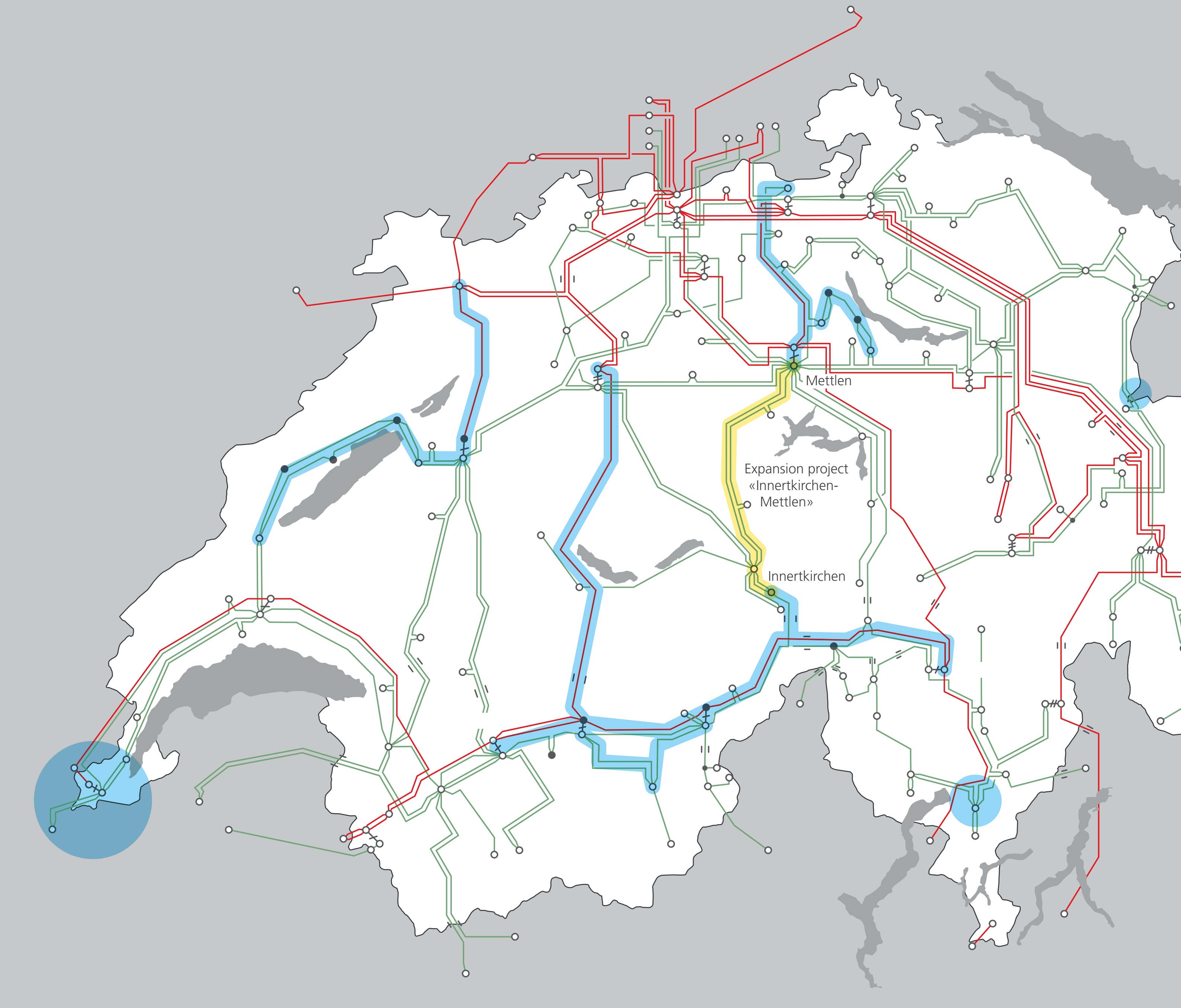
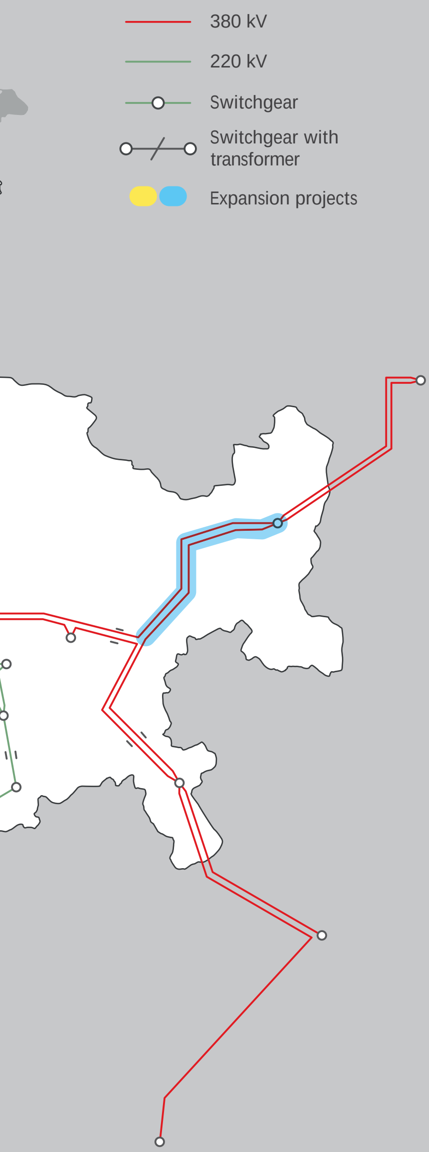


Figure 4: Energy research activities at universities in Switzerland (data 2016): ETH domain: ETH Zurich and EPF Lausanne, Empa, Paul Scherrer Institute PSI, Eawag and WSL. CSEM = Swiss Center for Electronics and Microtechnology, SCCER = Swiss Competence Centre in Energy Research.

Efficient energy use

Efficient energy use is a crucial factor for achieving the objectives specified in the Federal Council's "Energy Strategy 2050". Since 2013 research capacities in the areas of grids, buildings and industry, mobility and storage technologies are strengthened. In all these areas, potentials exist which to date are still a long way from being fully exploited. It is the task of energy research to identify these potentials and find technically feasible and economically viable solutions for exploiting them.





Geodata supports planning of electricity networks

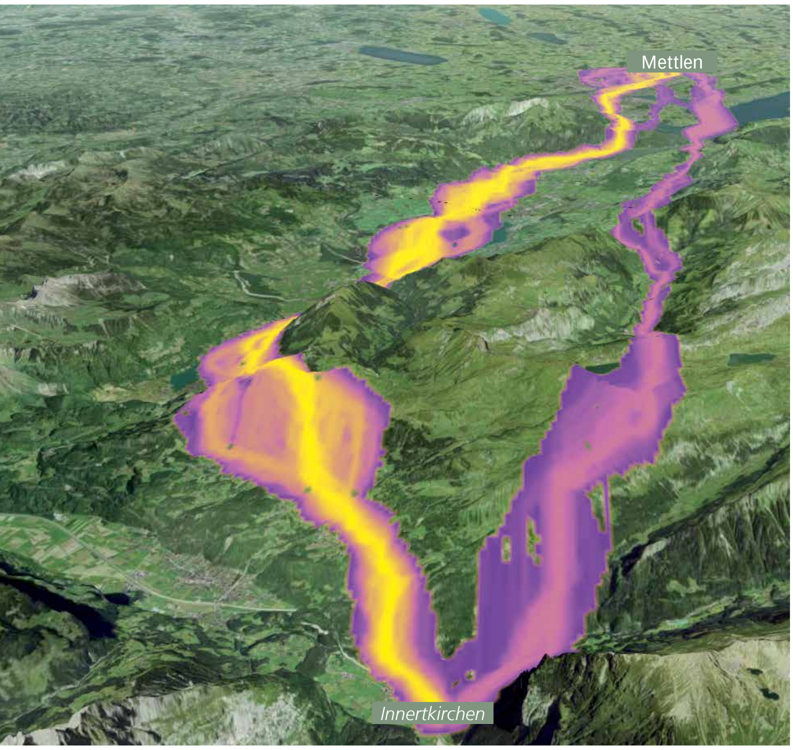
Construction of new overhead transmission lines requires balancing a number of interests. A research team at ETH Zurich has developed a software tool equipped with 3D visualisation that supports planners and simplifies communication about suitable routes for overhead lines.

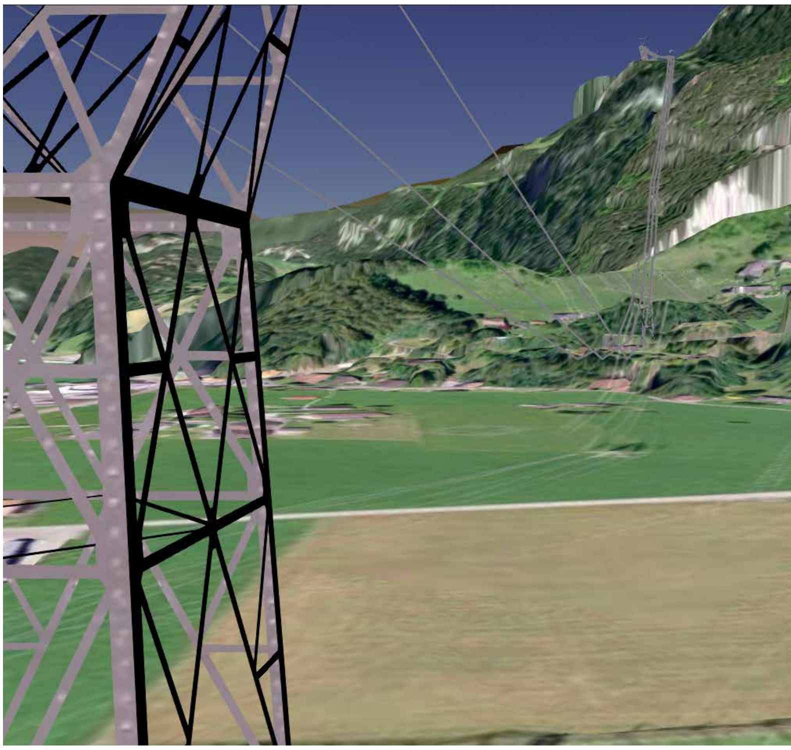
Today, Switzerland has an efficient high voltage grid. The grid is subject to a number of external factors which the national grid operator Swissgrid is unable to influence. This includes the Energy Strategy 2050 of the Confederation, the energy policies of Switzerland's European neighbours, power plant operations, trading with Europe and technological developments. Using a number of scenarios, nine grid expansion projects and four projects pertaining to legal matters were identified which together constitute "Strategic Grid 2025".

In future, Swissgrid will use a 3D decision support system for detailed design that was developed in a three-year research project by researchers at the Institute of Cartography and Geoinformation and the Institute for Spatial and Landscape Development at ETH Zurich. The planning tool uses data from geoinformation systems and derives suitable options regarding for spatial planning, corridors and routes for power lines. The objective is to route power lines through areas where people and the environment are least affected, and to improve communication among all stakeholders of a project.

Currently the planning tool takes 33 data categories into consideration from the three principal sectors; environment and landscape (moors, nature/bird conservation areas etc.), human habitation areas (residential and recreational areas, historic sites etc.), and technical feasibility (lakes, zones with natural hazards, terrain which is difficult to develop etc.). Data cate-

Strategic Grid 2025 as envisaged by Swissgrid network planning taking account of expansion plans. The grid will be expanded by 370 km in total and at the same time 270 km of grid will be dismantled (485 cabled kilometres) in distribution networks and 145 km (211 cabled kilometres) in the transmission grid, thus balancing out grid expansion and dismantling. The "Innertkirchen–Mettlen" expansion project served as a case study for the newly developed 3D decision support system (source: Swissgrid).





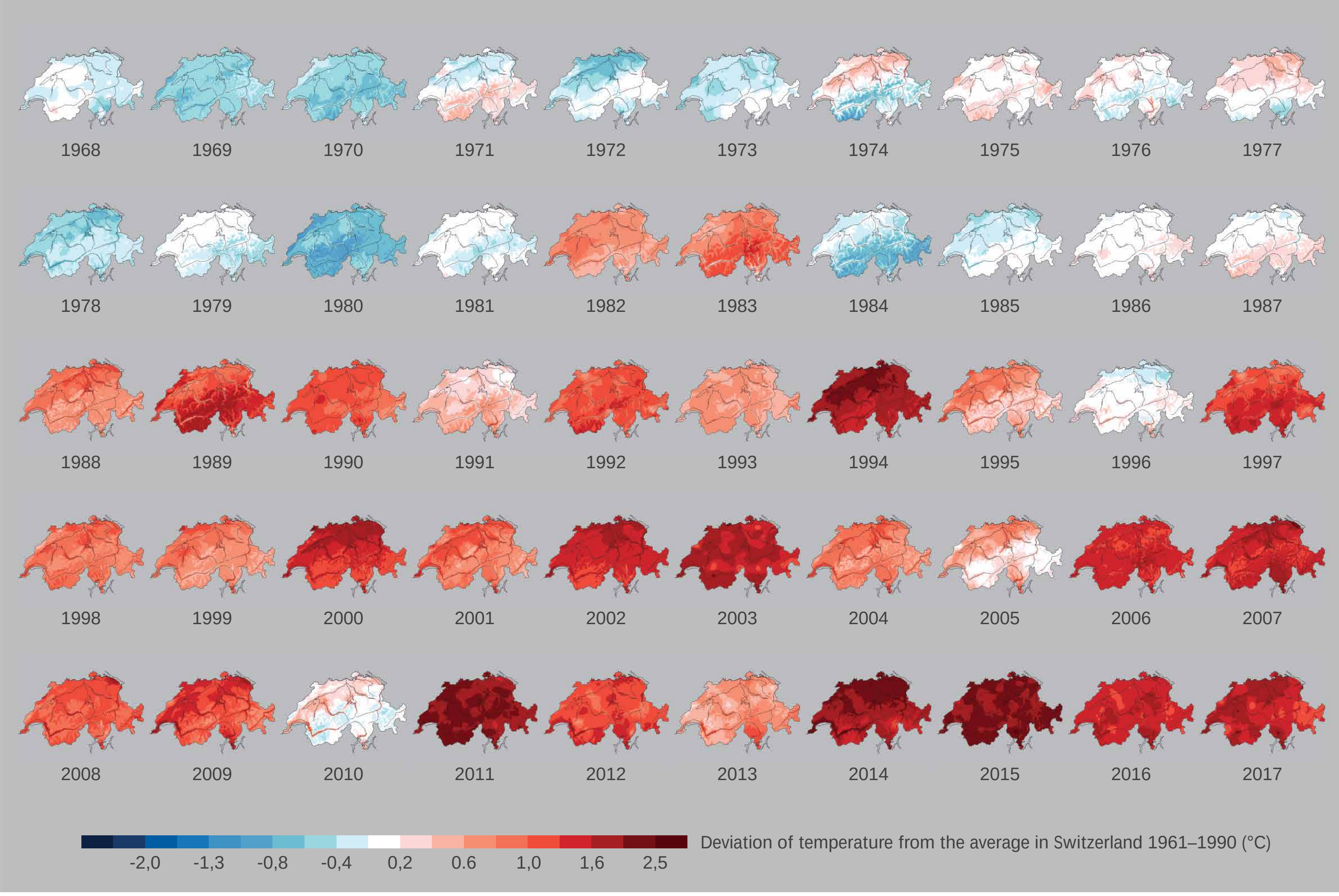
(Left) Visualisation of a potential planning area for the power line from Innertkirchen to Mettlen. The map shows the relative spatial costs for the construction of power lines considering the compilation of all categories of spatial resistance. The darker the shade of violet, the higher the spatial costs to cross the spaces. (Right) Visualization as a tool for decision making for the renewal or new construction of power lines (source: ETH Zurich).

gories can be adapted as needed for each project. The tool is conceived such that the user has to define in each case to what extent a data category constrains the construction of power lines.

As a result the software provides a three-dimensional visualisation of potential power line routes. Planners of the Austrian grid company APG, who also participated in the project, will use the results when determining the route of a 380-kV ring main in the State of Kärnten. Swissgrid will use the tool mainly as a communications instrument for use in discussion processes in which experts or interested parties explore possible routes for power lines within the framework of a sectoral plan procedure. Various routes for power lines can be displayed in real time.

Researchers at ETH intend to include the augmented or virtual reality approaches in a follow-up project. Interested parties could use these solutions in future to display potential routes in the landscape directly on a cell phone or tablet while standing at a specific location. The proposed options can then be evaluated and discussed by the different actors to arrive at a consensus. A new solution will also include an underground cable option. This is not included in the current tool because modelling of underground cable routes is much more complex than modelling overhead transmission lines. The ETH spin-off Gilytics GmbH, which was founded in Zurich in 2017, is currently commercialising and expanding the software tool for use in planning decentralised energy systems, such as wind turbine and solar plants, and for modelling the impact of such facilities on the landscape, economy and the environment.

Benedikt Vogel and Michael Moser



Deviation of temperature from the average in Switzerland 1961–1990 (source: MeteoSchweiz).

Climate change and need for cooling in buildings

The significant rise in temperature anticipated by the end of this century, will require less heating in winter but will increase the need for cooling in summer. The study "ClimaBau" at the University of Lucerne used specific examples of buildings to uncover the expected impact during the coming years, and what influence the type of building and behaviours of occupants will have on the temperature in buildings particularly in summer.

In the first phase hourly temperature data had to be prepared as the basis for the numerical simulations of the "ClimaBau" study. Sets of climate data from measurements for various locations in Switzerland were used and combined with projections from ten different climate models. In this study research was limited to residential buildings. In the simulation the Swiss housing stock was represented by four different types of residential building: two older buildings and two newly constructed buildings.

Change in the external temperature has a strong influence on the frequency of excess heating hours, that is, periods in which the room temperature exceeds 26.5 °C. Whereas only 27 hours were calculated in the average for "1995" from the standard period 1980–2009 at Basel, the number of hours increases to nearly 900 hours in the average calculated for "2060" for the period from 2045–2074. Taking into consideration the supplementary urban island effect in dense urban areas, the number of excess heating hours in "2060" increases to 1,200 and to even 1,400 hours at Lugano.

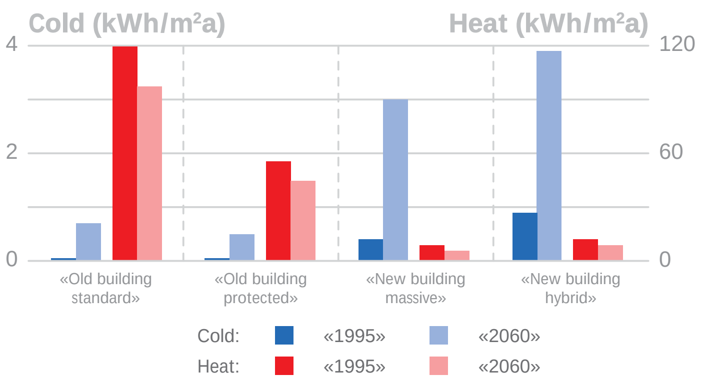
If the room temperature is to be kept at a normal level in summer using technical means, the energy requirement for air conditioning increases sharply depending on the circumstances to almost 50 % of the heating requirement. Correspondingly less heating will be required in winter. The average heating energy requirement for older buildings will be

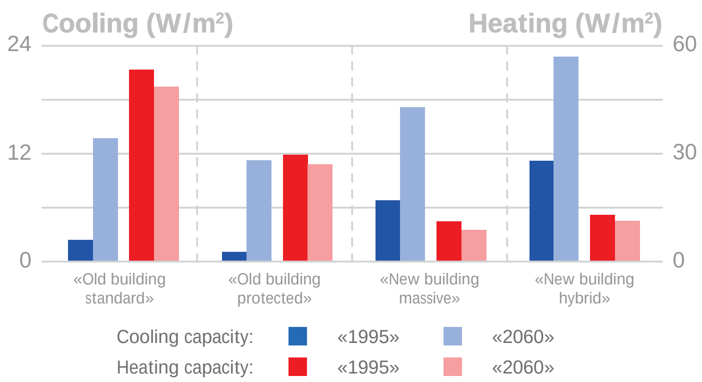
«Old building standard» (source: HSLU)

«New building massive» (source: Implenia Schweiz AG & BüroB, Bern)

«Old building protected» (source: HSLU)

«New building hybrid» (source: Renggli AG)





In a simulated case studies for four different types of building an estimate was made of the heating energy and capacity requirements as well as the cooling energy and capacity requirement to cope with future climate trends in Switzerland (data source: HSLU).

reduced during the period under consideration by 20 % and by 30 % in the case of new constructions.

In the second phase of the simulation the influence of individual characteristics of buildings was studied using a reference model. Perceptions of comfort (maximum temperature felt and the number of excess heating hours) in residential buildings depended substantially on the behaviours of residents. If sunblinds and shutters are not used efficiently and if the building does not cool down sufficiently during the night, then maximum room temperatures of over 40 °C and nearly 2,000 excess heating hours were calculated for "2060". At the same time comfort and the need for air conditioning depend substantially on the window area and the heat storage capacity of rooms. Where good conditions prevail along with optimal behaviours of residents, generally comfortable room temperatures can be ensured in the future.

To ensure that residential buildings can meet the major challenges posed by global warming they now need to be planned such that blinds and shutters can be operated simply and that buildings cool down efficiently at night. This implies a "reasonable" window area in proportion to the building in general. As an alternative depending on the expansion of renewable energies it will possible to cool buildings using photovoltaic electricity.

Rolf Moser

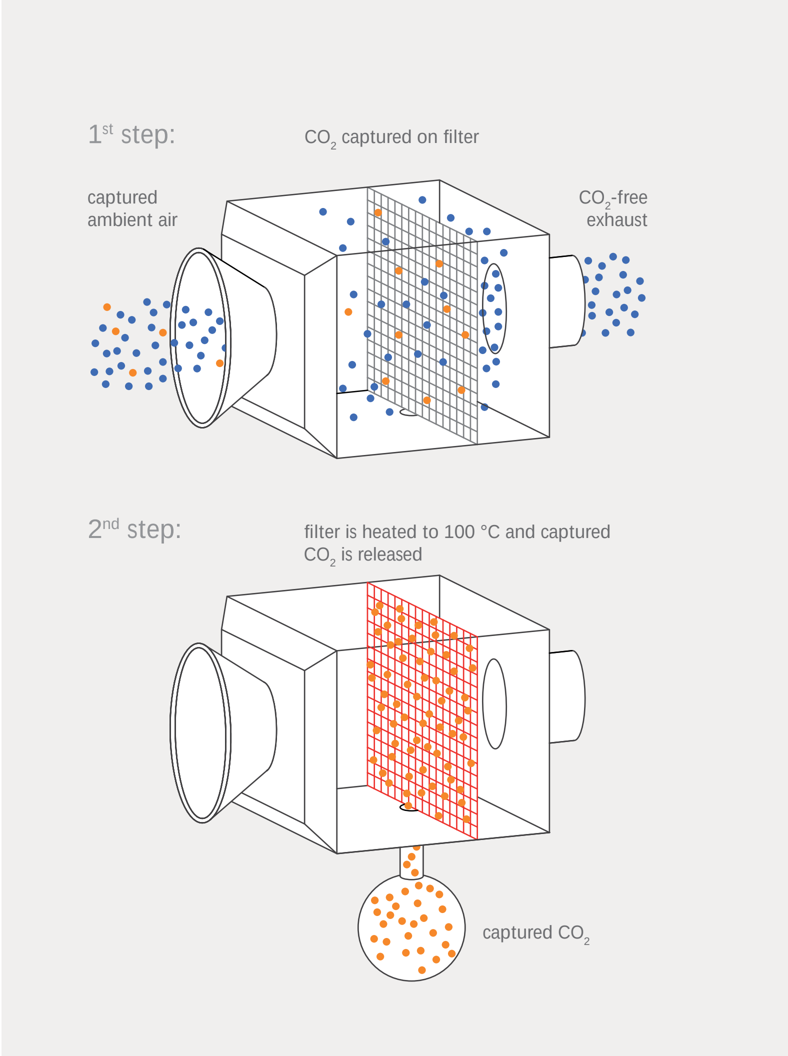
Installation to capture carbon dioxide from air with technology from the swiss company Climeworks AG (source: Climeworks AG).

Carbon dioxide from ambient air

In the transport sector – and in air transport in particular – there is little choice of an alternative energy supply. A potential solution are synthetic fuels, which would also permit long-term storage of renewable energies. Manufacture of synthetic hydrocarbons for use as fuels in aircraft or road vehicles encompasses a number of stages. First, sufficiently pure carbon dioxide (CO_2) has to be obtained to react with hydrogen to form hydrocarbon chains.

Currently, it is not possible to manufacture large quantities of synthetic fuels (hydrocarbons) in this particular way. However, pure CO_2 is used in a number of industrial applications, for example in the production of carbonated drinks, in welding and in food conservation. This CO_2 mainly originates from the production of ammonia and has to be transported by truck, ship or train to the place where it is to be used.

In recent years the Swiss company Climeworks AG has developed



Using its proprietary process, the Swiss company Climeworks can separate CO_2 from the atmosphere to a high degree of purity (up to > 99.9 %). A fan draws in surrounding air that is passed through a cellulose filter, which adsorbs CO_2. The filter saturated with CO_2 is subsequently heated to approximately 100 °C releasing the adsorbed CO_2 . In a pilot plant at Hinwil 18 collectors can separate up to 2.5 tonnes of CO_2 per day (image source: Climeworks AG).

an industrial scale plant for the precipitation of CO_2. This type of facility can be constructed adjacent to the consumer because the CO_2 is extracted from the surrounding air. In one demonstration project the CO_2 gained from the air is put to use in the greenhouses of a market garden. CO_2 extracted from the surrounding air is pumped into the greenhouses by Primatura AG, where it serves as a fertiliser. The location for the plant in Hinwil was specifically chosen because KEZO (Zweckverband Kehrichtverwertung Zürich Oberland), a large waste incineration plant, delivers the heat required for the separation process. During the process the absorption filter has to be heated to 100 °C to separate the adsorbed CO_2 from the membrane. After the concentrated CO_2 has been retrieved, the filter is regenerated and can be used in a subsequent process cycle.

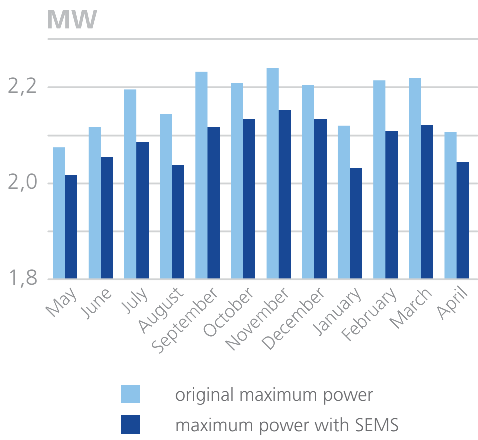
The plant is currently being optimised with a view to increasing its throughput. Developers are striving for separating 750 to 1,000 tonnes of CO_2 per year. For the process to be viable, the energy consumption has to be as low as possible. A target has been set of a consumption of less than 300 kWh of electricity and 2’200 kWh of low quality excess heat (heat that cannot be used industrially because of the low temperature). The technology currently serves in the first place as the starting point for returning CO_2 to the carbon cycle. Closure of the cycle – for example by manufacturing synthetic fuels – would facilitate a neutral CO_2 footprint overall. With storage of the captured CO_2 capture one enables a negative footprint, that is, a reduction of the CO_2 concentration of the atmosphere. At COP22 this procedure was recognised as being a promising way to attain climate goals.

Jean-Philippe Crettaz

Intelligent energy management in the factory

Industrial facilities are charged for electricity on the basis of the peak demand to ensure cost coverage of the supplementary infrastructure required. Usines Métallurgiques de Vallorbe decided to test a novel system to control plant facilities (mainly ovens and compressors) in a flexible manner. Owing to the smart energy management system (SEMS) developed by Stignergy, the quarter-hourly peak demand was reduced by three to six percent depending on the month. The reason for this relatively modest result lies in the stringent conditions initially laid down for operating the system so as not to impair production processes. Greater savings will be possible by gradually relaxing these conditions.

Jean-Philippe Crettaz



"Memory motor"

Conventional permanent magnet motors can usually only be used with a limited operational range. The range can be extended and the efficiency of such motors increased by magnetising and demagnetising permanent magnets dynamically with brief pulses of electricity. Based on this principle, Yverdon University of Applied Science has developed and tested a so-called «memory motor» based on a conventional stator. A conventional frequency converter adapted to work with the non-linear magnetisation cycle is used to control the motor. The higher energy efficiency of such memory motors compared to conventional synchronous motors could be demonstrated in the upper speed range in particular.

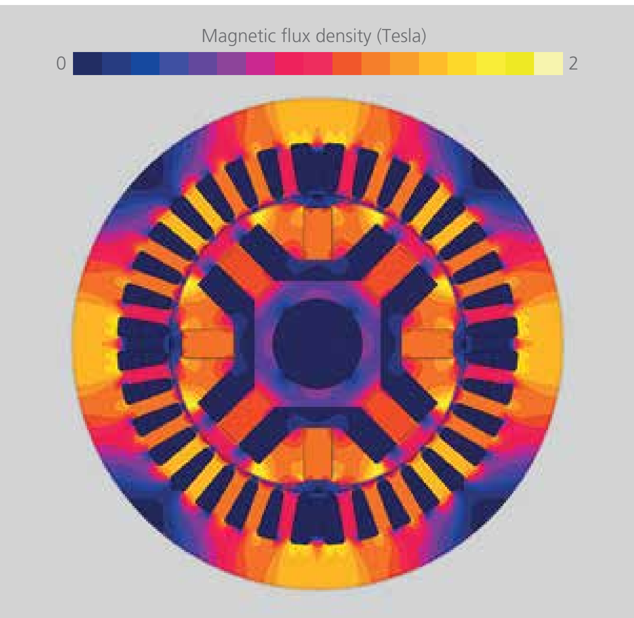
Roland Brüniger

"E-Dumper"

Huge quantities of materials have to be transported in the cement manufacturing process. Cement plants are often constructed at quarries to minimize the energy consumption of mining equipment. An electrically powered dumper truck manufactured in Switzerland by the «E-Dumper Consortium» uses the available energy potential more efficiently. The dumper recovers brake energy, which is generated when the loaded truck drives downhill. The main challenge in this project is the operation of a mobile 600-kWh battery, because the high current flow during charging and discharging requires a powerful cooling system to the service time of the battery.

Jean-Philippe Crettaz

(Left) Magnetic flux density in the rotor of a "Memory motor" (source: HEIG-VD). (Right) "E-Dumper": electrically driven 111 tonne dumper truck with a 600-kWh battery to transport 60 tonnes of lime and marl (source: Kuhn Switzerland AG).



Renewable energy

The proportion of renewable energy in the overall energy supply is constantly increasing throughout the world. Especially in the electricity sector annual percentage increase in the recent past are often in the double-digit range for technologies like wind power and photovoltaics. The use of other technologies such as hydropower, biomass and geothermal energy is also on the rise, with hundreds of gigawatts of additional capacity being installed throughout the world. In the area of renewable energy, the SFOE promotes research and development activities relating to technologies that can be directly applied in order to maintain a sustainable energy supply in Switzerland, as well as in other fields that have the potential to create industrial value-added in the country.

Solar process heat in Switzerland

About half of the final energy consumption in Switzerland is used for heating. An idea being discussed increasingly is to generate this heat with renewable sources of electricity, by means of heat pumps or even with simple resistance heaters. This implies sector coupling and electrification of the heating sector. However, it is also worthwhile checking where direct heat supply fromsolar-thermal collectors would be a more efficient way to reduce the use of fossil fuels.

In Switzerland 19 % of the overall energy consumption is in industry with about half that energy being used for process heat. This process heat, currently mostly created by combustion of oil and gas, can in parts be gained from solar thermal collectors. In Switzerland, too, this is an area of application which offers great potential for the reduction of CO_2 emissions.

According to the EU Solar Payback study, there are now more than 500 plants worldwide for the supply of solar process heat for industrial purposes with a total capacity of 280 MWth (400,000 m² of collector area). The efficiency of such solar-thermal process heating plants largely depends on the energy requirements of the selected processes, what temperatures are required and, above all, on the solar irradiance at the actual location. The most suitable industrial processes for this type of heating technology are preheating of raw materials, pasteurisation, sterilisation and washing, drying, preheating of boiler feed water, supplying hot water or steam, and heating of industrial and commercial facilities. High potential for use of solar process heating is seen in the food and beverage industries (including the tobacco industry), the textile and leather branches, and in paper and pharmaceuticals. Conventional solar-thermal collectors, which are well known from the building sector where they are used for water heating and complementary heating, easily cover the temperature range up to about 100 °C. Concentrating collectors can be deployed in situations where the temperature range lies between 100 °C and 250 °C.

A number of Swiss companies have installed in recent years solar process

Solar process heating plant at Emmi AG in Saignelégier (JU) with parabolic trough collectors made by NEP Solar AG (source: SPF/NEP Solar).

	Emmi	Cremo	Lesa	Colas	Zehnder	HUG
place	Saignelégier (JU)	Fribourg (FR)	Bever (GR)	Yverdon (VD)	Gränichen (AG)	Genf (GE)
altitude (m)	992	703	1710	438	420	381
coordinates (CH1903)	567 246, 234 605	576 015, 183 151	787 952, 158 421	539 278, 179 204	650 557, 244 957	500 325, 116 436
industrial sector	milk processing	milk processing	milk processing	road construction	radiator anufacturer	hospital
use	production	production	production	bitumen, building	varnishing	sterilisation
temperature (°C)	117	120/160	190	90/160	90/110	110/180
type of collector	parabolic trough	parabolic trough	parabolic trough collector	vacuum flat plate	vacuum tube	vacuum tube
heat transfer fluids	water-glycol	water	thermal oil	thermal oil	water	thermal oil
size (m²)	627	581	115	360	184	462

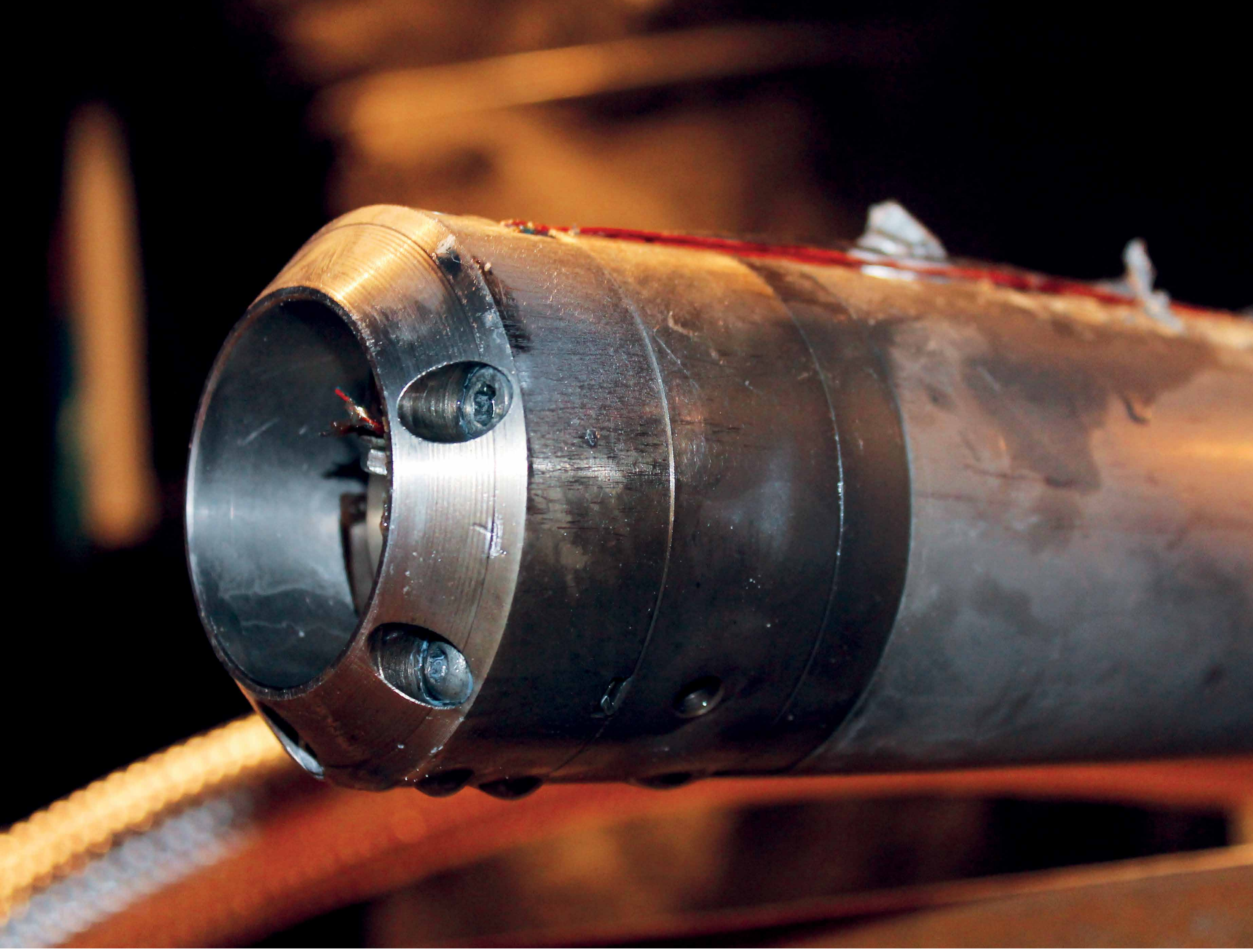
		Emmi	Cremo	Lesa	Colas	Zehnder	HUG
2013	solar irradiance (kWh/m²)	-	-	1162 (DNI)	-	-	-
	yield (kWh/m²/a)	-	-	353	-	-	-
	efficiency (%)	-	-	30	-	-	-
2014	solar irradiance (kWh/m²)	945 (DNI)	928 (DNI)	833 (DNI)	-	-	-
	yield (kWh/m²/a)	344	340	195	-	-	-
	efficiency (%)	36	37	23	-	-	-
2015	solar irradiance (kWh/m²)	1138 (DNI)	976 (DNI)	-	747 (GHI)	876 (GHI)	-
	yield (kWh/m²/a)	418	380	-	92	340	-
	efficiency (%)	37	39	-	12	39	-
2016	solar irradiance (kWh/m²)	928 (DNI)	843 (DNI)	-	1198 (GHI)	-	-
	yield (kWh/m²/a)	297	336	-	83	-	-
	efficiency (%)	32	40	-	7	41	-

Overview of solar process heating plant in Switzerland, which have been constructed in recent years and been the subject of intense evaluation. The lower bar illustrates the cost distribution for the realisation of the plant, broken down according to planning, adaptation of the roof, solar collectors, system integration and miscellaneous costs. Important for concentrating collectors is the proportion of the overall solar irradiance (GHI = global horizontal irradiance) coming directly from the sun (DNI = direct normal irradiance) (data source: SPF).

heating systems to supply heat for various industrial processes (see table). As part of a multi-annual evaluation study "EvaSP", these facilities were monitored by the SPF Institute for Solar Technology, a section of the HSR University of Applied Sciences Rapperswil. The objective of the study was to improve the understanding not just of collector facilities as such but of the overall system integration and the control system. The findings to date indicate that in general solar heating systems achieve good thermal outputs. For example, at the Emmi plant in Saignelégier parabolic trough concentrators deliver heat at 117 °C and contribute an average of 12 % (220 MWh per year) to the overall heating requirements of the plant with just solar energy.

The high capacity of solar process heating plant has been demonstrated in many cases: they can deliver high temperatures and supply clean, CO_2 neutral heat. However, before the technology can really spread and become more widely used there are a number of challenges to be met. System integration is generally technically complex and plants are not economically viable without subsidies. It is for these reasons that researchers and developers convinced of the potential of solar heat, concentrate on developing solutions that increase system efficiency and lower costs. The focus lies principally on improving collectors, plant design and on development of a simple, standardised system of integration.

Mercedes Hannelore Rittmann-Frank, Marco Caflisch und Andreas Häberle



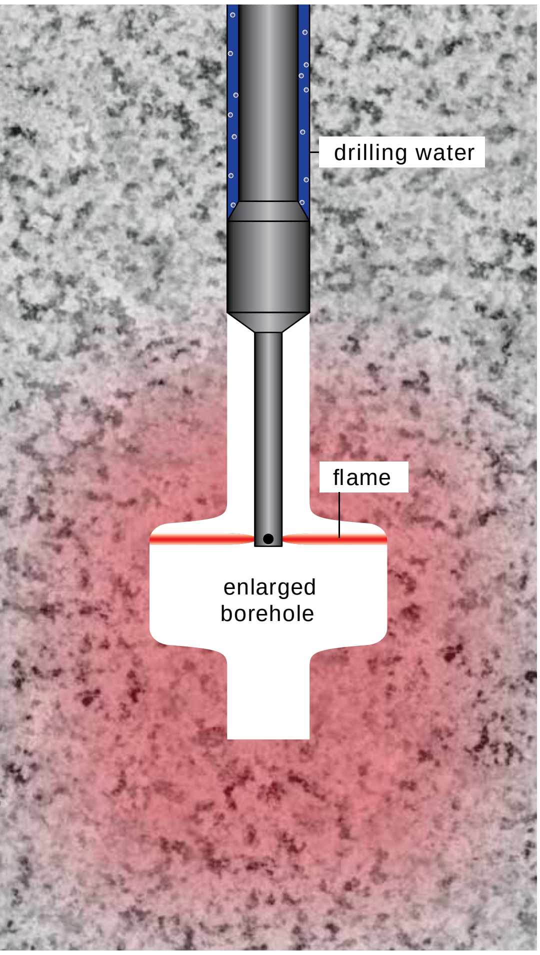
Wellhead for hydrothermal spallation drilling (source: ETH Zurich).

"Drilling with flames"

Deep geothermal technology is used to bring heat to the surface from depths of 3,000–6,000 m to supply climate-neutral, sustainable energy to the population. Geothermal power plants are not subject to changes in the weather nor daily or seasonable fluctuations in temperature, and thus represent an unrestricted alternative source to power plant which use non-renewable energy sources.

To effectively extract this energy from the Earth even where the rock is impermeable, a network of cracks and fissures has to be created using hydraulic stimulation – and all deep below the surface of the ground. This process in which water is injected into the well at high pressure is key for a working geothermal energy plant. Researchers at ETH Zurich have developed a new procedure to increase the efficiency of the stimulation process and thus contribute to realising the enormous potential of deep geothermal energy systems.

Researchers use a flame jet to create high thermal stress in the rock which is relieved when the rock splits. The "Thermal Spallation Drilling" procedure is used to enlarge the diameter of an existing borehole at specific well locations below ground. By enlarging the welllbore at select-



ed points, the position and direction of fractures created during a subsequent stimulation can be more exactly controlled. The procedure enables the creation of a larger fracture network at the ideal location and the entire stimulation process becomes more efficient, cheaper and safer.

The feasibility of this new technology was demonstrated at the Grimsel Test Site near the Grimsel Pass, an underground research laboratory of NAGRA, the National Co-operative for the Disposal of Radioactive Waste. A specially designed 50-m long prototype was developed in just three months that produced flames with a temperature of 1,500 °C and could efficiently drill hard rock surrounding the undergroundlaboratory. The deployed prototype successfully enlarged the diameter of an existing water-filled borehole to more than double its initial diameter at a depth of 15 m at various positions; thus multiplying the interface area available of wellbore andsurrounding rock. After this successful demonstration of the feasibility of the technology, researchers now aim to deploy the technology in well at intermediate depths thus further pushing ahead with the geothermal revolution.

Michael Kant, Edoardo Rossi und Philipp Rudolf von Rohr

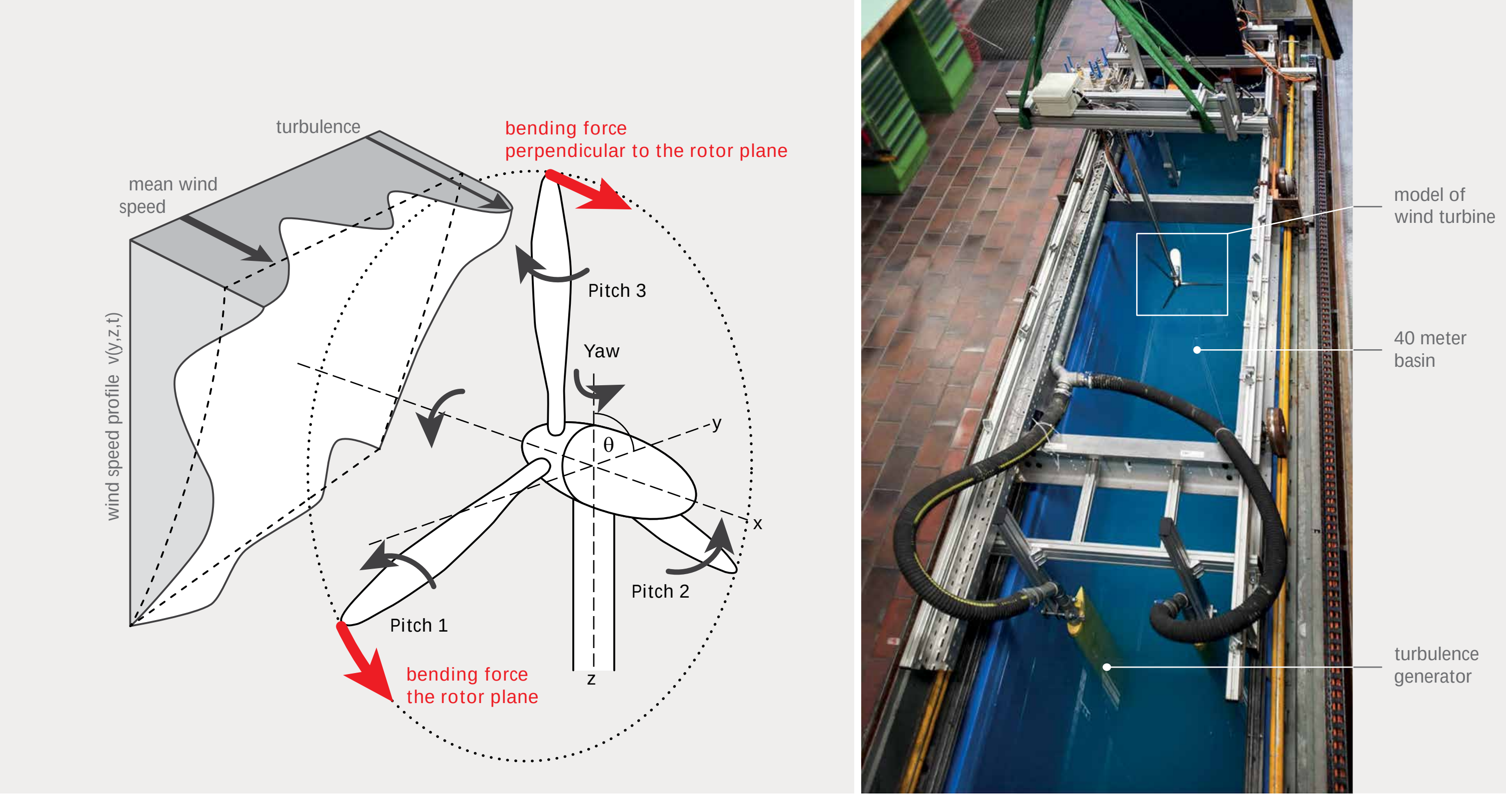
(Above) Testing the Thermal Spallation Drilling procedure in NAGRA's underground laboratory at the Grimsel Pass (source: ETH Zurich). (Left) In this drilling procedure the rock around the existing borehole is heated with a flame and the diameter is enlarged by creating thermal cracks.

Wind turbine model to study individual pitch control of the rotor (source: ETH Zurich).

Smart rotor control for wind turbines

Electricity production from wind energy is an integral component of the energy strategy and will be expanded to supply of about 4.3 TWh per year by 2050. This would mean that – along with photovoltaics – wind energy would be a major contributor to expansion of the “new renewables”. In 2016 Switzerland had 37 large wind energy plants (oder turbines) in operation, contributing a modest 0.2 % to overall electricity production (in comparison to the neighbouring countries Austria [7.5 %] and Germany [12.9 %]). In addition to the question of social acceptance and protracted permitting procedures, Switzerland’s complex topography and various technical challenges also have to be overcome when building multi-megawatt plants.

The rotor of a wind turbine plant is made to rotate due to lifting forces of wind impinging on the rotor blades. The total output power is proportional to the cube of the wind speed. So as not to exceed the nominal output of the generator, the power uptake of the rotor is restricted by altering the pitch of the rotor blades once a specific speed has been attained: by reducing the angle of attack of the rotor blades to the wind the lift created by the wind is reduced as is the power output. Actively adapting the rotor blades’ angle of attack is also done when the plant operates at partial output to achieve the maximum possible aerodynamic efficiency.



(Left) Inhomogeneities in the wind's velocity field lead to heavy loads on the rotor blades in large wind plant. Using IPC to steer the angle of attack of individual blades leads to a reduction in the loads on the rotor blades. (Right) At ETH Zurich elaborate experimental tests were conducted on this topic, in which the findings from simulations of IPC control algorithms could be validated experimentally (image source: ETH Zurich).

This poses challenges to the design considering the trend to construct ever-larger turbines. The larger the diameter of the rotor, the stronger the inhomogeneities in the wind's velocity field, which in turn leads to heavy mechanical loads on the rotor blades. Such inhomogeneities may include lower wind speeds close to the ground, the wake effect from neighbouring wind turbine plants or turbulence resulting from topographical features, such as Switzerland's foothills. Typically, the horizontal axis of the rotor is slightly tilted to increase the distance between the blades and the tower, leading to asymmetrical loads on the rotor blades.

Such fatigue inducing loads can be reduced to a minimum by not only adjusting the angle of attack of all the rotor blades but also that for single blades using individual pitch control. This should lead to an increased lifetime and lower maintenance costs for plant. The algorithms required for individual pitch control (IPC) are mainly formulated on the basis of simulations.

The Laboratory for Energy Conversion at ETH Zurich investigates experimentally the value of IPC. In a sophisticated study a unique scaled model of a modern, variable-speed, multi-megawatt turbine with individual pitch control was developed and tested in the wind-turbine test facility of the ETH laboratory. The test facility consists of a 40-m long water tank. The model turbine is pulled through the water on a skid thus simulating the air flow through the wind turbine. Using water as a test medium results in better approximation of the flow effect (Reynolds number) on a real turbine when compared to experimental models with air as the medium. More turbulence can be generated in the water in front of the model turbine to simulate a turbulent wind velocity field impinging on the rotor.

In initial tests it could be demonstrated that depending on the heading angle (yaw) individual sinusoidal pitch control (first order harmonic pitch), firmly coupled with phase θ of rotor rotation, can result in a power increase of 10–16 % in a turbine.

The literature contains reports of simulations of IPC algorithms with higher harmonic compensation. The aim here is to harness new measurement technology, such as LIDAR (light detection and ranging), to determine real-time inhomogeneities in the wind's velocity field to be able to control wind turbines dynamically. Experimental studies like those conducted at ETH Zurich are able to make a significant contribution in the field. In current studies the impact of increased turbulence on the load is being further quantified.

Stefan Oberholzer

Energetic potential of farmyard manure

Farmyard manure (slurry and dung from various domestic animals) has been little used as a substrate in biogas production because of its poor fermentation properties. By improving the fermentation process a significant increase in the gas yield from this raw material will be achieved to enable commercially viable operations of biogas plants running on farmyard manure. In this process slurry is treated with aerobic micro-organisms during the anaerobic fermentation stage. Polymers in the slurry are broken down to form water-soluble intermediate products that are simultaneously turned into methane and carbon dioxide by the microbial biogas assembly.

Sandra Hermle

Pilot reactor for aerobic microbial treatment of biomass which tends to ferment poorly (source: BFH).

New drivetrain concept for wind turbines

The average number of interruptions at a wind turbine plant is 0.13 per year. About 30 % of operating costs are allotted to maintenance and repair. Based on these findings, Swiss company GDC, the University of Applied Science of North-West Switzerland, and Brusa Elektronik AG have developed a new modular drive system. This concept employs an innovative distribution gearbox and a number of smaller generators instead of single one. These generators can be switched on and off independently depending on the wind strength thus increasing generator efficiency when operating at partial load. The advantage of this type of turbine lies primarily in the simplified maintenance and repair regime.

GDC Urs Giger GmbH

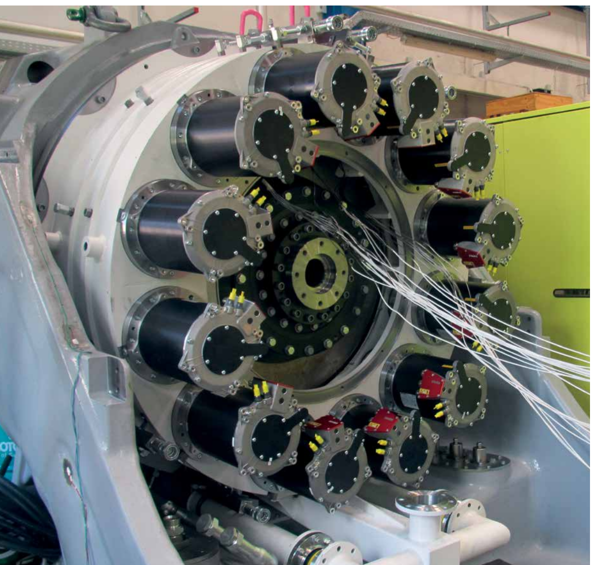
Simplified production of high efficient solar cells

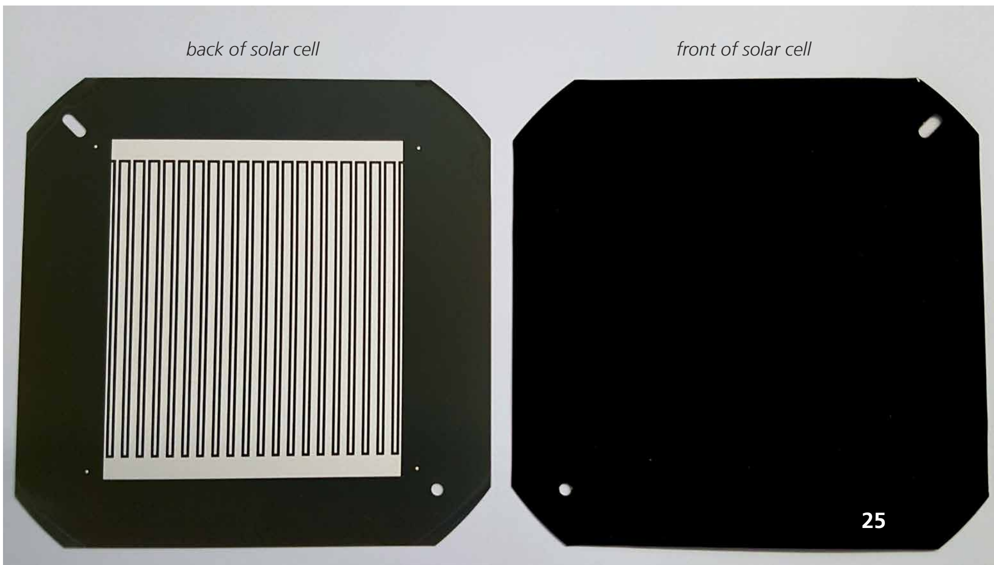
In 2017 a lot of interest was aroused by a new manufacturing method for highly efficient crystalline silicon solar cells presented by a research team from the EPFL and CSEM in Neuchâtel. To further increase the efficiency of such cells, all the electrical contacts are positioned on the rear of the cell to eliminate entirely any shade on the front face of the cell. Production of these cells is usually more demanding because the positive and negative electrical contacts have to be positioned exactly next to each other, involving various lithographical steps in the process. The innovation in this approach from the Neuchâtel company lies in the fact that the positive contacts and the negative contacts are self-selecting. Using this greatly simplified manufacturing procedure, the cells attained a degree of efficiency of 23 % at the first attempt. The researchers work closely with the Swiss company Meyer-Burger, a leading PV equipment supplier.

(see A. Tomasi et al. Nature Energy, 2017).

Stefan Oberholzer

(Left) Innovative drivetrain concept for wind energy turbines (source: GDC). (Right) All the electrical contacts are positioned at the back of these high efficient crystalline silicon solar cells so the face is entirely free of contacts and shadowing (source: CSEM).





Socioeconomic aspects

The Energy Economy Society (EES) cross-sectional programme focuses on economic, social, psychological and political issues throughout the energy sector supply chain. The research programme serves to develop new energy political instruments and to monitor existing instruments. In 2017 a broad range of research projects was sponsored covering such diverse topics as the behaviour of energy consumers, investment in renewable energies, the design of the energy market, and mobility.

How to reduce capital risks for renewable energy projects?

Implementation of Energy Strategy 2050 is contingent on the gradual reorganisation of the Swiss energy system. A substantial pillar of the strategy is expansion in the renewable energy field. Adequate provision of capital to finance renewable energy projects is crucial to successful implementation of the energy strategy.

A recently published study[1] at the University of St Gallen (HSG) addresses the question how financing renewable energy projects can be eased, and how the targets of the energy strategy can be attained at lower costs to society. Thanks to increasingly cheaper technologies (in the photovoltaic and wind sectors) the economic viability of such renewable energy projects is now more determined by the soft costs. Two important elements of soft costs were the focus of the HSG study: the premium for political risks and the capital costs.

With regard to the political risk component the project concentrated on wind energy. The aim was to identify, categorise and quantify the various components of an adequate risk premium to make investment in energy projects economically feasible. The second component of soft costs, the capital costs, was studied in two respects: first the Swiss investors' decision process was analysed when evaluating domestic againstenergy projects abroad – the thought being that a reduction in the capital drain to countries abroad could improve the availability of capital for Switzerland's renewable energy projects. Second, the risk-return preferences of existing and new investors in renewable energies were studied to find out whether and under what circumstance the inclusion of institutional investors could lower the cost of financing domestic products.

The findings showed that typical complications in the planning and approval process can increase the cost of the average wind project project by between 13 % and 49 %. A further challenge results from the combination of protracted permitting procedures and the planned expiry of the current (feed-in tariff) promotion

[1] R. Wüstenhagen, Y. Blondiau, A. Ebers Broughel, S. Salm: «Lowering the financing cost of Swiss renewable energy infrastructure: Reducing the policy risk premium and attracting new investor types», SFOE Final Report 2017 (www.aramis.admin.ch/Texte/?ProjectID=36929)

Fall protection while installing solar panels (source: ABS Safety GmbH)

The Swiss Center for Electronics and Microtechnology CSEM is testing the system «Skycam» based on cheap 360°-industrial cameras, that allows to recognize clouds in the sky and their movements via smart software algorithms. Thus, the solar radiation can be determined directly locally and by tracking the current cloud movement, the change in solar radiation can be precisely predicted in the short term (source: CSEM).

system in 2022 as foreseen in Energy Strategy 2050. This could endanger the realisation of numerous investments in wind energy.

As to the decision whether to invest in domestic or foreign projects, it was seen that 70 % of the capital provided by Swiss investors to energy projects flows abroad. However, an ex-post analysis of 20 case studies of Swiss investments in wind energy and in gas power plant projects (2004–2015) suggests, that the profitability of projects realised abroad is not systematically higher than that from those investments made in Switzerland.

One approach to reducing the capital costs could be cooperation between the energy suppliers (ES) and institutional investors. A survey of investors from both sectors revealed that there are specific risks which lead to excessive capital costs for both types of investor. If they are fully exposed to the risks of the price of electricity, both ES and pension funds demand a risk premium of between 5.98 percent and 7.94 %.

The findings of the study indicate that lowering the political risks along with a degree of hedging against fluctuating electricity prices could lead to more capital being provided to finance renewable energy projects in Switzerland.

Anne-Kathrin Faust

Multi-family house concept "swisswoodhouse" as wood hybrid with a large degree of prefabrication (source: Renggli AG, Sursee)

International collaboration

Switzerland attaches a great deal of importance to international cooperation in the field of energy research. At the institutional level, the SFOE coordinates its research programmes with international activities in order to utilise synergies and avoid unnecessary duplication. Cooperation and knowledge exchange with the International Energy Agency (IEA) are of particular importance: via the SFOE, Switzerland is involved in a variety of IEA "Technology Collaboration Programmes" (formerly known as "Implementing Agreements", cf. www.iea.org/tcp).

At the European level, wherever possible Switzerland actively participates in the research programmes of the European Union. Here, at the institutional level the SFOE coordinates energy research with the European Strategy Plan for Energy Technology (SET Plan), the European Research Area Networks (ERA-NET), European technology platforms, joint technology initiatives, etc. And, in some specific areas (e.g. smart grids, geothermal energy), Switzerland is involved in intensive multilateral cooperation with a variety of selected countries.

Impressum

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The "Mont Crosin" wind farm is the largest wind farm in Switzerland (Quelle: Loïc Schlüchter, © Suisse Eole, www.suisse-eole.ch).

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