

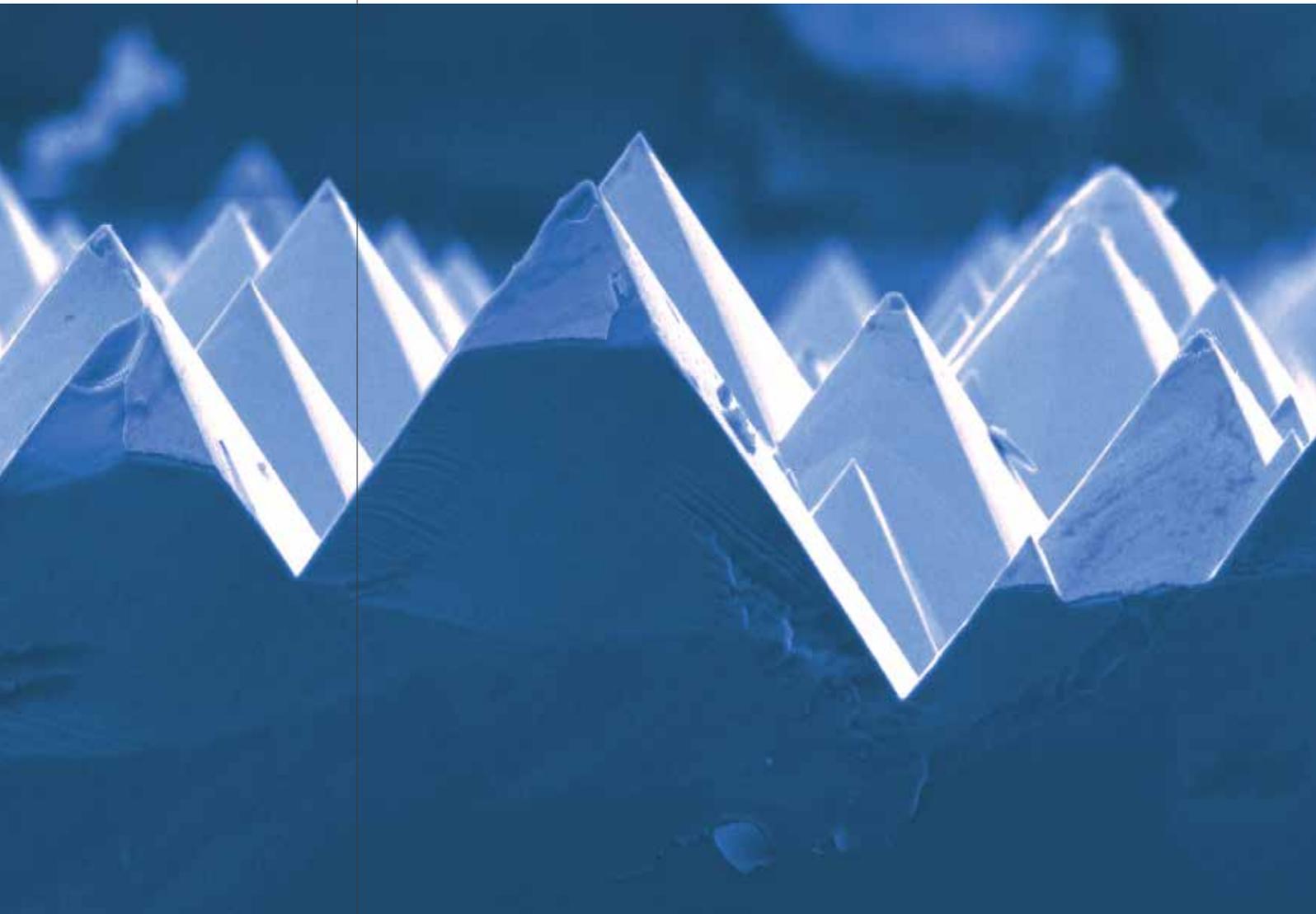


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**Swiss Federal Office of Energy SFOE**

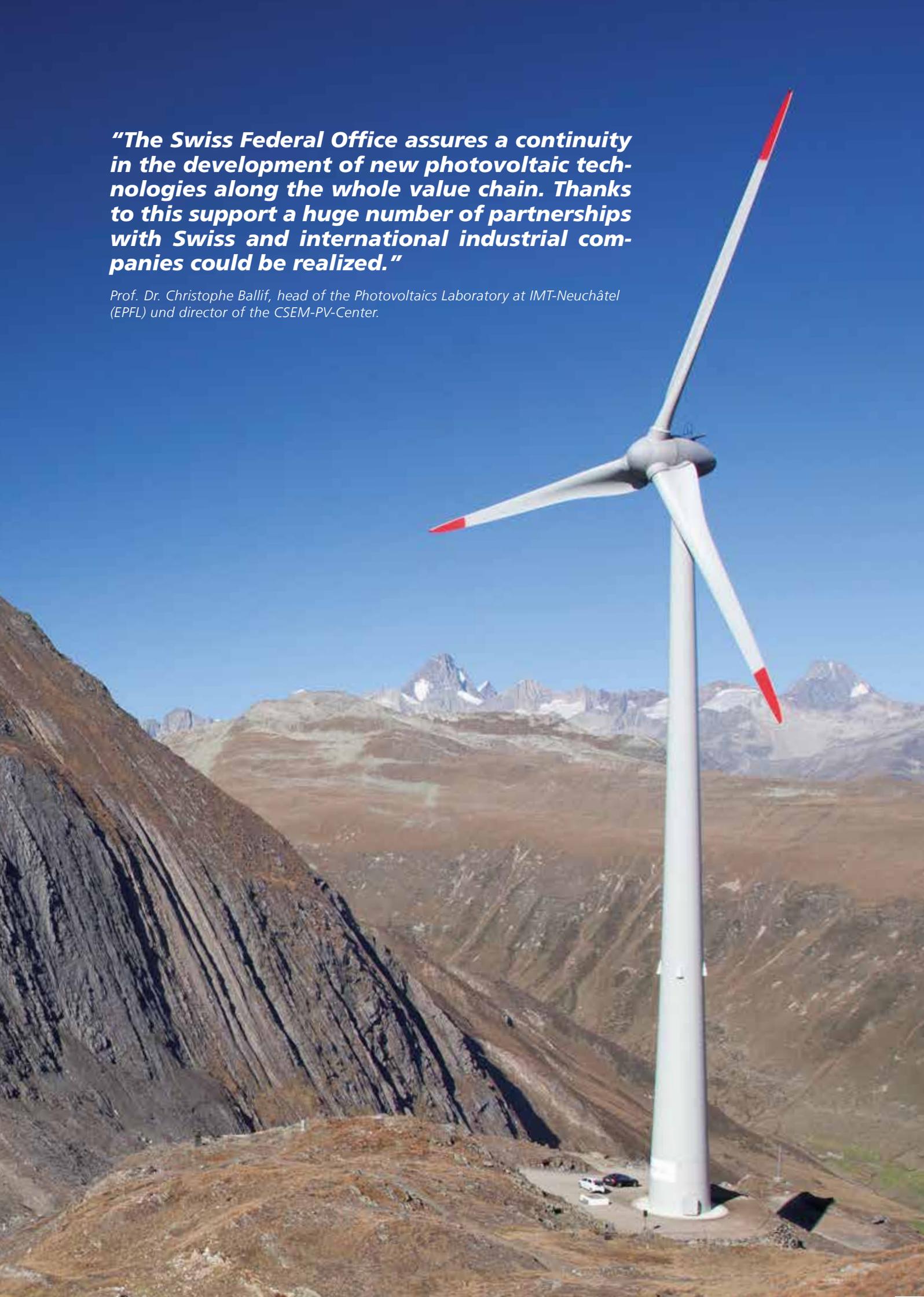
# **Energy research and innovation**

## Report 2013



***“The Swiss Federal Office assures a continuity in the development of new photovoltaic technologies along the whole value chain. Thanks to this support a huge number of partnerships with Swiss and international industrial companies could be realized.”***

*Prof. Dr. Christophe Ballif, head of the Photovoltaics Laboratory at IMT-Neuchâtel (EPFL) und director of the CSEM-PV-Center.*



## EDITORIAL

With its new energy strategy ("Energy Strategy 2050"), the federal government wants to create the requisite framework for a safe, economical and ecological energy supply. To this end energy efficiency is to be promoted and the use of renewable energy is to be stepped up. High quality and innovative energy research is one of the key factors for achieving these objectives.

The development of new energy technologies often requires lengthy periods of time, and in some cases it can take decades before a new product is finally brought onto the market. In Switzerland, the Swiss Federal Office of Energy (SFOE) has a major role to play by facilitating the development of expertise in various areas of energy technology and coordinating a wide variety of partners in more than twenty energy research programmes supporting research, pilot, demonstration and flagship projects.

This brochure presents a selection of projects and areas of research that have been supported by the SFOE and which yielded particularly noteworthy results in the course of 2013.



*Dr. Walter Steinmann*  
*Director*

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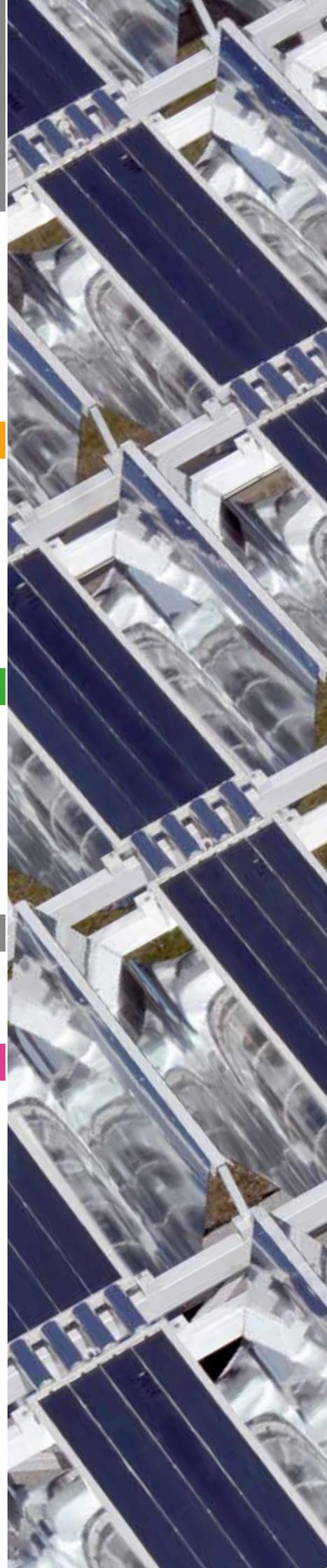
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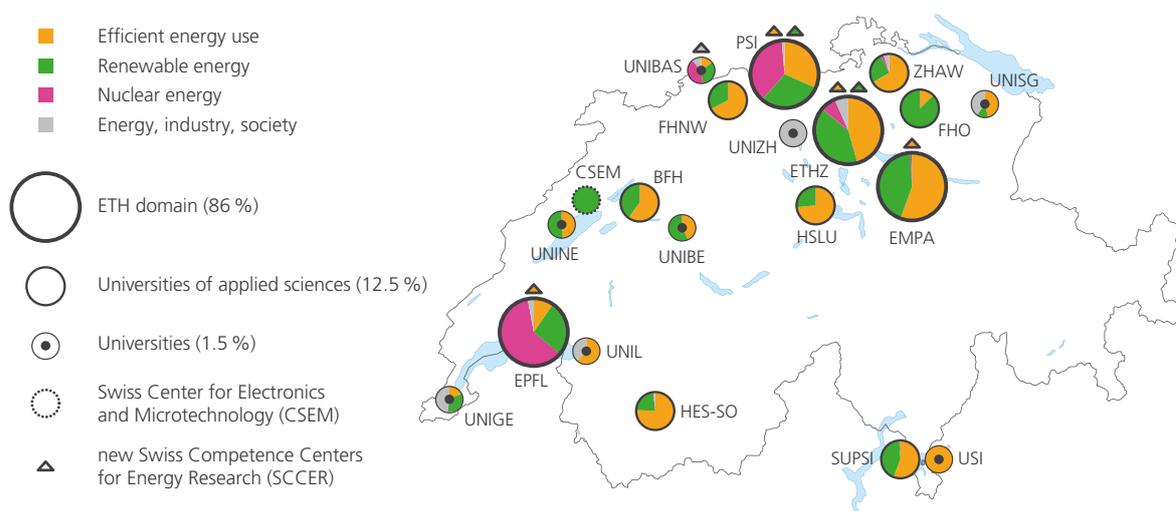


## ENERGY RESEARCH IN SWITZERLAND

Innovation is a significant factor in the competitiveness of a country's economy. The fact that Switzerland is able to hold its own with the best in the world is clearly underscored by its excellent international rankings. The 2013 edition of the "Innovation Union Scoreboard", for example, places Switzerland at the top of the table of the most innovative nations in Europe, and Switzerland is also regularly placed at the top of the "Global Innovation Index". The key factor for innovation is research, which gives rise to new discoveries and ideas that ultimately lead to the development of innovative and competitive products.

In order for Switzerland to maintain its leading position, it has to constantly review its performance in the field of research, as well as identify any existing gaps and, where necessary, increase its research capacities. Following the decision by the Federal Council and Parliament to phase out nuclear energy, this is particularly applicable in the field of energy research. In the wake of the major nuclear incident that occurred in Fuku-

shima, the Federal Council analysed Switzerland's research landscape and subsequently requested the creation of a coordinated action plan for energy research. During the 2013–2016 legislative period, Switzerland's research capacities are to be significantly increased within the framework of seven new competence centres and at the two Federal Institutes of Technology. Around 12 million Swiss francs a year are available for fostering the implementation of promising research concepts for competitive and innovative products and services. Funding at the disposal of the Swiss Federal Office of Energy for pilot and demonstration projects is to be increased from 5 million Swiss francs a year to 30 million. In addition, new national research programmes focusing on energy have been introduced for which financing to the tune of 45 million Swiss francs over five years has been approved. Public funding for energy research steadily declined from the early 1990s until 2006, when it began to pick up again, as it is expected to continue to do so in the next few years. (smr)



**Expenditure on research in the areas of efficient energy use, renewable energy, nuclear energy, and energy, the economy and society at various Swiss universities (figures for 2011). The involved sections of the Federal Institutes of Technology in Zurich and Lausanne, plus EMPA (Swiss Federal Laboratories for Materials Science and Technology), the Paul Scherrer Institute, Eawag AG and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), account for the highest proportion by far of energy research activities (86 percent), followed by colleges of technology (12.5 percent) and cantonal universities (1.5 percent).**



## EFFICIENT ENERGY USE

*Efficient energy use is a crucial factor for achieving the objectives specified in the Federal Council's "Energy Strategy 2050". Both the Federal Council and Parliament recognise this. Therefore, in the next four years, the sum of 72 million Swiss francs is to be spent on creating seven new Swiss competence centres, four of which will specialise in efficient energy use. This*

*will greatly increase the research capacities in the areas of grids, buildings and industry, mobility and storage technologies. 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. (smr)*





## No need to worry about flat batteries

Alongside the many advantages of battery-powered vehicles – including high efficiency of the drive train, no local emissions, existing infrastructure for power supply, etc. – lengthy charging times and a limited range due to the low energy density of batteries represent major challenges for this form of mobility. Here, the use of small auxiliary generators (or range extenders, as they are often called), which charge the battery in the vehicle, is one potential remedy. For such concepts a variety of technical solutions exist based on diesel, petrol and rotary piston engines or on micro gas turbines. The use of fuel cells, which convert hydrogen as the energy carrier into direct current for charging the battery, are a promising alternative. This concept is currently being developed in an ongoing Swiss project with the aim of doubling the range of small electric vehicles through the use of a compact fuel cell system.

**D**The need to reduce greenhouse gas emissions associated with individual mobility represents a major challenge. By electrifying the drive train it is possible to integrate renewable energy sources and thus bring about a diversification of primary energy carriers. For energy storage either batteries or fuel cells running on hydrogen may be used. Fuel cells convert chemically stored energy (hydrogen) directly into electricity, with the advantage that the energy (hydrogen storage) and output (size of fuel cells) can be scaled independently of one another. On the other hand, for the use of fuel cells it is necessary to provide hydrogen as the energy carrier, and this calls for additional infrastructure.

Whereas small electric vehicles exclusively intended for urban mobility can be operated satisfactorily

using batteries only, the situation becomes more challenging for larger vehicles and longer travel distances. Thanks to the combination of a largish fuel cell system (60 to 100 kW) and a battery with a relatively low capacity it is also possible for larger electric-powered cars to perform similarly to conventional motor vehicles in terms of speed and range. For medium distances, hybridisation using a largish battery in combination with a smaller fuel cell may function as a range extender. If the necessary supply of electricity and hydrogen can be reliably secured, such concepts have a great deal of potential for contributing towards a reduction of greenhouse gas emissions in the area of individual mobility. (*obs*)

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*Integrating a combined fuel cell and hydrogen system into a small vehicle is a major challenge from both a mechanical and an electrical point of view.*

*During the course of 2013, the Swiss company "Belenos Clean Power" decided to develop a hydrogen/air fuel cell for the automotive drive train and to keep the highly efficient hydrogen/oxygen technology for stationary applications. In less than half a year, the hydrogen/air fuel cell system was designed, assembled and successfully tested, mainly using automotive components and controls. Two months later, the same 10 kW fuel cell system was fully integrated into a series-produced Fiat 500 converted to electric drive. This plugin-hybrid hydrogen-battery vehicle achieved a record range of over 400 km and was tested for a further 33,000 km, demonstrating the fuel cell's viability. The filling station installed at the Belenos research site delivered all the hydrogen necessary for the drive tests. The vehicle integration and the road testing were funded*

*in part by the Swiss Federal Office of Energy. In addition, the fuel cell system development with the integration of a high-speed compressor was funded by the Commission for Technology and Innovation for collaborations with the Swiss Federal Institute of Technology in Lausanne and the University of Applied Sciences of the State of Vaud. The next step is to identify and bring together partners interested in commercializing the fuel cell for medium volume niche applications.*

*Due to the progress realized in the domain of battery technology and the strong potential synergies with the Swatch Group companies, Belenos decided to focus on the development of novel lithium batteries to satisfy the current demand for such devices.*



*In order to reduce the level of primary energy consumption in an existing building, it is essential to improve the thermal properties of the building shell.*

## Inspiration for renovation of buildings

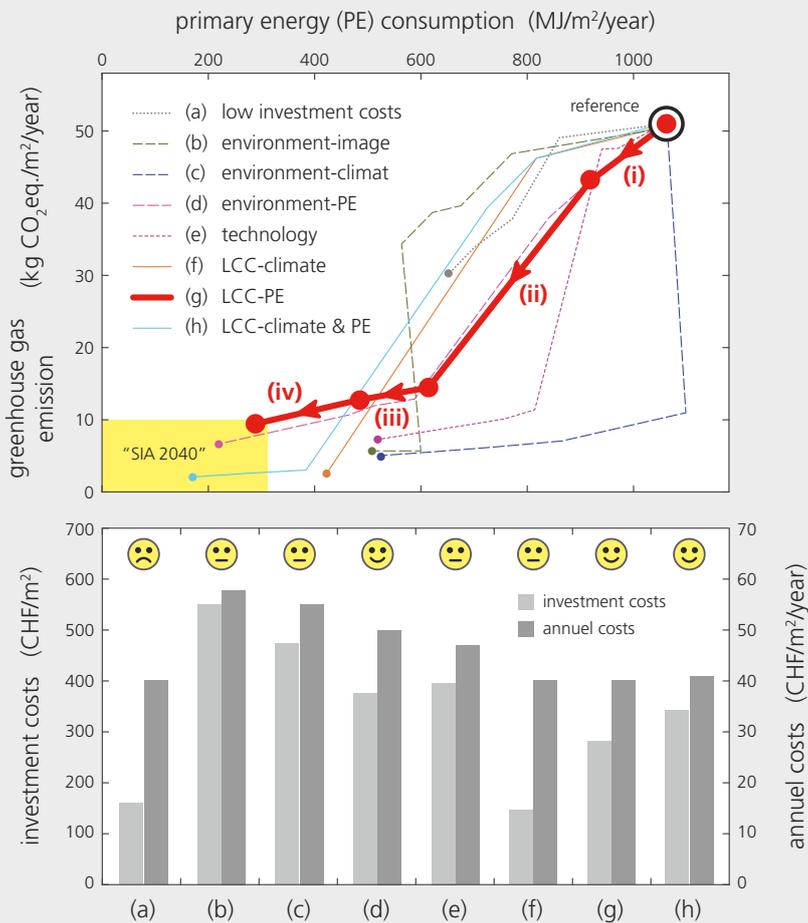
**Enhancing energy efficiency in buildings is one of Switzerland's declared political objectives. Since around two-thirds of the country's population live in apartment buildings, cost-effective renovation strategies for this category of building are of particular importance. Such strategies have been developed in a project called "INSPIRE" (which stands for integrated strategies and policy instruments for retrofitting buildings).**

**F**or the existing building stock in Switzerland, in order to bring about the greatest possible reduction in energy consumption and CO<sub>2</sub> emissions, it is essential to be able to identify and evaluate cost-optimised retrofitting strategies. For this purpose, a type of apartment house that is representative for Switzerland was studied within the scope of the "INSPIRE" project. Thanks to the development of a special software tool with the same name, it is possible to calculate energy, ecological and economic indicators, as well as to define greenhouse gas reduction and primary energy efficiency strategies. This project was implemented in cooperation with various European partners and was

supported by the European Commission and leading players in the field of sustainable construction in Switzerland.

The main focus of the studies was on apartment buildings of various ages. In view of the particular relevance of fossil-fuelled heating systems in existing buildings, a system of this type was taken as a reference building. Alternative heating systems were taken into account within the framework of the retrofitting strategies. A group of specialists from the real estate industry and the public sector defined four retrofitting strategies that reflect the various types of owners and their individual preferences: an investment-averse, an ecologically-

oriented and a technology-oriented strategy, plus a strategy with a focus on optimised lifecycle costs. Within these four strategy types, eight specific retrofitting sub-strategies were defined and the reductions in primary energy consumption and greenhouse gas emissions were estimated on the basis of the respective retrofitting measures. Each strategy comprises a variety of separate steps, for example (i) renovation of the facade, (ii) replacement of the oil heating system with a connection to a district heating network, (iii) use of highly efficient household appliances and efficient lighting, and (iv) installation of a solar thermal and/or photovoltaic system (cf. graph).



Through retrofitting measures it is possible to reduce a building's primary energy consumption and greenhouse gas emissions and thereby take it a step closer to meeting the specifications of "SIA 2040". The associated investment and annual costs vary considerably (smiley = achievement of "SIA 2040" target).

With all the strategies depicted in the graph – (a) to (h) – it is possible to achieve a significant reduction in greenhouse gas emissions, but only three of them are able to meet the requirements specified by the "SIA 2040" standard of the Swiss Society of Engineers and Architects (SIA). However, the investment and annual costs associated with these three strategies vary considerably. It is interesting to note that the investment costs associated with those strategies focusing on an optimisation of lifecycles – (g) and (h) – are relatively moderate. Strategy (f) is also noteworthy in that its low investment and annual costs come very close to the target range.

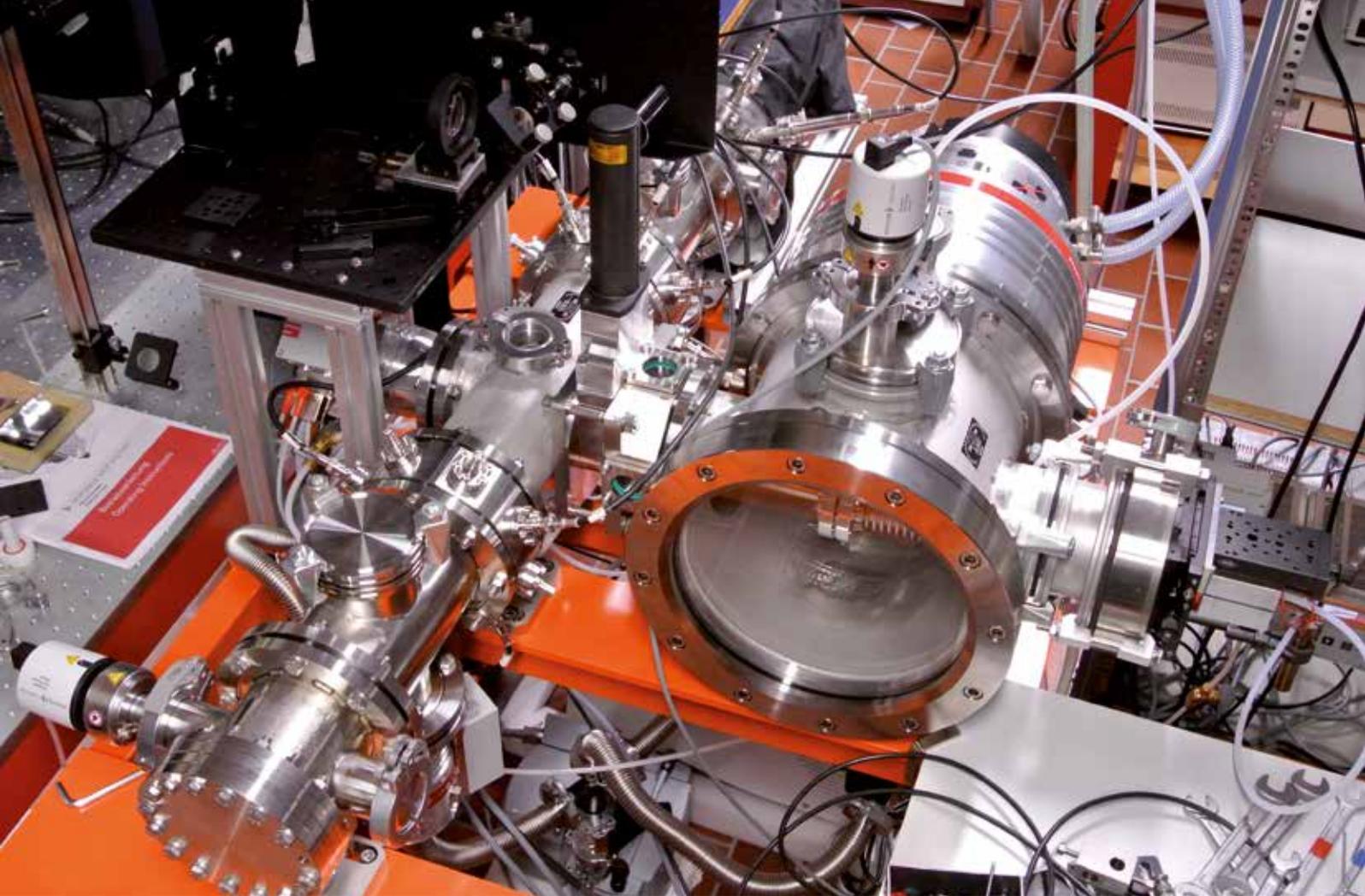
The studies revealed that the owners or managers of existing apartment buildings can adopt a broad range of retrofitting strategies in

order to achieve relatively ambitious reductions in primary energy consumption and greenhouse gas emissions. Generally speaking, it is possible to achieve notable results at an acceptable cost by implementing just a small number of measures. While it is possible to meet the CO<sub>2</sub> targets with most of the strategies, the primary energy objectives nonetheless represent a genuine challenge.

With respect to individual measures, a variety of recommendations of a general nature were formulated. For example, the use of efficient lighting and household appliances is almost always effective and in most cases is also financially beneficial. If a building is heated with oil or gas, improvements to the thermal properties of the shell (heat insulation, new windows) are

especially effective. In a comparison of various heating systems it was found that both heat pumps and the use of district heat result in a sharp reduction in greenhouse gas emissions and primary energy consumption. By contrast, while a wood-fired heating system is able to reduce CO<sub>2</sub> emissions, it cannot reduce primary energy consumption. The use of photovoltaics for the production of electricity in the building is certainly recommendable, whereas solar thermal systems only appear to be useful in buildings in which neither the use of a heat pump nor connection to a district heating network is possible. (eca)

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[www.energieschweiz.ch/inspire-tool](http://www.energieschweiz.ch/inspire-tool)



*Experimental set-up for photoelectron spectroscopy at the Paul Scherrer Institute laser laboratory.*

## On the trail of combustion-relevant molecules

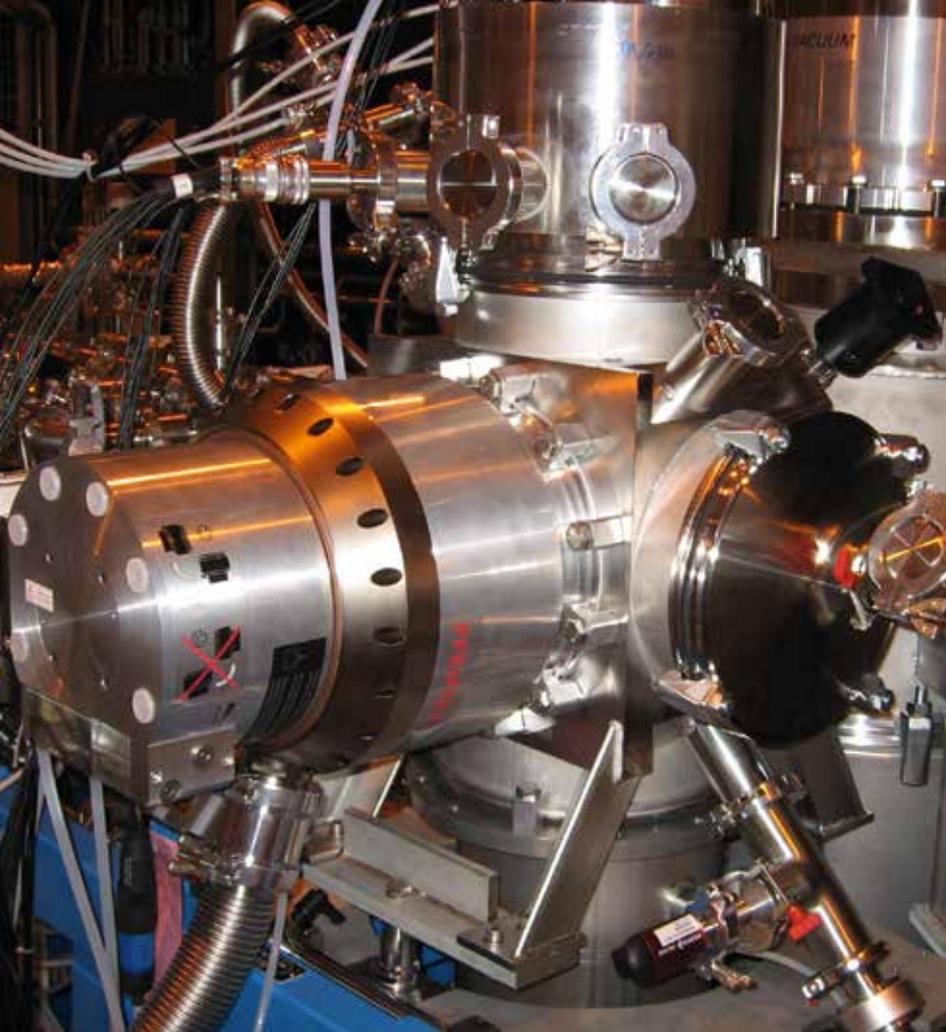
The use of fossil fuels in combustion engines, gas turbines and furnaces continues to be one of the most important energy conversion processes of our time. The consumption of primary fuels for combustion purposes accounts for the highest proportion by far of total energy demand, both in Switzerland (75 percent) and throughout the world (85 percent). In view of this, research activities and the development of cleaner and more efficient combustion technologies are of the utmost importance when it comes to meeting the declared energy and climate objectives.

Numerical simulations are widely used for optimising the associated processes, from carburetion and ignition, through to combustion. In the past few years, the resolution and accuracy of such model calculations has been significantly improved, and this means that the quality of the initial thermo-chemical parameters is having an ever greater influence on the end result.

Inaccuracies in the input basic data are multiplied in the calculation models and therefore require more comprehensive simulations and experimental validation.

Generally speaking, data relating to a combustion reaction (reaction speeds, elementary reactions, activation energy, etc.) can be obtained by studying the reaction kinetics, i.e. the chronological pro-

gress of the chemical reactions. The resulting characterisation of the radicals involved in a combustion process (reactive atoms and molecules with unpaired electrons) is too imprecise to allow detailed simulations, which are used, for example, for determining the ignition timing of a combustible gas mixture. One of the reasons for this is that it is generally not possible to carry out the necessary experi-



*Experimental set-up at the Paul Scherrer Institute for spectroscopic coincidence measurements of photoelectrons and ions using the Swiss Light Source (synchrotron source). The purpose of these studies is to determine the thermo-chemical properties of combustion-relevant molecules in order to obtain data for more accurate simulations of complex combustion processes.*

ments at the high temperature and pressure ranges required to enable a precise parameterisation of the combustion process.

Employing time-resolved spectroscopy, it is possible to directly examine the radicals that are formed, often in only very small quantities, during combustion processes and to determine their thermo-chemical properties (enthalpies of formation, energy states, etc.). In the past few years, comprehensive sets of instruments have been developed and installed at the Paul Scherrer Institute so that experiments of this kind can be carried out. In addition to various laser sources, the Swiss Light Source (synchrotron source) is also used

for the spectroscopy. Through the use of spectroscopy, with monochromatic vacuum ultraviolet radiation in the 4 to 30 eV range and a low meV bandwidth, it proved possible to accurately measure the dissociation mechanism of methane – with an accuracy factor ten times better than that obtained in standard experiments. Laser sources are used to carry out pulse probe experiments for the purpose of studying the internal dynamics of molecules in the femtosecond range ( $1 \text{ fs} = 10^{-15} \text{ sec}$ ) using angle-resolved photoelectron spectroscopy with a very high temporal resolution. Here, molecules are stimulated with ultrashort laser pulses and the emitted photoelectrons are detected with temporal and spatial

resolution. In this way it is possible to determine which partial reactions occur in a complex combustion process, which cannot be done by measuring species concentrations in a flame. Thus, one may identify significant and less significant reaction paths.

The research activities at the Paul Scherrer Institute are partially being carried out in close cooperation with European partners, and the infrastructure is also available for use by external researchers wishing to conduct experimental studies. (*obs*)

*[www.bfe.admin.ch/  
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## IN BRIEF ...

### Energy storage and grid stabilisation

The build-up of power generation capacity from fluctuating energy sources (wind and photovoltaics) increases the risk of grid instabilities, as well as the likelihood that conventional generators have to be taken off the grid due to voltage and frequency fluctuations. In response, Alstom has developed a technology to improve the fault ride-through capabilities for generator systems on the power plant side. The set-up focuses on the use of high-power energy storage elements and high performance semiconductor switching elements to compensate grid instabilities. Hence generators need not to be taken off the grid, thus increasing overall grid stability. (sig)

### Novel 2-watt router is 80 percent more efficient

There are currently more than three million routers and modems in use in Switzerland, which account for a total electricity consumption of over 230 GWh per year. Together with an indust-

ry partner, Swisscom has developed a router that consumes less than 2 watts, which is equivalent to around one-fifth of the power requirement of devices in use today. Alongside the use of extremely low-consumption components, the integrated VDSL (= Very High Speed Digital Subscriber Line) component completely turns itself off during periods of inactivity instead of switching into standby mode. An additional GSM (= Global System for Mobile Communications) module ensures connection to the Internet at all times and bridges the time during which the VDSL system starts up again when required. (mom)

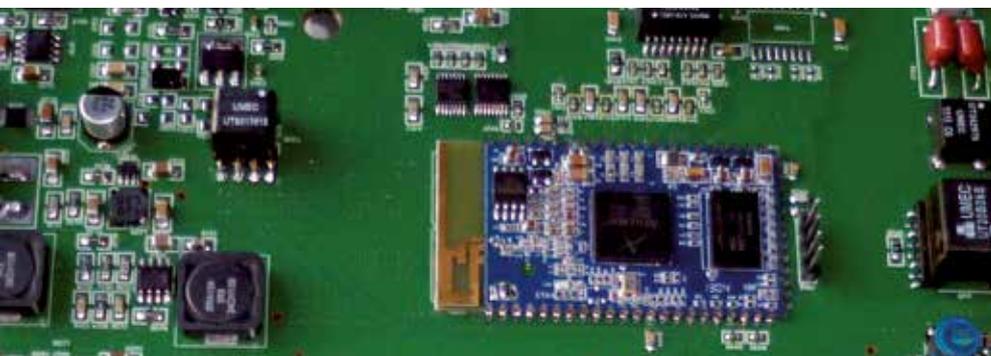
### Conversion of dust-laden waste heat into electricity

The Untervaz cement factory of Holcim Schweiz AG produces 800,000 tonnes of cement a year in a gigantic rotary kiln, and at the same time converts energy into 75 GWh of electricity and 555 GWh of heat. The sources of a large proportion of this energy are waste heat and the inher-



**Waste heat from a cement factory can be used for producing electricity with the aid of an ORC (Organic Rankine Cycle) system.**

ent heat of the produced cement. A portion of this energy is converted into electricity with the aid of an ORC (Organic Rankine Cycle) system. The hot air emitted from the system is heavily laden with cement dust (approx. 7 tonnes of dust per hour), which represents a major challenge. Using a heat exchanger and an intermediate water circuit, a portion of the heat is extracted from the emitted air and transferred to the ORC generator, which converts it into electricity with an output of around 2 MW. (pum)



**The power requirement of most routers in use today is between 7 and 10 watts. A new router has recently been developed that consumes less than 2 watts.**

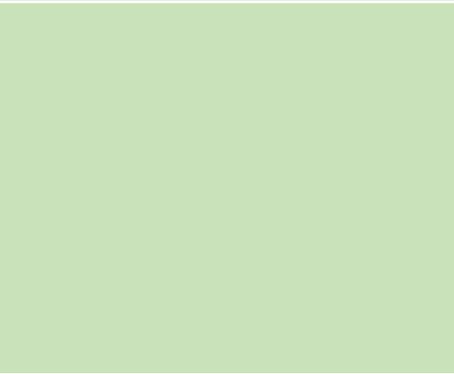


## RENEWABLE ENERGY

*The proportion of renewable energy in the overall energy supply is constantly increasing throughout the world, especially in the electricity sector, where the annual percentage increase is in the double-digit range for certain technologies, e.g. wind power (27 percent) and photovoltaics (42 percent). The use of other technologies such as hydropower, biomass and geothermal energy is also on the rise, with hundreds of gigawatts of additional capacity now being produced throughout the world.*

*However, the proportion of renewable energy in relation to total global primary energy demand has remained constant in the past 10 years at around 13 percent. In the area of renewable energy, the Swiss Federal Office of Energy 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. (obs)*





## Exporting solar technology from Ticino

**Due to the lack of strong direct solar radiation in the region, Switzerland is not able to exploit concentrated solar power (CSP) for the production of energy for its own use. Nonetheless, Switzerland has for decades been providing major impulses for the further development of this technology. A company based in Ticino (Airlight Energy) is breaking entirely new ground in its search for ways to further reduce the costs of solar power.**

Large-scale solar-thermal power plants, in which linear parabolic trough concentrators collect solar radiation and concentrate it on an absorber medium, have been in existence since the 1980s. Steam is then produced with the aid of heat exchangers, and this is used for operating a steam turbine and thus for the production of electricity. A broad variety of concepts have been introduced and developed during the past few decades. At the same time, new commercial power plants were constructed throughout the world in 2012 with a total capacity of around 2.5 GW, and power plants with a further capacity of 2.7 GW were under construction in 2013 or have already been connected to the grid. Concentrated solar power plants are combined with thermal storage systems, depending on whether they are designed for peak load or base load, and can operate for up to 5,500 full load hours a year or are designed for hybridising conventional fossil-fuelled power plants.

In recent years, the cost of electricity produced from solar-thermal power plants has fallen signif-

icantly. However, due to competition from cheap gas, sharply falling costs for photovoltaic systems, a generally difficult economic environment and abrupt changes in political conditions (e.g. feed-in remuneration at cost), this technology remains under strong pressure to further reduce the costs.

Airlight Energy, which was established in Ticino in 2007, is breaking entirely new ground. In the past few years, in cooperation with the Federal Institute of Technology, Zurich and the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), it has developed a large-scale parabolic trough concentrator with an aperture of almost 10 metres, comprising a pneumatic reflector system that is supported by a lightweight concrete structure. The reflector itself consists of an aluminium-coated foil, which together with a transparent cover foil forms an enclosed air volume that is under slight positive pressure. Air is used as an absorber medium for the concentrated solar radiation instead of the synthetic oil that is used in conventional parabolic trough technology. In view of the significantly lower number of heat storage media,



**Basalt thermal storage system for surplus solar heat.**

the use of air represents a considerable challenge, but it also offers the option of working at higher temperatures and thus attaining a higher degree of efficiency, as well as using potentially less expensive storage systems. The efficiency of the collector is very high thanks to the use of a secondary concentrator and a spiral-shaped absorber cavity with a highly absorbent surface and a smaller aperture.

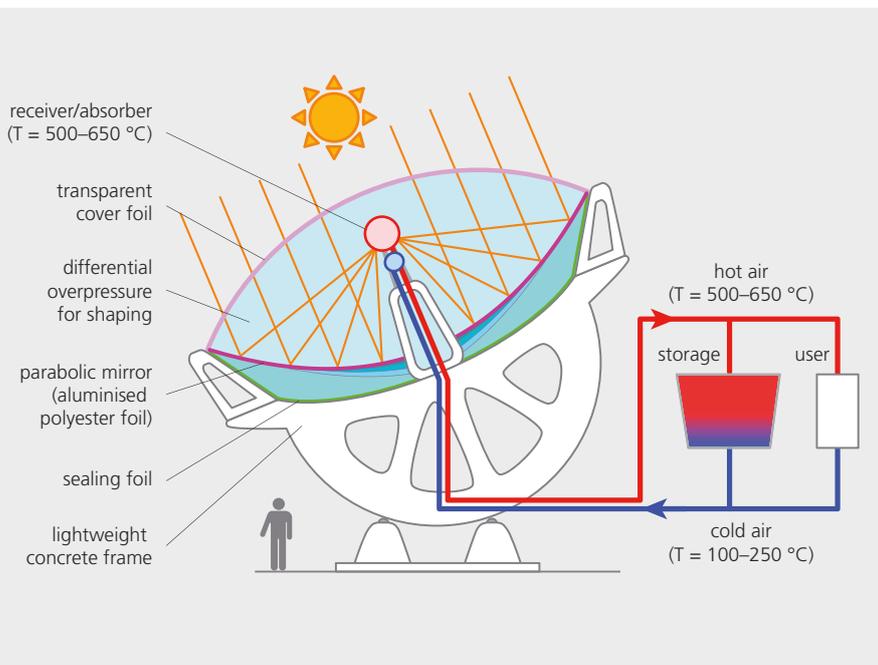
The first commercial system based on this technology is currently under construction in Ait Baha, Morocco. This facility will comprise a solar booster with a collector field with a thermal output of 3 MW, which together with waste heat from a cement factory is designed to deliver heat to an existing 12 MW Organic Rankine Cycle turbine. The client is Ciments du Maroc, which belongs to the Ital-

cementi Group. Excess solar heat will be transferred to an underground basalt storage system that will be heated up to 550 °C. The storage system has been designed so that the booster is able to supply a uniform quantity of energy (hot air) 24 hours a day.

A major portion of the facility is being constructed on site with the assistance of local companies, which has a positive effect on the grey energy of this technology. Airlight Energy is also working together with local universities, and at the end of 2012 was awarded the Moroccan "InnoTherm Prize".

Northern Africa, and Morocco in particular, is proving to be a highly promising market for concentrated solar power technology. The Moroccan Agency for Solar Energy (MASEN) plans to install additional concentrated solar power plants with a total capacity of 2 GW by 2020. Based on the experiences with the pilot facility in Ait Baha, this will be an opportunity for a Swiss company to participate in a growing market. (obs)

[www.bfe.admin.ch/forschungindustriesolar](http://www.bfe.admin.ch/forschungindustriesolar)



**Solar parabolic trough concentrator developed by Airlight Energy, with pneumatic reflector comprising an aluminised polyester foil that is enclosed with a transparent cover foil. Air is used as the absorber medium.**



*Heavy ice formation on a pylon of the Lukmanier transmission line after winter storm "Andrea" in January 2012.*

## Ice leads to heated emotions in the energy industry

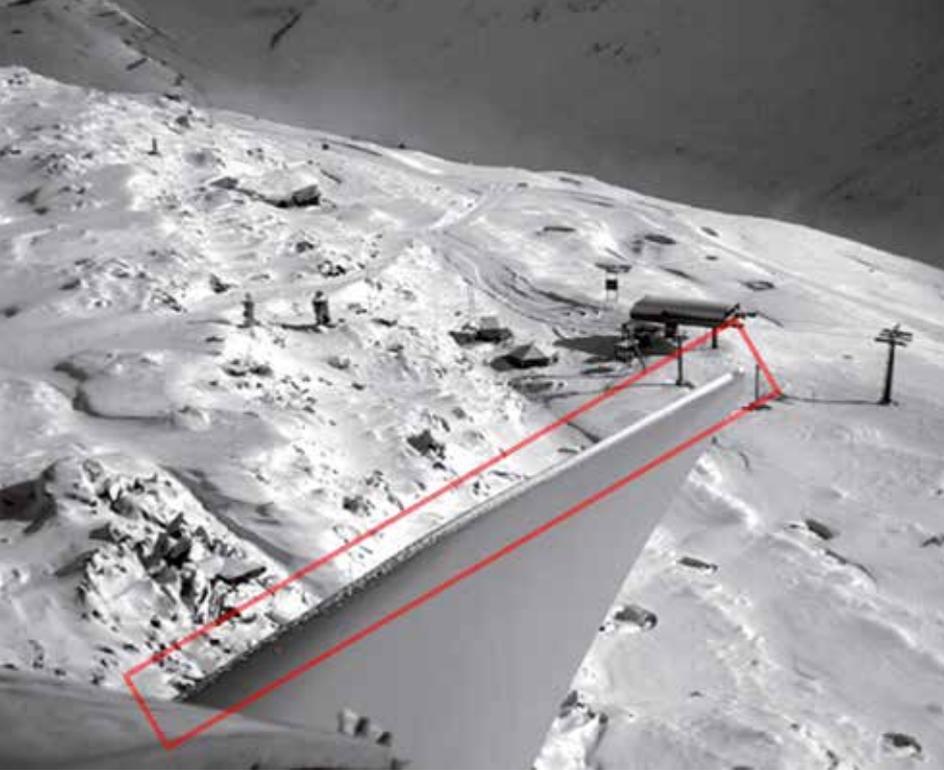
**Ice on windscreens is a nuisance, and icy roads are a major hazard for road users. But the formation of ice also poses problems for the energy industry. For example, it can bring down power lines or give rise to significant production losses and safety risks in wind parks.**

**W**hen ice builds up on electricity transmission lines, it can place a great deal of extra weight on the conductor cables. If the load becomes too heavy, isolators may be damaged or entire pylons may buckle or collapse. Ice on the rotor blades of a wind turbine interferes with its aerodynamic properties and efficien-

cy. And if the load becomes too heavy, the wind turbine even has to be switched off. In both cases, falling ice can endanger pedestrians or maintenance staff.

Ice is formed when supercooled raindrops from fog or clouds are transported by the wind onto a structure, where they freeze. If the water freezes instantly, an opaque

formation of hoarfrost appears on the windward side. If the temperature of the surfaces is slightly above 0 °C, the raindrops that land on it do not freeze completely. A layer of water is formed, which is distributed by the wind over the structure and then gradually freezes. This process results in the formation of clear ice.



***Ice formation on a wind turbine on the Güttsch above Andermatt (webcam image).***

A glance at the ice formation map of Switzerland shows that large areas of the country are regularly exposed to this phenomenon ([www.wind-data.ch](http://www.wind-data.ch)). In view of this, a great deal of importance is attached to ice formation research in Switzerland.

In the Jura range, practically all wind energy projects are affected by ice formation. In order to provide Swiss project developers with more detailed basic data, the operating behaviour of two wind turbines manufactured by Enercon have been undergoing intensive surveillance in St. Brais (canton of Jura) since 2009. The rotor blades of the two wind turbines can be heated with warm air on demand to cause the ice to melt and thus ensure the production of electricity during the winter. The icing conditions at this location were determined with the aid of camera images. This information formed the basis for a cost-benefit analysis for the use of rotor blade heating, and it was found that the use of heated rotor blades at locations sus-

ceptible to icing results in significantly higher yields. This project has meanwhile given rise to close cooperation with Enercon, the world's fourth-largest manufacturer of wind turbines, and thanks to continued development of rotor blade heating, the winter operation of the wind turbines in St. Brais has been greatly improved.

It is not only wind turbines that are affected by ice formation, but power lines, too, are susceptible to this phenomenon. Here, ice wraps around the conductor cable cylindrically like a sleeve, resulting in very heavy additional loads. In January 2014, it was this form of icing-up that caused a power line in Norway to collapse: a record weight of 69 kilograms of ice per metre was measured on the conductor cable. And in the Münster region of Germany, almost 70 high-voltage transmission line pylons snapped due to heavy ice formation in November 2005, leaving around a quarter of a million people without electricity.

A Swiss project currently investigates ways of optimising the operation of overhead power lines from the point of view of climatic influences. Ice formation is a central aspect of the study. Automatic cameras were installed directly on pylons at five locations in the Jura range and the Alps in order to monitor the condition of the power lines. The recorded images yield important insights with regards to frequency and intensity of ice formation. In addition, live images form a permanent component of the operational management of the transmission lines, and weather models are being used to make forecasts for the next few days regarding ice formation at the same five locations. Overall the study serves to make the operation of power lines that are susceptible to ice formation even more secure in the future. (*mak/mom*)

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[www.bfe.admin.ch/forschungwind](http://www.bfe.admin.ch/forschungwind)



*Construction of the sediment diversion shaft at the Solis reservoir on the Albula in the canton of Grisons.*

## Silting up of hydropower plant reservoirs in the Alps

The warming of the Earth's atmosphere is having a variety of impacts on the use of hydropower in the Alpine region. The chronological distribution of natural runoffs is changing and reservoirs in the Alps are increasingly silting up as a result of glacial retreat. At the same time, the Swiss and European electricity markets require additional storage and peak electricity capacities that can be provided through the use of hydropower.

**D**ue to a general climate warming the snow line is rising, too, and even at high altitudes, precipitation is in the form of rain and thus runs directly off the terrain. Furthermore, snow at high altitudes is now melting earlier than before. Since the natural interim storage of precipitation in the form of snow and ice is being reduced, natural and man-made reservoirs are having to assume this role to an in-

creasing extent. The general warming of the climate is also causing glaciers to recede and thawing areas of permafrost. As a result of increased erosion caused by water and wind, greater quantities of sediment and fine-grained suspended matter enter rivers and reservoirs and cause more rapid silting up.

These changes are taking place gradually and over decade-long pe-

riods. At the same time, however, the electricity markets in Switzerland and Europe are having to undergo significant adjustments due to the major increase in the use of regenerative energy. Storage and pumped storage plants will continue to be of central importance, both for Switzerland's future electricity supply as well as for its interaction with its European neighbours. In this connection, a variety of questions need to be clarified:



***Abrasion damage on a Pelton wheel caused by a high content of suspended matter in the water intake.***

Are there enough reservoirs? Can their capacity be increased, and if so, how are they to be managed in the future? What are the likely impacts of increased silting, and what steps can be taken to halt this process? Will hydropower be able to meet the expectations placed on it within the framework of “Energy Strategy 2050”?

As a consequence of the gradual silting up of reservoirs and the simultaneously increasing demands placed on hydropower production, the country's reservoirs will have to be managed much more intensively in the future. They will have to be filled to the maximum and drained to the minimum level more frequently than in the past. When the water is drawn off at low levels, intake eddies can be formed entraining air into the pressured pipeline system. These air bubbles cause malfunctions and instabilities in pipelines. Studies of this phenomenon are being carried out in order to identify the conditions under which these eddies are formed and to determine the quantity of bubbles that are subsequently sucked into the pipes, as well as to indicate ways in which

the formation of eddies can be prevented and how entrained air can be evacuated from the pipeline system. Research is also being carried out to determine the effect that an intensification of storage cycles (i.e. the interchange between pump and turbine operation) has on the silting-up of reservoirs due to the content of suspended matter in the water that is transported to and fro. These studies are intended to identify ways in which the operation of existing reservoirs can be optimised.

There are various ways in which the build-up of silt in reservoirs can be prevented. For example, flood waters carrying large quantities of sediment can be directed past the reservoir with the aid of diversion shafts. Although such installations are only in use for several days a year, they are nonetheless exposed to extreme loads as a result of the fast flowing mixture of water and debris. This means that they have to be frequently inspected and repaired. A variety of research projects are studying ways in which these shafts can be optimally designed and constructed, as well as which non-corrosive materials are

most suitable for providing protection at the most vulnerable locations. Suspended matter in water is normally filtered out with the aid of a sand trap. But if the trap is not sufficiently effective, the material collides at high velocity with the buckets of the Pelton wheels and causes abrasion damage, which has a negative impact on the efficiency of the machines. The impellers therefore have to be removed and serviced at defined intervals. The harder and sharper the suspended matter in the water, and the greater the content, the more frequently this costly and time-consuming measure has to be carried out. Here, ongoing research is focusing on the correlation between content of suspended matter and the resulting abrasion damage. Studies are also being carried out to determine which are the best models for the numeric simulation of sedimentation processes in sand traps so that the criteria for specifying the dimensions of sand traps can be more precisely defined. (*mom/jok*)

*[www.bfe.admin.ch/  
forschungwasserkraft](http://www.bfe.admin.ch/forschungwasserkraft)*



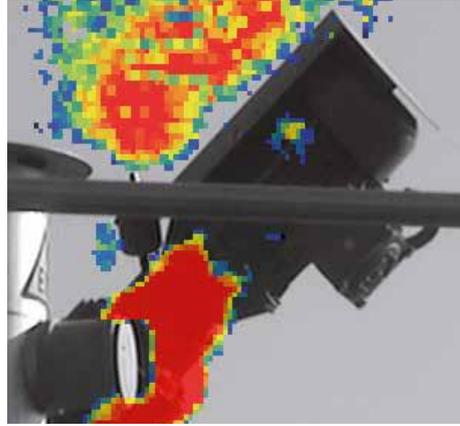
## IN BRIEF ...

### Leaks in biogas systems

**M**ethane leaks pollute the environment, result in financial losses and increase the safety risk of a biogas facility. Losses may occur via leaks in the cover of the fermenter and at pipe feed-throughs, or on a larger scale from fermentation residue and pre-fermentation depots. An ongoing study has found that losses from fermentation residue depots account for between 2 and 37 percent of the remaining methane gas potential, which is equivalent to around 2 percent of the total production of the facility, while losses from pre-fermentation depots amount to approximately 0.4 percent of total production. The most common sources of losses can be reduced through careful planning, construction and maintenance of a biogas facility. Lengthy storage times and two-stage facilities reduce the residual methane gas potential and thus methane losses. (hea)

### Fruits & vegetables thanks to geothermal energy

**W**ith a great deal of courage and determination, and the investment of considerable resources, fruit and vegetables producer Grob, based in Schlattingen (canton of Thurgau) has embarked on the changeover from fossil fuel to renewable geothermal energy for the supply of heat to its production facilities. Two shafts drilled to depths of around 1,200 and 1,400 metres – including the application of a horizontal drilling method in the field of geothermal energy for the first time in Switzerland – indicated that there is sufficient hot water (60 °C) in the shell limestone layer in the



**Gas losses at the agitator of a biogas plant. The areas in red represent high methane concentrations, while areas in blue indicate low concentrations. Left: before lubrication; right: after lubrication.**

northern region of Thurgau to be able to supply a portion of the heat required for the company's agricultural activities. (sig)

### Efficient thin-film solar cells

**E**fficiency has always been one of the main criteria for determining the performance of the various solar cell technologies. Copper indium gallium selenide (or CIGS for short) solar cells suggest a high potential for very high degrees of efficiency in comparison with other thin-film solar cells. Major efforts are currently under way all over the world to increase the efficiency of CIGS modules to the range of polycrystalline silicon modules. In close cooperation with EMPA (Swiss Federal Laboratories for Materials Science and Technology), Swiss company Flisom is developing a facility for the roll-to-roll production of CIGS modules on flexible substrates. This technology promises not only a high degree of efficiency, but also a short energy payback time, as well as potentially very low investment costs. (obs)



**Empa (Swiss Federal Laboratories for Materials Science and Technology) is one of the world's leading laboratories researching efficient CIGS thin-film solar cells. Since 1999, the degree of efficiency has been increased from around 13 percent to more than 20 percent in a series of development stages, with each stage representing a new record level worldwide.**

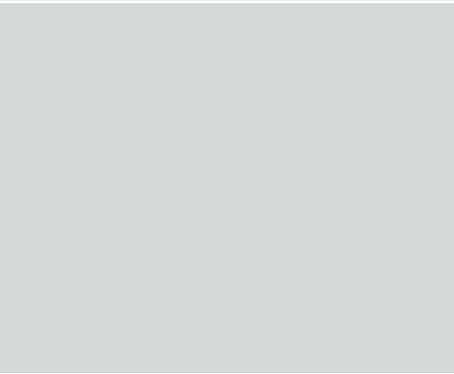


## ENERGY, ECONOMY, SOCIETY

*In addition to promoting technological development in the energy sector, the Swiss Federal Office of Energy also focuses strongly on economic, sociological, psychological and political issues along the entire value chain. Energy markets are characterised by a variety of deficiencies, and this often means that economically efficient results can only be achieved through state in-*

*tervention. In view of this, it is essential to carry out socioeconomic research, which provides the basis for energy policy. Here the aim is to simultaneously focus on meeting a broad range of objectives such as security of supply, fair pricing and protection of the environment. (faa)*





## How does information affect electricity consumption?

**In addition to an increase in the share of renewable energy, Switzerland's "Energy Strategy 2050" also calls for a reduction of end energy and electricity consumption. A variety of instruments can be applied in order to achieve this goal. One of these concerns the provision of higher quality information to consumers about their electricity consumption.**

In an ongoing study, consumption behaviour of 5,000 households – customers of Electricity Company of the City of Zurich (ewz) – was analysed in detail to discover whether, and in what ways, it is possible to reduce electricity consumption by providing consumers with additional information. Participants were divided randomly into five groups, each of which received different kinds of information about their electricity consumption. A control group was not provided with any information at all, while in another group the participants received constant and detailed information about their consumption via a smart meter. This enabled the households to obtain information about their electricity consumption in real time. Another group received professional advice on electricity consumption, and the remaining two groups were provided with information to varying degrees about the electricity consumption in similar households. As part of the study, the electricity meters of the involved households were read a total of eight times during a period of 15 months.

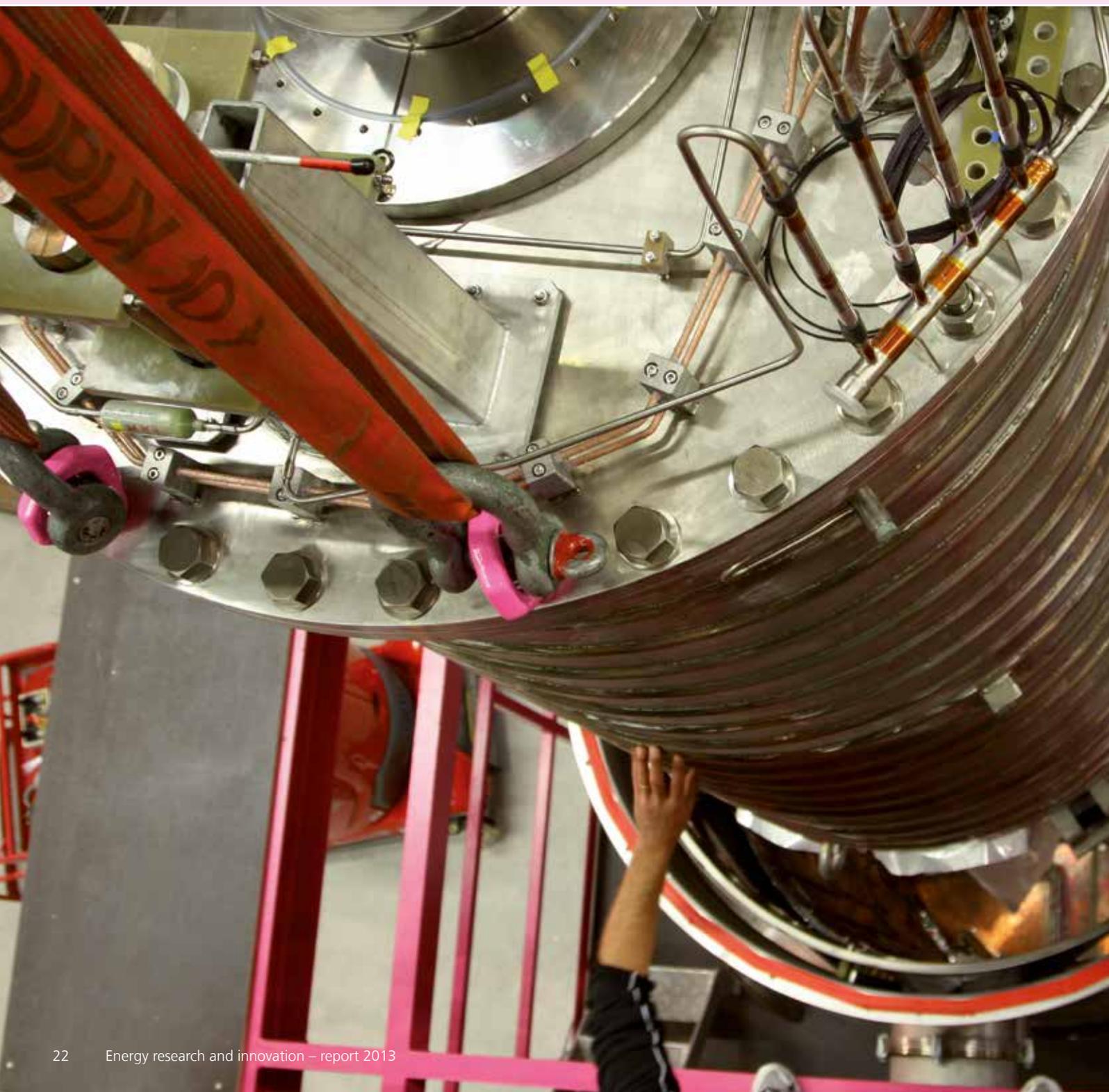
The findings showed that it is possible to significantly reduce electricity consumption simply by providing consumers with information. Thanks to the information provided by smart meters, daily consumption levels were reduced by around 3.2 percent in the medium term. A reduction in consumption was noted not only immediately after smart meters had been installed, but also in the course of the entire observation period. The display of data on smart meters also enabled a partial shift of consumption to off-peak tariff periods. Social competition, however, only gave rise to minor savings. The reductions in consumption in both groups that received information about the level of consumption in similar households were in fact negligible at the end of the observation period. The frequency of feedback appears to play a significant role. This project underscores the importance of providing a constant flow of up-to-date and detailed feedback in order to bring about a significant reduction in electricity consumption. (faa)

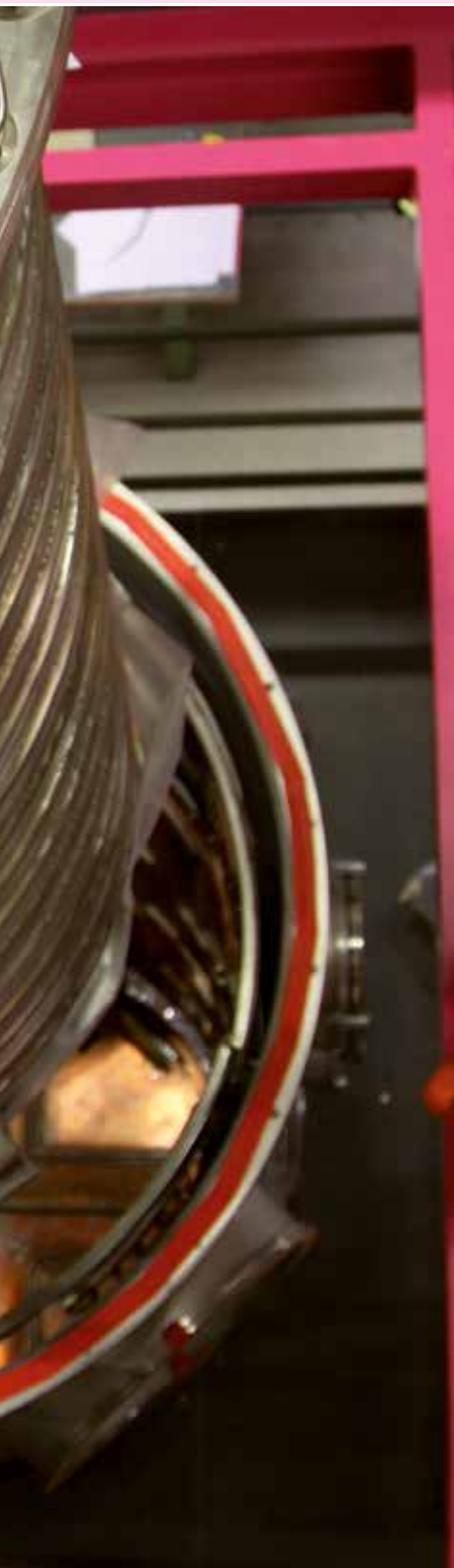
[www.ewg-bfe.ch](http://www.ewg-bfe.ch)



## NUCLEAR ENERGY

*By and large, the Swiss Federal Office of Energy (SFOE) does not directly promote and coordinate research in the technology-focused areas of nuclear technology and nuclear safety, regulatory safety and nuclear fusion. For detailed information regarding the activities and research projects in these fields, refer to the websites of the following organisations: Paul Scherrer Institute (<http://nes.web.psi.ch>), Federal Nuclear Safety Inspectorate ([www.fnsi.ch](http://www.fnsi.ch)) and Fusion Research Centre at the Federal Institute of Technology, Lausanne (<https://crppwww.epfl.ch>). The SFOE only directly supports research activities at the University of Basel that are associated with the International Thermo Nuclear Experimental Reactor (ITER). In the area of radioactive waste disposal, the SFOE coordinates a variety of federal social research activities relating to regulatory issues. (obs)*





## Radioactive waste and regional participation

**In order to take the interests of the population into account with respect to the selection of suitable sites for deep geological repositories in Switzerland, participation bodies (regional conferences) comprising representatives from the involved communities and organisations, as well as other local residents, were formed in each of the six potential site regions.**

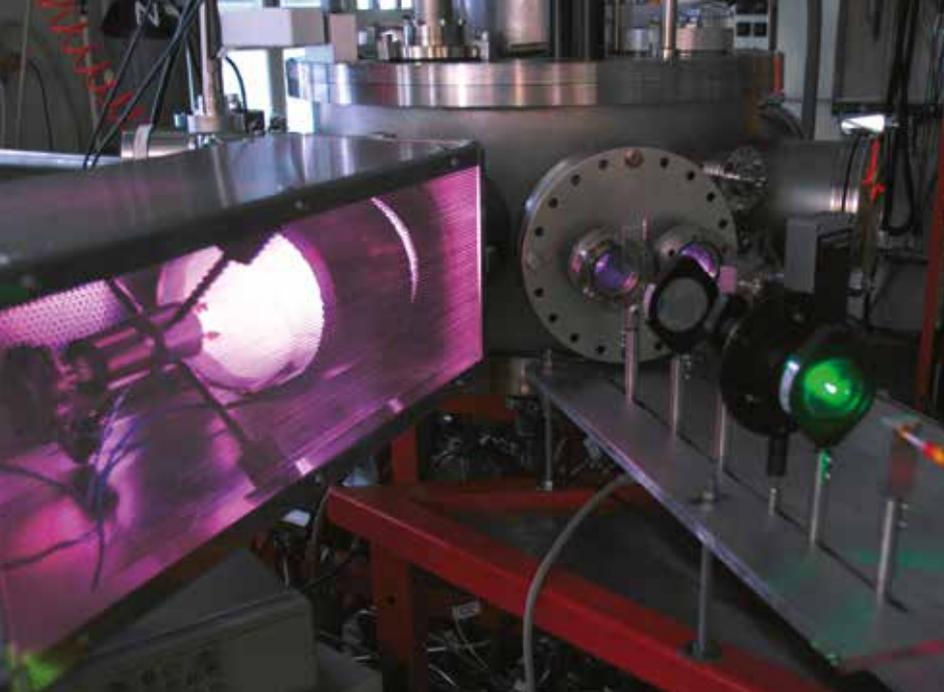
In the participation process, the involved parties are given the opportunity to introduce regional interests and issues into the planning of the disposal of radioactive waste in Switzerland. The process of forming these bodies was closely examined in accompanying research activity between 2009 and 2011, concluded in 2013 and published in January 2014. For this purpose, a comprehensive analysis of documentation was carried out, and qualitative interviews were conducted with people involved in the development of the participation process. Alongside the documentation of the development process, the aim was to obtain a portion of the know-how and experience of the involved players and incorporate it into the next stage of the participation process. The main findings were summarised in the form of lessons learned, and these were used as a basis for formulating corresponding recommendations.

In the communication process, a variety of points were addressed which have room for improvement. For example, right from the start, one has to communicate the objective of the participation process in a clear and comprehensible manner. Furthermore, the roles and responsibilities of the players involved also have to

be precisely defined. However, the way in which objectives are to be achieved needs to be deliberately left open for a given site region. An exchange between the regions concerning their experiences is also recommended. With respect to the composition of the regional conferences, it became clear that the various interests are being adequately represented. However, from the point of view of socio-demographic factors, the composition of the conferences is not balanced, in particular young participants as well as women are underrepresented. In order to achieve a more balanced representation of the population, the awareness of the participants with regard to the inclusion of the various population groups needs to be intensified, and a corresponding strategy with requisite communication measures would have to be developed.

Along with the initiation of research to accompany the second stage of the participation process, a number of smaller studies are planned that will focus on the participation of women and young people in long-term technical projects. The aim here is to obtain additional insights and integrate them into the ongoing process. (brs/min)

[www.bfe.admin.ch/radioaktiveabfaelle](http://www.bfe.admin.ch/radioaktiveabfaelle)



*Development of reflectors for the ITER experimental reactor: Left (purple): Plasma source for simulating the conditions for particle irradiation. Right (green): Light source for the simultaneous measurement of the reflection properties of the reflector.*

## Mirrors for the fusion reactor ITER

**Nuclear fusion could become a potential alternative energy conversion technology. In Cadarache (France), the latest test reactor ITER (International Thermonuclear Experimental Reactor) is currently being built. An international team including experts from the University of Basel is developing a new measurement and diagnosis system for characterising fusion plasma.**

The environment inside a fusion reactor is very harsh. Together with high plasma temperatures, neutron and ion radiation pose enormous challenges in terms of materials in use. In order to control the plasma of the reactor, a number of measurement and diagnostic systems are required. Because of the intensive neutron bombardment, direct visibility into the interior of the reactor is not possible. For this reason, light from the vacuum chamber has to be transmitted to the measurement points via a reflector system that is able to withstand high temperatures. At the University of Basel, new types of material coatings are being researched in order to ensure that these primary reflectors are able to perform their task upon start-up and during operation of the fusion reactor over the long term.

The development of these diagnostic and measurement systems is therefore a major factor for the successful operation of the experimental fusion reactor that is currently under construction. The development of this first international experimental reactor and its complex infrastructure in Cadarache in the south of France heralds a new era in fusion research. And the objective of economical energy conversion will then be pursued in the subsequent development of an even larger reactor, DEMO. The ring-shaped vacuum chamber of ITER, called Tokamak, is to be equipped with around 50 different measurement and diagnostic systems in order to steer, control and optimise the formed plasma. Optical measurements are to be carried out for determining temperature, plasma density, plasma dilation, quantity of helium, and concentrations of pollutants. They draw on

the entire visible and invisible spectrum of light. Material is detached from the walls in the reactor due to high energy densities, and is carried along by the plasma in the form of atomic dust. If this dust deposits onto the diagnosis reflectors, their reflectivity is reduced and spectrally altered. In order for a reactor to work economically, it must be operated without interruption, and to ensure this the optical diagnostic instruments, and thus intact reflector systems, are essential. In the currently favoured method,, reflectors are cleaned in vacuum with the aid of ion etching, without being removed. Suitable cleaning processes are currently being tested in Basel in an international research project. (*mom/mal*)

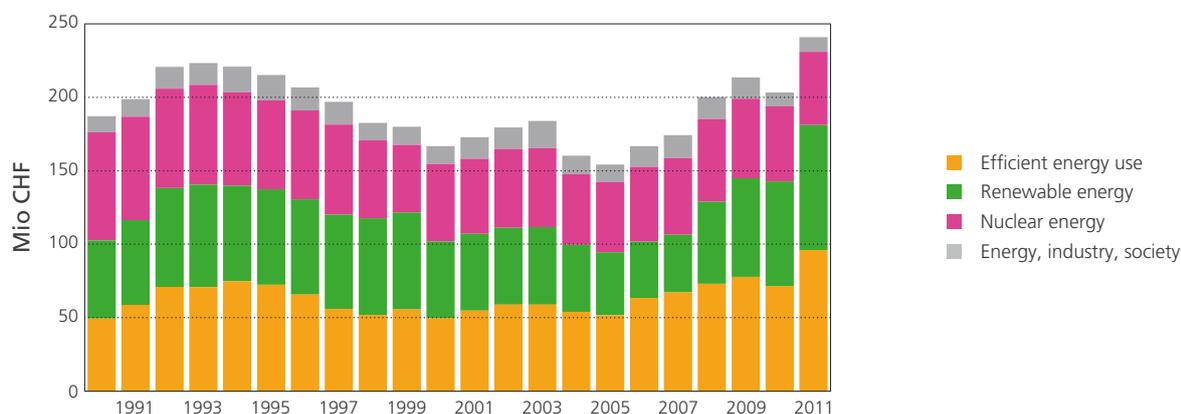
*[www.bfe.admin.ch/  
forschungkernenergie](http://www.bfe.admin.ch/forschungskernenergie)*



## FACTS AND FIGURES

Since 1977 the Swiss Federal Office of Energy (SFOE) has been recording public expenditure for energy-related research and pilot and demonstration projects. The information is collected through self-reporting of project data, though the SFOE is responsible for the thematic classification and detailed examination of

the projects. Actual levels of public expenditures are therefore probably somewhat understated. Each year around 1,500 projects are recorded, examined and statistically evaluated. An overview of the data collection process is published on the energy research website ([www.energy-research.ch](http://www.energy-research.ch)). (mak)



Long-term overview of public expenditure on energy research. Figures are shown as real data, i.e. after adjustment for inflation for 2012, and vary between 0.03 and 0.065 percent of GDP.

	ETH	SNF	CTI	SFOE	ENSI	SERI	EU	Kt./Gmd.	others
2011	138.1 (78.6 %)	4.5 (2.6 %)	20.3 (11.6 %)	23.6 (13.4 %)	2.2 (1.3 %)	0.4 (0.2 %)	28.9 (16.5 %)	8.9 (5.1 %)	14.0 (8.0 %)
2010	120.1 (68.4 %)	3.6 (2.0 %)	13.9 (7.9 %)	25.2 (14.4 %)	2.3 (1.3 %)	1.0 (0.6 %)	19.2 (10.9 %)	7.9 (4.5 %)	10.0 (5.7 %)

Sources of public funding for research, development and pilot and demonstration projects, in million Swiss francs. (ETH = Federal Institutes of Technology and associated entities: Federal Institute of Technology, Zurich; Federal Institute of Technology, Lausanne; Empa [Swiss Federal Laboratories for Materials Science and Technology]; Paul Scherrer Institute; Eawag; Swiss Federal Institute for Forest, Snow and Landscape Research [WSL] / SNF = Swiss National Science Foundation / CTI = Commission for Technology and Innovation / SFOE = Swiss Federal Office of Energy / ENSI = Swiss Federal Nuclear Safety Inspectorate / SERI = State Secretariat for Education, Research and Innovation / EU = European Union / Kt./Gmd. = cantons and municipalities).

	2010	2011
<b>Efficient energy use</b>	<b>71.5</b>	<b>96.0</b>
Energy in buildings	12.3	15.1
Mobility and transport	9.5	18.3
Accumulators and supercapacitors	2.7	1.7
Electricity technology and applications	10.1	12.9
Grids and systems	4.9	6.0
Combined heat and power	1.3	1.3
Fuel cells	7.1	16.2
Combustion	12.8	11.5
Power plant 2020 and carbon capture and sequestration	7.3	6.4
Process engineering	3.6	6.6
<b>Renewable energies</b>	<b>71.3</b>	<b>85.0</b>
Solar	33.5	41.8
Solar heat and heat storage	5.4	5.5
Photovoltaics	17.3	21.4
Concentrated and high temperature solar (CSP)	10.7	14.9
Hydrogen	14.9	15.8
Heat pumping technologies and refrigeration	2.7	2.1
Biomass and wood energy	9.2	12.7
Geothermal energy	6.8	5.9
Wind energy	2.0	3.5
Hydropower	2.2	3.2
<b>Nuclear energy</b>	<b>51.0</b>	<b>50.0</b>
Nuclear Fission	28.2	26.6
Nuclear Security	19.4	17.4
Radioactive waste	5.4	5.4
Future-oriented research	3.4	3.8
Nuclear fusion	22.8	23.4
Plasma physics and heating technology	16.1	16.6
Nuclear fusion technology	6.7	6.8
<b>Cross-sectional themes</b>	<b>9.4</b>	<b>9.9</b>
Energy, economy, society	7.6	6.8
Knowledge and technology transfer	1.2	2.1
General coordination	0.6	1.0
<b>Total</b>	<b>203.2</b>	<b>240.9</b>

*Public expenditure on applied energy research, including pilot and demonstration projects, in million Swiss francs (nominal amounts). In the area of nuclear fusion it is primarily basic research that is carried out, but in accordance with international practice, research activities are nonetheless included in energy research. Interdisciplinary projects are allocated to the respective overlying research area.*



## INTERNATIONAL COLLABORATION

International cooperation in energy research has a high priority in Switzerland. At institutional level the Swiss Federal Office of Energy (SFOE) coordinates its research programmes with international activities in order to exploit synergies and avoid duplication. The cooperation and exchange of experience within the International Energy Agency (IEA) is of particular importance. Switzerland participates through the SFOE to more than 20 programmes of the IEA (Implementing Agreements, [www.iea.org/techno/index.asp](http://www.iea.org/techno/index.asp)). At European level, Switzerland is actively involved in the Framework Programmes for Research and Technological Develop-

ment of the European Union. The SFOE coordinates at institutional level energy research with European activities through participation in relevant committees: the Industrial Initiatives of the European Strategic Energy Technology Plan (SET Plan), the European Research Area Networks (ERA-NET), the European Technology Platforms, the Joint Technology Initiatives (JTI), Euratom, etc. In certain areas ("smart grids", geothermal energy) intensive multilateral cooperation exists with individual countries. (*obs*)

[www.energy-research.ch](http://www.energy-research.ch), [www.seri.admin.ch](http://www.seri.admin.ch)

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### Impressum:

Redaction:  
Dr. Stefan Oberholzer  
Swiss Federal Office of Energy  
CH-3003 Bern  
([stefan.oberholzer@bfe.admin.ch](mailto:stefan.oberholzer@bfe.admin.ch))

### Contributions:

smr:	Dr. Rolf Schmitz (BFE)	jok:	Dr. Klaus Jorde (Skat Consulting AG)
obs:	Dr. Stefan Oberholzer (BFE)	hea:	Dr. Sandra Hermle (BFE)
eca:	Andreas Eckmanns (BFE)	faa:	Dr. Anne-Kathrin Faust (BFE)
sig:	Dr. Gunter Sidiqqi (BFE)	min:	Annina Michel (BFE)
mom:	Dr. Michael Moser (BFE)	brs:	Simone Brander (BFE)
pum:	Martin Pulfer (BFE)	mal:	Dr. Laurent Marot (Universität Basel)
mak:	Dr. Katja Maus (BFE)		



***"The Electrochemistry Laboratory at the Paul Scherrer Institut (PSI) highly appreciates the support from the Swiss Federal Office of Energy, since it directly and efficiently enables exploratory projects at the borderline between fundamental and applied research, and thus innovation."***

*Prof. Dr. Thomas J. Schmidt, head of the Electrochemistry Laboratory (PSI) und director of the Swiss competence center for energy research (SCCER) "Storage".*

Swiss Federal Office of Energy (SFOE)  
CH-3003 Bern

[www.energy-research.ch](http://www.energy-research.ch)  
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