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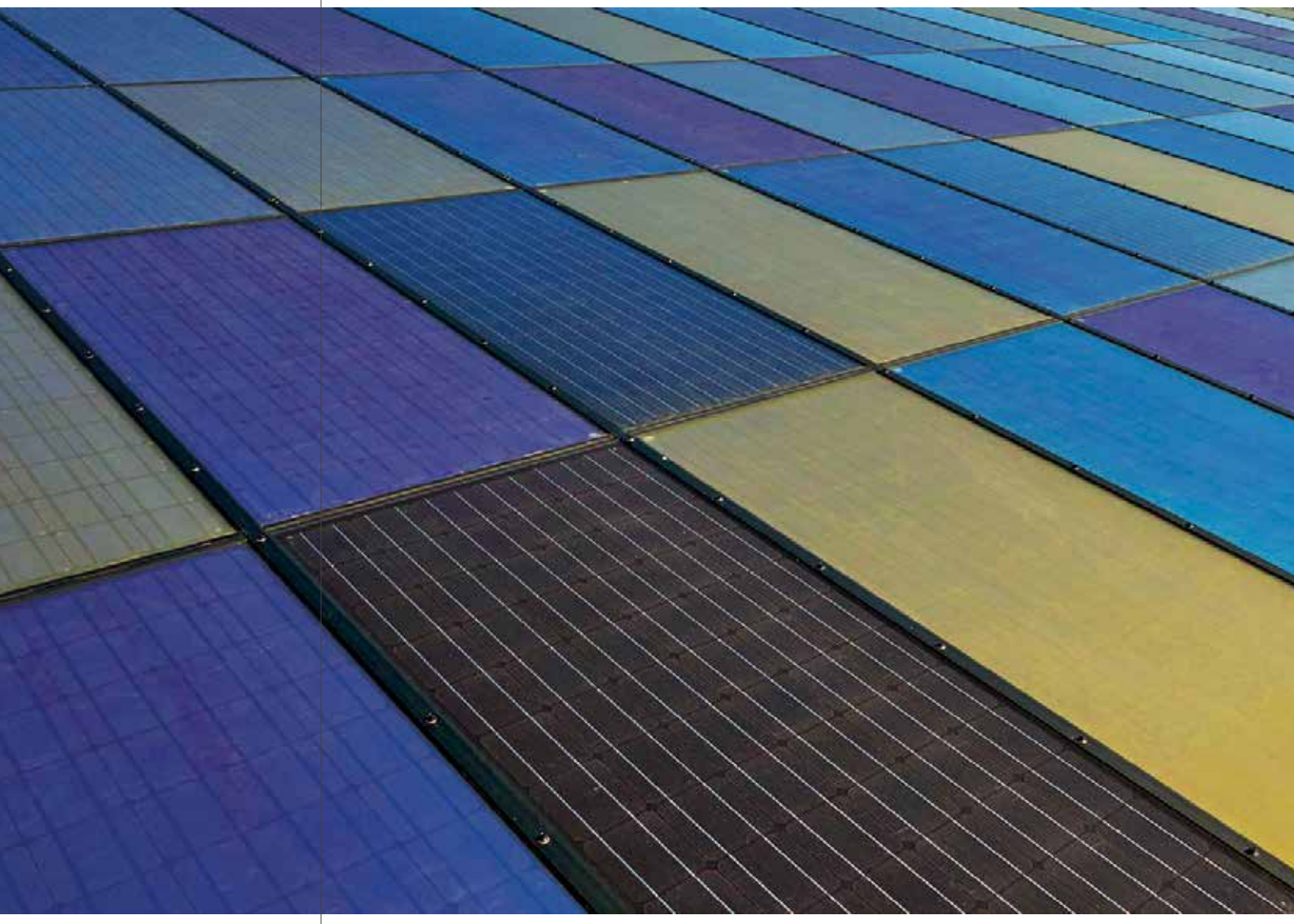
Swiss Federal Office of Energy SFOE

Energy research and innovation
Report 2015



"As a company specialising in energy-efficient facades and windows, as well as solar systems, we greatly appreciate the Swiss Federal Office of Energy as a long-term and dependable partner, whether directly, for its support of pilot and demonstration projects and access to international projects of the IEA, or indirectly, for example via the Commission for Technology and Innovation, for the implementation of innovations. In particular, the Swiss Federal Office of Energy has built and consistently promoted the network of organisations and academic institutions which is of enormous importance to us."

Hans-Ruedi Schweizer,
CEO and Chairman of the Board of Ernst Schweizer AG

EDITORIAL

Energy research in Switzerland is currently in full swing. With the two National Research Programmes, "Energy Turnaround" and "Managing Energy Consumption", plus the eight Swiss Competence Centres in Energy Research and the Swiss Competence Centre for Photovoltaics, energy research has never before been carried out so comprehensively and in such an interdisciplinary manner. The federal government has budgeted considerable financial resources to support the build-up of human resources for energy research, and at the same time has increased the funding of the Swiss Federal Office of Energy (SFOE) for the support of pilot and demonstration projects, as well as for the promotion of innovation by the Commission for Technology and Innovation.

The Federal Energy Research Commission (CORE) has incorporated these developments into its Federal Energy Research Masterplan for the period from 2017 to 2020, and further focused the objectives of Swiss energy research. The Masterplan and the latest findings from the field of energy research will be presented and discussed at the 10th Swiss Energy Research Conference to be held in April 2016.

This publication focuses on the support activities of the SFOE – as one of the most important promotional bodies in Switzerland's energy sector – in the in the areas of research and innovation. With its support programmes for application-oriented research and for pilot, demonstration and flagship projects, as well as the market-oriented SwissEnergy programme, the SFOE supports innovation from the laboratory to the marketplace. The examples presented in this brochure are exemplary of the numerous projects that contribute towards the broad variety of fields covered by the Federal Energy Research Masterplan.

Dr. Walter Steinmann
Director

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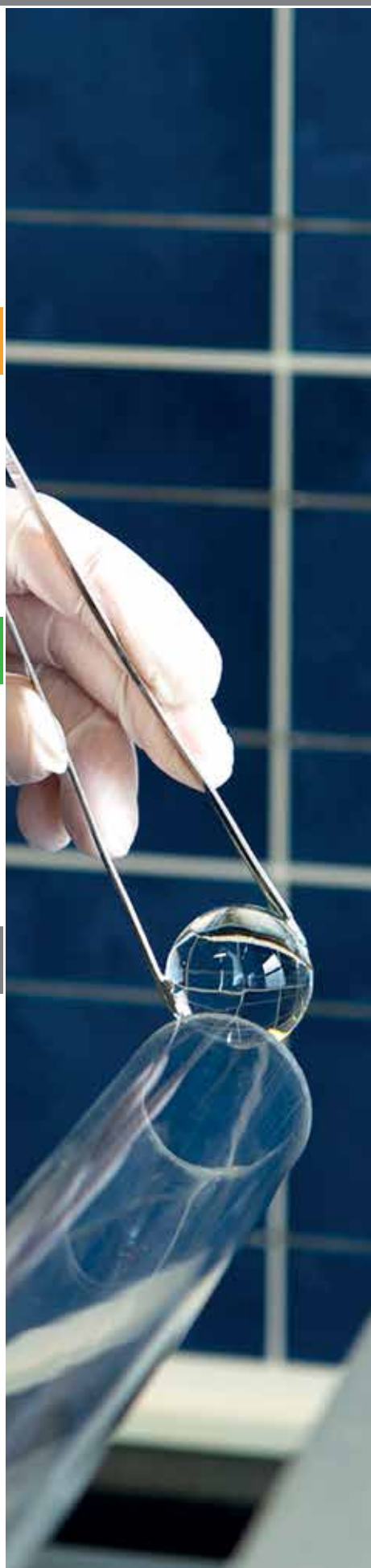
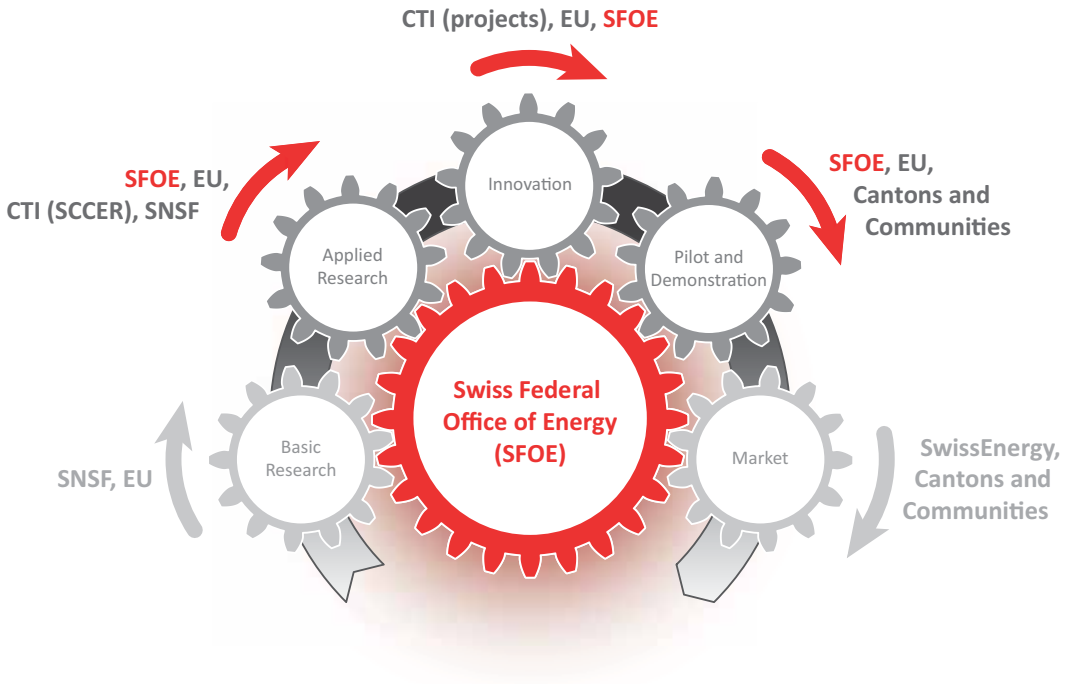


The ability to develop new ideas and bring them onto the market is an important factor for the competitiveness of a country's economy. The key is research, where novel findings and ideas are born that lead to the development of innovative and competitive products. In the context of the new energy policy ("Energy Strategy 2050") proposed by the Federal Council and the landmark decision to withdraw from the use of nuclear energy, this applies in particular to research and development in the energy sector. Here, the Swiss Federal Office of Energy (SFOE) has a central role to play.

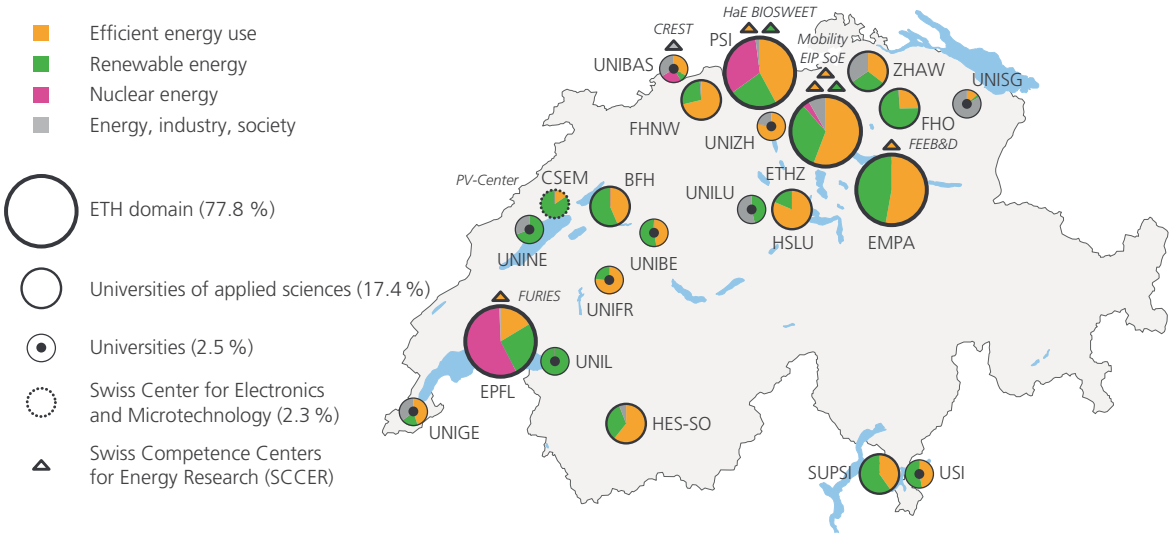
The role of the SFOE in the promotion of research and innovation

The SFOE promotes and coordinates national energy research, and supports the development of new markets for a sustainable energy supply. To successfully perform its coordination activities, the SFOE allocates its resources within a programmatic framework and in a targeted manner to promote the development of innovative technologies and concepts. It provides subsidiary support wherever there are gaps in Switzerland's research support landscape. Players include the private sector, the Swiss Federal Institute of Technology domain, plus universities and universities of applied sciences. The SFOE closely monitors the projects it supports, and on a case-by-case basis also calls on experts and representatives from other funding agencies. The SFOE also provides expert reviews and know-how to project proposals that have been submitted to other national, cantonal, city or private funding bodies. In addition, the SFOE contributes to the regular exchange of information among various national research programmes, as well as to measures aimed at knowledge transfer. Thus, the SFOE is tightly networked with all research segments along the entire value chain, and enables continuous development of know-how and its translation into practical applications.



In close cooperation with the most important funding agencies that competitively award grants, the SFOE supports and coordinates research and innovation in the energy sector along a major portion of the value chain. Its activities are based on a programmatic and subsidiary approach that is governed by the Federal Energy Research Masterplan. In addition to national networking, the SFOE's central pillars are active dissemination of knowledge as wells as international exchange and cooperation (CTI = Commission for Technology and Innovation, EU = European Union, SNSF = Swiss National Science Foundation).

ENERGY RESEARCH IN SWITZERLAND AND INTERNATIONAL COLLABORATION



Investment in the four fields of research, "efficient energy use", "renewable energy", "nuclear energy" and "energy, economy and society" at various Swiss universities and colleges of technology (figures for 2014). The largest proportion of Swiss energy research activities (78 percent) is carried out at the Swiss Federal Institutes of Technology Domain (atZurich and Lausanne and Empa (Swiss Federal Laboratories for Materials Science and Testing), the Paul Scherrer Institute, Eawag and WSL (Swiss Federal Institute for Forest, Snow and Landscape Research), followed by universities of applied sciences (17 percent) and cantonal universities (3 percent).

International research cooperation in the energy sector

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.

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, the sum of 72 million Swiss francs is being spent on creating eight Swiss competence centers, 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.

Keeping an eye on the distribution network

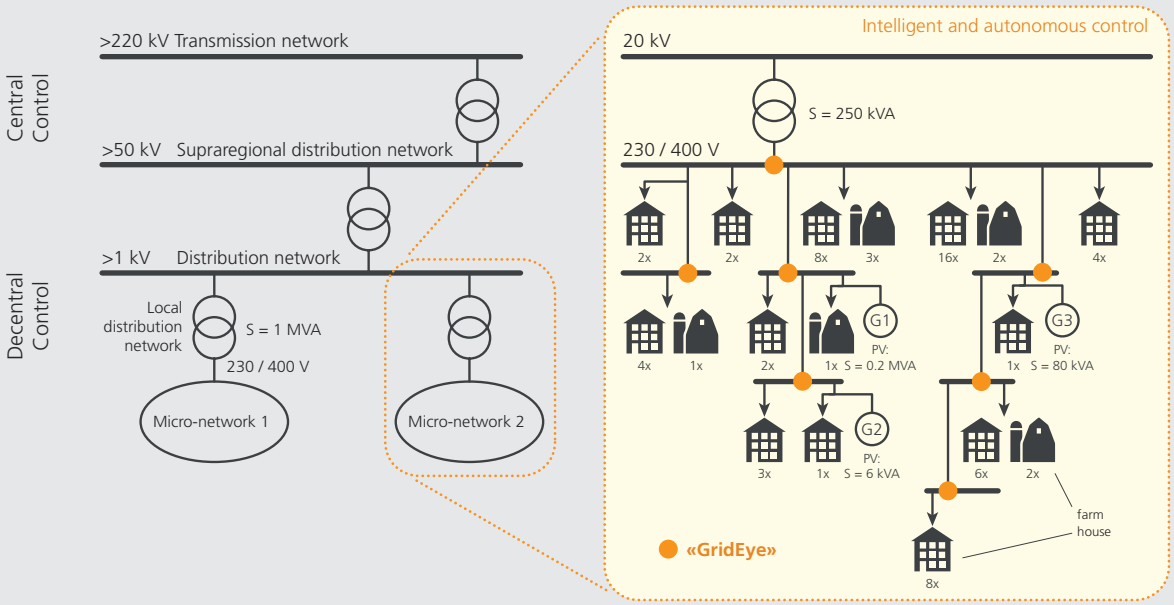
A variety of research projects focus on technologies for real-time monitoring and control of electricity distribution networks. Here the objective is to develop systems to be deployed in decentralised production and storage facilities to ensure regulatory compliance.

Electricity grids that permit the integration of the cheapest possible and most reliable forms of renewable energy are often referred to as "smart grids". Several Swiss project teams are currently working on such concepts. Each of these projects is based on the idea of equipping the distribution network with measuring devices, and using recorded data for centralised or decentralised grid control.

In the "Gridbox" system, currently being tested by BKW Energie AG and ewz (Electricity Utility of the City of Zurich), centrally processed data are used for controlling decentralised production and storage facilities, as well as consumers, in such a manner as to ensure that as many facilities as possible can be operated in the distribution network without compromising their functionality. It is conceivable that, in this way, the need for an expansion of the grid may be avoided. Because a large quantity of measurement data are recorded via "Gridbox" at high frequency, it is possible to accurately assess the status of the grid and thus optimise the overall distribution network.

The "GridSense" system applied by energy group Alpiq hasthe same objective. However, this system comprises autonomously operating measurement and control devices which implies no data exchange data either with a central processing unit or with neighbouring devices. They merely measure voltage levels that locally trigger commands based on an algorithm. Thanks to its decentralised structure, the "GridSense" concept continues to function even if an individual module stops working, unlike the case with a centrally controlled system. However, this also implies that the optimisation of the distribution network is restricted to a local level.

DEPSys SA, a start-up of the University of Applied Sciences Yverdon, has built on combining the positive features of the previously described concepts to arrive at "GridEye" Here, too, measuring devices are installed in the electric-



The "GridEye" system measures voltage at grid points in the distribution network and enables the optimum operation of the grid via a smart and autonomous control system.

ity grid for the purpose of monitoring voltage levels at the respective network points. The collected data can be used for displaying the status of the grid. Industrielle Werke Yverdon has been using these boxes since 2014 to monitor a regional grid comprising around 1,000 electricity consumers.

In order to take things a step further, DEPsys has joined forces with the Federal Institute of Technology Lausanne and the University of Applied Sciences Yverdon to develop a novelalgorithm that enables modules to control power plants, battery storage facilities or loads in a low-voltage network such that system overloads as well as irregular voltage fluctuations and peaks are avoided. In the next few years, energy distributor RomandeEnergie aims to test this new grid monitoring and management system in a large-scale field trial.

While "GridEye" modules exchange data between one another, they do not have to transmit them to a central server for processing. This means that each module operates decentrally and processes the data locally in the network node where it is installed. The main innovation is the algorithm which once a minute calculates a parameter that can be used to infer voltage variations at specific grid nodes, caused by injection and withdrawal of power plants distributed throughout the grid and storage facilities. A variety of technologies can be used for data transfer between the individual modules: transmission via the electricity grid, radio frequency technology or GSM mobile networks. If required, decentrally processed data can also be transmitted to a central control system and thus enable the optimisation of the entire distribution network. In the event of an interruption in data transmission, just as in other centrally controlled systems it is no longer possible to optimise the entire network, but the "GridEye" modules distributed in the network can nonetheless continue to quasi optimise the grid locally by obtaining data from neighbouring modules.

Benedikt Vogel, Michael Moser

Container for measuring daylight illuminance set up at the Lucerne University of Applied Sciences and Arts in Horw: view of exterior (above) and interior (below).

Sun blinds as the focal point

Optimising the energy demand of buildings is regarded one of the most promising ways of reducing energy consumption in the future, but at the same time it also represents one of the biggest challenges. The requirements of occupants often run contrary to the energy-optimised operation of buildings. In view of this, a precise understanding of user demand is essential when it comes to improving the level of energy efficiency in buildings. This applies in particular to sun blinds.

Sun blinds have to meet a variety of conflicting requirements: for example, they have to protect the occupants against sunlight, and at the same time let sufficient light into the interior so that there is no need for artificial lighting. The need for protection against sunlight has increased considerably in the recent years. Sunlight is a problem in offices with computer screens in use, and as a consequence blinds are frequently drawn during periods in which sunlight would in fact be desirable as a source of light and heat.

In a project carried out by Estia SA (a spin-off of the Federal Institute of Technology Lausanne), the operation of blinds on three office buildings was monitored throughout an entire year. Webcams installed on neighbouring buildings took hourly photographs of a total of 125 windows equipped with manually operated blinds. One of the facades faced east, one faced south and the third faced west. In the course of the year, the cameras recorded more than 500,000 images. Estia SA used these as the basis for recording all movements of the blinds, and found that the occupants were very bad at managing their protection against sunlight. For example, on average only 1.74 movements were recorded per window per week, and only 12 percent of the occupants changed the position of the blinds more

West facade of an office building with manually operated blinds on a cloudy day: use of blinds is random and only a few are in the appropriate position (shown in red). The lights are on in some of the offices with the blinds partially drawn (shown in yellow).

than four times a week. The blinds were only drawn if the occupants were blinded by the sun. And later on nobody thought about opening them again.

The study set out to determine whether automated blinds lead to better result than manually operated ones. The study showed that savings of between 17 and 20 percent in terms of lighting requirement were achieved during office hours, depending on the method of automation. These calculations were based on a light-level requirement of 500 lux in the offices as specified in the relevant SIA standard. During the study, however, it was observed that lighting levels in offices was often only around 150 Lux because the occupants focussed on their computer screens and only sporadically needed lighting at their desk. At such low lighting levels, savings were even higher at 27 to 35 percent).

In early 2014, the Lucerne University of Applied Sciences and Arts set up an experiment using a container in which a work desk was continuously and precisely oriented towards the sun. With the aid of this revolving container it was possible to study the effects of various types of sun blinds on the quality of lighting at the workplace. Seven commercially available sun protection systems were analysed and the manufacturers' supplied specifications concerning translucency were also closely examined. A surprising finding was made regarding the difference between slat blinds and vertical fabric blinds: until now it had always been assumed that, if the slats are opened horizontally, slat blinds let in more daylight than vertically oriented fabric blinds, but this assumption was not confirmed by the measurements carried out by the University of Lucerne researchers. Instead they found that both types of blinds let in roughly the same amount of daylight if they are of the same colour. For both types, dark colours should no longer be used because they excessively limit daylight illuminance.

Also, in this study the importance of the control mechanism was emphasised: the operating strategy defined in the building automation system is a decisive factor when it comes to use of daylight, and is more important than the design and material of the blinds themselves. In both studies it was noted that control mechanisms should not be too complex, otherwise they would be susceptible to malfunctions. Frequent movements of blinds disturb building occupants and thus reduce the acceptance of automated control.

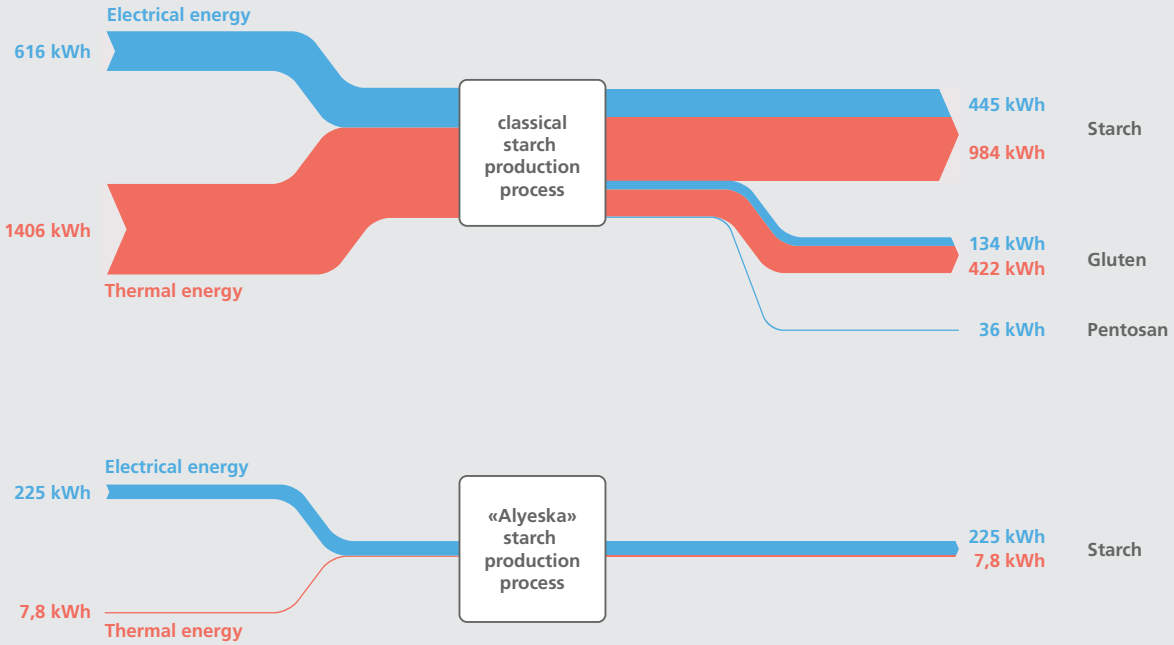
Rolf Moser

An extruder is the central component in the new facility at Meyerhans Mühlen AG for the production of starch for use by the papermaking industry.

Energy-efficient starch production

Profit margins of Swiss grain mills are under pressure due to overcapacities in the production of flour and growing imports of dough and baked products. Against this backdrop Meyerhans Mühlen AG (based in Weinfelden, canton of Thurgau) has developed a process for manufacturing a starch product from wheat flour for use by the paper industry. This product can compete with imported products in particular because the innovative manufacturing process requires significantly less energy.

Corrugated cardboard is a light and sturdy packaging material, and more than 350,000 tonnes of it were produced by the Swiss paper industry in 2014. To ensure that it attains the requisite strength, the cardboard is reinforced with starch during the production process. Generally, paper mills produce the necessary starch-based adhesive themselves using imported wheat, potato or corn starch. The conventional production uses and energy-intensive wet process: water heated to 55° C is turns wheat flour into dough that is then separated into starch, gluten and pentosans (mucilaginous substances) in a series of processing steps that require electricity. The starch then has to



Sankey diagram relating to one tonne of starch product: the innovative "Alyeska" process for starch production requires significantly less heat (red) and electricity (blue) than the conventional starch production process.

be dried, which requires a considerable amount of heat, and is subsequently transformed into a powder.

Meyerhans Mühlen AG has developed a new process to directly manufacture starch from wheat flour for use by the paper industry. In an entirely new process, a so-called extruder is used to squeeze wheat flour treated with process additives through a perforated plate with the aid of a screw conveyor. Thus pellets are produced which are then finely ground to finish up as a starch product which contains starch in its released form. This means it can be directly used in the paper mill for the production of the required starch-based adhesive.

The advantage of the new versus the conventional process is that the two-step process involving heating and subsequent drying is no longer required resulting in major energy savings. But the new process also offers advantages for paper mills: because the starch is already available in released form and there is no need to use natural starch for producing the adhesive, the two energy-intensive process steps (oxidative / enzymatic breakdown of the starch and additional breakdown of the starch by means of steam injection) are no longer necessary. When compared to the conventional, wet method of producing starch, the new process requires 84 percent less energy. The electricity consumption is reduced by 49 percent and the heat requirement by 99 percent.

Benedikt Vogel

IN BRIEF ...

A fuel-cell powered post bus on its way from Birmenstorf to Gebenstorf.

"Smart" distribution network for increasing uptake of photovoltaics

An increase in the number of photovoltaic systems can give rise to inadmissible voltage increases in the distribution network in a situation with maximum feed-in and simultaneously low load. In the "Smart Grid Eich" project, Basler & Hoffmann and its partners are developing a solution to this problem that does not require a local expansion of the network or other expensive measures such as active load management or battery storage. In a housing development in Frenkendorf (canton of Basel-Landschaft), voltages are measured in the distribution network of the 29 installed photovoltaic systems and data are transmitted to the control centre of the local network operator. If the voltage increases too sharply, individual photovoltaic systems are dynamically regulated in that, in the event of a minor deviation, only the reactive power is initially adjusted and only subsequently the active power of the systems reduced. In contrast with static regulation, with this method losses of energy yield can be largely avoided.

Stefan Oberholzer

A million kilometres on hydrogen

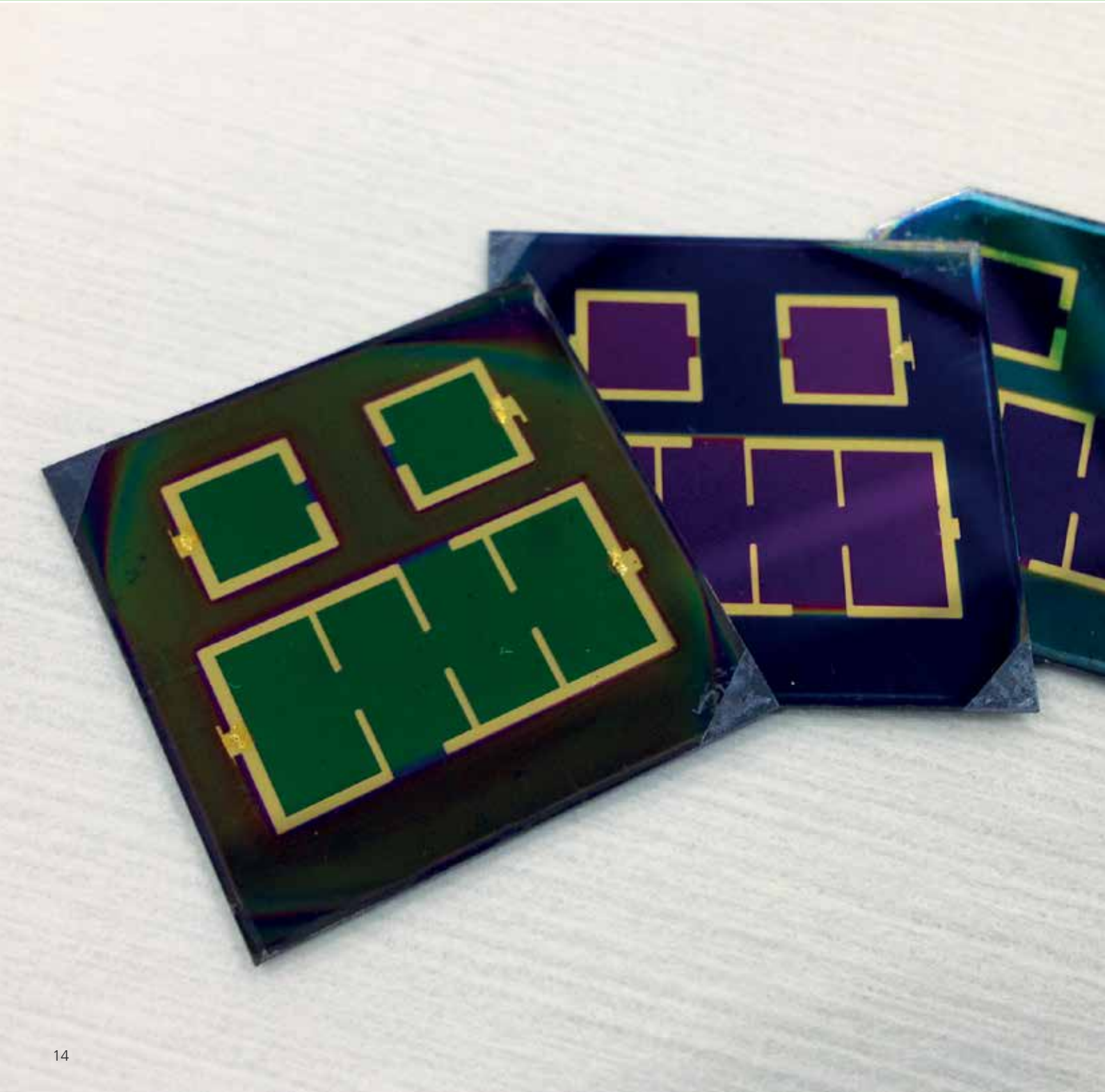
For more than four years now, Postauto Schweiz AG has been operating five fuel-cell powered buses in the Brugg (canton of Aargau) region on 14 of its scheduled post bus services. This field trial is being carried out as part of a major European project (CHIC) in which the driving profile of post buses is being tested in interurban transport. To date, valuable findings relating to the use of this alternative drive technology in the public transport sector have been obtained from the project, especially concerning the operation of Switzerland's first hydrogen fuelling station. Here, hydrogen is produced electrolytically from renewable energy sources, and thanks to this fuel, CO_2 emissions of around 1,200 tonnes have been avoided.

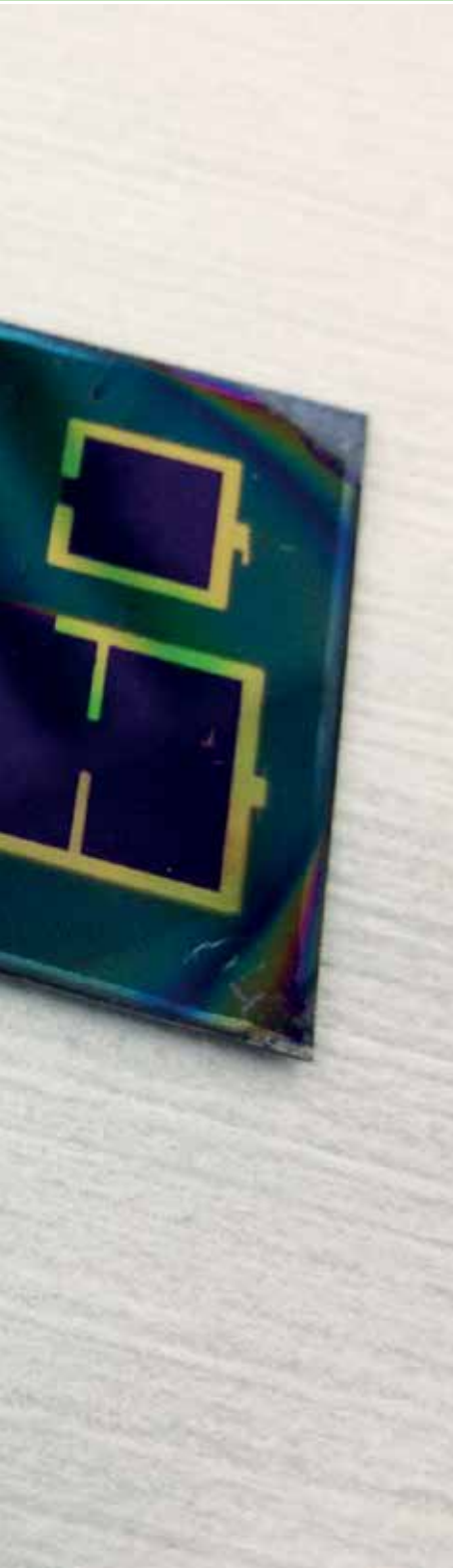
Stefan Oberholzer

Thanks to the dynamic regulation of reactive and active power from photovoltaic systems, it is possible to prevent inadmissible voltage increases in the distribution network without the need to expand the network capacity and without incurring losses in terms of energy yield.

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 installed 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 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.





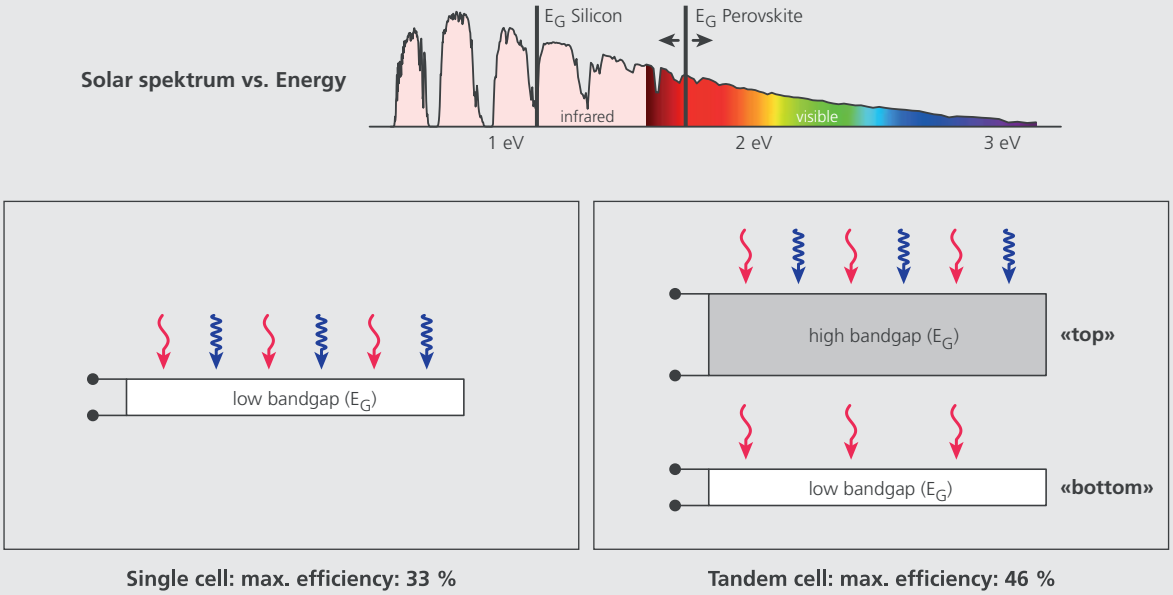
Tandem solar cells for more power

Few experts anticipated the decline in the production cost of photovoltaic electricity by around 80 percent over the past decade. Today, in a number of countries photovoltaic electricity is competitively priced, in comparison with electricity from other renewable sources as well as from fossil-fuelled or nuclear power plants. Additional efficiency gains of photovoltaic modules will drive the reduction of production costs even further.

Solar cells based on crystalline silicon (Si) dominate today's photovoltaics market with a share of more than 90 percent. In the past few years, this technology has seen notable reductions in cost of up to 25 percent for every doubling of production capacity. Key factors include economies of scale (industrialised production) and continuous technological development, resulting for example in a sharp reduction in the utilisation of materials. At the same time, system costs (assembly, land, maintenance, etc.) have risen sharply vs. module costs and now account for around half of the total cost of a typical rooftop installation. Increasing the efficiency of photovoltaic modules even further would reduce system costs significantly.

Since the turn of the century, only a minor increase in the efficiency of crystalline silicon solar cells could be demonstrated in laboratories (from 25.0 to 25.6 percent). Such levels are close to the theoretical maximum for silicon of 29.4 percent. This limit is attributable to the fact that solar cells with a single absorber can only use the portion of the solar spectrum which energy is above the band (or energy) gap of the utilised semiconductor material (cf. illustration on page 16). Most of the higher-energy light is converted into heat and does not contribute to electricity production. Thus, conventional silicon cells are insensitive to a portion of the solar spectrum, both in the blue as well as in the low-energy (infrared) part.

One possibility to make better use of the solar spectrum is to place two cells with different absorber materials on top of each other. Such concepts have already been successfully proven in cell technologies with relatively low efficiency, as well as in highly efficient (but also very expensive) photovoltaic systems. However, tandem cell concepts that include crystalline silicon cells, or solar cells based on copper-indium-gallium-selenide

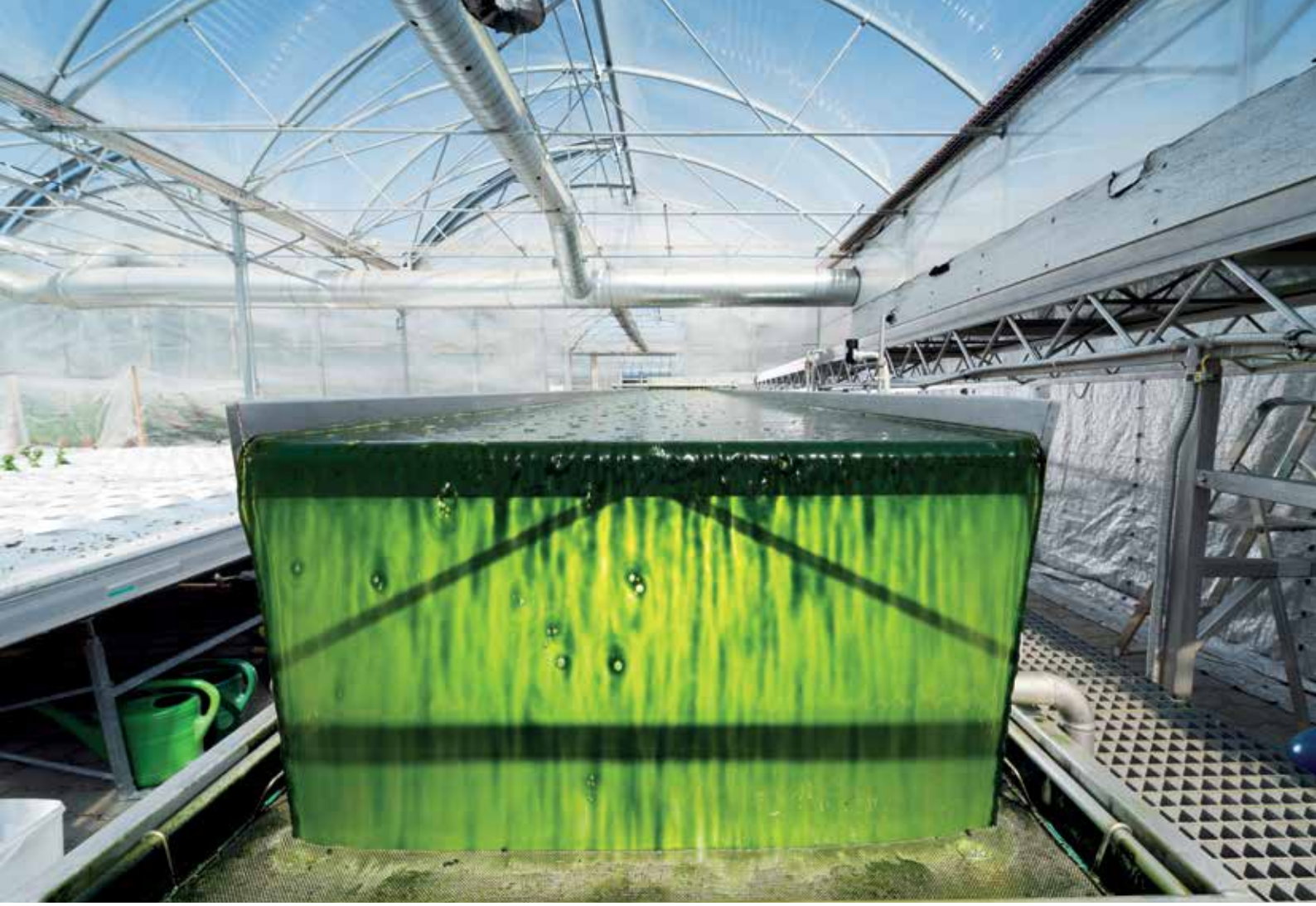


Single cells with one absorber (left) can only use the portion of the solar spectrum with energy larger than the band gap of the specific semiconductor material. Light with a "too high" energy level is transformed into heat. In a tandem cell (right), materials with differing band gaps are stacked so that the top cell absorbs in the blue range. The red light is transmitted and absorbed by the bottom cell.

(CIGS) absorber films, are relatively new. Finding suitable (and above all, inexpensive) "top" cells with a large band gap that can absorb the blue light but are transparent for the infrared part of the sunlight remains a challenge. The so-called perovskite solar cells are regarded as a promising solution. The efficiency of such cells has been increased in laboratory experiments from below four to above 20 percent in only six years. The Federal Institute of Technology, Lausanne achieved a record level of 21.02 percent last year.

In Switzerland, various laboratories at Empa (Swiss Federal Laboratories for Materials Testing and Research), at the Federal Institute of Technology laboratories in Neuchâtel and Lausanne, and at the Swiss Centre for Electronics and Microtechnology (CSEM) are among the world leaders in research and development of cell technology such as CIGS and perovskite cells, as well as crystalline silicon cells, where the focus lies on heterojunction technology. Collaboration among these teams generates synergies in the development of new tandem cells. Current projects explore various options for combining perovskite cells with crystalline silicon or CIGS. One option is to process the upper and the lower cell individually, then join them together mechanically; another is to build up both cells sequentially (monolithic approach). Each approach faces its own challenges: in the first option, four highly conductive contact electrodes are required, three of which need to be transparent, while for the second option, various process parameters (e.g. temperature) of the different cell technologies have to be matched. In early 2016, the Federal Institute of Technology laboratory in Neuchâtel together with the CSEM presented the first stable monolithic tandem cell comprising a perovskite and a silicon heterojunction cell, with an overall efficiency well above the efficiencies of the individual cells.

Stefan Oberholzer



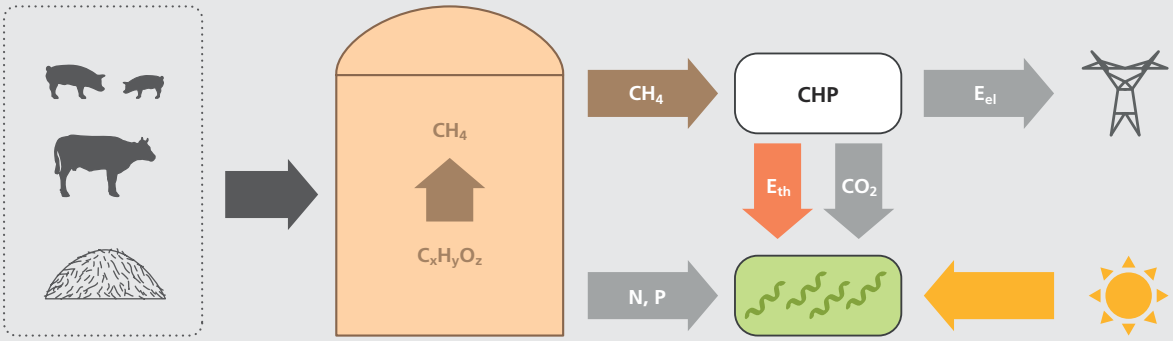
Production of "Chlorella vulgaris" blue-green algae in an open thin-film photo-bioreactor at the Zurich University of Applied Sciences (ZHAW).

Algae from fermentation residue and use of surplus heat

Combining agricultural biogas facilities with spirulina (blue-green algae) production is an attractive concept for extracting an added-value product from residues of anaerobic fermentation. This permits a higher degree of energy recovery from the waste heat and exhaust gases produced by cogeneration plants used in combination with biogas facilities.

Most of the agricultural biogas facilities in Switzerland use the gas obtained from manure and co-substrate to produce electricity and heat via a cogeneration plant. However, only around 20 percent of the produced heat is actually utilised, which limits the facility's overall energy efficiency. Thus an increasing number of agricultural biogas projects in Europe consider the combination of these facilities with spirulina production plants, which are able to make good use of the waste heat. Furthermore, combining these facilities allows to recover nutrients contained in fermentation residue (primarily nitrogen and phosphorous), and utilise the carbon dioxide contained in the exhaust gas of a cogeneration plant.

The production of spirulina microalgae (Arthrospira platensis and Arthrospira maxima) is particularly attractive because this cyanobacterium has a high growth rate and is easy to extract due to the fila-



Combination of an agricultural biogas plant and a spirulina (blue-green algae) production facility.

mentary morphology of adjacent cells. This bacterium is rich in proteins, vitamins, essential amino acids and fatty acids, as well as minerals. Since Spirulina is a valuable source of nutrients, it is the most-cultivated type of micro-alga in the world. On the Swiss market, spirulina products are primarily available in the form of nutritional supplements. Most of the supply is currently imported.

A recent study explored the possibility of technically feasible and economically viable spirulina production in an agricultural biogas plant in Switzerland. To answer this question, an evaluation model was developed that incorporated the reference size of agricultural biogas facilities, the average degree of solar radiation in Switzerland, common types of micro-algae production plants (open tank systems and photo-bioreactors), as well as the various growth parameters for spirulina algae. The resulting model was then applied in scenario analyses, with parameter variations for the sources of carbons and nutrients, the solar radiation conditions and the applicable feed-in conditions for the electricity produced via biogas plants, while energy autonomy was defined as the main criterion for facility sizing.

The findings indicated that, in view of the prevalent solar radiation conditions in Switzerland, only a modest level of spirulina algae production could be reached. In a facility with integrated spirulina production more than 50 percent of the surplus heat from the cogeneration plant could be use, and in theory it would also be possible to utilise the exhaust gas from the cogeneration plant as a carbon source. However, the limited light transmission of the fermentation residue would result in significantly lower algae growth compared to set-ups with external nutrient feed. Consequently, the combination of a biogas plant and an algae production facility would not be economically attractive for any of the examined scenarios.

Nuria Montpart

Transects in the snow in a radius of 100 metres around a wind turbine at the Peuchapatte plant, which were used for carrying out searches for collision victims

Wind turbines and bird migration

The protection of birds is often cited as one of the main arguments against the expansion of wind energy. While the fact that birds can collide with wind turbines cannot be disputed, the actual number of such collisions is not well known.

On their way to warmer climates or nesting sites, migrating birds are likely to encounter numerous wind turbines. In view of this, it is important to understand the correlation between migration intensity and the number of collisions with wind turbines in order to define corresponding countermeasures.. However, there are no studies at all that set out to calculate how many birds pass by a given location, and simultaneously record the number of birds killed there as the result of collisions with wind turbines. A science-based study involving three wind turbines located in the municipality of Peuchapatte in the canton of Jura aims to help close this knowledge gap. In parallel to the search for birds killed as the result of collisions, the study uses permanent radar surveys to determine the intensity of bird migration.

Fox prowling in the immediate vicinity of a wind turbine during the night. The images were shot with the aid of a camera trap.

One of the problems associated with the search for victims on the ground (birds and bats) is that not all of them can in fact be found. On one hand, the probability of finding a collision victim depends on the conditions of the terrain (e.g. height and density of vegetation), the size of the cadaver, the intensity of the search and the skills of the searchers. On the other hand, an unknown number of collision victims disappear naturally (scavengers, decomposition), which depends on a variety of factors such as temperature and humidity. This means that studies aimed at determining the number of collision victims always have to define the discovery probability and disappearance rates under a range of conditions, and take these into account when making their analyses. Obtaining this additional information requires systematic experiments involving the controlled placement of cadavers. The lower the probability of finding a cadaver, the greater the inaccuracy of the calculation of the effective number of collision victims.

With the objective to achieve the highest possible probability rate for the discovery of collision victims, a high frequency of searches in a very confined area was specified for the Peuchapatte study. Searches for collision victims were carried out in the vicinity of each of the three wind turbines on average every three days between March and November 2015. The searches were carried out in a radius of 50 to 100 metres along parallel lines 5 metres apart from one another. At the same time, every two weeks a number of bird and field mouse (as a substitute for bats) cadavers were placed around the site in order to find out how long they remained there. In addition, in the course of the study, test cadavers and dummies of bats were placed on the ground, without the knowledge of the searchers, in order to determine the degree of efficiency of the searches. Some of the cadavers were placed in the vicinity of camera traps in order to investigate what happens to them on site. The recorded data are currently being analysed, and the results will shortly be published on the www.energy-research.ch website.

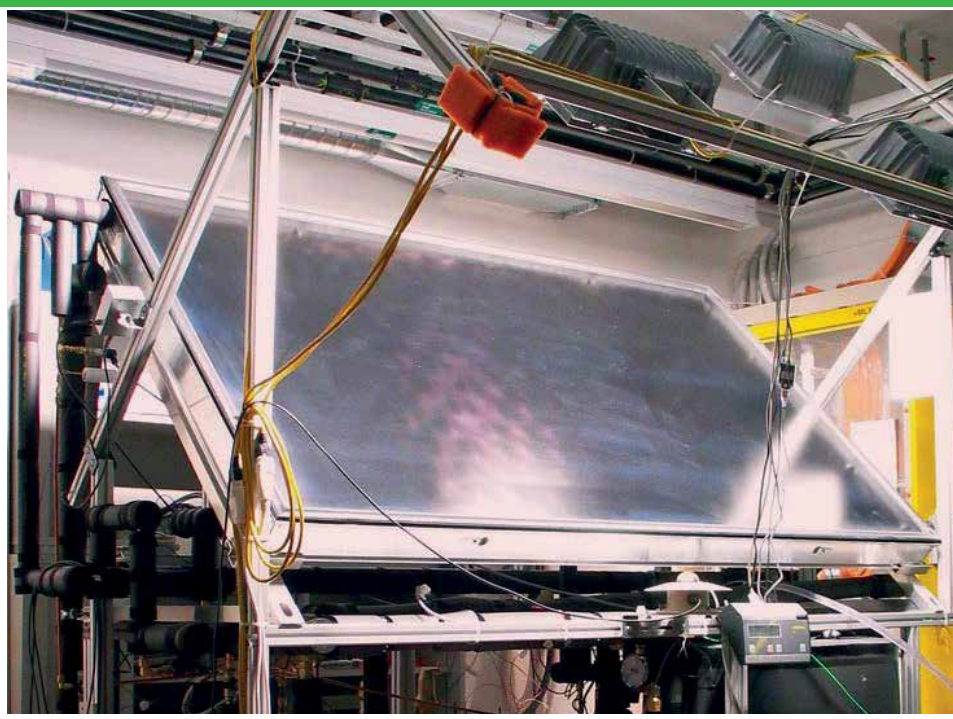
Janine Aschwanden

IN BRIEF ...

Thermo-hydraulics of solar energy systems

Thermo-hydraulic modelling and simulation is one of the essential methods to reduce the costs of solar thermal energy. As part of a thesis prepared at the University of Zurich, a variety of thermo-hydraulic methods and tools were developed and subsequently incorporated into a manual that addresses all tasks associated with the sizing of solar energy systems, except for energy-related sizing, where excellent tools already exist. The new tools help to avoid costs resulting from damage and malfunctions, and thus reduce production costs.

Andreas Eckmanns



At the Federal Institute of Technology, Zurich, a new low-cost method for the solar thermal degasification of hydraulic circuits was developed and patented. Its feasibility was demonstrated on a test bench set up specifically for this purpose.

Laboratory tests for estimating industrial methane production

Operators of biogas facilities need low-cost methods that in order to estimate energy production and the associated economic viability of the plant with an acceptable degree of accuracy. For this purpose, the estimated level of methane production (based on laboratory tests) was compared with the actual quantity measured at selected biogas plants. The results indicate that the level of methane production in the full scale facility is very similar to the estimated level, and that an extrapolation factor of 0.9 can be proposed. Thus it appears reasonable to estimate the level of methane production of an industrial biogas plant with the aid of laboratory tests using the individual substrates.

Sandra Hermle

Biogasplant of Biopower Nordwestschweiz AG in Pratteln (BL).

SOCIOECONOMIC ASPECTS OF ENERGY TECHNOLOGY AND SYSTEMS

The comprehensive "Energy / Economy / Society" research programme focuses on economic, sociological, psychological and political issues along the entire energy value chain. Its purpose is to foster the development of new energy policy instruments and review existing ones. In 2014 a broad range of research projects have been supported that focus on topics as diverse as behaviour of energy consumers, electricity market structure, potential of demand-side management and the potential impacts of energy policy instruments on the national economy.

Communication and planning tool for wind power plants

In order to increase the degree of acceptance of wind power projects among the local population, it is essential to inform residents about the impacts of wind turbines on their surroundings. In a pilot project, a demonstrator was developed with the aim of simulating visual and acoustic conditions in representative Swiss landscapes with wind power plants as realistically as possible.

Today the visualisation of wind power plants usually takes the form of static individual views of a planned wind park, together with abstract noise maps. With these methods, however, the impacts are neither adequately demonstrated nor made sufficiently perceptible to the senses. Therefore the Federal Institute of Technology, Zurich and the Swiss Federal Laboratories for Materials Testing and Research (Empa) joined forces to develop a new type of simulation tool that produces a realistic depiction of landscapes with wind power plants, and also makes noise levels audible.

The novel tool called "VisAsim" comprises a realistic virtual 3D landscape based on digital spatial data provided by the Federal Office of Topography (swisstopo). The virtual landscape is combined with an audible simulation of noise produced by wind turbines. The noise simulation does not only take the type of wind turbine into account, but also the landscape context and the weather situation. In the planning phase of wind power plants, "VisAsim" offers new possibilities to help the local population understand and evaluate projects in their vicinity.

Simulations of wind parks in three typical Swiss landscapes are available as prototypes. With the objective to make simulated wind parks accessible to as broad a public audience as possible, an audio-visual demonstrator was developed in a mobile laboratory.

The "VisAsim" demonstrator was used for the first time in the travelling exhibition, "Wind energy, naturally!", at the Autumn Fair in Weinfelden (canton of Thurgau), where it was perceived as an attractive information tool for the general public. Investors as well as planning authorities believe that the demonstrator has a great potential to facilitate the dialogue with the local population in the planning process.

Ulrike Wissen Hayek, Reto Pieren, Adrienne Grêt-Regamey

Members of the regional conferences visit as part of a training the rock laboratory Mont Terri in St-Ursanne (Canton of Jura).

Site Selection for a deep geological repository

The procedure for selecting a suitable site for a deep geological repository in Switzerland, which is the responsibility of the SFOE, includes a form of participation that is unique not only in Switzerland, but also at the international level, both in terms of its breadth and structure: in the six regions of the country that are under consideration as suitable sites for the storage of radioactive waste, more than 500 people are involved in the participation process. But is this process able to meet the specified requirements? And what are its strengths and weaknesses?

In all six regions, special participation bodies (referred to as "regional conferences") have been established, comprising representatives from the involved municipalities and organisations, as well as local residents. They all bringregional aspects into the selection process.

In 2014, an additional political-science research project focusing on the regional conferences, "Participatory waste disposal policy", was initiated at the University of Bern. The aim of this project is to analyse the actual, ongoing implementation of regional participation in all six site regions. The findings will help the SFOE identify weaknesses and strengths and improve the participatory process based on recommendations for action. The process is to also be compared with other major projects so that the findings and experiences can be put to broader use.

In order to answer the various research questions, the first step was to define the assessment criteria for a participatory. In addition to examining the characteristics of the process itself, the project is also analysing the composition and characteristics of the involved players, as well as their access to information and the results of their participation. The ongoing participation process will then be analysed on the basis of the specified criteria and an evaluation of the relevant literature, plus interviews and surveys.

This comprehensive examination of the participation process forms an integral part of the SFOE's "Radioactive waste" research programme, which coordinates the federal government's regulatory research activities relating to the disposal of radioactive waste. Beyond technical and scientific projects that are the responsibility of the Federal Nuclear Safety Inspectorate (ENSI), the programme also addresses social and cultural issues.

Annatina Foppa

Improved understanding of the behaviour of energy consumers verstehen

The decision by the Federal Council and Parliament to withdraw from the use of nuclear energy on a step-by-step basis calls for a step-by-step restructuring of Switzerland's energy system. The implementation of the proposed new energy policy (Energy Strategy 2050) goes hand in hand with increased energy efficiency and a change in the behaviour of consumers. An arrayof studies is examining the question of how much unutilised potential can still be exploited in order to reduce individual energy consumption.

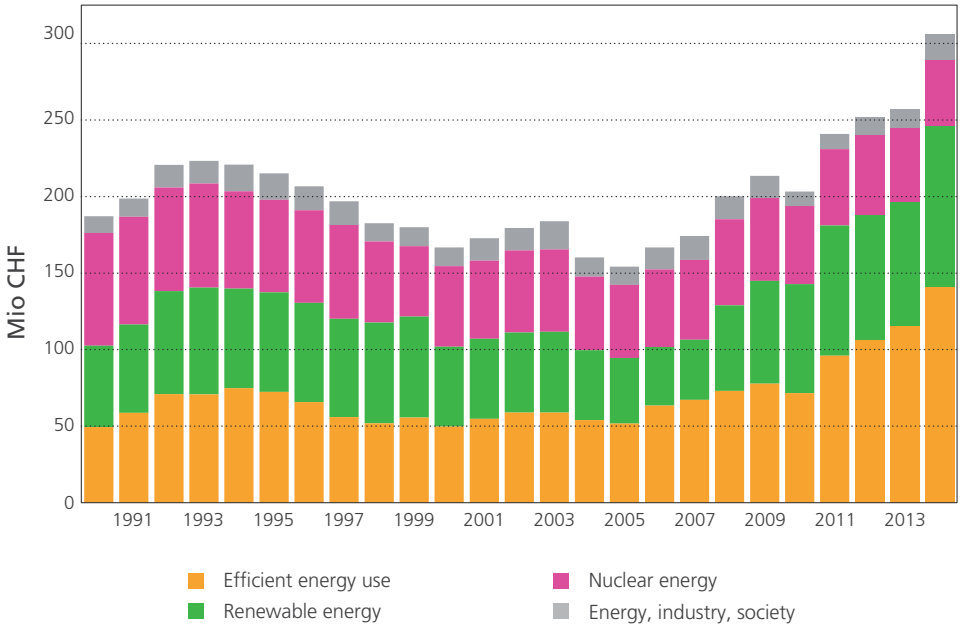
In order to develop and introduce effective energy policy instruments it is necessary to gain an understanding consumers' reactions to price increases, and the working mechanisms of energy efficiency measures. A project initiated by the Federal Institute of Technology, Zurich, set out to assess the reactions of consumers to electricity price increases, and to evaluate energy efficiency measures introduced by Swiss electricity suppliers. The econometric assessments indicate that, in the short term, a pricing policy could have a minor impact on electricity demand, while over the long term, sensitivity to pricing is higher. This means that, over the long term, households do in fact react to a pricing policy. Analyses have also revealed a statistically significant effect of current demand-side management activities in Switzerland on electricity consumption in households. In view of this, demand-side management appears to be a valuable instrument for pursuing the objectives of Energy Strategy 2050.

It is often the case that political instruments aimed at improving energy efficiency focus on price increases, which can be an effective solution, as confirmed by the Federal Institute of Technology study cited above. However, literature relating to psychological and behavioural aspects shows that decisions are not always based on rational considerations, but can also be influenced by a variety of cognitive and emotional factors. The "mental accounting" effect is a phenomenon that illustrates the limits of rational thinking. Consumers can establish symbolic ties between the consumption of specific goods and specific expenditure that can have a considerable influence on their decision-making.

A joint project of the University of Geneva and the University of St. Gallen is currently examining the concept of "mental accounting" in the context of behaviour relating to the environment in general, and in particular to energy consumption. The main objective of this study is to identify to which extent "mental accounting" is of relevance to decisions relating to energy consumption. In particular it also wants to determine whether people apply such principles to environmentally-friendly behaviour, even in a non-financial context. The ultimate objective is to identify the potential of "mental accounting" mechanisms for promoting environmentally-friendly behaviour. The study is to be concluded at the end of 2017, and it is expected that its multi-disciplinary approach will make a valuable contribution towards a better understanding of the energy-related behaviour of consumers.

Anne-Kathrin Faust

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).



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 (FP6)*	*EU*	*Kt./Gmd.*	*others*
2013	148.9	5.0	21.5	28.5	2.4	0.2	23.8	12.6	14.0
	(58.0 %)	*(2.0 %)*	*(8.4 %)*	*(11.1 %)*	*(0.9 %)*	*(0.1 %)*	*(9.3 %)*	*(4.9 %)*	*(5.5 %)*
2014	158.0	17.8	38.4	34.2	2.3	5.3	22.0	21.3	6.4
	(51.7 %)	*(5.8 %)*	*(12.6 %)*	*(11.2 %)*	*(0.7 %)*	*(1.7 %)*	*(7.2 %)*	*(7.0 %)*	*(2.1 %)*

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).

	2013	2014
Efficient energy use	**115.7**	**140.8**
Energy in buildings	26.9	29.0
Mobility and transport	13.9	18.2
Accumulators and supercapacitors	3.4	12.4
Electricity technology and applications	13.1	12.2
Grids and systems	9.2	20.7
Combined heat and power	0.6	0.9
Fuel cells	15.3	15.5
Combustion	18.2	10.8
Power plant 2020 and carbon capture and sequestration	4.3	10.5
Process engineering	10.7	10.6
Renewable energies	**81.0**	**105.1**
Solar	37.6	44.7
Solar heat and heat storage	10.9	6.8
Photovoltaics	21.4	30.2
Concentrated and high temperature solar (CSP)	7.2	7.7
Hydrogen	12.2	15.4
Heat pumping technologies and refrigeration	1.7	3.3
Biomass and wood energy	12.7	16.7
Geothermal energy	9.6	11.5
Wind energy	6.7	3.6
Hydropower	3.3	9.0
Dams	0.6	0.7
Nuclear energy	**48.0**	**43.5**
Nuclear Fission	26.9	21.8
Nuclear Security	12.6	7.5
Radioactive waste	3.4	3.7
Future-oriented research	10.9	10.6
Nuclear fusion	23.4	21.7
Plasma physics and heating technology	16.3	17.2
Nuclear fusion technology	4.8	4.5
Cross-sectional themes	**12.3**	**16.5**
Energy, economy, society	10.2	14.6
Knowledge and technology transfer	1.8	1.3
General coordination	0.3	0.6
Total	**256.9**	**305.9**

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.

PHOTO CREDITS

cover	Integrated photovoltaic system (12.8 kW_p) on the roof of the "Kohlesilo" silo in Basel. The monocrystalline modules in different colors have been developed by the company Swissinso SA in collaboration with the EPFL. Other partners to the project: Kantensprung AG, in situ AG, Solvatec AG and SFOE (Swiss Solar Award 2015 www.solaragentur.ch).
page 0	80 high-performance vacuum tube collectors with a total area of 400 m^2 at the Zehnder Group Switzerland AG in Gränichen (AG) to provide solar process heat (Zehnder Group Schweiz AG/HSR-SPF).
page 2	Ice ball at the "Swiss PV Module Test Center" in Lamone (TI) for the simulation of hail, with a grain size of up to 50 mm (Swiss PV Module Test Center/Renato Quadroni).
page 5	Lago del Zött (Swiss Army, Air Force).
page 6,7	Distribution unit with "GridEye" module for active monitoring in a distribution network (DEPsys SA).
page 8	Swiss Federal Office of Energy SFOE.
page 9	Lucerne University of Applied Sciences and Arts.
page 10	Estia SA.
page 11	Meyerhans Mühlen AG.
page 12	Swiss Federal Office of Energy SFOE.
page 13	Solvatec AG (top), Tis Meyer / Planepics.org (bottom).
page 14,15	EPFL, Institute of Microengineering (IMT), Photovoltaics and Thin-Film Electronics Laboratory (http://pubs.acs.org/doi/full/10.1021/acs.jpclett.5b02686).
page 16	Swiss Federal Office of Energy SFOE.
page 17	ZHAW (Frank Brüderli).
page 18	Swiss Federal Office of Energy SFOE.
Page 19	NATURA biologie appliquée, Sàrl.
page 20	Swiss Ornithological Institute in Sempach.
page 21	ETH Zurich (top), Verband der Schweizerischen Gasindustrie VSG (bottom).
page 22,23	"VisAsim" simulation of a wind farm in the mountains, ETH Zurich.
page 24	Swiss Federal Office of Energy SFOE.
page 27	ETH Zürich, Institute of Process Engineering.
page 29	Winterthur Gas & Diesel (WinGD).

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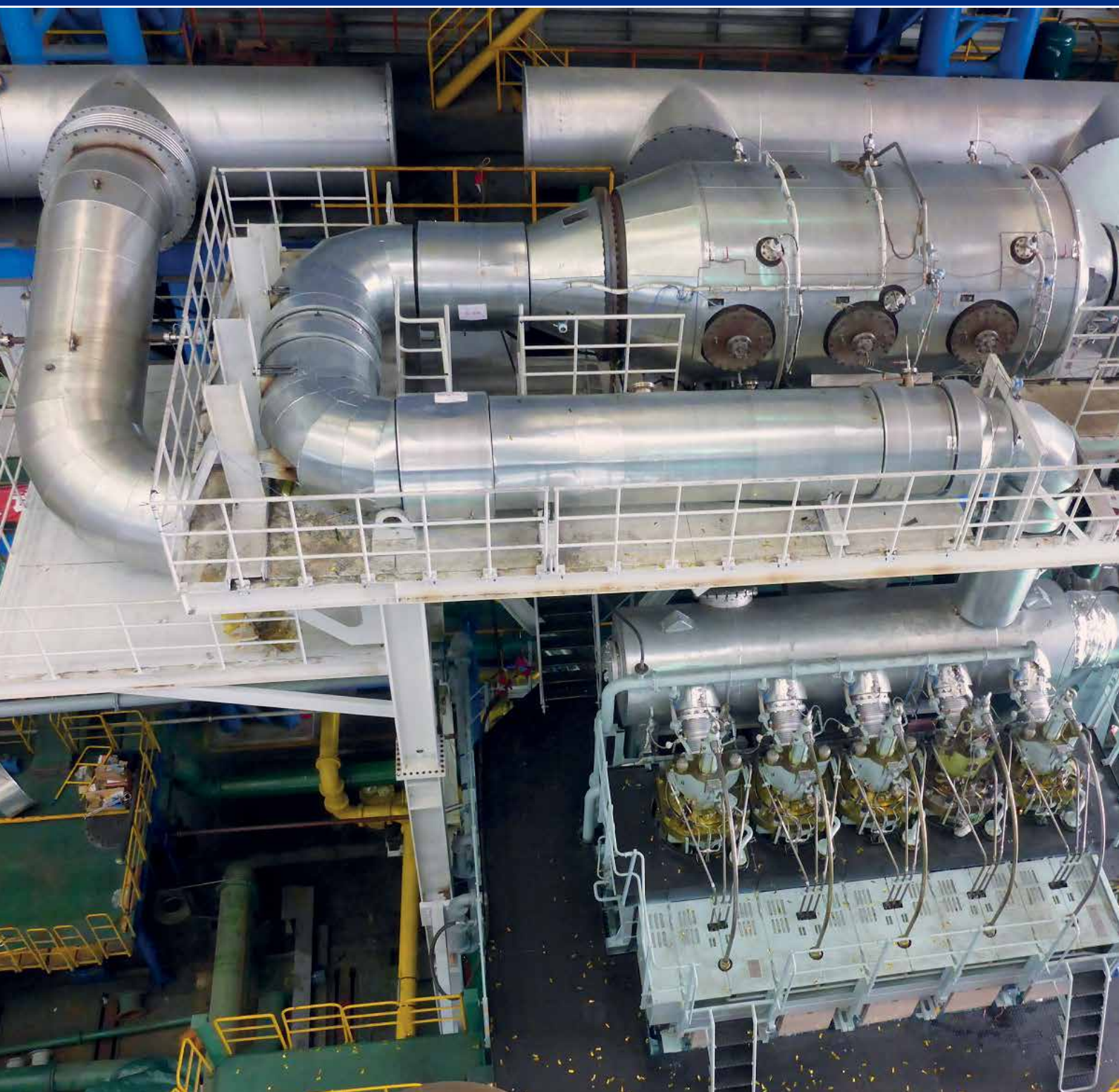
"For Winterthur Gas & Diesel (WinGD), the Swiss Federal Office of Energy is making a major contribution towards the research and development of innovative technologies. Our long-term and highly successful cooperation enables us to consistently perform research at the highest level, particularly in the areas of alternative fuels and environmentally friendly combustion, and thus to secure the Winterthur site in a competitive international environment."

Dr. Sebastian Hensel,
General Manager Engine Performance, Winterthur Gas & Diesel AG



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