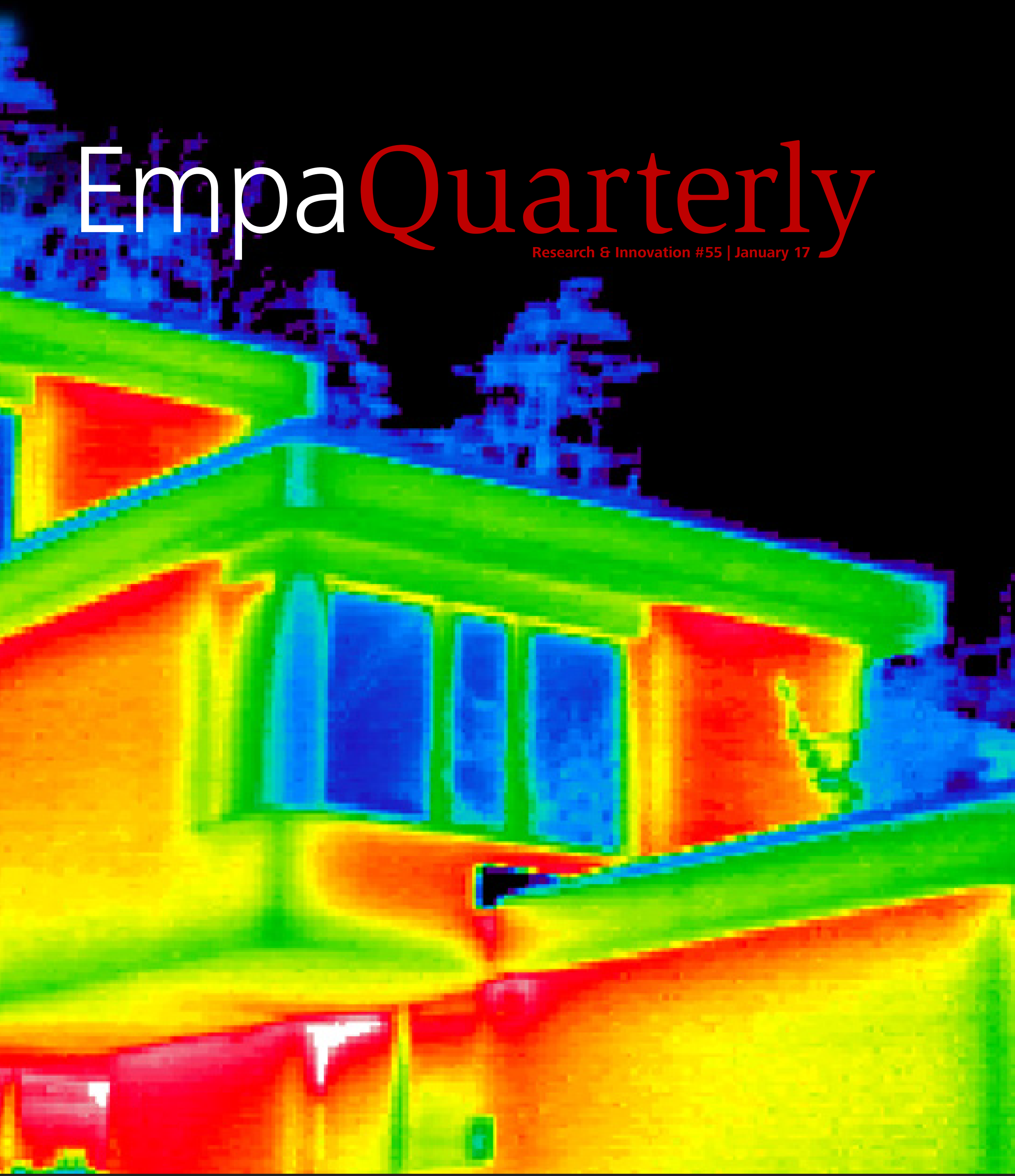
Empa Quarterly

Research & Innovation #55 | January 17



Heat for cold winter days

Energy management in residential areas

Soda lye as heat storage

Health diagnosis for power lines

Empa
Materials Science and Technology

MICHAEL HAGMANN Head of Communications

Dear readers

πάντα ῥεῖ

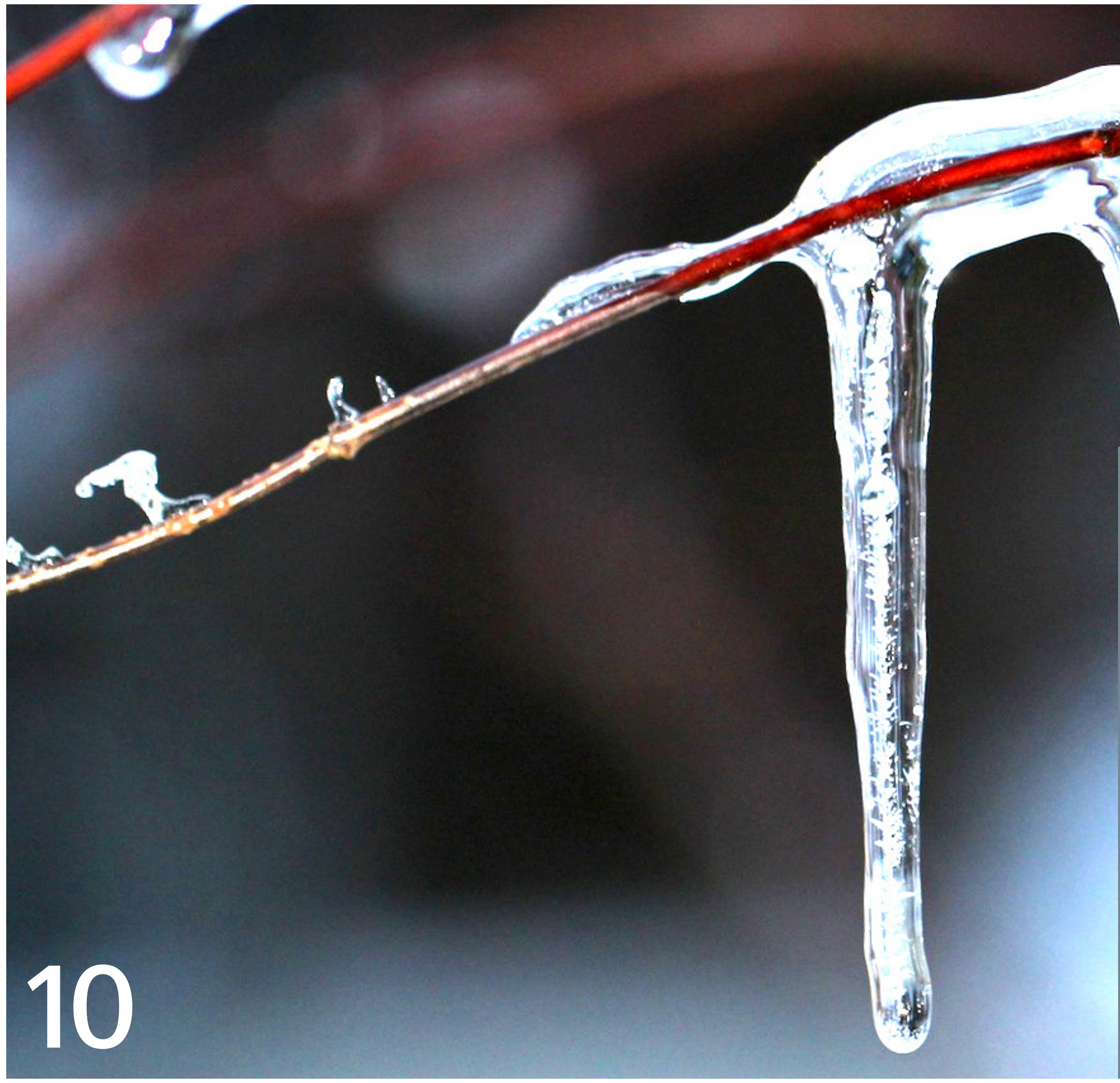
Or panta rhei, which means "everything flows", a phrase coined by old Heraclitus in around 500 BC. His insight applies to everything, especially energy. After all, according to the first law of thermodynamics, energy can't be (re-)created or destroyed, merely converted from one form – such as electrical, chemical or kinetic energy – into another.

And if something flows continually and keeps changing form, it is difficult to harness and store. Although we are able to produce electricity from sunlight thanks to photovoltaic cells – or rather convert solar energy into another form, electrical current (the flow – of electrons – is even in the name!) – it is relatively tricky to store. And not for an unlimited period, either. As we know from our own experience, even the best batteries eventually run down by themselves. So if we want to satisfy our energy demands increasingly with natural energy sources, such as the sun and wind (which fluctuate heavily over time), efficient, long-term energy storage systems are desperately needed.

At the building lab NEST on the Empa campus in Dübendorf, no fewer than 13 different energy storage systems and converters are in use (page 08). And others are in the pipeline, such as a seasonal "heat tank", which is able to store surplus heat from warm summer's days and release it again as and when needed for heating in the cold season (page 12).

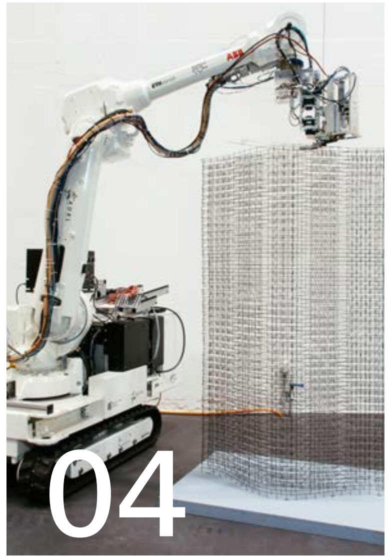
In general, NEST is coming on in leaps and bounds. For instance, several new units are scheduled for the coming year, including on the topics of digital fabrication, material recycling and ultra-light construction (page 04). To finish on a fitting quote for this time of year from the Holy Scriptures: That My House May Be Full!

Happy reading – and all the best for the new year!!!



Focus: next gen energy management

Saving summer heat for cold days



Cover: Thermographic photo of a private home:
An infrared camera is used to measure the heat emitted by an object. The surface temperatures can be displayed in a pseudo color image. For comprehensible, energetic interpretations, high standards are required in terms of photographic conditions and image evaluation. In this case sunlight has warmed up the walls the day before, which compromises the evaluation of heat losses. Photo: QC-Expert AG / Christoph Tanner http://qc-expert.ch.

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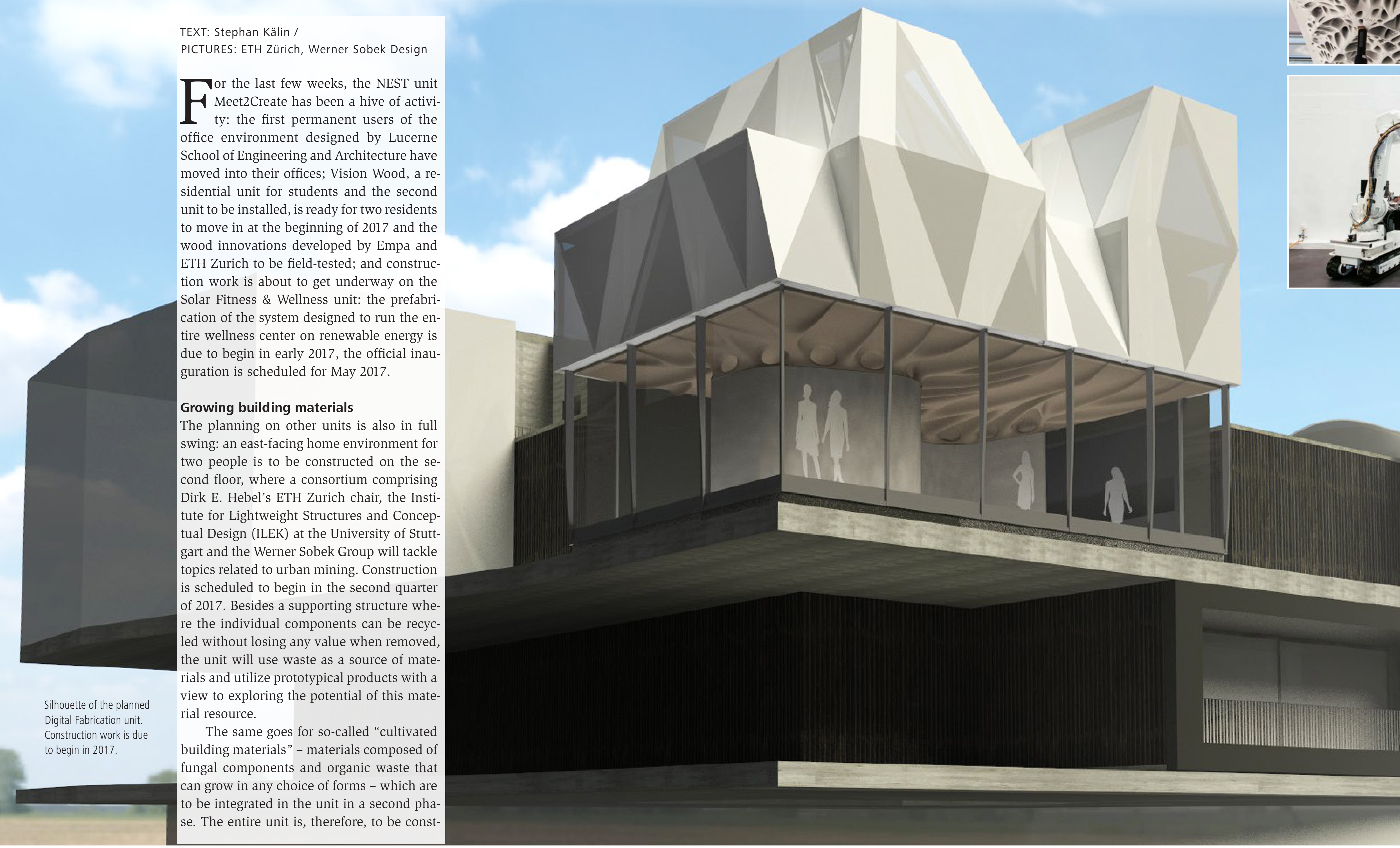
Four new units are to join the research building NEST in 2017. The topics: digital fabrication, material recycling, energy-saving wellness and energy-yielding façades. The prototype for the lightweight roof of a fifth unit is in the pipeline at ETH Zurich.

New NEST units about to arrive



TEXT: Stephan Kälin /
PICTURES: ETH Zürich, Werner Sobek Design

For the last few weeks, the NEST unit Meet2Create has been a hive of activity: the first permanent users of the office environment designed by Lucerne School of Engineering and Architecture have moved into their offices; Vision Wood, a residential unit for students and the second unit to be installed, is ready for two residents to move in at the beginning of 2017 and the wood innovations developed by Empa and ETH Zurich to be field-tested; and construction work is about to get underway on the Solar Fitness & Wellness unit: the prefabrication of the system designed to run the entire wellness center on renewable energy is due to begin in early 2017, the official inauguration is scheduled for May 2017.

Growing building materials

The planning on other units is also in full swing: an east-facing home environment for two people is to be constructed on the second floor, where a consortium comprising Dirk E. Hebel's ETH Zurich chair, the Institute for Lightweight Structures and Conceptual Design (ILEK) at the University of Stuttgart and the Werner Sobek Group will tackle topics related to urban mining. Construction is scheduled to begin in the second quarter of 2017. Besides a supporting structure where the individual components can be recycled without losing any value when removed, the unit will use waste as a source of materials and utilize prototypical products with a view to exploring the potential of this material resource.

The same goes for so-called "cultivated building materials" – materials composed of fungal components and organic waste that can grow in any choice of forms – which are to be integrated in the unit in a second phase. The entire unit is, therefore, to be const-

Silhouette of the planned Digital Fabrication unit. Construction work is due to begin in 2017.

1
Self-supporting concrete floor from a 3D printer. This manufacturing method is to be tested at NEST in 2017.

2
In the construction of the Digital Fabrication unit, a robot will be used to build a supporting concrete wall.

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ructed in such a way that it can be re-used fully as a materials store after demolition. In order to actually be able to exhaust the urban mine in future, an overview of the material flows and the "stock" is required. The Urban Mining and Recycling unit aims to pave the way for the creation of a corresponding 4D cadastral plan.

Robots on the building site
The National Center of Competence in Research (NCCR) "Digital Fabrication" based at ETH Zurich is working on another unit. The researchers' common goal is to combine digital technologies seamlessly with the physical construction process. NEST serves as a real-world test environment for completely novel on-site fabrication and bespoke digital prefabrication technologies. The former involves using the building site robot In situ Fabricator, which will build a steel wire mesh on the building site within the scope of the new construction technology Mesh Mould. At the same time, this mesh will serve as formwork and reinforcement for a supporting concrete wall on the unit's second floor. In bespoke digital prefabrication, non-standardized, highly integrated wooden construction elements that together will form the unit's third floor will be produced at the world's largest architecture and robotics lab at ETH Zurich. Construction on the Digital Fabrication unit on NEST's top platform is due to commence in the spring of 2017 and be completed in 2018.

Façade as an energy source
An der EPF Lausanne schreitet die Planung The planning of the unit SolAce is making headway at EPF Lausanne. The unit will contain living and office space for two people located on the second floor on the southern face of NEST. Construction is scheduled to begin in the second quarter of 2017. In SolAce, the researchers will focus on the façade and the integration of photovoltaics and photothermals. Besides energy production, however, their research will also center on increasing the comfort inside the unit – achieved via optimum daylight control and other active façade elements.

One-to-one prototype of the HiLo roof
The research and innovation unit HiLo demonstrates the possibilities of lightweight construction. For the two-storey penthouse, which will serve as living and office space for guests, the researchers and architects from ETH Zurich are combining ultra-lightweight construction in the flooring and roof and adaptive building technology based on the example of a solar façade. They are currently concentrating on producing prototypes of the roof construction and the adaptive solar façade. Both cases involve novel developments from ETH Zurich, which enable vast quantities of concrete to be saved. However, the novel plank constructions pose major production challenges, which is why one-to-one prototypes are being made before the construction work actually gets underway. The smooth and safe production of the roof construction is the top priority for the entire project. The experiences and test results will then be channeled into realizing the unit, which is currently scheduled to be up and running in 2018.

ehub with its own research group
A separate research group has formed at Empa to run the Energy Hub (ehub). Following a busy few months with the launch and even the first expansions of the systems, the team is now starting the first research projects (see page 08). Meanwhile, the majority of the Water Hub has been installed: all the urine that accumulates at NEST and is separated by the separator toilets is already being converted into liquid fertilizer by Eawag researchers. A proportion of the graywater is being filtered through membranes and finally the fecal matter will be processed into pellets from December onwards. //

3
Layout of the Urban Mining and Recycling unit.

The façade and partition of the Urban Mining and Recycling unit are composed of recyclable materials that can be separated easily after use.

1
Rote Keramikpartikel nach dem Sintern. Neben Chrom sind winzige Mengen weiterer anorganischer Zusatzstoffe nötig, um die satte Farbe zu erzeugen.

2
Keramische Probekörper aus verschiedenen Rezepturen: von Blassgelb über Rostbraun bis zu schönem, tiefem Rot.

3
Das Spitzenmodell der Omega Speedmaster «Moonphase» ist aus Platin gefertigt und auf 57 Exemplare limitiert. Nicht nur die Lünette, sondern auch die Mondphasenanzeige und die Lupenfassung des Datumzeigers sind aus roter Empa-Keramik gefertigt.

Underground energy revolution

How can we organize energy supply in the post-fossil era? How can energy be stored efficiently? And how can we organize distribution as economically and conveniently as possible? Empa's research platform "ehub" is searching for answers to these questions.

These men distribute energy: Reto Fricker, Ralf Knechtle, Philipp Heer and Sascha Stoller conduct research at ehub and control the energy network.

Video
«ehub – Energy Hub»
https://youtu.be/9AYjA7-lmxA

TEXT: Rainer Klose / PICTURES: Empa

The "NEST" research building on the Empa campus in Dübendorf proudly shows off its research projects assembled on open platforms: the wooden façade of the "Vision Wood" unit, the projecting meeting rooms of the "meet2create" office experiment and soon the glass façade of the "Solar Fitness & Wellness" unit spanning two floors. Yet a decisive – and perhaps the most visionary – part of the research work is hidden behind the scenes. The NEST research modules and the mobility demonstrator "move" are connected via an innovative and particularly flexible energy network. Together they form a kind of neighborhood of the future, which could demonstrate how we should design and operate energy supply in our cities over the next decades.

State-supporting or independent?

Homes of the future can self-supply with energy for extended periods. However, they are not entirely independent. They connect to the public electricity grid at regular intervals, feeding in electricity from solar units or collecting additional energy at times of peak load or over longer periods, like in winter.

But what's the best way to regulate this system? And whose interests ultimately determine how it is run? Is it the energy suppliers, who understandably want an electricity network with maximum stability and predictable loads as well as access to emergency reserves at times of peak demand? Should they be allowed in such cases to switch appliances in private households on and off in order to keep the grid stable, serve the public good (and maximize their profits at the same time)? Should energy suppliers install and operate new technologies for residents, or is it the job of the private households to use energy in the most economical way? Is it up to the residents to run their homes ecologically and reduce their carbon footprint – or should they instead use energy from the most reasonably priced source in each case?

What about suppliers who are looking to establish new, personal services with knowledge gathered from the internet – and thus overload the grid in a way hardly foreseeable for network operators? What if a storage battery in the building is not just used to optimize one's own consumption, but also to avoid high tariffs and any usage restrictions from the operator?

These questions are relevant not only from a social and economic perspective but also from a technical point of view, as there has been insufficient research to date on the technical solution for future feed-in and procurement rules. Empa's energy research demonstrator, the "Energy Hub" ("ehub" for short) aims to provide answers and demonstrate what is possible. Once NEST is fully occupied, up to 15 research units with apartments, offices and leisure facilities will be supplied by ehub. This means that it will cover the energy consumption of 40 residents as well as 40 people working in the building during the day. The energy consumption of the individual units will change several times during the day, thus altering the direction of the energy flow. For example, the midday sun will shine on the solar panels on the roofs of the residential modules where no-one is using energy, while at the same time energy is needed in the office section. In the evenings, the excess heat from the modules with southwest-facing façades can be diverted to heat the sauna in the gym and spa.

Summer heat for the winter

Together with energy management throughout the course of a day, storage media are also being tested that can store energy over a day, a week or even an entire season. The interplay of all these components should then show what is possible in terms of the optimum distribution and use of energy in a renewables age. ehub has an ice storage unit comprising 65 cubic meters, two geothermal probes drilled 260 meters into the earth and one spiral geothermal probe that goes down twelve meters into the ground. In the summer time, heat from the sun is used to defrost ice, while in the winter a heat pump cools the water to freezing. This allows the crystallization heat released upon freezing to also be used.

Warm water with a temperature of up to 80 degrees is circulated around the three geothermal probes in the summer, and the stored heat in the ground can then be recuperated into the homes during the winter half-year. NEST also has supercondensators for fast elec-

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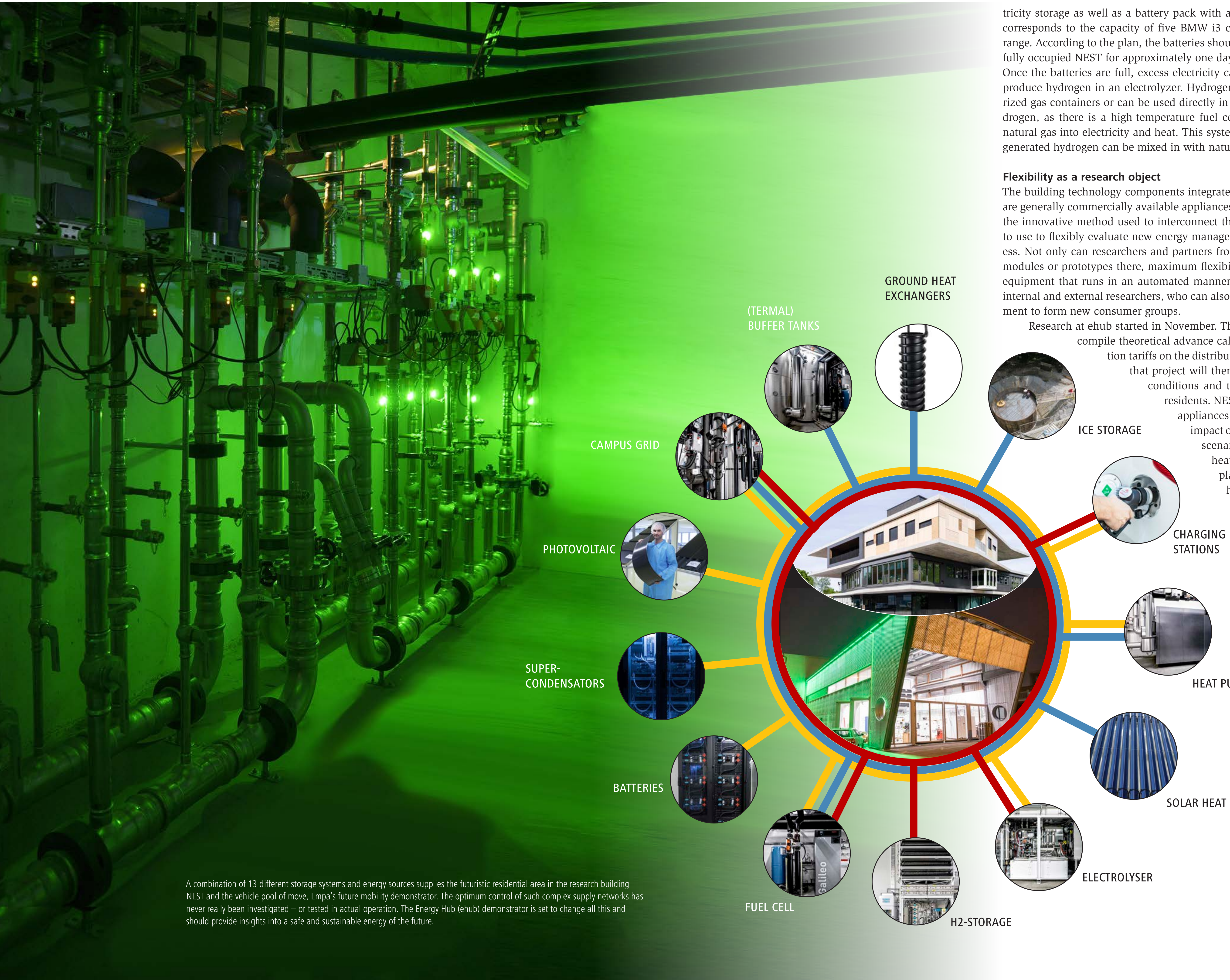


A combination of 13 different storage systems and energy sources supplies the futuristic residential area in the research building NEST and the vehicle pool of move, Empa's future mobility demonstrator. The optimum control of such complex supply networks has never really been investigated – or tested in actual operation. The Energy Hub (ehub) demonstrator is set to change all this and should provide insights into a safe and sustainable energy of the future.

tricity storage as well as a battery pack with a capacity of 96 kWh (kilowatt hours). That corresponds to the capacity of five BMW i3 cars or one Tesla Model S at the top of the range. According to the plan, the batteries should be able to store enough energy to fuel the fully occupied NEST for approximately one day.

Once the batteries are full, excess electricity can be diverted to move, where it is used to produce hydrogen in an electrolyzer. Hydrogen can be stored for several weeks in pressurized gas containers or can be used directly in fuel cell cars. NEST itself can also reuse hydrogen, as there is a high-temperature fuel cell in the basement that normally converts natural gas into electricity and heat. This system is to be used to test how much internally generated hydrogen can be mixed in with natural gas.

Flexibility as a research object

The building technology components integrated in NEST are not prototypes. Instead, they are generally commercially available appliances in line with the state of the art. The trick is the innovative method used to interconnect the components, which the researchers hope to use to flexibly evaluate new energy management scenarios and analyze their effectiveness. Not only can researchers and partners from industry install and validate new control modules or prototypes there, maximum flexibility of regulation is also possible. All of the equipment that runs in an automated manner in normal operation can be overridden by internal and external researchers, who can also add new algorithms and combine the equipment to form new consumer groups.

Research at ehub started in November. The first project for the ehub researchers is to compile theoretical advance calculations of the effects of electricity production tariffs on the distribution network. The hypotheses resulting from that project will then be implemented in ehub under real-world conditions and tested in practice in collaboration with the residents. NEST can also be used to simulate the effects of appliances and users that have a positive or negative impact on the stability of the network – in an extreme scenario even blackouts or the breakdown of the heating and ventilation system. The research platform allows for risk-free simulations, as it has a fallback level that can quickly re-establish normal operations.

The ehub research project will provide findings on how much energy is needed in residential areas and what the peaks are as well as on how the required energy volume can be sensibly reduced to a minimum. Some of the information gained will tell us how independently residential and office districts can manage their energy supply, and to what extent future legislation and directives can be used to encourage behavior that serves the interests of the grid. This makes ehub a political as well as a technical and ecological research project. //

The 13 energy sources and storage media at ehub are attached to three different interconnected energy grids: natural gas and hydrogen (red ring), thermal network (hot + cold water) (blue ring) and electricity (yellow ring). A fuel cell, for instance, can convert hydrogen into electricity and heat. The heat pump needs electricity and generates hot water.

Summer heat for the winter

Can thermal solar energy be stored until wintertime? Within a European research consortium Empa scientists and their colleagues have spent four years studying this question by pitting three different techniques against each other.

TEXT: Rainer Klose / PICTURES: Empa

We are still a far cry from a sustainable energy supply: in 2014, 71 percent of all privately-owned apartments and houses in Switzerland were heated with fossil fuels, and 60 percent of the hot water consumed in private households is generated in this way. In other words, a considerable amount of fossil energy could be saved if we were able to store heat from sunny summer days until wintertime and retrieve it at the flick of a switch. Is there a way to do this? It certainly looks like it. Since autumn of 2016, following several years of research, Empa has a plant on a lab scale in operation that works reliably and is able to store heat in the long term. But the road to get there was long and winding.

The theory behind this kind of heat storage is fairly straightforward: if you pour water into a beaker containing solid or concentrated sodium hydroxide (NaOH), the mixture heats up. The dilution is exothermic: chemical energy is released in the form of heat. Moreover, sodium hydroxide solution is highly hygroscopic and able to absorb water vapor. The condensation heat obtained as a result warms up the sodium hydroxide solution even more.

Summer heat in a storage tank

The other way round is also possible: if we feed energy into a dilute sodium hydroxide solution in the form of heat, the water evaporates; the sodium hydroxide solution will get more concentrated and thus stores the supplied energy. This solution can be kept for months and even years, or transported in tanks. If it comes into contact with water (vapor) again, the stored heat is re-released.

So much for the theory, anyway. But could the beaker experiment be replicated on a scale capable of storing enough energy for a single-family household? Empa researchers Robert Weber and Benjamin Fumey rolled up their sleeves and got down to work. They used an insulated sea container as an experimental laboratory on Empa's campus in Dübendorf – a safety precaution as concentrated sodium hydroxide solution is highly corrosive. If the system were to spring a leak, it would be preferable for the aggressive liquid to slosh through the container instead of Empa's laboratory building.

Unfortunately, the so-called COMTES prototype didn't work as anticipated. The researchers had opted for a falling film evaporator – a system used in the food industry

Heat exchangers from instant water heaters provided the solution: the sodium hydroxide solution spirals along a pipe, absorbs water vapor and emits heat.

to condense orange juice into a concentrate, for instance. Instead of flowing correctly around the heat exchanger, however, the thick sodium hydroxide solution formed large drops. It absorbed too little water vapor and the amount of heat that was transferred remained too low.

Then Fumey had a brainwave: the viscous storage medium should trickle along a pipe in a spiral, absorb water vapor on the way and transfer the generated heat to the pipe. The reverse – charging the medium – should also be possible using the same technique, only the other way round. It worked. And the best thing about it: spiral-shaped heat exchangers are already available ex stock – heat exchangers from flow water heaters.

Fumey then optimized the lab system further: which fluctuations in NaOH concentration are optimal for efficiency? Which temperatures should the inflowing and outflowing water have? Water vapor at a temperature of five to ten degrees is required to drain the store. This water vapor can be produced with heat from a geothermal probe, for instance. In the process, 50-percent sodium hydroxide solution runs down the outside of the spiral heat exchanger pipe and is thinned to 30 percent in the steam atmosphere. The water inside the pipe heats up to around 50 degrees Celsius – which makes it just the ticket for floor heating.

"Charged" sodium hydroxide

The While replenishing the store, the 30-percent, "discharged" sodium hydroxide solution trickles downwards around the spiral pipe. Inside the pipe flows 60-degree hot water, which could be produced by a solar collector. The water from the sodium hydroxide solution evaporates; the water vapor is removed and condensed. The condensation heat is conducted into a geothermal probe, where it is stored. The sodium hydroxide solution that leaves the heat exchanger after charging is concentrated to 50 percent again, i.e. "charged" with thermal energy.

"This method enables solar energy to be stored in the form of chemical energy from the summer until the wintertime," says Fumey. "And that's not all: the stored heat can also be transported elsewhere in the form of concentrated sodium hydroxide solution, which makes it flexible to use." The search for industrial partners to help build a compact household system on the basis of the Empa lab model has now begun. The next prototype of the sodium hydroxide storage system could then be used in NEST, for example. //

Benjamin Fumey at his test facility in the lab. The heat cycle has been working since the fall of 2016.

European heat storage technology contest

In the realm of the European research project COMTES, three different heat storage system demonstrators were pitted against each other from 2012 to the spring of 2016.

Project group A (Austria, Germany) studied the storage of water in zeolites. These microporous silicate minerals are found as additives in detergents or as a coolant in self-cooling beer kegs, for instance. They are hygroscopic and emit heat when they become moist.

Project group B (Switzerland, Northern Ireland) studied the storage of heat at a test plant with concentrated sodium hydroxide solution (see article on the left). See all storage projects in Switzerland *www.sccer-hae.ch*

Project group C (Denmark, Austria) examined the storage of heat in so-called phase change materials that melt and solidify. For the experiments, they used sodium acetate, a substance also found in small warming cushions, which are popular among hunters and outdoor enthusiasts. *http://comtes-storage.eu/*

The fight against creeping cables

Switzerland's overhead power lines are showing signs of old age and can be damaged by power surges. But how long will they actually last? Empa researchers have developed a tool to keep tabs on the aging process. This could help to prevent power outages in future.

Stuart Holdsworth preparing a performance test at his test facility.

TEXT: Thomas Gschwind / PICTURES: Empa, Swissgrid

Switzerland's power grid comprises over 250,000 kilometers of lines. Composed of a transmission and a distribution network, the voltage is gradually reduced from 380,000 to 230 volts enroute to the consumer. The aboveground transmission network, some sections of which are more than 40 years old, measures 6,700 kilometers. As it is designed for considerably smaller amounts of electricity from predominantly central power stations, it only partially satisfies today's needs. Nowadays, considerably larger quantities of electricity are transported, and an increasing number of decentralized (small-scale) power stations feed electricity obtained from renewable energy into the grid. The power lines are, therefore, becoming increasingly overloaded and getting hotter and hotter. As Switzerland's overhead high-voltage power lines are almost exclusively made of aluminum alloy while those in neighboring countries are usually composed of pure aluminum and a steel core as interconductors, international research results can only be applied to local conditions to a limited extent. In other words, national research is necessary.

Since 2012 a research group at Empa headed by Edoardo Mazza (ETH Zurich and Empa) and Stuart Holdsworth (Empa) has been studying Switzerland's overhead power lines. As well as examining the properties of individual wires they constructed their own nine-meter-long test facility, which enables the properties of the complete conductor cable to be examined. Aldrey, the special alloy used in Swiss power lines, consists of aluminum (99 %), magnesium (0.5 %) and silicon (0.5 %). The advantage of these conductors: they are highly conductive, more corrosion-resistant and stronger than pure aluminum – and lighter than the steel-reinforced power lines in our neighboring countries with the same tensile strength.

The capacity of today's power grid is limited by several factors. First of all, the actual load limit of the power lines is not known, merely estimated, as there have not been any concrete figures or analyses to date. Now, for the first time, the Empa facility enables the Aldrey wires to be studied for more than 20,000 hours at temperatures between zero and 150 degrees. Below 100 degrees, Holdsworth and his team did not detect any accelerated aging processes or change in electrical resistance. If the temperature rises above 100 degrees, however, the cables age more rapidly and the alloy's strength declines for ever.

The gradual sagging of the high-voltage cables is a major problem on Switzerland's power grid. This kind of distortion is irreversible, which means the cables have to be restressed by a repair crew once they sag. Sagging is also linked to the lines' thermal record: how long has the line been hanging on the pole? and how hot has it become over which period? In the Empa lab, the researchers studied the common conductors – three centimeters in diameter and made of 61 individual wires – to check the predicted sagging values by analyzing the sagging behavior for 2,000 hours and at temperatures of up to 80 degrees. Compared to other metals, aluminum – i.e. including the Aldrey alloy – already tends to "creep" at low temperatures. The wires grow longer in the course of time, causing the sag in the line to increase and the distance from the ground to decrease.

Two different measuring methods developed at Empa might provide clues as to when a line has reached its cut-off age in future. In the case of "offline measuring", a piece of the line is removed and its mechanical hardness tested. By comparing it with a control piece, the condition (aging) can be determined accurately.

The "online measuring" technique can even detect the aging process from resistance measurements of the power line while in operation. This means that aging lines can be monitored remotely. The results of the measurements may help use Switzerland's existing power grid more effectively and at the same time keep it intact. The search for an industrial partner is now underway to develop the concept for monitoring the condition of high-voltage power lines for the market. //

Fighting fungi with fungi

Every pest has a natural adversary, which keeps them in check in nature. Empa researcher Francis Schwarze drew inspiration from this: with the right helper organism, trees and even timber can be protected against fungal parasites, an idea that triggered a new Empa spin-off: MycoSolutions.

TEXT: Martina Peter / PICTURES: Empa

Fungus researcher Francis Schwarze with the granules that can be sprinkled around infested trees. They contain the harmful fungus's antagonist.

There are half a million wooden telephone poles in Switzerland. They are easy to erect and last up to 35 years without the need for any major upkeep. However, the Swiss telecommunications company Swisscom has to replace as many as 5,000 poles a year for its landline infrastructure – many because fungi have caused them to rot. Although the poles are impregnated with biocides such as copper, they are ineffective if copper-resistant fungi transform the copper using oxalic acid and then destroy the wood – resulting in the poles needing to be replaced far sooner than planned.

Francis Schwarze, a wood, tree and fungus researcher at Empa has now discovered a means to protect the wooden poles against copper-resistant fungi: if deployed early enough, another fungus, a natural adversary of wood decay fungi, is able to inhibit the formation of oxalic acid and kill off the pole destroyers. "In nature," explains Schwarze, "fungi keep each other in check." In a forest, this works by itself: "A fungus that destroys wood has an antagonist that stops it in its tracks," says the scientist. In the case of trees and wooden constructions that are planted or erected outside their natural habitat, however, this equilibrium spirals out of control and the pest can spread unimpeded.

The roots of trees planted in cities and parks, where the soil contains little microbial diversity, are especially afflicted by fungi, such as the shelf fungus or the honey fungus. This can cause them to lose their solid footing and become fragile. Quite a few even die off completely from such infections. With these very old, locally important trees and the fungi infesting them, however, Schwarze discovered a corner of the market, which he has been studying closely in recent years. In his spare time, he advised parks commissions in Europe, Australia or Asia on how they could get fungus-stricken trees back in shape again using customized plant fortifiers.

First of all, Schwarze set about isolating and identifying the harmful organisms on the tree. Then all he had to do was "simply" find a natural adversary and turn it into a product – granules – which tree surgeons could scatter in the soil around the trees' stricken roots. As Schwarze recounts, things can sometimes get quite emotional, too: "I've seen seasoned tree surgeons shed a tear when treated trees suddenly start sprouting new roots again."

Identifying the pest and finding its nemesis

For Schwarze, the priority was always the knowledge of the fungi, which he continually channeled into his research projects at Empa. With time, however, he eventually decided to market the knowhow as well. Not only could the condition of trees suffering from a fungal infestation be improved; he also discovered that timber could also be protected as a precautionary measure, as long as its structure still remained intact. And so Schwarze founded a spin-off in St. Gallen with backing from Startfeld, the innovation network of the St. Gallen-Lake Constance region. The fledgling company, MycoSolutions, is looking to develop products from beneficial organisms that might be used as plant fortifiers, fertilizers in organic farming or for the biological control of wood-destroying fungi. The spin-off recorded its first successes with customized products for valuable exotic trees in Northern Italian parks and gardens infested with wood-destroying fungi. MycoSolutions analyzes the samples from a tree's affected area supplied by tree surgeons, isolates the pathogen and evaluates it to customize the suitable antagonist to a certain degree.

Fungi against pests on telephone poles

Schwarze eventually pitched the proposal of using fungi to treat telephone poles infested with fungi to Swisscom. They were extremely interested in environmentally friendly treatments. The telecommunications company agreed to submit a project to the Commission for Technology and Innovation (CTI) together with Empa and MycoSolutions to find out whether and how the lifespan of wooden poles might be preserved and even extended thanks to biological control.

Once the CTI project had been completed successfully, Swisscom signed up for an extended field trial. They are planning to use the substance proactively in the soil around afflicted telephone poles where there is evidence of a fungal infestation. 2,400 bags have been ordered from MycoSolutions already and are expected to be deployed in the summer of 2017. //

Wooden telephone poles are still commonplace in rural areas, like here near Stein am Rhein.

A wooden telephone pole felled by fungi. With the right non-toxic remedies, the poles' lifespan can be extended significantly.

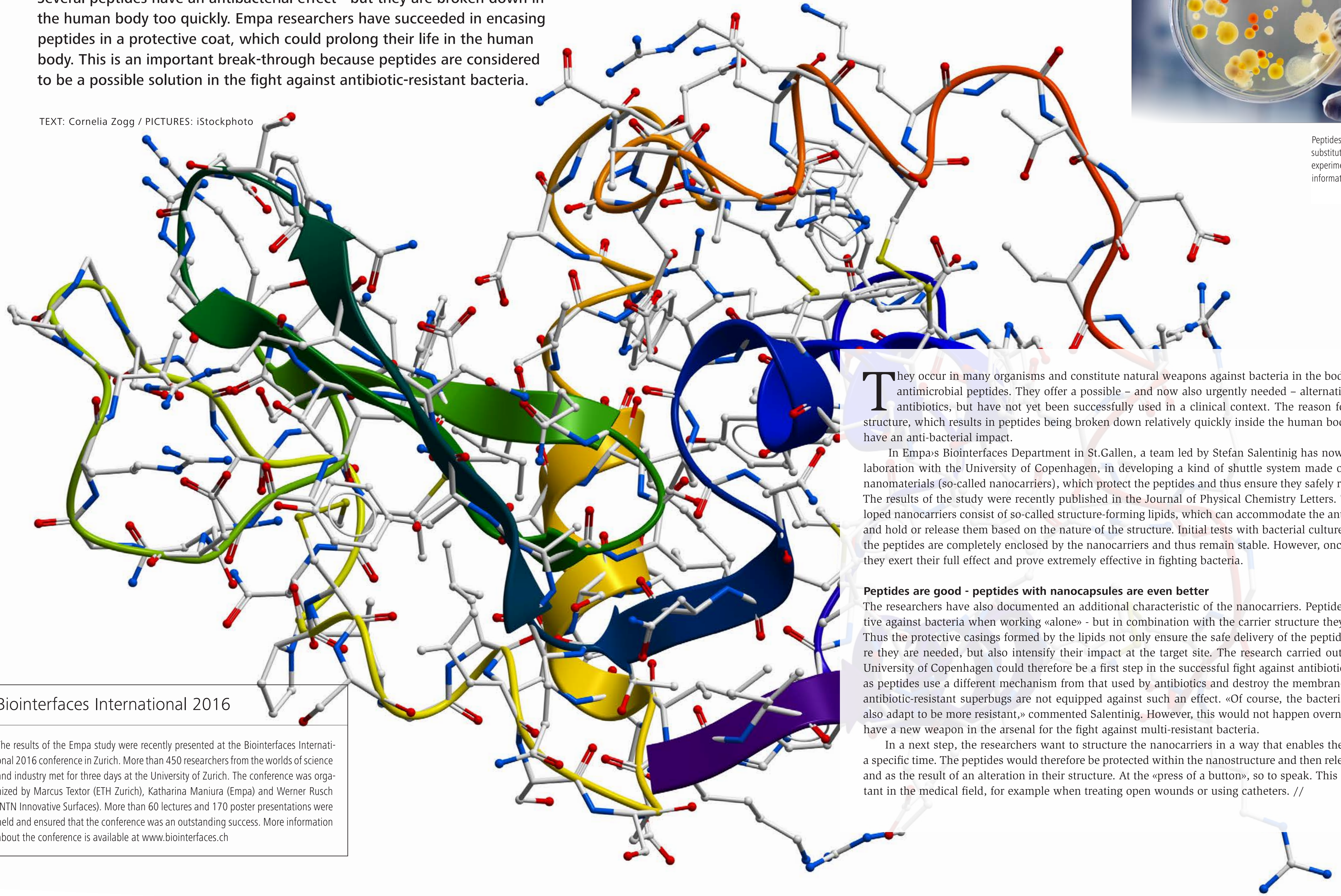
Market entry and production set-up

In the spring of 2016, Reto Vincenz, a business economist with longstanding experience in industrial companies and start-ups, became CEO of MycoSolutions and took over the operative management of the fledgling company. Thanks to start-up funding, in which Vincenz and Swisscom Ventures (the venture capital division of the Swisscom Group) were also involved, MycoSolutions can now make its entrance on the international market and ramp up production.

New weapon against superbugs

Several peptides have an antibacterial effect - but they are broken down in the human body too quickly. Empa researchers have succeeded in encasing peptides in a protective coat, which could prolong their life in the human body. This is an important break-through because peptides are considered to be a possible solution in the fight against antibiotic-resistant bacteria.

TEXT: Cornelia Zogg / PICTURES: iStockphoto



Peptides can kill bacteria and thus substitute antibiotics. A growth experiment in a Petri dish provides information.

They occur in many organisms and constitute natural weapons against bacteria in the body, being known as antimicrobial peptides. They offer a possible – and now also urgently needed – alternative to conventional antibiotics, but have not yet been successfully used in a clinical context. The reason for this lies in their structure, which results in peptides being broken down relatively quickly inside the human body, before they can have an anti-bacterial impact.

In Empa›s Biointerfaces Department in St.Gallen, a team led by Stefan Salentinig has now succeeded, in collaboration with the University of Copenhagen, in developing a kind of shuttle system made of liquid-crystalline nanomaterials (so-called nanocarriers), which protect the peptides and thus ensure they safely reach the target site. The results of the study were recently published in the Journal of Physical Chemistry Letters. The specially developed nanocarriers consist of so-called structure-forming lipids, which can accommodate the antibacterial peptides and hold or release them based on the nature of the structure. Initial tests with bacterial cultures have shown that the peptides are completely enclosed by the nanocarriers and thus remain stable. However, once they are released they exert their full effect and prove extremely effective in fighting bacteria.

Peptides are good - peptides with nanocapsules are even better

The researchers have also documented an additional characteristic of the nanocarriers. Peptides are already effective against bacteria when working «alone» - but in combination with the carrier structure they are even stronger. Thus the protective casings formed by the lipids not only ensure the safe delivery of the peptides to the area where they are needed, but also intensify their impact at the target site. The research carried out by Empa and the University of Copenhagen could therefore be a first step in the successful fight against antibiotic-resistant bacteria, as peptides use a different mechanism from that used by antibiotics and destroy the membrane of bacteria. Even antibiotic-resistant superbugs are not equipped against such an effect. «Of course, the bacteria might eventually also adapt to be more resistant,» commented Salentinig. However, this would not happen overnight and we would have a new weapon in the arsenal for the fight against multi-resistant bacteria.

In a next step, the researchers want to structure the nanocarriers in a way that enables them to take effect at a specific time. The peptides would therefore be protected within the nanostructure and then released when needed and as the result of an alteration in their structure. At the «press of a button», so to speak. This is especially important in the medical field, for example when treating open wounds or using catheters. //

Biointerfaces International 2016

The results of the Empa study were recently presented at the Biointerfaces International 2016 conference in Zurich. More than 450 researchers from the worlds of science and industry met for three days at the University of Zurich. The conference was organized by Marcus Textor (ETH Zurich), Katharina Maniura (Empa) and Werner Rusch (NTN Innovative Surfaces). More than 60 lectures and 170 poster presentations were held and ensured that the conference was an outstanding success. More information about the conference is available at www.biointerfaces.ch

Hot on the heels of cement's formulae

Bridges, houses, dams – for decades, cement has been a permanent feature of our urban environment. What is deemed a robust and lasting material, however, is actually fragile and highly complex on the inside. Barbara Lothenbach understands the building material right down to every last detail – and how it opens up fabulous new possibilities. The Empa researcher was recently elected a Distinguished Senior Researcher in recognition of her many years of outstanding research in cement chemistry.


Empa's concrete expert Barbara Lothenbach.


Lothenbach, environmental chemist by trade, rotates crops in her private garden in a scientific manner.

TEXT: Cornelia Zogg / PICTURES: Empa, private

When we talk about cement, it is usually about its mass, stability and wealth of possible applications. Very few associate the gray building material with the term "environment". Cue Barbara Lothenbach, a researcher from Empa's Concrete/Construction Chemistry laboratory. For her, cement is more than just a run-of-the-mill construction material. Apart from anything else, it can be optimized – both as a material and ecologically. After all, between five and eight percent of the global CO_2 emissions can be attributed to the production of cement. "The most commonly used cement, Portland cement, is made of lime marl, a mixture of chalk and clay, and produced in a combustion process at approximately 1,450°C," explains Lothenbach. This produces 'cement clinker', which is then ground up and mixed with plaster. And limestone contains large quantities of bound CO_2, which escapes into the atmosphere during combustion. However, it is exactly the calcium oxide contained in limestone that gives Portland cement many of its excellent properties.

An environmental chemist by trade, Lothenbach is thus particularly interested in how emissions might be curbed, for instance by replacing cement clinker with alternative materials, such as fly ash from coal burning or slag from the iron smelting furnace. However, fly ash and slag contain far more aluminum than Portland cement, which reduces the cement's solidity and durability. Moreover, different types of cement react very differently to environmental influences such as water, wind, temperature or – in tunnel construction, for instance – the composition of the groundwater. "The better we understand these relationships on a chemical level," explains Lothenbach, "the more efficiently and above all ecologically we will be able to produce cement and use it in practice, such as cement with a higher proportion of fly ash, slag or other promising materials like calcined clay or even unburnt lime-stone."

But even if new types of cement display good solidity and durability, the road to their practical application is long and requires sound proof that these new materials are capable of withstanding any influence. After all, what engineer wants to build a bridge with materials, for which there are no empirical values? While industry can look back on more than a century of experience with Portland cement, our knowledge of such new materials needs to be expanded further, especially when it comes to their long-term behavior.

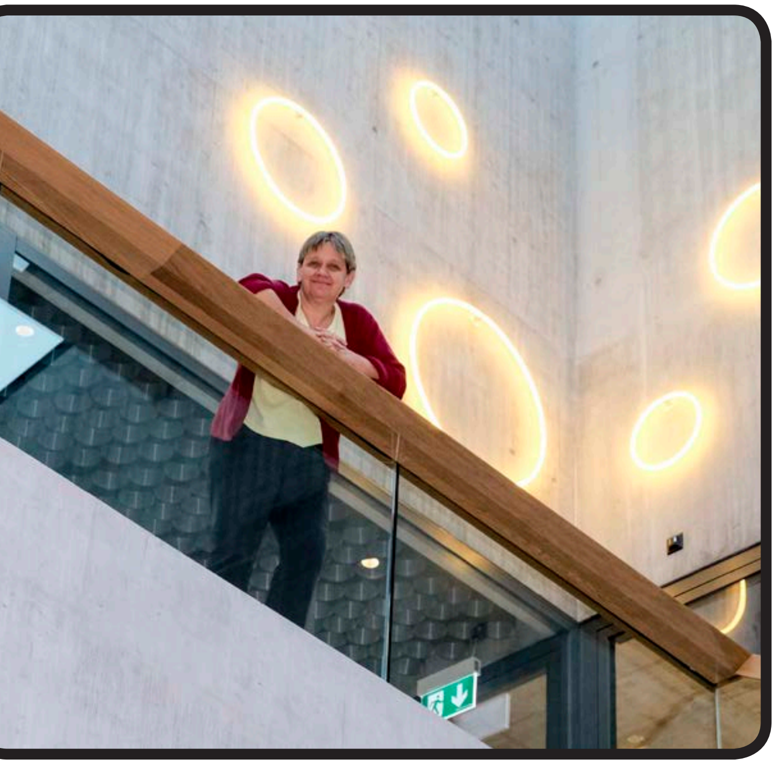
Chemistry and especially the simulation of chemical reactions on the computer can help exclude certain compositions with unsuitable properties from the outset and make predictions on how the cement will behave in different situations and over a period of several years. To this end, Lothenbach uses a giant database that contains the behavior and mutual interactions of countless chemical components. She varies the mixture on the computer and can then use a simulation to calculate how different mixtures will behave under real conditions. For this to work, however, it is vital to know the properties of all the possible cement components in detail and how they interact with each other – knowledge that Lothenbach has acquired during years of research at Empa and that made her one of the world's leading researchers in cement chemistry.

Industry is also actively looking for other substitute materials besides fly ash and slag. In particular, cements based on calcium sulfoaluminates are in the pipeline. The resulting cement has definite advantages: compared to Portland cement, it requires less limestone in the production phase and is burned at temperatures that are approximately 200°C lower, which reduces the CO_2 emissions. If the composition is wrong, however, the cement can expand in volume, which may cause cracking in a structure, as Lothenbach explains. Not only does she conduct basic research with her team; she and her colleagues also collaborate regularly with industrial partners who would like to optimize their product or use it to tackle certain problems. One of these industrial projects focuses on magnesium phosphate cement, which can be used as repair mortar on the one hand, but also as a food additive, in dentistry and as bone substitute.

Finishing touch for large structures

So cement is not just cement. Whether it can be used in bridges, houses, dams, subterranean sewers or to stabilize nuclear waste disposal sites, however, is ultimately all pure chemistry. It is just that you don't immediately think of the smallest components in concrete responsible for its sturdiness when you see a massive highway bridge. "We also have concrete mixers here in our research lab, of course," explains Lothenbach. "But my team doesn't have anything to do with them directly." Instead, her work takes place in the lab – in small test tubes and with samples on a gram scale – and on the computer, where she makes predictions with the aid of simulation programs before checking them in lab tests.

This interplay between lab research and computer simulation carries numerous advantages. By comparing the results of the simulations with lab tests, Lothenbach can keep improving the reliability and validity of the database. The lab tests, on the other hand, give the scientist more leeway when it comes to evaluating the viability of new mixtures or new combinations for industry. "The computer simulations benefit from our



lab experience and vice versa," says Lothenbach.

Besides a mixture of empirical (lab) research and virtual simulation, the exchange between industrial projects and basic research is also what Lothenbach particular cherishes about her job. "This makes working at Empa incredibly varied." Which is in stark contrast to her first impression as a student at the start of her biology degree in Zurich: she had to learn how to skewer insects with pins so they could be catalogued, for instance. "I realized the biology degree was – at least back then – too restricted to the systematics of the living natural world instead of examining topics like ecology and environmental protection." She wanted to get to the bottom of things, understand them and then alter them so they benefit the environment. Consequently, after a year, she switched to environmental chemistry and has never looked back.

A garden blooming with knowledge

Although her professional passion is now cement, she has not forgotten her love of soil, plants and other living organisms. Her main hobby is her garden, where from time to time the scientist in her also bursts through. For instance, she regularly draws up plans of which plants she has planted where and in which year to guarantee a good yield – much like our ancestors, who always rotated crops between different fields. Like novel cement components, plants do not always make happy cohabitants. "Some plants are good neighbors, others have to be planted far apart. One might like dry soil, another enjoy the shade and moisture," says Lothenbach.

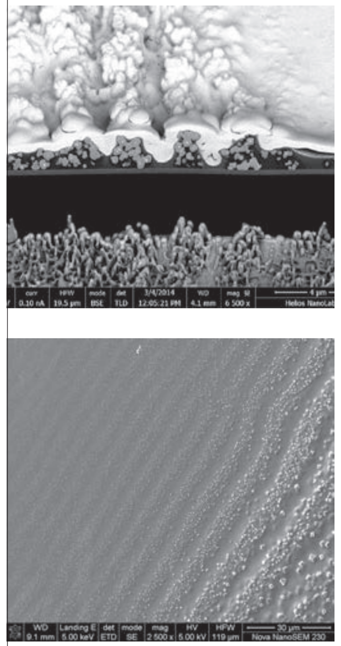
And external influences are to cement what snails are to garden plants – whether it be sulfate in the San Bernardino Tunnel or in the groundwater, which wears away the cement pipes. "In my garden, I have to know where the snails are and use hardy plants there." By the same token, cement needs to measure up to the demands of its respective environment. In other words, the basic recipe for the cement mixture has to be adapted to the external influences.

In other words, the awarded researcher – incidentally, only one of three Distinguished Senior Researchers at Empa – did not escape insects on pins entirely. With the difference that she not only knows the individual chemical components of "her" cement systematically inside and out, but can also use them accordingly to tweak certain processes and properties for the better. While she cannot influence the color of her potatoes as she likes, for instance, she can make their surroundings as ideal as possible. In the case of cement, on the other hand, it is the exact opposite: she can alter the cement mixture so that it adapts perfectly to a particular environment.

With her broad range of knowledge in this field, she has been a key contact for experts from industry and research for a number of years. This is also thanks to good collaboration with other experts in the department and the excellent research infrastructure at Empa and in Switzerland. Technical advancements enable Lothenbach to keep expanding her expertise and pave the way for other future and, where possible, more efficient and ecological methods to produce and process cement. After all, the same ultimately goes for cement and the plants in her garden: the chemistry needs to be just right. //

Video
«Introduction to cement chemistry»
https://www.youtube.com/watch?v=L4OLBNXMdHk

Ring structures that form by themselves



Concentric Liesegang rings, as produced at Empa.

DOI:10.1039/C6SM01564F

"We produce pretty, regular micropatterns – without so much as a pen, brush or printer in sight," says Empa researcher Rita Toth. Teaming up with colleagues from the University of Basel and the University of Technology and Economics in Budapest, she studied chemical processes that form small, microscopic, concentric ring structures all by themselves. They can be used to produce Fresnel lenses, for instance, which used to focus the light in lighthouses and are very useful today as micro-components in fiber optical data transfer. The self-forming micro-rings might also be used to coat catalyst surfaces evenly and effectively.

The chemical basis for the self-forming ring structures are so-called Liesegang rings, named after the German chemist and photographic paper manufacturer Raphael Liesegang who first described them in 1896. His famous peer Wilhelm Ostwald then began to study the rings. Using state-of-the-art analysis methods, the Empa research team has now examined the formation process of Liesegang rings, which had not been understood entirely, in detail in their laboratory and on the synchrotron accelerator at the Paul Scherrer Institute – and made an unexpected discovery: Toth and her colleagues observed that the size of the rings could be adjusted practically at will by altering the chemistry. Distances between the rings of between a thousandth and a hundredth of a millimeter are possible. The striking thing here is that the rings form independently of each other. For the first time, the scientists were able to explain the principles according to which Liesegang rings form. The formation takes place according to the so-called Cahn-Hilliard equation, which describes an advancing front of a chemical reaction. Behind the front, a homogeneous precipitation forms, which settles periodically – and forms the visible rings. As a result, the phenomenon could now come within touching distance of commercial usage for inexpensive optical structures and coatings.

Fresnel lens at the Point Arena Lighthouse Museum, Mendocino County, California. Picture: Frank Schulenburg / Wikimedia

Empa know-how in the "Magic Tent"

As of December 2016 the all-in-one sleeping system developed by the "Polarmond" start-up company is ready for delivery. Thanks to its special humidity management feature and sophisticated temperature regulation, conditions in the "Magic Tent" are always pleasant. Adventurers and nature lovers can enjoy sleeping as comfortably as at home, even if the outside temperature is down to -30° Celsius. The patented sleeping system combines the conventional functions of a sleeping bag, vapour barrier liner, Isomat and tent into one product. The spacious sleeping chamber is heated solely by the occupant's own body warmth, a feature which results from the use a high-tech insulation layer developed jointly by Empa and Polarmond, and made of a fluffy synthetic filling with reflecting layers. Other problems which had to be overcome during the development process included ensuring that moisture was transferred to the outside the sleeping zone whilst at the same time keeping the insulating layer dry. This is only possible thanks to the design of the sleeping chamber, which is fitted with an integrated humidity barrier. *www.polarmond.ch*

Award for new flame retardant

The Empa Innovation Award 2016 went to chemist Sabyasachi Gaan and his team. The researchers were recognized for the development of new, non-toxic and environmentally friendly fireproofing agents for the production of flame retard polyurethane foams, which are used in mattresses, seat upholstery and insulation modules for house façades, for instance. The prize was awarded in the context of the Empa Technology and Innovation Forum.

Events (in German)

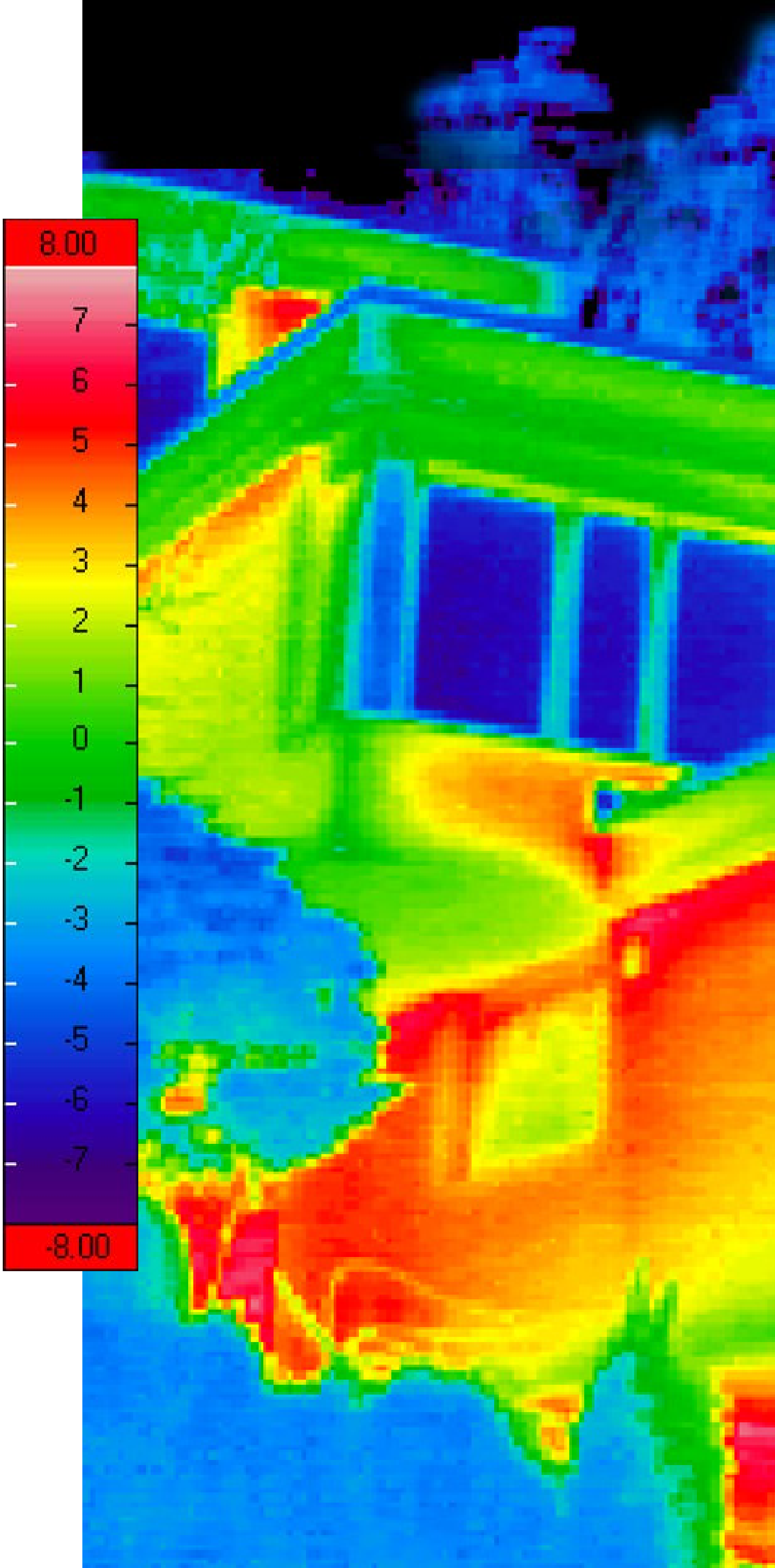
12. Januar 2017
Klebetechnik für PraktikerInnen
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/klebetechnik
Empa, Dübendorf

18. Januar 2017
Additive Manufacturing – quo vadis?
Industry and Science
www.empa-akademie.ch/tbaddmanu
Empa, Dübendorf

5. – 11. März 2017
30th Symposium on Surface Science 2017
Industry and Science
http://3s17.empa.ch/
Hotel Laudinella, St. Moritz, Switzerland

15. März 2017
8th VERT Forum
Industry and Government
www.empa-akademie.ch/vert
Empa, Dübendorf

Details and further events at
www.empa-akademie.ch



3. FACHKONGRESS
Energie + Bauen

Olma Messen, St. Gallen
Freitag, 12. Mai 2017, 9 – 18 Uhr

Online-Anmeldung unter
www.empa-akademie.ch/eub