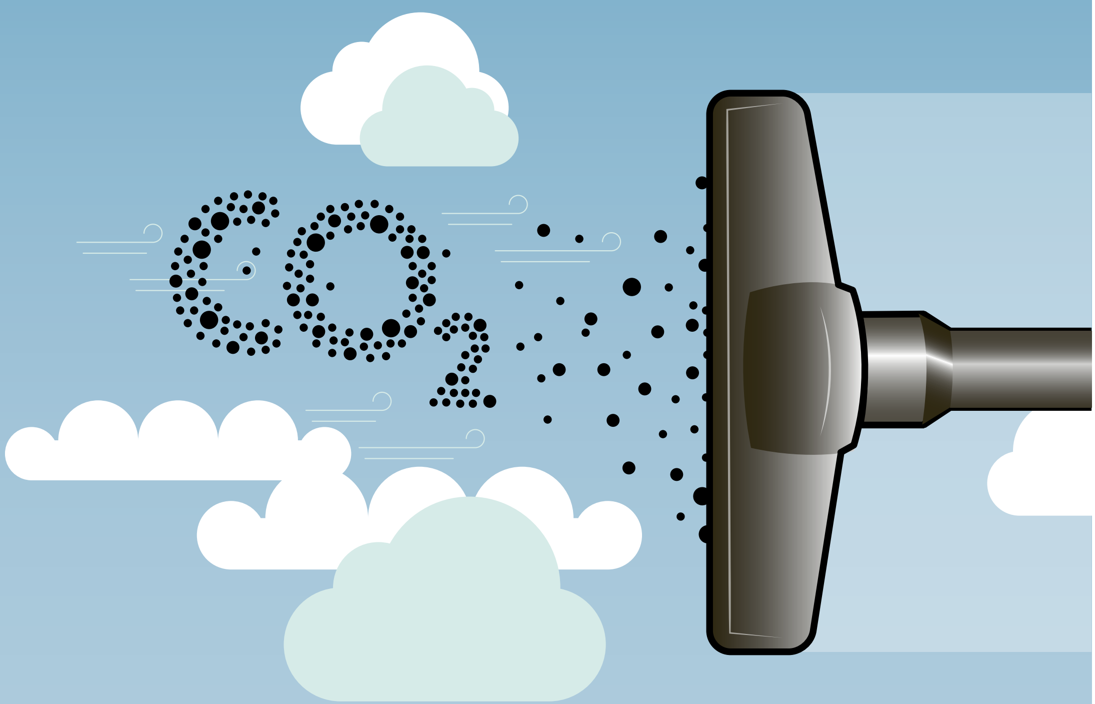
Empa Quarterly

RESEARCH & INNOVATION II #82 II DECEMBER 2023

FOCUS

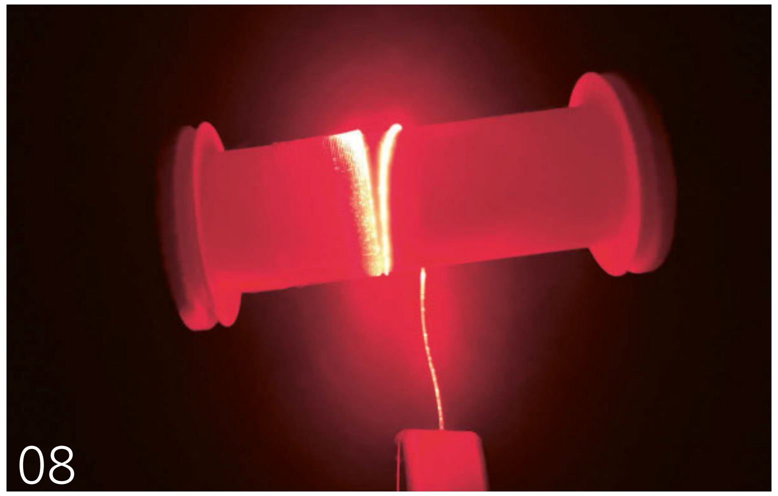
MINING THE ATMOSPHERE

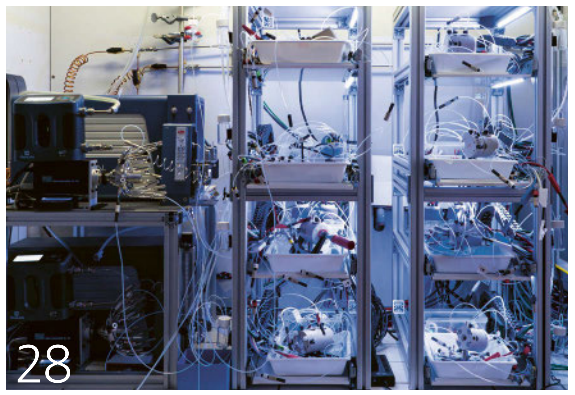


AEROGEL FROM WASTE
RECYCLED REINFORCEMENTS
PROTECTION FOR SENSITIVE SKIN

[CONTENT]

[FOCUS: MINING THE ATMOSPHERE]





Photos: Marion Nitsch (2), Empa (2), Nicolas Zonvi

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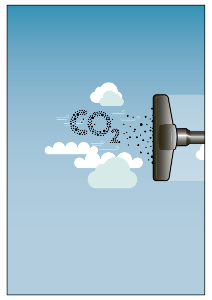

To curb climate change, we need to compensate not only for future emissions, but also for historical ones. The idea of an "atmospheric vacuum cleaner" is simple, the implementation, however, is anything but. Empa is researching concrete solutions for processing CO_2 captured from the atmosphere.
Image: Empa

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THINK BIG

Dear Readers,

Indeed. Because there is an enormous task ahead of us: We have been clogging up the atmosphere with CO_2 for more than 200 years. Now we have to clean it up. This is anything but trivial with a trace gas as diluted as carbon dioxide; the current (record-high) concentration is just 420 ppm, a little more than one particle of CO_2 per 2,500 "air molecules". So our CO_2 vacuum cleaner has to "filter" quite a lot of air in order to extract the 1,500 billion tons of CO_2 that we need to remove from the atmosphere altogether.

And then? What to do with the CO_2 rubbish? Just put it in some kind of underground landfill? The raw material is actually too good for that. It would be better to use the carbon it contains to manufacture innovative, value-adding products. After all, the whole endeavor has to be financed somehow. This is the idea behind the new Empa research initiative, Mining the Atmosphere. The idea behind it is simple, yet in technical terms extremely challenging: Instead of extracting the carbon for polymers, medicines, fibers, fuels and the like from crude oil, we use atmospheric CO_2 – and thus counteract further global warming. Hence a classical win-win situation. However, there is still a lot of work to be done before we can pop the corks. The current issue of Empa Quarterly provides an initial insight into the numerous approaches that we want to implement in future. After all, we can only master this massive challenge if innovative ideas are actually turned into practical solutions. This is what we are working on every day with our partners from research and industry.

An inspiring read!
Your MICHAEL HAGMANN

YOUR BRANCHES GREEN DELIGHT US!

The Christmas tree in this picture doesn't need any candles. It glows bright green all by itself – thanks to bioluminescence. Empa researcher Francis Schwarze has developed a process for producing bioluminescent wood using fungi. The fungal filaments of a white rot fungus penetrate the wood and feed on wood components, producing the light-generating substance luciferin. Similar to fireflies, the functionalized wood emits a greenish light in the dark thanks to the glowing fungal filaments. Glowing "snow" also piles up at the base of the tree. Here, the fungi grow in cellulose fibrils made from wood residues. So when the lights in Empa's fungal lab go out in the evening, the bioluminescent Christmas tree shines in all its glory.

Further information on the topic is available at:
www.empa.ch/web/s302

Photo: Empa

MONITORING GREENHOUSE GASES GLOBALLY

MEASURABLE
A global data set on the distribution of greenhouse gases in the atmosphere will help researchers to better understand climate change.

In order to better understand climate change, we need to know the concentration and distribution of greenhouse gases in the atmosphere as accurately as possible. The Global Greenhouse Gas Watch (GGGW) is an initiative of the World Meteorological Organization (WMO) for the development of a global infrastructure for measuring and monitoring greenhouse gases. Empa researchers from the Air Pollutants / Environmental Technology lab are playing a key role in this. Central to this is WMO's Global Atmosphere Watch program. Empa operates a world calibration center for the gaseous components in this program. Among other things, Empa carries out audits and provides training and support for measuring stations around the world. It thus ensures that all partners provide reliable and comparable data and promotes the international exchange of knowledge in the field of atmospheric research.

www.empa.ch/web/s503

MOVING X-RAY IMAGES: DYNAMIC IMAGING CENTER OPENS ITS DOORS

EXPERTISE
Empa is one of the partners who have jointly established the new Dynamic Imaging Center (DIC) in Bern.

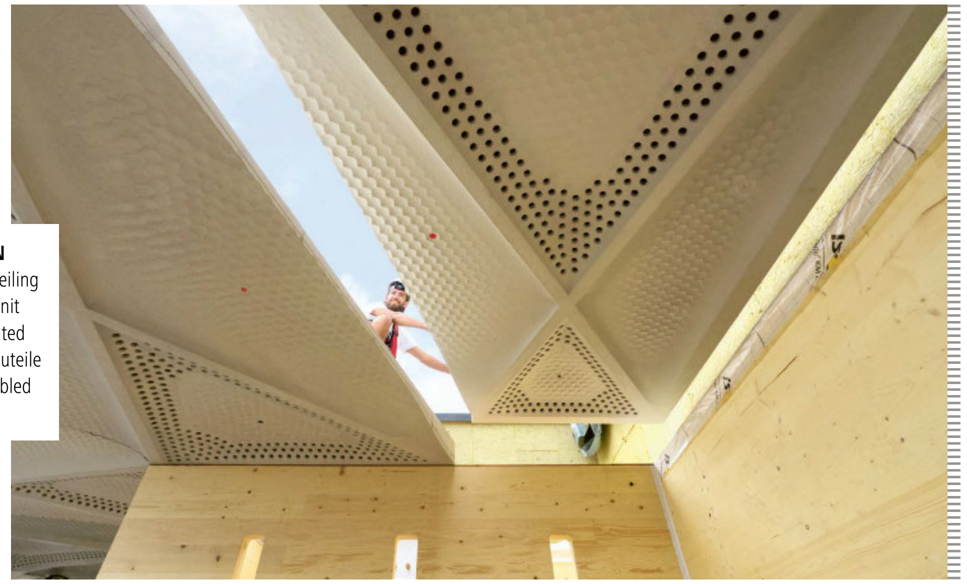
At the beginning of November, the Dynamic Imaging Center (DIC) was opened at sitem-insel, the Swiss Institute for Translational Medicine and Entrepreneurship. It is the first customized laboratory of its kind in Europe to be operated in a clinical environment. Here, X-ray images of a moving person can be taken simultaneously from two different directions. This is unique in Europe and a milestone in the investigation of musculoskeletal disorders. The center is a collaboration between sitem-insel, Inselspital / Bern University Hospital and Empa.

sitem-insel.ch

Photos: Adobe Stock, sitem

Photo: ROK, Empa, Marion Nitsch

STEP2: A NEW NEST UNIT IS TAKING SHAPE



INNOVATION
The modular ceiling of the STEP2 unit was prefabricated by Stahlton Bauteile AG and assembled on site.

Construction is underway, once again, at the research and innovation building NEST. The new unit goes by the name of STEP2. Over the past three years, project partners from various disciplines have developed innovations with high market potential, which will be implemented in a real-world construction project for the very first time, such as the newly designed ribbed filigree ceiling, a digitally constructed concrete staircase or an innovative façade system. STEP2 is scheduled to be completed in spring 2024.

www.empa.ch/web/s604/step2-baustart

BRIGHT MINDS: FROM EMISSIONS TO INNOVATION

In the future, excess man-made CO_2 is to be captured from the atmosphere and converted into valuable materials such as building materials or polymers. This is the goal of Empa's new research initiative: Mining the Atmosphere. A special edition of "Bright Minds: Bold Ideas – Smart Materials". is dedicated to this vision – from CO_2 capturing to converting carbon into innovative materials. This special edition kicks off with Nathalie Casas, head of the Department Energy, Mobility and Environment, together with Peter Richner, head of the Department Engineering Sciences. In the first episode, the two shed light on the potential of this promising vision as well as on the hurdles and challenges.

www.empa.ch/bright-minds

SPECIAL EDITION
Mining the Atmosphere

VULNERABLE
Babies who are born prematurely and spend their first days of life in intensive care have sensitive skin. Empa researchers have therefore developed a mattress that prevents skin damage.

Photo: Universitäts-Kinderspital Zürich

SMART PROTECTION FOR DELICATE SKIN

Skin injuries caused by prolonged pressure often occur in people who are unable to change their position independently – such as sick newborns in hospitals or elderly people. Thanks to successful partnerships with industry and research, Empa scientists are now launching two smart solutions for pressure sores.

Text: Andrea Six

If too much pressure is applied to our skin over a long period of time, it becomes damaged. Populations at high risk of such pressure injuries include people in wheelchairs, newborns in intensive care units and the elderly. The consequences are wounds, infections and pain.

Treatment is complex and expensive: Healthcare costs of around 300 million Swiss francs are incurred every year. "In addition, existing illnesses can be exacerbated by such pressure injuries," says Empa researcher Simon Annaheim from the Biomimetic Membranes and Textiles laboratory in St. Gallen. According to Annaheim, it would be more sustainable to prevent tissue damage from occurring in the first place. Two current research projects involving Empa researchers are now advancing solutions: A pressure-equalizing mattress for newborns in intensive care units and a textile sensor system for paraplegics and bedridden people are being developed.

OPTIMALLY NESTLED AT THE START OF LIFE

The demands of our skin are completely different depending on age: In adults, the friction of the skin on the lying surface, physical shear forces in the tissue and the lack of breathability of textiles are the main risk factors. In contrast, the skin of newborns receiving intensive care is extremely sensitive per se, and any loss of fluid and heat through the skin can become a problem. "While these particularly vulnerable babies are being nursed back to health, the lying situation should not cause any additional complications," says Annaheim. He thinks conventional mattresses are not appropriate for newborns with very different weights and various illnesses. Annaheim's team is therefore working with researchers from ETH Zurich, the Zurich University of Applied Sciences (ZHAW) and the University Children's Hospital Zurich to find an optimal lying surface for babies' delicate skin. This mattress should be able to adapt individually to the body in order to help children with a difficult start in life.

In order to do this, the researchers first determined the pressure conditions in the various regions of the newborn's body. "Our pressure sensors showed that the head, shoulders and lower spine are the areas with the greatest risk of pressure sores," says Annaheim. These findings were incorporated into the development of a special kind of air-filled mattress: With the help of pressure sensors and a microprocessor, its three chambers can be filled precisely via an electronic pump so that the pressure in the respective areas is minimized. An infrared laser process developed at Empa made it possible to produce the mattress from a flexible, multi-layered polymer membrane that is gentle on the skin and has no irritating edges.

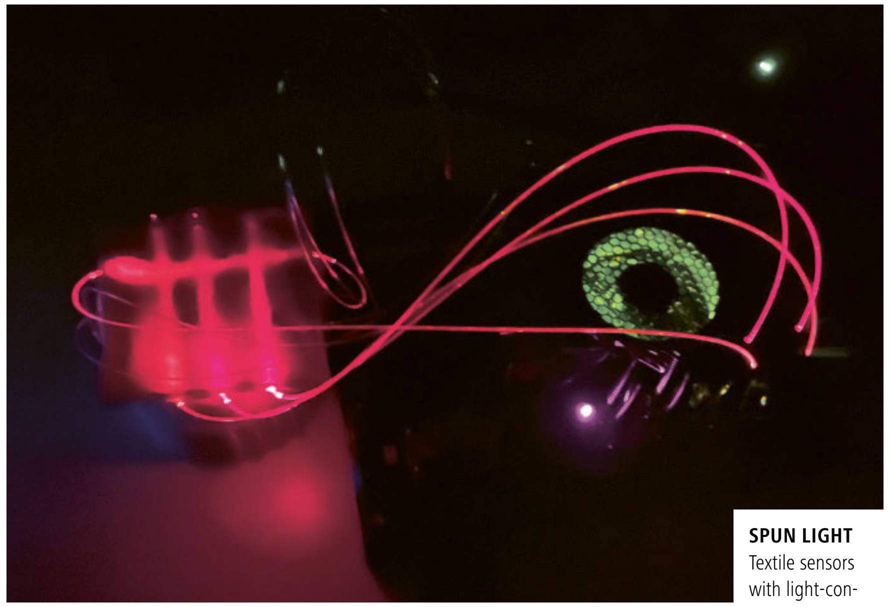
After a multi-stage development process in the laboratory, the first small patients were allowed to lie on the prototype mattress. The effect was immediately noticeable when the researchers filled the mattress with air to varying degrees depending on the individual needs of the babies: Compared to a conventional foam mattress, the prototype reduced the pressure on the vulnerable parts of the body by up to 40 percent.

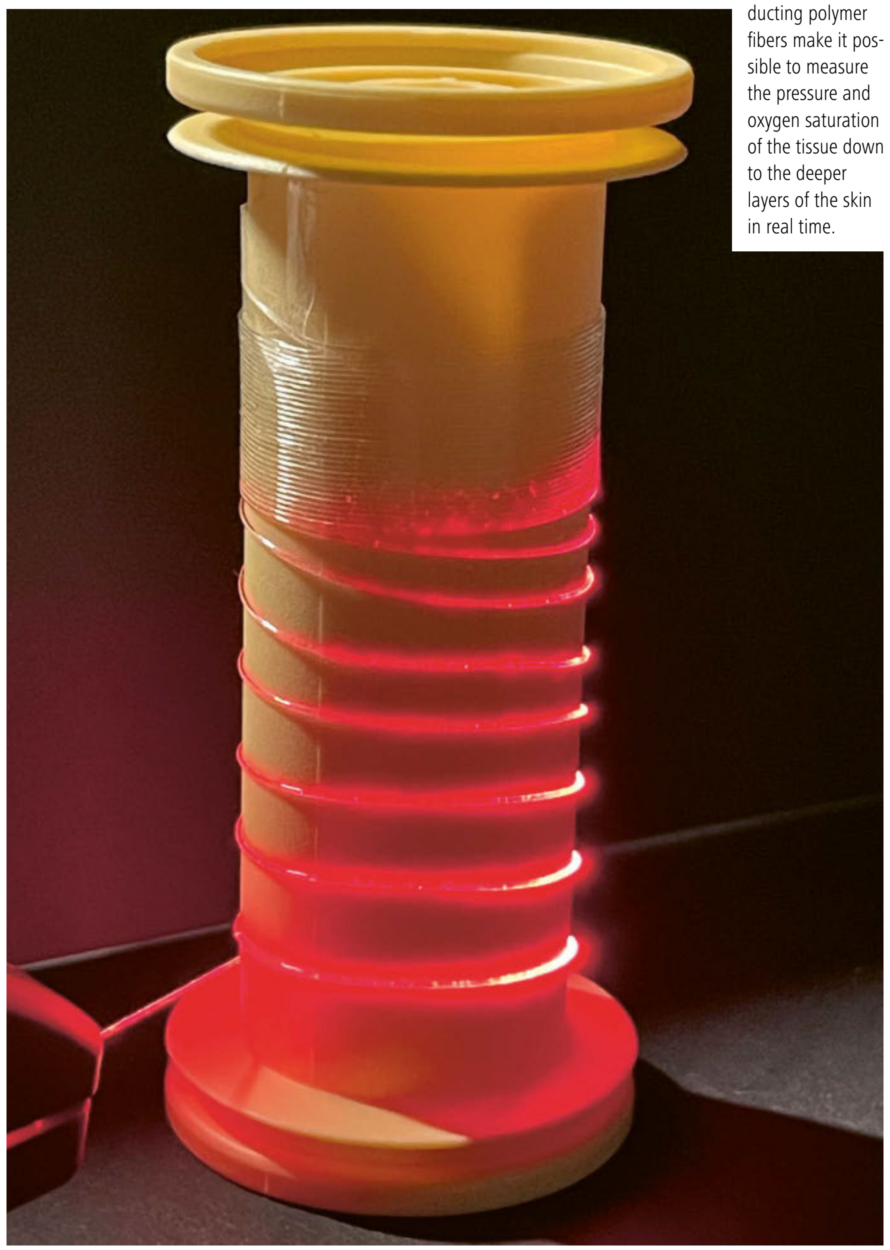
Following this successful pilot study, the prototype is now being optimized in the Empa labs. Simon Annaheim and doctoral student Tino Jucker will soon be starting a larger-scale study with the new mattress with the Department of Intensive Care Medicine & Neonatology at University Children's Hospital Zurich.

INTELLIGENT SENSORS PREVENT INJURIES

In another project, Empa researchers are working on preventing so-called pressure ulcer tissue damage in adults. This involves converting the risk factors of pressure and circulatory disorders into helpful warning signals.

If you lie in the same position for a long time, pressure and circulatory problems lead to an undersupply of oxygen to the tissue. While the lack of oxygen triggers a reflex to move in healthy people, this neurological feedback loop can be disrupted in people with paraplegia or coma patients, for example. Here, smart sensors can help to provide early warning of the risk of tissue damage.





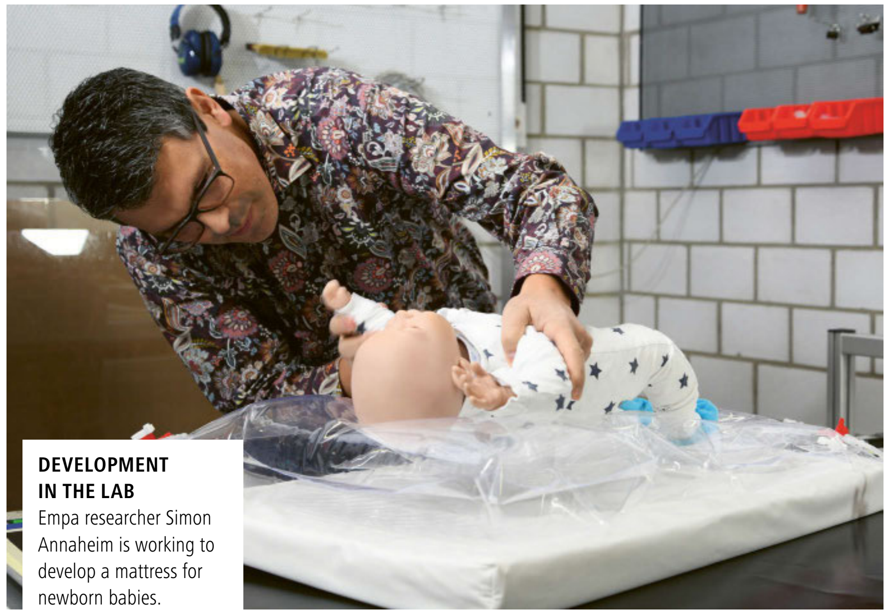
SPUN LIGHT
Textile sensors with light-conducting polymer fibers make it possible to measure the pressure and oxygen saturation of the tissue down to the deeper layers of the skin in real time.

Photos: Empa

In the ProTex project, a team of researchers from Empa, the University of Bern, the OST University of Applied Sciences and Bischoff Textil AG in St. Gallen has developed a sensor system made of smart textiles with associated data analysis in real time. "The skin-compatible textile sensors contain two different functional polymer fibers," says Luciano Boesel from Empa's Biomimetic Membranes and Textiles laboratory in St. Gallen. In addition to pressure-sensitive fibers, the researchers integrated light-conducting polymer fibers (POFs), which are used to measure oxygen. "As soon as the oxygen content in the skin drops, the highly sensitive sensor system signals an increasing risk of tissue damage," explains Boesel. The data is then transmitted directly to the patient or to the nursing staff. This means, for instance, that a lying person can be repositioned in good time before the tissue is damaged.

ProTex: A SUCCESSFUL INTER-INSTITUTIONAL TEAM

With the BRIDGE funding scheme, the Swiss National Science Foundation (SNSF) and the Swiss Innovation Agency Innosuisse support projects that demonstrate scientific excellence, a clear implementation strategy and economic and social potential. The team led by Luciano Boesel (Empa), Guido Piai (OST) and Ursula Wolf (University of Bern) was convincing, and ProTex was funded as part of BRIDGE Discovery. "Together, we have the necessary expertise in the fields of materials, optics, electronics, medicine and technology," says Empa researcher Boesel, describing the successful collaboration in the interdisciplinary team.



DEVELOPMENT IN THE LAB
Empa researcher Simon Annaheim is working to develop a mattress for newborn babies.

Photo: Empa

PATENTED TECHNOLOGY

The technology behind this also includes a novel microfluidic wet spinning process developed at Empa for the production of POFs. It allows precise control of the polymer components in the micrometer range and smoother, more environmentally friendly processing of the fibers. The microfluidic process is one of three patents that have emerged from the ProTex project to date.

Another product is a breathable textile sensor that is worn directly on the skin. The spin-off Sensawear in Bern, which emerged from the project in 2023, is currently pushing ahead with the market launch. Empa researcher Boesel is also convinced: "The findings and technologies from ProTex will enable further applications in the field of wearable sensor technology and smart clothing in the future." ■

Further information on the topic is available at:
www.empa.ch/web/s401

CLEAN-UP
Mining the Atmosphere means removing excess CO_2 from the air.

THE BIG CLEAN-UP

If we want to achieve our climate goals, we must not only curb greenhouse gas emissions, but also remove the already emitted CO_2 from the atmosphere. Peter Richner, Deputy Director of Empa, explains how to do this while creating a completely new economic system.

Text: Peter Richner

Photo: Empa

Since the 19th century, cheap energy in the form of coal, oil and natural gas has been the catalyst for a surge in development that has never occurred before in such a short time in human history – and which continues to this day. Productivity has literally exploded, life expectancy in Europe has increased by several decades and the global poverty rate has never been as low as it is today (even though it is still too high in many regions of the world). At the same time, however, rapid growth has also led to overuse of our planet's natural resources. The consequences are dwindling biodiversity and global warming, both of which jeopardize the basis of life in the long term.

Global warming – and thus part of the decline in biodiversity – is due to man-made greenhouse gas emissions, primarily in the form of CO_2 and methane. With the Paris Agreement of 2015, which aims to limit global warming, many countries, including Switzerland, have set themselves the goal of reducing their greenhouse gas emissions to net zero by 2050. To achieve this, we must significantly increase the energy efficiency of numerous processes throughout our lives and replace fossil fuels with renewable energies. However, it will hardly be possible to prevent all emissions, for instance in agriculture and other areas. In order to compensate for this – and actually achieve net zero – so-called negative emission technologies (NET) are indispensable, with which the amount of greenhouse gases in the atmosphere can be actively reduced.

One thing is clear: Net zero by 2050 requires huge efforts that go far beyond what Switzerland or other countries have decided and implemented to date. What's more, net zero is only a first step; in the second half of this century, we need to achieve a negative CO_2 balance of around 10 to 20 billion tons worldwide – each year! The reason for this is the longevity of CO_2 in the atmosphere. While the much more potent greenhouse gas methane is completely degraded within a few decades, CO_2 once emitted is only naturally eliminated from the atmosphere over the course of many centuries. Therefore, even at net zero, global warming will not stop or even decrease "overnight". However, if we allow temperatures to remain at a significantly higher level, irreversible changes in the Earth's climate system are likely to occur with consequences that are almost impossible to predict, such as the melting of the Greenland ice sheet, which alone would cause sea levels to rise by almost seven meters.

But even if our energy sector succeeds in doing without coal, oil and gas, there is yet another challenge to meet: Crude oil and the like serve as the starting materials for a wide variety of carbon-containing materials, from kerosene to polymers and medicines to bitumen for asphalting our roads. Producing all these materials from biomass is hardly technically possible and would probably far exceed the sustainable supply of biomass available. In other words: We need a new source of carbon.

The answer to this twofold challenge is Mining the Atmosphere. The idea is to remove the excess man-made CO_2 from the atmosphere and use it as a resource for carbon-containing materials. We then use these materials in closed cycles for as long as possible before they end up in final sinks. In this way, we ensure that the carbon is fixed for more than 1000 years. The necessary development of materials and processes ultimately promotes the transition from a CO_2-emitting to a CO_2-binding society.

Empa's research initiative Mining the Atmosphere is – in line with the topic in question – designed for the long term and comprises various "pillars": CO_2 extraction, its chemical conversion, applications of the new materials in various areas and systemic considerations such as life cycle analyses. Regardless of which solutions we develop in future, we must never forget one thing – compliance with planetary boundaries.

One key element is the exclusive use of renewable energy in all areas and the question of whether this will be available in sufficient amounts.

Our considerations are based on the assumption that this will be the case, not now but in a few decades. The potential is undoubtedly there: The sun sends around 10,000 times more energy to the earth than we need today. In addition, around 99% of our planet is hotter than 1,000 degrees – to name just two of the most important sustainable energy sources.

The "atmospheric raw material" CO_2 can be extracted from three sources: directly from the air using Direct Air Capture (DAC), from the oceans, which absorb around a third of anthropogenic CO_2, using electrolytic processes, and from biomass. CO_2 from the air and the oceans can then be stored directly in suitable geological formations (Carbon Capture and Storage, CCS). With Mining the Atmosphere, however, we are pursuing an alternative path, in which CO_2 is converted into short- or longer-chain hydrocarbons using hydrogen and can thus replace existing – mainly fossil – raw materials.

At the same time, existing logistics chains can continue to be used, as chemically, we are dealing with the very same compounds. Key elements for the successful implementation of this idea are catalytic processes for the various chemical conversion reactions and, above all, energy management. This is because the entire scheme depicted here requires a lot of energy. Many of the processes will therefore hardly take place in Switzerland, but rather in places where there is an abundance of renewable energy, such as in the Earth's sunbelt.

In the first phase, we are focusing on two use cases for the application of CO_2-based materials: mass products with the potential to bind billions of tons of carbon and products with a high added value, which thus make a significant contribution to financing the project. Building materials account for by far the largest share of global material flows. Carbon-based aggregates for concrete and asphalt as well as thermal insulation materials are therefore currently the focus of our research. The carbon can be obtained either through the pyrolysis of biomass or from synthetic methane, which also supplies hydrogen for energy applications.

With Mining the Atmosphere, we want to show a viable way of avoiding climate change with incalculable risks. However, in order to achieve our goal along this path, we first need to quickly and massively reduce our greenhouse gas emissions and significantly accelerate the expansion of renewable energies. With Mining the Atmosphere, we are already setting the stage for the next chapter – the big clean-up of our CO_2-polluted atmosphere. ■

Further information on the topic is available at: www.empa.ch

HIGH GOALS
Peter Richner is Deputy Director of Empa and head of the Engineering Sciences department.

Photo: Empa

THE CO_2-BINDING SOCIETY AS A GOAL

COLLABORATION
Tanja Zimmermann, Director of Empa, and Martin Ackermann, Director of Eawag

Photo: Marion Nitsch

▶

Tanja Zimmermann and Martin Ackermann want to provide answers to the current climate crisis with new initiatives and ambitious goals. In this interview, Eawag Director Ackermann and Empa Director Zimmermann explain why this is primarily a water crisis, what is needed to tackle it and what can be produced from the greenhouse gas CO_2.

Interview: Michael Hagmann

Finding solutions to the climate crisis and using the atmosphere as a "mine" of sorts to extract CO_2 and produce valuable materials from it – this is not a small feat. Aren't you afraid of not meeting expectations?

Martin Ackermann: First of all, a personal assessment: We are not on track. The targets for efficient climate protection, such as net zero by 2050, are a long way off at the moment, plus there is a lot of catching up to do in terms of climate adaptation, our ability to react appropriately to a changing climate. So there is still a lot to do. And we better start sooner rather than later …

Tanja Zimmermann: Indeed, the problems are urgent. Even if we achieve net zero and master the energy transition, there is still way too much CO_2 in the atmosphere – with the corresponding consequences such as melting glaciers and increasing extreme weather situations. It is therefore extremely important to act now and do our bit. And I sense a great deal of motivation among our young researchers in particular to work on these meaningful topics. So respect for the task – absolutely; fear of not being able to offer solutions – no.

What specific contribution can research offer to solve the climate crisis?

MA: When we talk about climate research, we usually think of measurements and modeling, i.e. describing the problem. Although this is absolutely essential, we need more than that, namely solutions. We can roughly distinguish between two types of response to the climate crisis: On the one hand, climate protection or mitigation, i.e. technologies and political strategies to reduce greenhouse gas emissions and remove CO_2 from the atmosphere – as Mining the Atmosphere envisages. On the other hand, climate adaptation, to contain or minimize the harmful effects of climate change on natural and human systems, such as protection against extreme weather events. To put it bluntly: climate adaptation is about protecting yourself, i.e. looking after your own well-being. Climate protection is altruistic and has a global impact. We need both, not either-or.

So as an aquatic research institute, what is Eawag's role in all this?

MA: According to the UN, climate change is first and foremost a water crisis. It is getting warmer, yes, but this is also changing water availability and precipitation patterns. Winters are getting wetter, summers hotter and drier. And that means we face two problems at once: In wintertime, extreme amounts of water can come in the form of heavy rainfall and cause major damage, while in summer we have too little water in some places. So we have to limit the damage caused by extreme precipitation – and at the same time save some of this water for the summer. We have therefore defined climate as one of our key topics at Eawag – something that was less explicit in the past.

TZ: Incidentally, the opposite is true for sustainable energy: In future, with the expansion of photovoltaics and the like, we will have surplus energy in summer, but too little energy in winter. To compensate for this, we are trying to "materialize" energy, i.e. convert it into storable chemical energy carriers, such as hydrogen or methane using CO_2 from the atmosphere.

Which brings us to Mining the Atmosphere ...

TZ: Exactly. Our vision is to transform ourselves from a CO_2-emitting to a CO_2-binding society through the development of appropriate materials and technologies. And this is a necessity, I would like to stress that once again, because even after the energy transition, we still have to "clean up" the atmosphere from the CO_2 pollution we have caused over the last 200 years in order to prevent a further rise in temperature.

> "All sectors will change as a result of climate change – agriculture, mountains, settlements."

What specific questions do you want to answer?

MA: Just one example: We are setting up a real-world laboratory in Bern, where we are working with authorities, residents and research partners. The aim is to adapt the neighborhood so that life will still be pleasant and safe in 15 years' time – thanks to blue-green infrastructure, the integration of water and vegetation in neighborhoods: so that people are prepared for extreme weather events and at the same time have sufficient water and cooling available in summer.

TZ: At Empa, the focus is on the development of innovative, carbon-based materials and corresponding technologies as well as on systemic approaches. To start from the end, for example, new building materials with a negative CO_2 footprint, new manufacturing technologies to produce these – but also other raw materials, say, for the chemical industry – on an industrial scale, efficient methanation reactors and catalysts for the conversion of CO_2 and hydrogen into methane as well as new concepts to "suck" CO_2 out of the atmosphere as energy-efficiently as possible. We consider all materials and processes over their entire life cycle – which, wherever possible, is circular instead of linear.

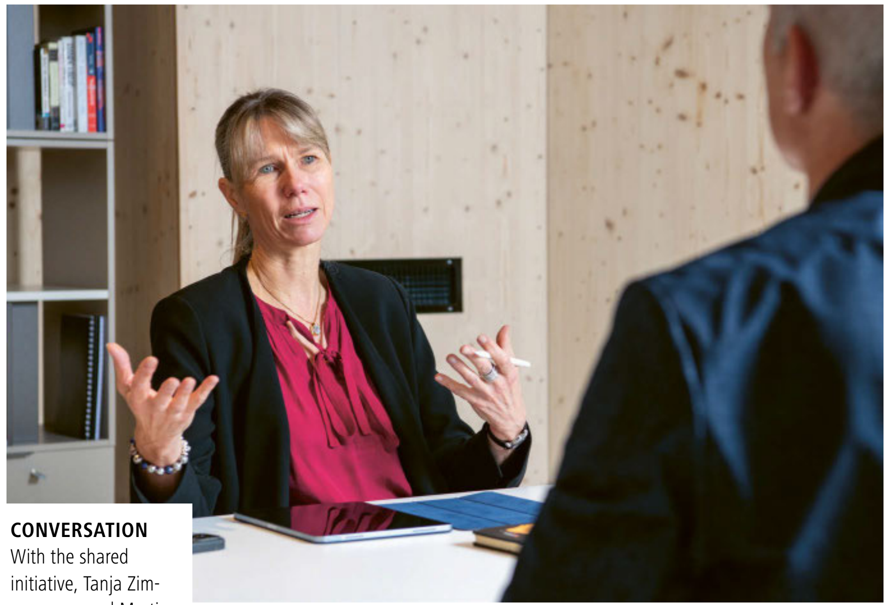
Why is it important for Switzerland to play a pioneering role here?

MA: There are two aspects to climate protection: The first is responsibility. As a highly innovative, wealthy country with correspondingly high CO_2 emissions, Switzerland has a greater responsibility, which it should also fulfill. The second is an economic argument: Innovations in the field of climate protection and adaptation have enormous potential and could become a huge market for Swiss industry. In the area of climate adaptation, there is an additional factor: All sectors will change as a result of climate change – agriculture, mountains, settlements. It is thus in Switzerland's own interest to prepare for and protect itself from the negative effects of climate change.

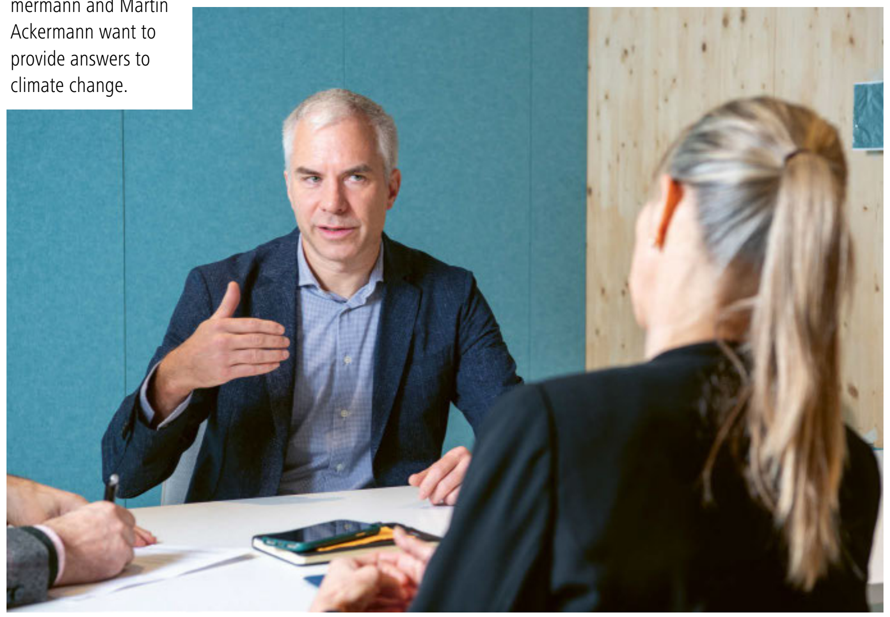
TZ: Switzerland continues to be an international leader in innovation, mainly due to the good framework conditions. We are therefore ideally positioned to develop technologies and concepts in the current initiatives and then apply and bring them to market. This will further boost the international competitiveness of Swiss industry. ■

Further information on the topic is available at: www.empa.ch

Photos: Marion Nitsch



CONVERSATION
With the shared initiative, Tanja Zimmermann and Martin Ackermann want to provide answers to climate change.



BUILDING ON CO_2

Sophisticated chemical processes can bind climate-impacting carbon dioxide in various forms – and in considerable amounts in the long term. The construction sector, with its massive turnover and huge volumes, is a perfect candidate to making use of them. Empa researchers are working on various processes that give reason for optimism.

Text: editorial team

In order to bind CO_2 and thus make the construction sector more climate-friendly, experts all over the world are working on new processes – for example, for exhaust vents of factories in the cement industry, which emits large quantities of the greenhouse gas. But what to do with the CO_2 once captured? One hope is large-scale underground storage in reservoirs made of porous rock that can store the gas over long periods of time in liquefied form.

Other possibilities are offered by circular economy, especially in the construction sector with its large mass turnovers. CO_2 can, for instance, be bound to concrete recycling material using a process known as carbonation to produce new types of concrete. Other chemical processes such as pyrolysis, a heating process under the exclusion of oxygen, of methane to hydrogen – for example for high-temperature industrial processes – yield solid carbon as the final product, which can then be used as a CO_2-negative material in the construction industry.

CONCRETE AS A CO_2 TRAP – ALREADY IN THE FACTORY

Concrete is capable of re-binding the climate gas emitted during cement production, at least partially. "Carbonation" is the name of this process – a leisurely reaction that takes years and the pace of which depends on numerous factors. The DemoUpCARMA project, led by ETH Zurich, investigated how this process can be used and, above all, accelerated in a concrete plant – in a facility operated by Kästli Bau AG in Rubigen (BE) and using recycled material from concrete structures. The carbon dioxide from a sewage treatment plant was delivered liquefied and converted back into gas at the plant to continuously "flood" the recycled granulate using a process developed by the Bern-based company neustark AG.

Andreas Leemann and Frank Winnefeld from Empa's Concrete & Asphalt lab investigated how efficiently the granulate absorbs CO_2. Samples showed clear changes under the microscope: Smaller particles had patches of dark and light portions on the surface where the original cement had changed. Analyses showed that the light portions were calcium carbonate, while the dark phases consisted mainly of calcium silicate hydrate – C-S-H for short – the main product of cement hydration that gives concrete its strength. Carbonation removed some of the calcium from C-S-H: It thus became less calcareous and could in turn react with newly formed cement phases in recycled concrete – with the result that its compressive strength increased.

Tests with concrete types frequently used in Switzerland confirmed these findings. They showed that the process can make concrete more climate-friendly in two ways. Firstly, by absorbing CO_2 directly from the atmosphere: in the case of these novel building materials, this absorption can be up to 10 percent of the emissions initially released into the atmosphere during the production of the cement for the original concrete. Secondly, by reducing the cement content in recycled concrete by 5 to 7 percent – thanks to its higher strength. The bottom line, according to the Empa experts, is a CO_2 saving potential of a good 15 percent.

When, if and to what extent these results can be applied in practice is, of course, still open – partly because of the question of how well and at what technical and financial expense the process can be implemented in concrete plants.

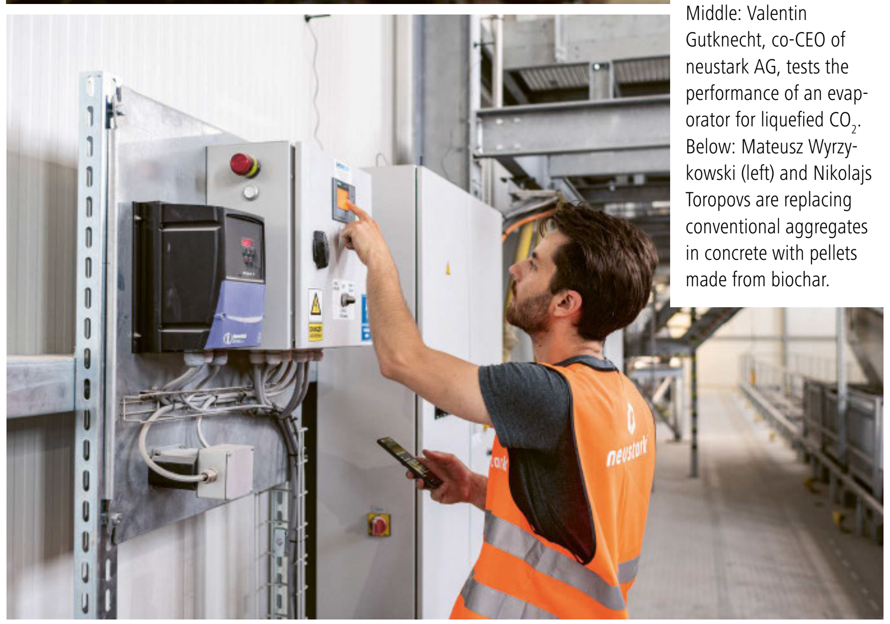
BIOCHAR AS CONCRETE INGREDIENT

Another team from Empa's Concrete & Asphalt lab is developing a process for integrating plant-based charcoal – biochar – into concrete. This material is produced by pyrolysis of biological material and consists to a very large extent of pure carbon, which the plants had taken up from the atmosphere in the form of CO_2 during their growth (in a process called photosynthesis).

While concrete products containing biochar are already on the market – the charcoal is often added to concrete in untreated form, which can lead to problems. "Plant-based carbon is very porous and therefore absorbs not only a lot of water, but also expensive admixtures used during concrete production," says Empa researcher Mateusz Wyrzykowski.

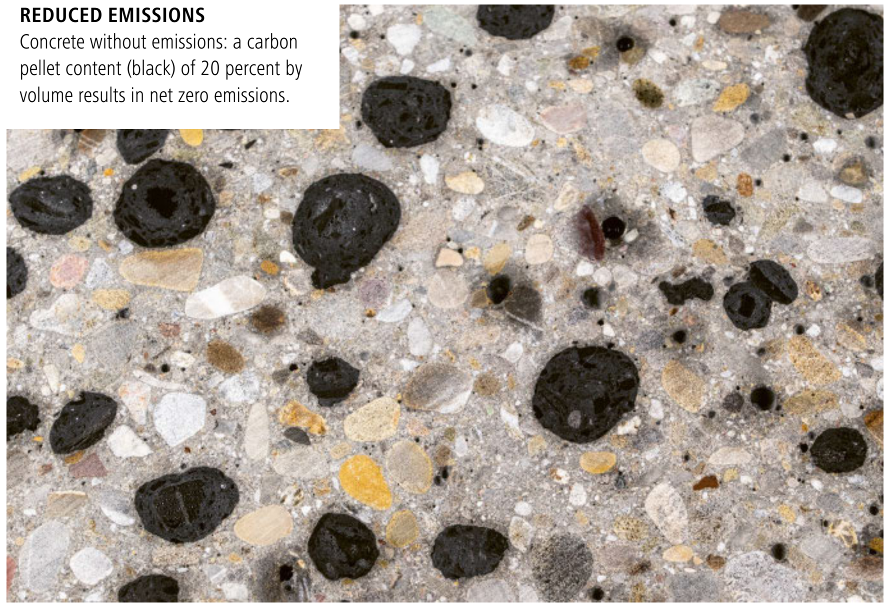
Therefore, the experts suggested processing it into pellets. To produce them, they used a rotary mixer filled with biochar, water and a binder, which yielded pellets with diameters between 4 and 32 millimeters. The researchers used the pellets to produce concrete of strength classes C20/25 to C30/37, which are widely used in building construction and civil engineering.

The resulting carbon footprint: With 20 percent by volume of carbon pellets in the concrete, the team achieved net zero emissions, according to Wyrzykowski – so the amount of carbon contained



GREENER CONCRETE
Above: CO_2 must be converted from a liquid to a gaseous state after delivery to the plant. Middle: Valentin Gutknecht, co-CEO of neustark AG, tests the performance of an evaporator for liquefied CO_2. Below: Mateusz Wyrzykowski (left) and Nikolajs Toropovs are replacing conventional aggregates in concrete with pellets made from biochar.

Photos: neustark AG (2), Empa



REDUCED EMISSIONS
Concrete without emissions: a carbon pellet content (black) of 20 percent by volume results in net zero emissions.

in the concrete offsets all emissions produced in the production of the pellets as well as the concrete. In the case of lightweight concrete with a density of around 1800 kg/m³, the balance becomes even better: A carbon content of 45 percent by volume leads to negative emissions of minus 290 kg CO_2/m³.

In the long term, Empa lab head Pietro Lura sees potential for negative emissions that go far beyond biochar. In a concept pursued by several Empa labs together, synthetic methane is produced in the Earth's sunbelt using just solar energy, water and atmospheric CO_2 followed by the subsequent pyrolysis of the gas (see infographic on page 21. "This gives us hydrogen, which can be used in both industry and mobility, and solid carbon, which we can incorporate into concrete – just like biochar," says Lura.

INSULATION MATERIALS FOR BUILDINGS

Biochar is also a topic in Empa's Building Energy Materials and Components lab. A team led by Jannis Wernery is developing a new type of insulating material from plant-based raw materials or waste that permanently binds the CO_2 it contains and thus acts as a permanent carbon sink. This is a promising idea, especially in view of the great importance of insulating materials in the task of making many buildings more energy-efficient and thus more climate-friendly in the future.

Most of the carbon plants had captured from the atmosphere in the form of CO_2 during their growth can be permanently fixed by pyrolysis. The resulting biochar can then be bound in the insulation of buildings throughout their lifetimes. What's more, after demolition of the buildings, the biochar could be brought out on fields, where it would increase the fertility of the soil, yet remain bound for centuries – unlike other plant-based building materials such as cellulose insulation, which release the stored CO_2 as it rots.

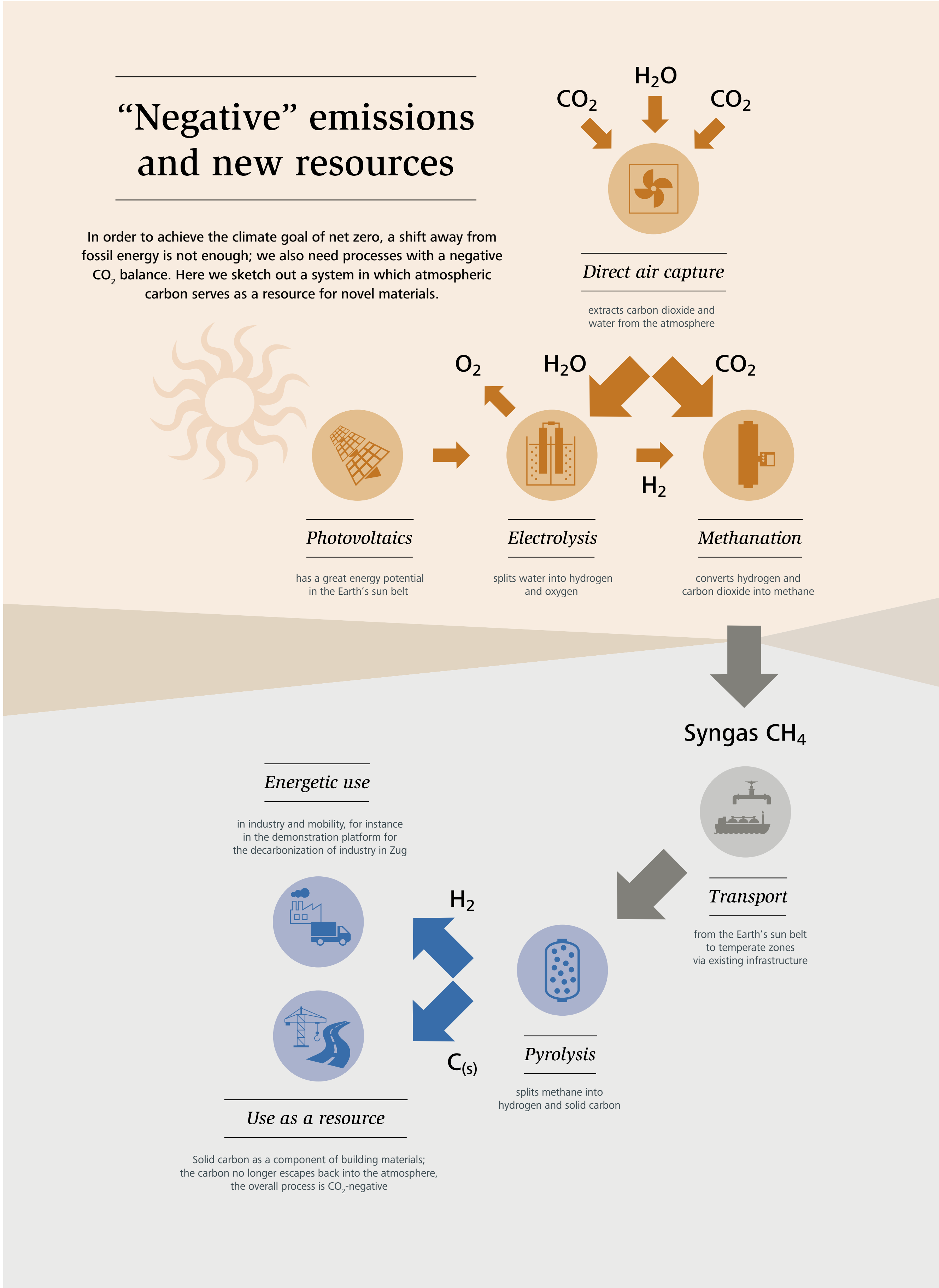
Of course, there are still many details to be clarified before the material is ready for use. For example, it must be ensured that all the ingredients of the insulation materials are suitable to be used as fertilizer. Moreover, a marketable product would have to be competitive in terms of thermal insulation and, at the same time, guarantee adequate fire protection. According to Empa researcher Wernery, preliminary studies showed that these goals are well within reach.

In the long term, biochar-based insulation materials could significantly improve Switzerland's carbon footprint. According to model calculations, a realistic partial replacement of conventional insulation materials with biochar could save around half a million tons of CO_2 equivalents each year – on the one hand through reduced emissions during their production, and on the other through the long-term storage of atmospheric CO_2. That would be equivalent to one percent of Switzerland's total greenhouse gas emissions. A project with a huge potential upside that also convinced funding institutions: The Minerva Foundation, the ETH Board and the Swiss Federal Office of Energy (SFOE) are supporting the project, as is the Stadtwerk Winterthur climate fund. ■

Further information on the topic is available at:
www.empa.ch/web/s308 / www.empa.ch/web/s312

Photo: Empa

Graphic: Empa



EMBRACING CHANGE

In October 2023, Nathalie Casas took over the lead of Empa's Energy, Mobility and Environment research department. Familiar with science and technology since childhood, she believes that humanity can save the climate from collapse – but that it will take more than "just" technology.

Text: Anna Ettlin

Nathalie Casas never intended to pursue a doctorate. But when she completed her Master's degree in chemical engineering at ETH Zurich in 2008, her supervisor at the time offered her a doctoral position, which she accepted without hesitation. "It was just so exciting," she recalls. This curiosity and her courage to occasionally throw her own plans overboard would shape her entire career. "I never had a fixed idea of what my path should look like. I just always did what felt right at the time."

Her latest move followed exactly that pattern: Since October 2023, the 40-year-old has been heading the Empa department Energy, Mobility and Environment. The topic of her doctoral thesis, CO_2 capture, has been a recurring theme throughout her career, first at Sulzer Chemtech and later at the Swiss start-up Climeworks.

New threads are now being added, which makes Casas particularly happy. "We have a very broad spectrum of research in the department, from mobility to analytics and life cycle assessments all the way to batteries," she says. CO_2 capture is – of course – also part of this, but it doesn't stop there: Empa researchers are also investigating how the captured CO_2 can be processed to produce valuable materials and compounds. Casas: "It's incredible what Empa does. I'm learning something new every day."

OF GOALS AND COINCIDENCES

Casas' love of science began in early childhood. Her mother is a microbiologist, her father a mechanical engineer. While her father was away on business trips, her mother took her to the lab on weekends. "I was allowed to count bacteria under the microscope and felt terribly important," laughs Casas. "But now I suspect that my mother only invented this task to keep me busy."

When she graduated from school, Casas was determined to study at ETH Zurich, either chemistry or materials science. She found it difficult to make up her mind, so she let chance make the decision. "For materials science, I would have had to do an internship first," she recalls. "I set myself a deadline and said: If I have an intern position by that date, I'll study materials science." The acceptance for the internship came three days too late: Casas went on to study chemistry and chemical engineering.

Casas has no regrets about this chance decision – it has ultimately led her back to materials science, now as a manager instead of a researcher. As much as she enjoyed working in the lab during her doctorate, the new department head likes working with people even more. They are also what she most appreciates about Empa. "The people here are very intrinsically motivated," she says. "They are enthusiastic about their subjects and about science, and they want to make a difference."

NATHALIE CASAS

CAREER: Nathalie Casas studied chemical engineering at the ETH Zurich, where she obtained her Master's degree in 2008 and went on to complete her doctorate. She then took up a position as Application Manager at Sulzer Chemtech, where she was responsible for a large part of the CO_2 capture projects. In 2017, Casas moved to Climeworks, a spin-off of ETH Zurich, where she first worked as Head Development & Engineering, then as Head of Technology before joining Empa in October 2023.

TOGETHER, WE ACHIEVE MORE

The researchers in Casas' department can certainly make a difference. After all, energy, mobility and the environment are all pressing issues that concern not only Empa and Switzerland, but the whole world. The climate targets can only be achieved with major societal changes – and changes are some-

Photo: Marion Nitsch

DECISIVE
Nathalie Casas has always done what felt right in her career.

times painful, Casas knows. "Many climate-neutral solutions are just as good as the technologies and habits we have today. It's the change itself that is challenging for us," she says.

Empa is up to this challenge, the department head believes. "We have a great deal of expertise that we can use to support society and industry in this change," Casas says. As an example, she cites the Mining the Atmosphere initiative, which interconnects a wide variety of research groups and approaches and thus bundles Empa's strengths for the greatest possible impact. "Our advantage at Empa is that we can also take the first step out of the laboratory. With our demonstration platforms move, ehub and NEST, we can show society and policymakers: The technology is here – and it works in practice," says Casas.

So will technologies such as CO_2 capture solve all of our problems? Casas firmly denies this. "Cleaning up is always more expensive than avoiding emissions in the first place," she explains. Although the technology is key to offsetting unavoidable residual emissions, the complex process is not a solution for the large-scale elimination of avoidable car exhaust gases and the like.

Since Casas first studied carbon capture in 2008 as part of her doctoral thesis, the field has developed considerably. At the same time, the urgency has grown. Nevertheless, she remains optimistic. "My generation is the first to feel the effects of climate change – but we can still do something about it," says Casas. "Our parents' generation was barely aware of the damage. And our children will have to face the consequences. We are feeling the consequences, but we can still prevent a lot of them – although it won't be easy." ■

Further information on the topic is available at:
www.empa.ch/web/empa/mobility-energy-environment

MORE THAN TECHNOLOGY
Casas believes that we can solve our problems – but that technology alone will not be enough.

Photo: Marion Nitsch

BEYOND ZERO

Are buildings that affect our climate in a positive way soon going to be a reality? In order to achieve the ambitious net zero target by 2050, we as a society need to rethink the standards and procedures we are living by. One of the most impactful sectors is the construction industry. Through the use of advanced technologies, buildings could soon serve as carbon sinks and thus help to ensure that the CO_2 concentration in the atmosphere no longer increases, or at best even decreases. A set of innovations from the Empa laboratories that are strongly CO_2-reduced and even CO_2-negative, are therefore going to be installed and tested in a real environment – inside a new unit at NEST, the innovation building of Empa and Eawag.

Text: Annina Schneider

In Switzerland, the construction sector is responsible for approximately 28% of total CO_2 emissions, which gives it a key role in the ambitious goal of emitting no more greenhouse gases into the atmosphere by 2050. In addition to low-emission construction and operation of buildings, there is another promising solution: CO_2 from the atmosphere can be bound in building materials and thus stored in buildings in the long term. Empa's large-scale research initiative Mining the Atmosphere is aimed precisely at this goal. Through the construction of a new unit called Beyond Zero by 2026, NEST will demonstrate how a building that serves as a long-term storage facility for CO_2 can be constructed and operated in a real-world environment.

REALIZING VISIONS
The architects from OOS cooperate with Empa researchers to align new CO_2-negative innovations from the Empa laboratories with the requirements of the construction sector.

Photo: Empa

NET ZERO IS JUST THE FIRST STOP ALONG THE WAY

With low-emission concrete constructions or carbon-negative insulation materials, promising technologies already exist on the market. "At NEST, we now want to go one step further and only see net zero as an interim goal. Our vision is to use buildings as CO_2 sinks in the future – in other words, they should have a negative overall CO_2 footprint," explains Reto Largo, Managing Director of NEST. "We see huge potential in new technologies for mineral building materials such as concrete in particular, as these are among the most commonly used building materials globally."

ADVANCING AND INSTALLING NEW TECHNOLOGIES

In order to develop new CO_2-negative building materials, install them and assess them in terms of emissions, different areas of expertise need to be pooled. In addition to support from various Empa laboratories under the direction of Mateusz Wyrzykowski, Group Leader Concrete Technology, the NEST team is also being supported in this project by the architectural firm OOS. Andreas Derrer, founding partner of OOS, says: "In order to usher in this new era in the construction industry, we do not only need new mineral building materials, but above all real examples that allow a holistic CO_2 balance and a real analysis of potential. With this new unit, we want to provide answers to the pressing question of whether and how buildings can contribute to reducing the atmospheric CO_2 concentration in the future." ■

Further information on the topic is available at:
www.empa.ch/web/nest/beyondzero

IGNORING EFFICIENCY

From the desert to Swiss industry: according to the idea behind the new Mining the Atmosphere initiative, energy is harvested in the Earth's sun belt, converted several times and transported over long distances to where it is needed. Although this reduces the overall efficiency of the process, a closer look at the energy and greenhouse gas balances for the pyrolysis of synthetic methane shows that this is not a problem.

Text: Stephan Kälin

Photo: Nicolas Zonvi

Industry is Switzerland's third-largest energy consumer, alongside buildings and mobility. In particular, high-temperature processes in metal processing and the chemical industry, which are often operated with natural gas, lead to an overall energy consumption in this sector of around 22 terawatt hours per year. Together with the Tech Cluster Zug, the Canton of Zug and over a dozen additional partners, Empa has joined forces in 2022 to form the Association for the Decarbonization of Industry (AfDI). Within this framework, Empa researchers want to contribute to the decarbonization of high-temperature process heat. "We take decarbonization literally," says Christian Bach, Head of Empa's Automotive Powertrain Technologies lab. "We use a pyrolysis process to separate the carbon in natural gas before combustion." What remains is pure hydrogen, with which the industrial high-temperature processes can be operated, and the separated carbon as a powder, which is to be further processed for applications in construction and agriculture (see page 18). A demonstration plant is currently in the design phase and will be set up in Zug over the next two years. The hydrogen will then be used in the enameling furnace at V-Zug AG.

DOUBLE SOLAR RADIATION

If synthetic methane is used instead of natural gas, it is even possible to achieve negative greenhouse gas emissions over the entire process. This is because, for the production of synthetic methane, CO_2 is extracted from the atmosphere, which is then no longer emitted but is available in the form of solid carbon in the end. "It is not realistic, however, to think that we will be able to cover the huge energy needs of our industry through the domestic production of renewable hydrogen or synthetic methane," says Bach. The focus is therefore on desert regions of the world – areas where the solar radiation per square meter is twice as high as in Switzerland.

THE GOAL: HIGH-TEMPERATURE HEAT WITH NEGATIVE EMISSIONS

However, the production of synthetic methane in the desert, its transport to Europe and the subsequent pyrolysis are processes that reduce the overall efficiency. Accordingly, the energy and greenhouse gas balances of the entire process must be closely scrutinized. Christian Bach and his team analyzed the entire value chain with partners from AfDI and compared it with other processes. One megawatt hour (MWh) of high-temperature heat for industry serves as a comparative value. If natural gas is to be used – as is currently the case – 1.2 MWh of primary energy is required and 288 kg of CO_2 (resp. CO_2 equivalents) are emitted. The primary energy also includes the energy used to extract the gas – for example in the Middle East – and transport it, and also takes into account the losses due to methane slip. Around one-fifth of the emissions are generated during the production of natural gas, the rest during its use.

If natural gas is decarbonized by pyrolysis beforehand and only the resulting hydrogen is used to generate high-temperature heat, CO_2 emissions can be reduced by 40% to 178 kg. At the same time, however, the primary energy requirement increases because more natural gas is required and because additional electricity is needed for pyrolysis. In this scenario, 1 MWh of high-temperature heat requires 2.6 MWh of primary energy.

MORE ENERGY, FEWER EMISSIONS

If renewable synthetic methane is used instead of natural gas, CO_2 emissions actually fall into the negative range, but the primary energy requirement continues to rise. The calculation is based on the assumption that the CO_2 required to produce synthetic methane is extracted directly from the atmosphere using a direct air capture plant. "This requires a great deal of energy," explains Bach, which is also the reason why he can only imagine such plants being operated in desert regions. Moreover, the construction of solar and wind power plants is also associated with emissions. If all these factors are taken into account, the direct use of synthetic methane to generate 1 MWh of high-temperature heat results in a primary energy requirement of 3.5 MWh and greenhouse gas emissions of 126 kg of CO_2. If, however, the carbon is again separated from hydrogen using pyrolysis, the emission balance turns negative: The entire process leads to emissions of –77 kg CO_2 – but with an even higher primary energy requirement of 6.2 MWh per MWh of high-temperature process heat.

"Of course, the primary energy requirement of this concept is high – around 2.5 to three times higher than the most efficient hydrogen production in Switzerland," admits Bach. "But since two to 2.5 times more electricity can be generated per square meter of photovoltaics in desert regions compared to here, this approach hardly needs any more photovoltaic area." One challenge is costs. However, Bach is convinced that if it were possible to market the carbon as a raw material for non-energy applications, the entire process could certainly be economically viable. ■

Further information on the topic is available at: www.empa.ch/de/web/s504

DEFECTS WELCOME

Is it possible to convert CO_2 back to fuels or other useful chemicals? Absolutely – but not in a very targeted way just yet. Empa researcher Alessandro Senocrate is looking at defects in materials that will help us achieve this goal.

Text: Anna Ettlin

EXPERIMENTAL
In this system, the researchers are testing different catalysts and electrode materials.

Photo: Empa

Can we undo the burning of oil, gas and coal? With a renewable source of electricity, some water and a suitable catalyst, the excess CO_2 in the atmosphere could become a resource, for example for the production of synthetic fuels, so-called synfuels.

This promising idea is drawing a lot of research, including at Empa, because the conversion is challenging to implement. For instance, a reaction using a copper catalyst – the most commonly studied catalyst for the conversion of carbon dioxide – yields around 15 to 20 different types of molecules, from carbon monoxide and methane to propanol and acetic acid. "Some of these compounds are liquid at room temperature, others are gaseous," says Empa researcher Alessandro Senocrate. "It is extremely difficult to separate all these products from each other."

Senocrate, who works in Empa's Materials for Energy Conversion laboratory led by Corsin Battaglia, intends to investigate a possible solution to this problem over the next four years. The project is funded by a Swiss National Science Foundation (SNSF) Ambizione grant and embedded thematically into the National Center of Competence in Research (NCCR) Catalysis. The goal of the project is to develop novel catalysts for CO_2 conversion. For this, Senocrate is focusing not on the material itself, but on so-called defects. Defects in a crystalline material occur, e.g., when an atom is missing in its crystal lattice or is replaced by a different atom. These defects introduce different properties in their host materials, and thus can serve as unique active sites, where catalysis takes place.

WHERE BATTERIES AREN'T AN OPTION

First, the researcher plans to investigate which defects lead to which reaction products. "Ideally, we can use this knowledge to design catalysts that produce specific molecules during the CO_2 conversion instead of a mixture," he explains. Some of the potential target molecules are of particular interest to industry. These include carbon monoxide and ethylene. These molecules are so-called platform chemicals: They are the starting materials for numerous chemical processes, including the production of most plastics. "We already have a complete value chain for such platform chemicals," says Senocrate. "However, today they are almost exclusively produced from fossil sources." Alternative, greener sources for carbon-based chemicals – whether from CO_2 conversion or from biomass – are thus in high demand.

In addition to plastics, platform chemicals can also be used to make fuels. Other research projects at Empa focus on the production of synfuels (see page 26). "Cars can be electrified very well," says Alessandro Senocrate. "But it's a different story for aircraft and for many energy-intensive industrial processes."

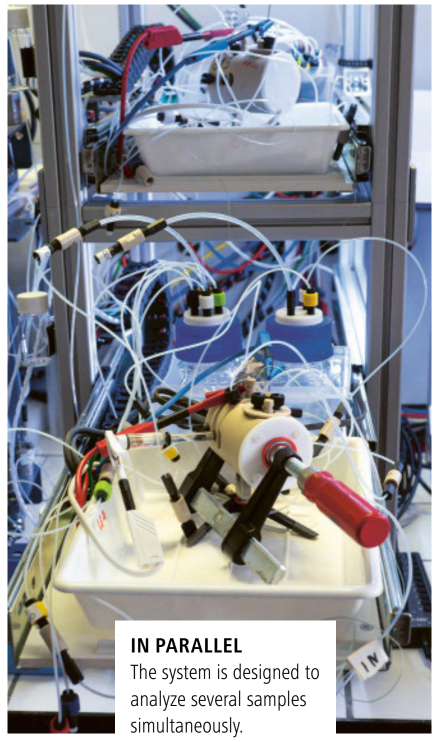
The advantage of liquid fuels such as kerosene is their very high energy density, which can exceed that of batteries by a factor of up to 100. Fuels produced with renewable energy are therefore also an especially attractive option for seasonal energy storage. The infrastructure for the transportation and storage of synfuels is already in place, as they are almost identical to fossil fuels in terms of their composition. The only thing missing is the ability to produce them on a large scale. Senocrate is optimistic: "I've only been working in this field for a few years, and yet I have already seen incredible progress," says the scientist. "Of course, it will also require major political and societal change. But from a materials science perspective, the progress is rapid."

PERFECTING THE TECHNOLOGY

Before Senocrate can contribute to this progress with his Ambizione project, he still has a few challenges to overcome. One of the biggest: introducing enough defects into the target material to achieve a measurable catalytic effect. This is because the researcher deliberately uses an inert starting material that has no influence on the electrochemical reaction without the defects. "This allows me to determine very precisely what effect the respective defects have," he explains.

Once the defects have been characterized, they can also be inserted into existing catalytic materials. "Ideally, at the end of the project, we will be able to improve an existing system for CO_2 conversion in a targeted manner," says Senocrate. Such systems are already in use in the Materials for Energy Conversion lab, where researchers are developing different catalysts and electrode materials.

The demands placed on these materials are high: "For industrial use, the catalyst must be selective, active and stable," explains Senocrate. Selectivity means that it only produces a single chemical – or at least a small number of chemicals that can be easily separated. High activity is required to produce a maximum amount of chemicals or fuels with minimal energy. And, of course, a market-ready catalyst should maintain high selectivity and activity over thousands of operating hours, i.e. be stable. "We still need to get much better at all three properties," says the researcher. "But we are making progress." ■



IN PARALLEL
The system is designed to analyze several samples simultaneously.

Photo: Empa

Further information on the topic is available at:
www.empa.ch/web/s501

LONG-LIVED LAMELLAS

Carbon fiber-reinforced polymer lamellas are an innovative method to reinforce buildings. There are still many unanswered questions regarding their recycling, however. A research project by Empa's Mechanical Systems Engineering lab is now set to provide answers. Thanks to the generous support from a foundation, the project could now be launched.

Text: Loris Pandiani

The construction sector is responsible for around 60 percent of Switzerland's annual waste. The industry's efforts to recycle demolition materials are steadily increasing. Nevertheless, there are still end-of-life materials that, for the time being, cannot be reused as recycling would be too time-consuming and expensive. One of these are carbon fiber-reinforced polymer (CFRP) lamellas.

VALUABLE The dismantling of buildings yields numerous reusable materials – including carbon fiber-reinforced polymer lamellas.

Photo: Pixabay

MAKING BUILDINGS "LIVE" LONGER

The reinforcing method developed by Urs Meier, former Empa Director at Dübendorf, has been used in infrastructure construction for 30 years. CFRP lamellas are attached with epoxy adhesive to bridges, parking garages, building walls and ceilings made of concrete or masonry. As a result, the structures can be used for 20 to 30 years longer. The method is increasingly being applied worldwide – mainly because it massively improves the earthquake resistance of masonry buildings.

"By significantly extending the lifespan of buildings and infrastructure, CFRP lamellas make an important contribution to increasing sustainability in the construction sector. However, we need to find a way how we can further use CFRP lamellas after the buildings are being demolished," explains Giovanni Terrasi, Head of the Mechanical Systems Engineering lab at Empa. To achieve this, he wants to develop a method for recycling CFRP lamellas. Convinced by this idea, a foundation supported it with a generous donation. The project officially launched in October.

GENTLE SEPARATION

First, a mechanical process will be developed to detach the CFRP lamellas from the concrete without damaging them. Initial tests at Empa are encouraging: After the lamellas were separated from the concrete, they still had a strength of 95 percent – even if they had already been used for 30 years.

Then, the demolished CFRP lamellas shall be used to produce reinforcement for prefabricated components. Terrasi's goal: saving thousands of tons of CFRP lamellas from ending up in landfills after the demolition of old concrete structures and reuse them in low-CO_2 concrete elements. After completion of the project, Giovanni Terrasi and his team – consisting of Zafeirios Triantafyllidis, Valentin Ott, Mateusz Wyrzykowski and Daniel Völki – want to produce railroad sleepers from recycled concrete, which will be reinforced and prestressed with demolition CFRP lamellas. This would give the "waste-to-be" material a second life in Swiss infrastructure construction. ■

PRIVATE SUPPORT THAT MAKES THE DIFFERENCE

The Empa Zukunftsfonds is looking for private funding for pioneering research projects that are not yet supported. If you would also like to give our research an extra boost, you can find more information here:
www.empa.ch/web/zukunftsfonds

PACKAGED IN BEER

Empa researchers have extracted nanocellulose from a waste product of beer brewing and processed it into an aerogel. The high-quality biodegradable material could be used in food packaging.

Text: Anna Ettlin

It all starts with the mash: the mixture of malt and water, which is stirred and gently heated for several hours. The resulting liquid is known as the wort, and eventually, several processing steps later, as beer. The remaining malt – known as brewer's spent grain – has a much less glamorous path ahead of it. It usually ends up as animal feed or on the compost heap.

Researchers from Empa's Cellulose and Wood Materials laboratory, led by Gustav Nyström, are looking for ways to valorize this residue. They have developed a process to produce high-quality nanocellulose from brewery waste – a versatile biodegradable raw material that can be processed, for example, into packaging materials or fiber-reinforced polymers. The researchers published their findings in the journal ACS Sustainable Chemistry & Engineering.

RESIDUE
Today, brewery spent grain is used as animal fodder or composted.

Photo: Adobe Stock

GRAIN INSTEAD OF WOOD

The paper's first author, Nadia Ahmadi Heidari, is a doctoral student at Isfahan Technical University who came to Empa for a year through a Swiss Government Excellence Scholarship. She was particularly interested in making biodegradable packaging materials from waste products – one of the focal points of Empa's Cellulose and Wood Materials laboratory. "We are very interested in exploring new sources of valuable raw materials such as cellulose fibers and lignin," says Gustav Nyström.

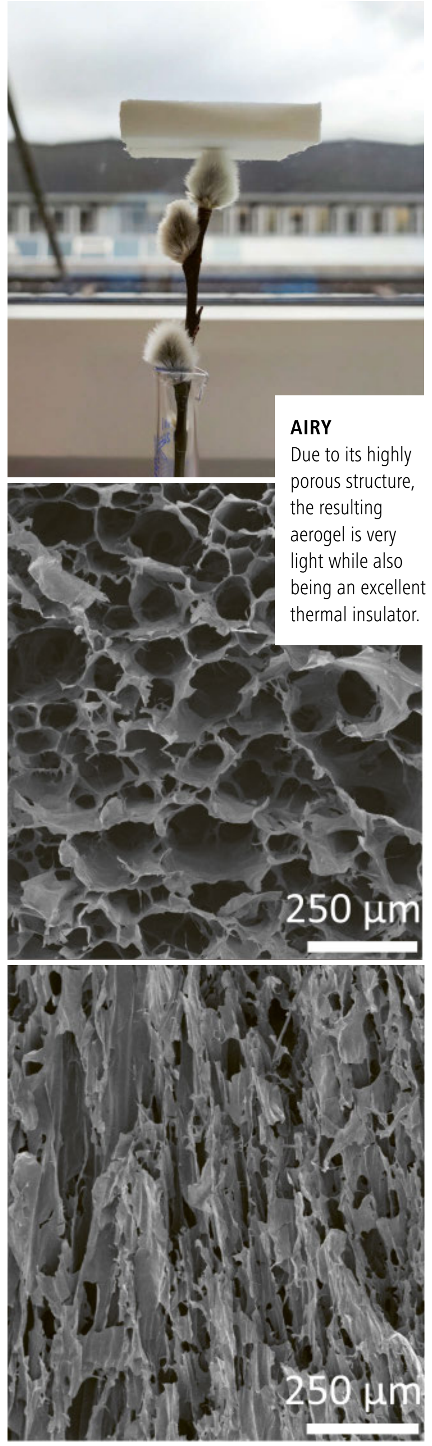
At present, micro- and nanofibrillated cellulose products, are usually extracted from wood pulp. But wood is better utilized elsewhere. "Wood is very good at binding CO_2 from the atmosphere, but it grows slowly," explains Nyström. "Therefore, it is much better suited for long-lasting applications like construction or furniture." Annual plants, which grow much faster, can be an excellent source of raw materials, but they have hardly been used for this purpose thus far. "With our process, we can obtain high-quality materials from a waste product that is very cheap and available in large quantities, and which is largely discarded today," adds Empa researcher Gilberto Siqueira, co-author of the paper. "This also benefits small companies, which can get more out of the resources they already use."

The spent grain that the researchers used for their experiment came from such a small company, the Pentabier brewery in Dübendorf. They extracted the nanocellulose fibers from the grain and processed them into an aerogel by freeze-drying. This "airy" material contains a large number of pores, which gives it excellent thermal insulation properties. Aerogels can be made from a variety of substances – a particularly well-known example are silica aerogels, which are used in construction. Nanocellulose-based aerogels have the added advantage of being extracted from renewable resources and being biodegradable. The final goal is to use them for packaging, especially for temperature-sensitive foods such as meat.

A SIMPLE PROCESS

To explore the potential of nanocellulose from brewer's spent grain in greater detail, the researchers varied the individual pretreatment and processing steps in order to test their effects on the final product. For example, the quality of the nanocellulose fibers was improved by bleaching and oxidation of the starting material. Different freezing processes can be used to control the size and orientation of the pores in the aerogel, which in turn influences its insulating and mechanical properties.

"We aimed to keep the whole process as simple as possible," says Siqueira. After all, having a convincing product is not enough to gain traction in the real world – it should also be as simple and inexpensive to manufacture as possible. That's another reason the researchers are interested in extracting raw materials from waste products. "Compared to the agricultural residues, wood is a more expensive source of cellulose and it already has so many applications," Siqueira explains. In further research projects, the scientists are therefore investigating even more residues from the food industry and from forestry. And although Nadia Ahmadi Heidari has already returned to Isfahan, the Empa team is planning another publication together with the young researcher, in which they will describe aerogels from brewer's spent grain in more detail. ■



AIRY
Due to its highly porous structure, the resulting aerogel is very light while also being an excellent thermal insulator.

Photos: Empa

Further information on the topic is available at:
www.empa.ch/web/s302

A VISIT FROM THE FEDERAL PALACE

GUIDED TOUR
Federal Councillor Guy Parmelin and Empa Director Tanja Zimmermann.

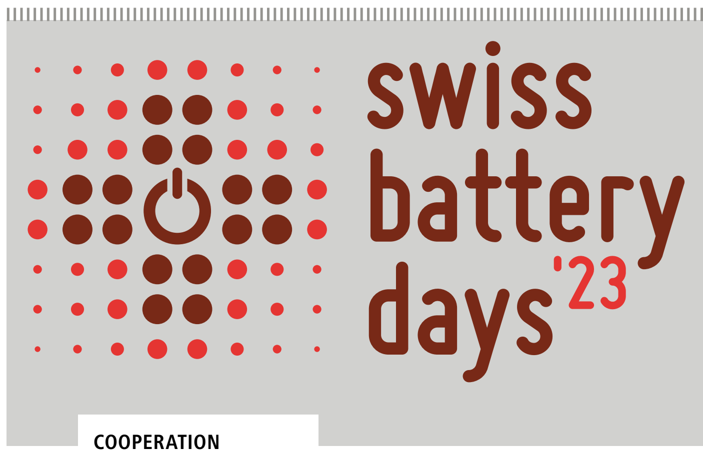
Federal Councillor Guy Parmelin, Head of the Federal Department of Economic Affairs, Education and Research (EAER), visited the Empa, Eawag and WSL research institutes on 6 November. At Empa, he got updated about the latest developments and research results in the fields of sustainable mobility, new materials as CO_2 sinks, Additive Manufacturing (AM) and innovative coating technologies and exchanged views with Empa Director Tanja Zimmermann, Deputy Director Peter Richner and Directorate member Lorenz Herrmann, who heads the Department Advanced Materials and Surfaces.

wbf.admin.ch

INTERNATIONAL CONFERENCE ON BATTERIES

The Swiss Battery Days, organized this year by PSI, Empa and the Swiss Battery Association iBAT, bring together battery researchers and industry experts. What began as a small event five years ago attracted around 150 participants from all over Europe from 18 to 20 September. The first two days were dedicated to science, with both renowned researchers and young Swiss scientists presenting their work on batteries. The subsequent Industry Day, which was organized with Swissmem, the Swiss Association of the Tech Industry, served to network innovative Swiss companies with battery giants from abroad, including LG, Freyer and Innolith. "Batteries are becoming increasingly important for Swiss industry. Swiss companies are supplying major manufacturers with innovative technologies," says Corsin Battaglia, Head of Empa's Materials for Energy Conversion laboratory, Vice-Chairman of the conference and Vice-President of the Swiss Battery Association iBAT. "At Empa, we are therefore conducting more and more joint research projects with companies to help them achieve new breakthroughs in this market."

indico.psi.ch/event/14214



COOPERATION
At the Swiss Battery Days, young researchers and innovative companies from Switzerland network with the big names in international battery research and development.

Images: Empa

Photos: Swissnex, Empa

EMPA MEETS JAPAN …

INTERNATIONAL
Empa Director Tanja Zimmermann speaks at the opening of the new Swissnex site in Osaka, Japan.

Empa Director Tanja Zimmermann traveled to Japan in October for the opening of the new Swissnex site in Japan. Swissnex, an initiative of the State Secretariat for Education, Research and Innovation (SERI) in collaboration with the Federal Department of Foreign Affairs (FDFA), connects Switzerland with players in education, research and innovation around the world. Zimmermann also attended the Science and Technology in Society (STS) Forum and visited Empa's "sister institute", the National Institute for Materials Science (NIMS) in Kyoto, with which Empa maintains a close partnership.

swissnex.org/japan

… AND POLAND

EXPERT
Peter Richner gave a talk about sustainable construction at the Polish-Swiss Innovation Day.

On 4 October, the 8th Polish-Swiss Innovation Day took place in Warsaw, this year on the topic of sustainable buildings. At the conference, Empa's Deputy Director Peter Richner gave a guest lecture at the Warsaw University of Technology, in which he talked about the decarbonization of buildings and the need to reuse building materials, and presented Empa's research and innovation building.

psid2023.pl

EVENTS
(IN GERMAN AND ENGLISH)

16.–19. JANUAR 2024
NEST IM SWISSBAU FOCUS
Ort: Messe Basel

16. JANUAR 2024
Keynote-Session: Mining the Atmosphere: CO_2-negative Baumaterialien

17. JANUAR 2024
Praxistalk: Reisst die Mauern ein! Nur gemeinsam entsteht wahre Innovation

18. JANUAR 2024
Praxistalk: Kreislauf im Bau: Heute bereits erfolgreich umsetzen

19. JANUAR 2024
Praxistalk: Integrated Project Delivery – Modell der partnerschaftlichen Zusammenarbeit im Bauwesen

Anmeldung: nest.empa.ch/swissbau2024

BESUCHEN SIE UNS AUCH AM INFOPOINT.
HALLE 1.0, MESSE BASEL

19. MÄRZ 2024
Kurs: Additive Fertigung von Metallen
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/metalle
Empa, Dübendorf

14. MAI 2024
Kurs: Klebetechnik für Praktiker
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/klebetechnik
Empa, Dübendorf

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

THE PLACE WHERE INNOVATION STARTS.

Empa

Materials Science and Technology