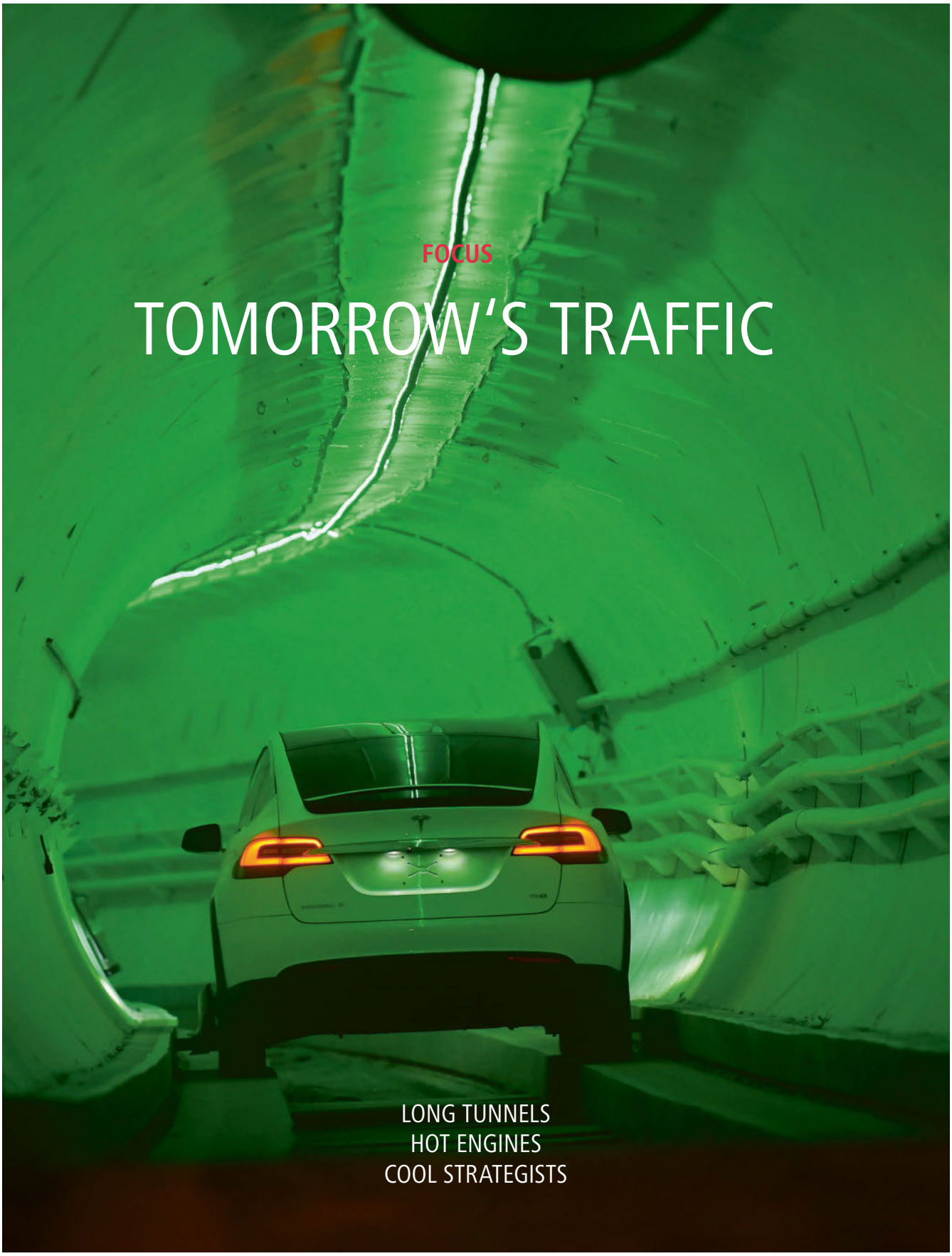
Empa Quarterly

RESEARCH & INNOVATION II #74 II DECEMBER 2021



FOCUS

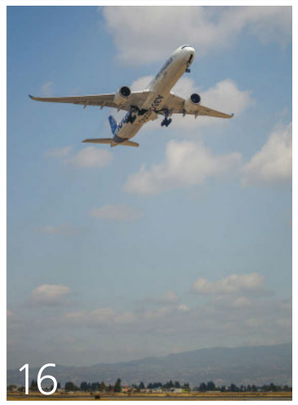
TOMORROW'S TRAFFIC

LONG TUNNELS
HOT ENGINES
COOL STRATEGISTS

www.empaquarterly.ch

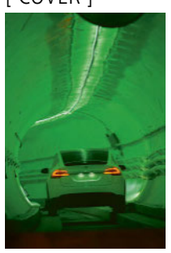
[CONTENT]

[FOCUS: TOMORROW'S TRAFFIC]



Photos: ZAMG / SBO, Airbus, Swissloop tunneling, Empa

[COVER]



Electric cars as a cheap subway? A self-driving Tesla rolls into the Hawthorne Tunnel, built in 2018 by Elon Musk's Boring Company. In April 2021, Musk opened the first commercial installation: the LVCC Loop under Las Vegas consists of 2.7 km of tunnel tubes and three stops. Plans call for expansion to 47 km and 51 stops. Image: KEYSTONE/EPA AFP POOL /Robyn Beck

myclimate neutral Printed Matter
myclimate.org/01-21-236805

[IMPRINT]

PUBLISHER Empa
Überlandstrasse 129
8600 Dübendorf, Switzerland
www.empa.ch
EDITORIAL Empa Kommunikation
LAYOUT PAUL AND CAT.
www.paul-and-cat.com
CONTACT Phone. +41 58 765 47 33
empaquarterly@empa.ch
www.empaquarterly.ch
PUBLISHING SEQUENCE
quarterly
PRODUCTION
rainer.klose@empa.ch

ISSN 2297-7414
Empa Quarterly (English edition)

ALWAYS ON THE MOVE

Dear Reader,

We live in moving times. And quite literally: mobility, both of people and goods, has probably never been greater than in our globalized present – apart from the restrictions imposed by Corona, of course. And this is unlikely to change in future.

This means developing new concepts and ideas on how we can manage this increased flow of people and goods both quickly and efficiently as well as in an environmentally friendly and safe manner. Tesla founder Elon Musk, for instance, is pushing the so-called Hyperloop, a system of virtually airless tunnels, in which capsules – pods – transport people and goods from A to B, faster than by air. First, however, the vacuum tubes for the pods have to be built. In September, Swissloop Tunneling, a student team from ETH Zurich based at Empa, took part in the Not-a-Boring Competition in Las Vegas – and got kudos for their innovative Groundhog Alpha drilling rig (p. 8). And almost simultaneously, their colleagues from the Swissloop team presented their brand-new floating pod "Simon Ammann", in the presence of the pod's namesake (p. 11).

But Empa researchers also want to further improve familiar technologies, be it the combustion engine, which is still indispensable in some applications (p. 12), or rail traffic, for which they are developing a sleeper that allows trains to roll much more quietly (p. 18).

Enjoy reading, and have a great start into the New Year!

Your MICHAEL HAGMANN

Image: Empa

TEACHING FUNGI HOW TO WRITE

Spalted wood is a highly sought-after material in the high-end furniture industry. In a newly developed process, Empa scientists led by Francis Schwarze have succeeded at controlling the spread of fungi in native wood types. Recently, they created an elaborate clock 1 meter in diameter made of spalted ash, beech and maple wood using the soft rot fungus Kretzschmaria deusta. The fungi were even taught to write some words, and just like first graders, they are still a bit shaky when writing particular letters.

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

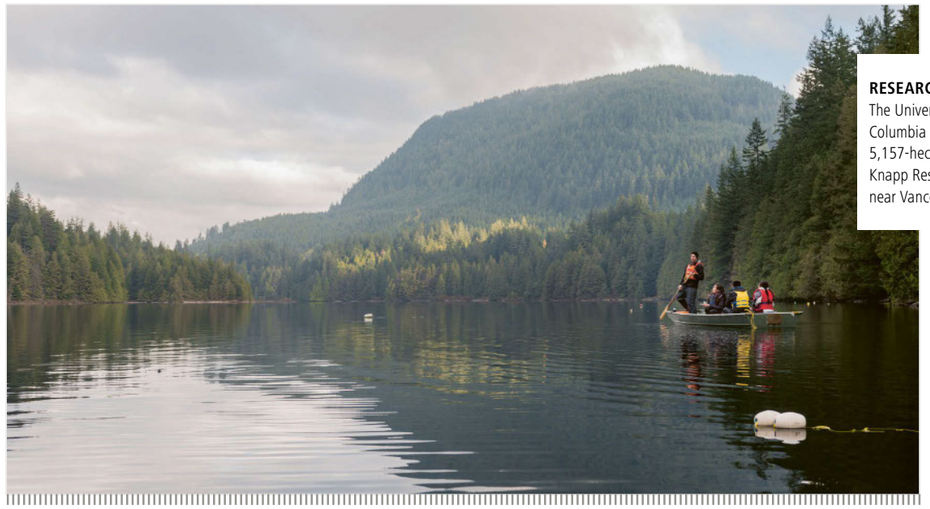
APP ALLOWS VIRTUAL INSIGHTS

This is how augmented reality (AR) works: the co-operate AR app allows virtual insights into co-operate, the new research campus of Empa and Eawag in Dübendorf. On site, so-called anchor points have been set up on the ground, which can be targeted with a smartphone.. This allows virtual models of the buildings to be viewed in their actual environment and displayed on individual floors. At the same time, construction progress can be checked in reality. The app is available in the Apple Store and the Google Play Store.

www.empa.ch/web/s604/co-operate-grundsteinlegung

PREVIEW
While a construction pit yawns in the real world, the new Empa campus is already virtually visible in the app.

RESEARCH COOPERATION ON SUSTAINABLE BIOMATERIALS



RESEARCH FOREST
The University of British Columbia operates the 5,157-hectare Malcolm Knapp Research Forest near Vancouver.

With the signing of a statement of cooperation, the BioProducts Institute at the University of British Columbia (BPI) and Empa are celebrating a new partnership to promote innovation and collaboration. The BioProducts Institute is situated in Vancouver (Canada) and operates four research themes, which might be complementary to the research acitvities at Empa: biocatalytic transformation and engineering of biomass, bio-nanoparticle enabled materials, bio-based polymers and carbon materials and biorefinery & biofuels systems. With this new cooperation agreement, Empa and BPI will seek to share best practices through knowledge exchange, co-involvement in scholarly meetings, fora, and conferences, and provide reciprocal access to research infrastructure and develop bilateral funding opportunities.

www.empa.ch/web/s604/cooperation-bpi

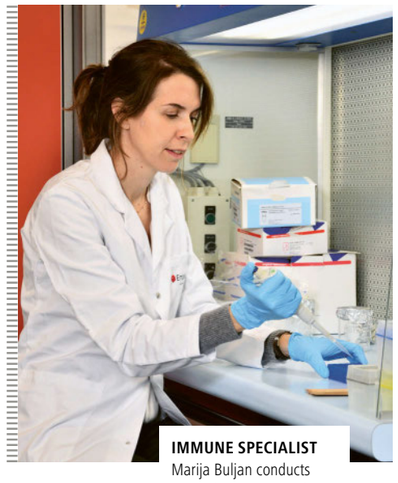
Photos: Empa, Paul H. Joseph / UBC Brand & Marketing

THE AGONY OF CHOICE
Diesel for everything? That was a thing of the past. Today, Migros logistics specialists can choose between hydrogen, biogas or electric trucks.

WHICH TRUCK FOR WHICH DELIVERY ROUTE?

Migros operates 11 hydrogen trucks, 78 biodiesel and biogas trucks and 13 electric trucks. The fleet is to be further expanded, as the cooperative plans to reduce its CO_2 emissions from road transport by 70 percent by 2030. The «M Opex Towers« software was developed together with Empa. It evaluates data from the more than 1,000 different Migros transport routes, including the distance of the route, the differences in altitude along the way, the weight of the load or the fuel consumption. This treasure trove of data is used to calculate which truck drive type is the most environmentally friendly for which route.

www.empa.ch/web/s504



IMMUNE SPECIALIST
Marija Buljan conducts research at Empa on the signals of somatic cells.

Photos: Empa, Migros

COLLABORATION IN IMMUNOLOGY

The newest member of the advisory board of the «Swiss Personalized Health Network« (SPHN) is Marija Buljan. The Board of Directors approved the appointment of the scientist, who heads a research group on «Materials Science and Technology« at Empa. The main focus of her research is to decipher the disease-related signals that body cells use to activate the immune system. This work is particularly relevant to the development of personalized cancer therapies.

The SPHN is an initiative of the Swiss Academy of Medical Sciences and the Swiss Institute of Bioinformatics. The goal of the federally funded research initiative is to promote exchange and collaboration around personalized health.

www.empa.ch/web/s403

LAS VEGAS BREAKTHROUGH

Ultra-fast capsules in vacuum tubes: all around the world, companies and research institutes are working on "Hyperloop" concepts. Swissloop Tunneling, a student initiative, is developing a drilling machine for underground transport tubes. The first reward for their efforts: a second place in an international competition in Las Vegas.

Interview: Norbert Raabe

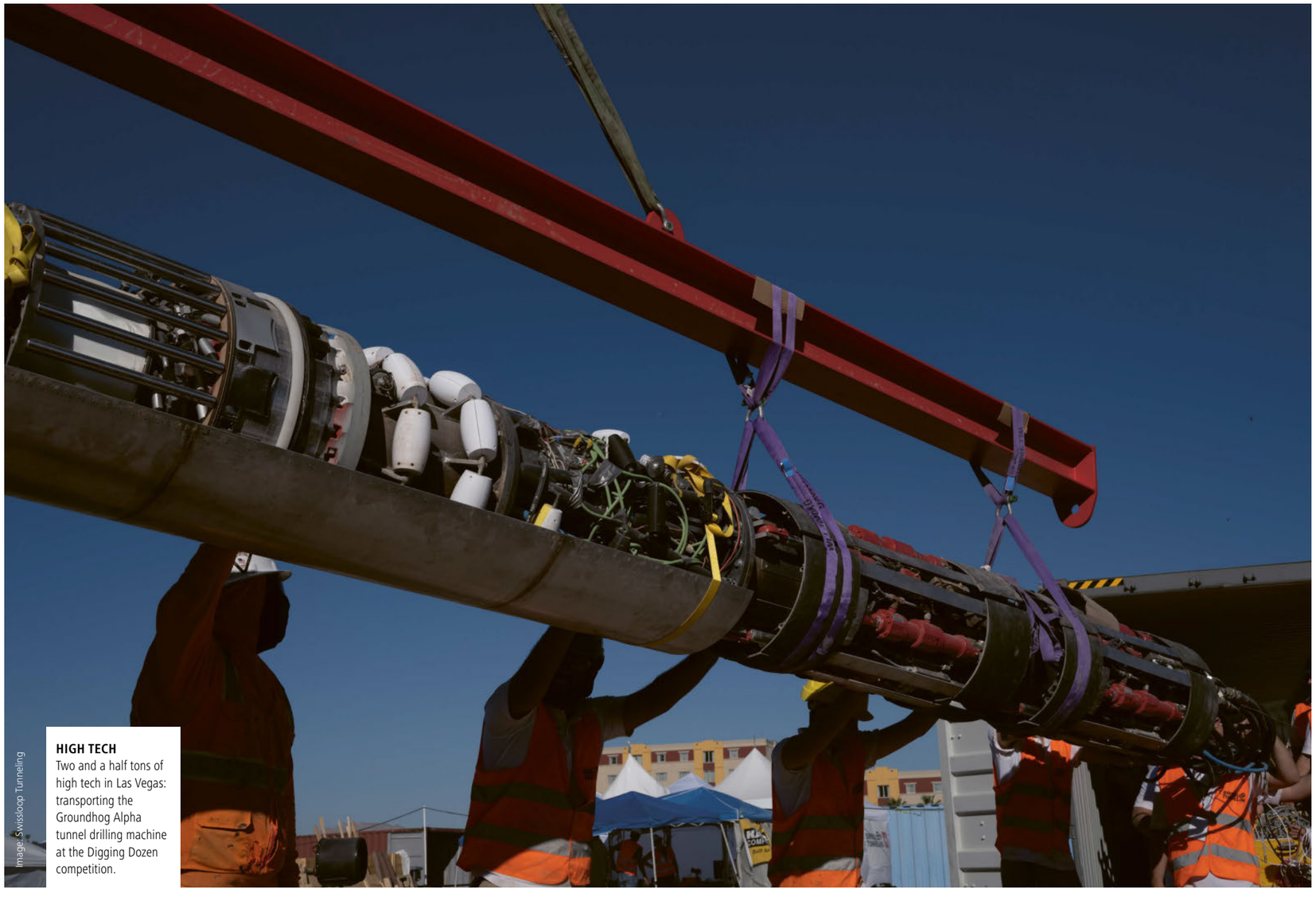


Image: Swissloop Tunneling

HIGH TECH
Two and a half tons of high tech in Las Vegas: transporting the Groundhog Alpha tunnel drilling machine at the Digging Dozen competition.

Over 400 student teams from all over the world had applied; only a dozen qualified last September for the "Not-a-Boring Competition" in Las Vegas, the tunneling competition that entrepreneur and Hyperloop promoter Elon Musk had launched. Inspections by a jury of experts on the Groundhog Alpha drilling rig lasted for days (infobox, p.10); then the Swissloop Tunneling team from ETH Zurich and other Swiss universities qualified for the final: the attempt to drill a 30-meter-long tunnel with a diameter of 50 centimeters. An endurance test for people and material, as Eugenio Valli and Lukas Heller from Swissloop Tunneling can tell.

Mr. Valli, Mr. Heller, second place in Las Vegas – was that a victory or a defeat?
Lukas Heller: For us it was a huge victory! Although eventually we couldn't dig into the ground at all with our drill in the final …

Why was that?
Heller: There were many factors. A storm in the desert damaged the drill: There was damage to various systems, especially the electronics due to lightning and rain. We also had error messages that we couldn't fix in time: When we were about to be able to start, the deadline had just passed.
Eugenio Valli: But we were one of only two teams to get permission to start at all …
Heller: … and we achieved what we aimed for. We wanted to innovate – and we won the prize for the most innovative system and for the best design.

It was the first competition of its kind. What do you take away for the future?
Valli: At the beginning, you imagine it's almost too easy to drill a tunnel. But the more experience you gain, the clearer potential problems become. For this year, we have therefore concluded: We're going to do much, much, much more testing!
Heller: We learned an enormous amount. Our motivation now is to be able to improve a few things as a result.

Many tasks still to be solved. Are real drilling tests already on your schedule?
Heller: We had already considered doing a test on Empa's construction site here in Dübendorf in the summer before the competition. But then it rained heavily; that was too risky for us. But in spring it must happen, and it will; the only question is: where?

According to your website, you not only have Hyperloop tunnels in your sights, but also conventional tunneling. Instead of half a meter in diameter, far larger scales – quite a bold vision …
Heller: Exactly. But at the moment, what's most important to us is that we innovate. In future, we could perhaps work with manufacturers to initially scale up individual systems of our Groundhog Alpha for machines that already exist.
Valli: The costs and necessary infrastructure would then also become much greater.

But you are sticking to this ambition?
Heller: Definitely! (Both laugh.)

You were recently at an important technology trade fair, Gitex, in Dubai to present your concept. What were the reactions?
Valli: Many people are fascinated by Hyperloop technology, especially the high speeds of up to 1,200 kilometers per hour. And a connection between Dubai and Abu Dhabi: There is a lot of interest in that region.
Heller: Something is also happening in Switzerland. SBB is cooperating with our new partner Eurotube, which is developing vacuum tubes, for a test tube in Collombey-Muraz in the canton of Valais.

Hyperloop routes appear to many contemporaries to be a distant future or even science fiction, but work on them has long been underway in many places – and not just at universities such as ETH Zurich or EPFL. Companies like Virgin Hyperloop in the U.S. and others have long been investing in this technology, although many technical questions remain unanswered. The most important argument is environmental protection: Floating in a vacuum tube could drastically reduce energy consumption and CO_2 emissions.

YOUNG EXPERTS INTERVIEWED
Eugenio Valli (left) is studying mechanical engineering at ETH Zurich and recently became president of the board of Swissloop Tunneling. Previously, as Head Mechanical, he was responsible for the construction of the drilling machine. This task has now been taken over by Lukas Heller (right), who is about to complete his master's degree at ETH Zurich in civil engineering with a focus on geotechnics/tunneling.

You have recently formed an alliance with Eurotube and Swissloop to speed up the Hyperloop concept. What are you planning spcifically?
Heller: For our "lining" system, i.e. the tunnel shell with 3D printing, Eurotube will help us with expert advisors, because our work does touch on this point. Eurotube already supported our team a lot with selecting the materials for the polymers for printing.

How many partners do you have thus far?
Valli: About 80. Some support us financially; others mainly contribute know-how. Or even manufacture systems for us, like the unique control mechanism from the Hagenbuch company in Ebikon. Six movable hydraulic cylinders that allow the machine to move freely at the front or even retract the drill head – for example, when it hits an obstacle in the ground.

Could you have done that without partners?
Valli: No, not in this short time. Something like this is really a big help!
Heller: And you shouldn't forget Empa as a founding partner. Our working space on campus is priceless, with the crane in the workshop and so forth. The drilling machine weighs two and a half tons – without that: no chance!
Valli: Empa is home for us.

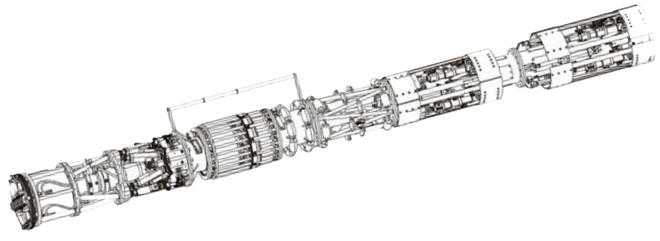
And how do you look to the future after the first year?
Heller: We have two goals. Of course, the exciting vision, the technology and the innovation. But just as close to our hearts is getting the brilliant minds at ETH Zurich out of the lecture halls and giving them an opportunity to work hands-on, so they can manufacture something from A to Z.

While Groundhog Alpha is still on its way back to Dübendorf by sea, the team is starting to prepare for the coming year – with about 30 new students joining. One focus will be on the particularly important parts of the machine. For example, on the "liner" segment, which 3D prints the tunnel wall as it is being driven, using polymers that in turn encase tear-resistant fiberglass foils. Designers want to rework this novel technology to make it work reliably. ■

Further information on the topic is available at:
https://swisslooptunneling.ch

GROUNDHOG ALPHA – AN INNOVATIVE TUNNEL DRILLING MACHINE

The prototype of the drilling machine with the Swiss groundhog in its name was created from summer 2020 for the "Not-a-Boring-Competition". The requirement: new solutions to speed up tunneling for transport tubes. Swissloop Tunneling sets itself the goal of one centimeter per second – thanks to new ideas. The machine produces the tunnel wall itself while drilling with a built-in 3D printer: a 15-millimeter layer of two polymers surrounded by protective fiberglass lamellae. In order to navigate precisely and dig curves if necessary, the drill head is mounted on six movable hydraulic cylinders. In addition, an inclined launch platform eliminates the need for a vertical excavation pit; this saves a great deal of time. The prototype is around 7 meters long and weighs 2.5 tons. In addition to ETH Zurich, the University of St. Gallen and Zurich University of Applied Sciences (ZHAW) are involved in its development.



Photos: Swissloop Tunneling

THE "SIMON AMMANN POD"

In mid-July, students from ETH Zurich traveled to Valencia with their latest pod, developed at Empa, and discussed a possible implementation of the Hyperloop concept with researchers and industry representatives.

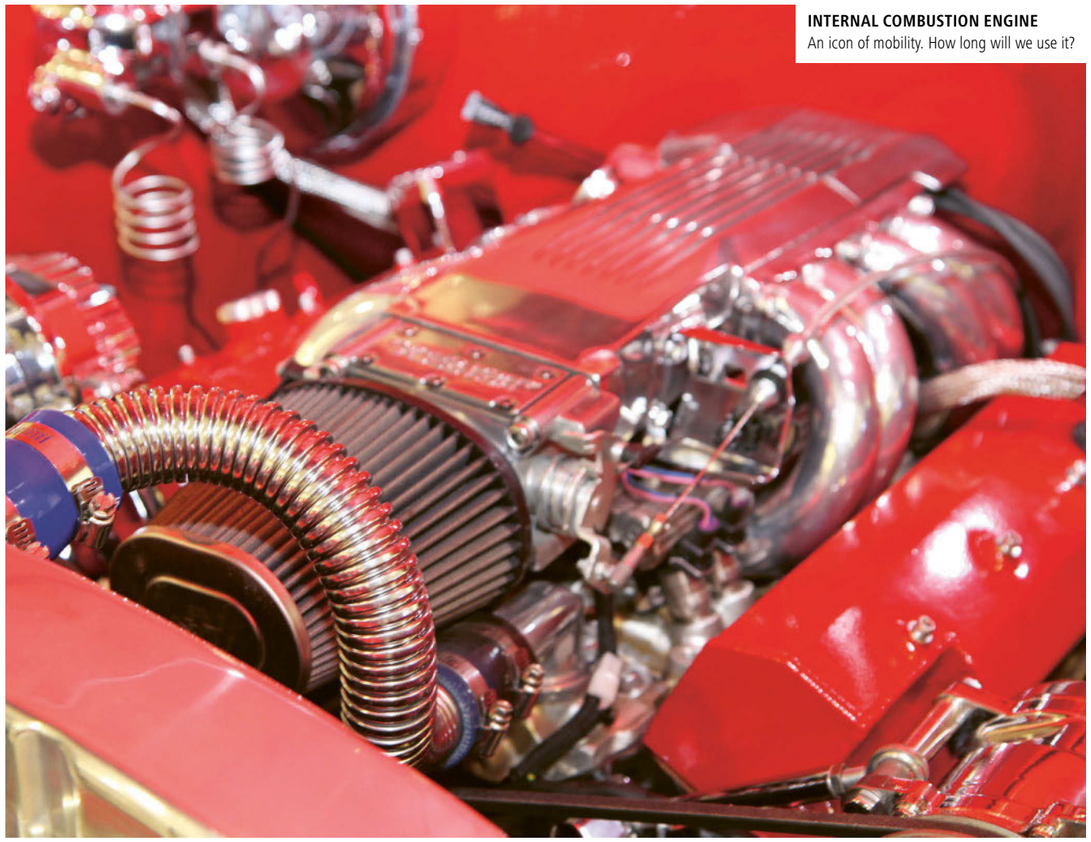
Text: Stephan Kälin

SWISSLOOP POD
In July 2021 at the ceremonial roll-out together with the name sponsor Simon Ammann (right).

In 2013, Tesla and SpaceX founder Elon Musk presented his Hyperloop concept for the first time. Since then, student teams from all over the world have competed in annual Hyperloop Pod Competitions to develop high-speed vehicles – so-called pods – for travel in vacuum tubes. Successful participants included teams from ETH Zurich, which took part every year until 2019 with new prototypes. In the Corona year of 2020, the event was cancelled, and in 2021 the "Not-A-Boring Competition" was held for the first time instead. Nevertheless, Swissloop continues to dedicate itself to vehicle development. In mid-2021, the ETH Zurich team unveiled its latest prototype. True to its namesake Simon Ammann, four-time Olympic champion in ski jumping, the pod has the ability to hover – and can thus greatly reduce friction losses. However, unlike in previous years, the team did not travel to California with it, but competed with other European teams at the European Hyperloop Week in Valencia – with great success: The expert jury rewarded Swissloop with four out of five technical awards. The team is currently working on a new prototype for 2022, when the next competition will be held in Delft. ■

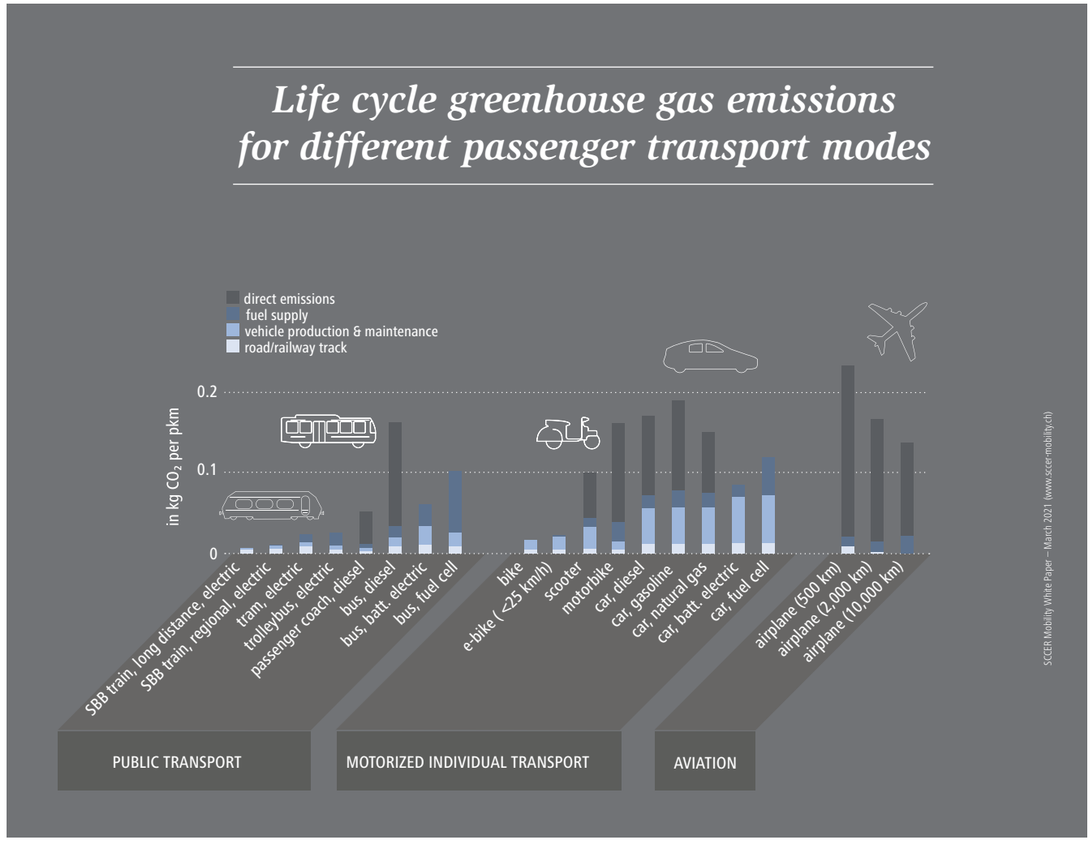
Further information on the topic is available at:
https://swissloop.ch

Photos: Swissloop



INTERNAL COMBUSTION ENGINE
An icon of mobility. How long will we use it?

Photo: iStockfoto



Grafic: Empa

THE COMBUSTION ENGINE IS NOT YET DEAD

A lot has happened in 2021: in January, the Swiss government adopted the "Long-Term Climate Strategy for Switzerland" with the goal of net zero by 2050. Over the course of the same year, Empa published a series of research papers on the internal combustion engine. But how does this fit together? Aren't combustion engines yesterday's technology?

Text: Rainer Klose

The familiar engine hum of the 20th century will become quieter in the coming years. "The switch to electric drives will happen gradually," says Christian Bach, head of the Automotive Powertrain Technologies Laboratory at Empa. "But in some applications, it will be difficult or even impossible to do without combustion engines."

Even the venerable Deutz AG in Cologne is saying goodbye to the combustion engine as its main business model. The company was founded in 1872 by Nikolaus August Otto, counted Gottlieb Daimler and Wilhelm Maybach among its employees, and built the world's first four-stroke engine in 1876. Now Frank Hiller, the CEO of Deutz, plans to generate half of the company's revenues from hydrogen engines and electric drive systems as early as 2031, according to a report in Germany's "Manager Magazin". The money for the conversion is to be generated through traditional engine manufacturing. Hiller expects that combustion engines will be needed for a longer time, for example in construction and harvesting machinery, according to the magazine. This would give the company some time to master the conversion.Hence research on internal combustion engines is focused on the coming two to three decades. The goal is to emit as few greenhouse gases as possible. On the one hand, this involves CO_2 emissions from engines, and on the other, methane, a particularly potent greenhouse gas. Methane generated from green electricity is one of the key fuels for the mobility of the future. But even this climate-neutral methane must not be allowed to escape unburned from the exhaust, otherwise little would be gained in terms of the greenhouse effect.

We therefore need a new generation of fuel-efficient engines. At the same time, we must keep a close eye on the composition of exhaust gases so that as little climate damage as possible occurs in areas where combustion engines are, for the time being, hard to replace. On the next two pages you will learn how Empa is tackling this issue. ▶

RESEARCH IN EMPA'S ENGINE LAB – THE INTERNAL COMBUSTION ENGINE ON NEW PATHS

EXHAUST MEASUREMENT BY THE ROADSIDE

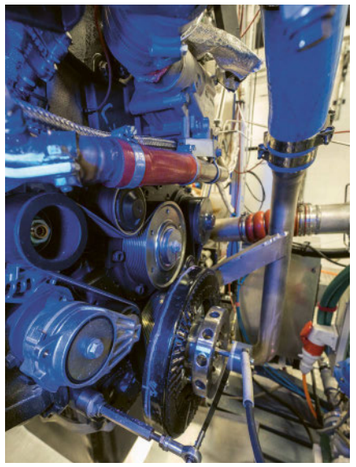
Emissions under real driving conditions can be measured using a technique called remote sensing. The measuring system records the concentration of pollutants in the exhaust gas of passing vehicles from the roadside. During a measurement, the vehicles pass through a light barrier generated by ultraviolet and infrared sources. By absorbing light of different wavelengths, a spectrometer determines the concentration of various pollutants. The measurement system is thus fixed on site and determines the real-world emissions of passing vehicles in a snapshot under the conditions prevailing at the measurement site.

the exhaust values verified in the laboratory and request the owner of the vehicles to repair them.

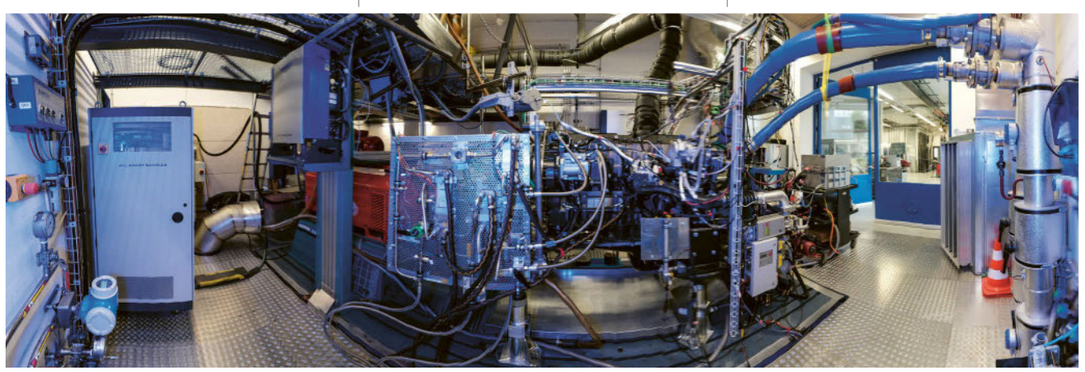
SOOT PARTICLES FROM NON-FOSSIL FUELS

To reduce greenhouse gases, internal combustion engines could in future be powered by biofuels such as vegetable oil or by synfuels such as polyoxymethylene dimethyl ether (OME). OME can be produced from green hydrogen and CO_2 from ambient air, for example. It can be used in self-igniting engines (i.e., diesel engines).

However, it is still unclear what kind of soot particles are produced from these alternative fuels and how they can be removed from the exhaust gas. In a laboratory at ETH Zurich, a single-cylinder engine was operated with vegetable oil, OME as well as various fuel mixtures. Empa researchers collected the resulting soot in particle filters and burned the filter under controlled conditions. The result: OME produced far fewer soot particles, but they were difficult to ignite and could therefore only be removed from the filters at higher temperatures.



is difficult to oxidize in a catalytic converter. It then slips through the exhaust tract into the atmosphere, causing a greenhouse effect that is 30- to 80-times greater than that of CO_2, depending on how you look at it. This would reduce the ecological benefit of methane-powered trucks. Empa researchers conducted tests with truck engines



Photos: iStockphoto, Empa

In collaboration with the Federal Roads Office (Astra), Empa evaluated two measuring devices that are already on the market. The long-term goal is to identify vehicles with defective exhaust or engine management systems in flowing traffic, have

GAS ENGINES WITHOUT METHANE SLIP

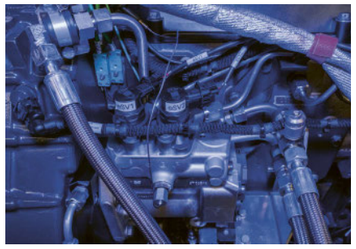
Just like OME, methane can be produced from green hydrogen and ambient CO_2, making it a suitable climate-neutral synfuel for long-haul trucks. But there is a problem: Unburned methane

in "rich" operation (with surplus fuel), in "lean" operation (with surplus air) and in lambda-one operation (methane and oxygen in a perfect combustion ratio). This corresponds to a truck that drives uphill or downhill at a constant speed.

A model experiment was conducted to investigate the chemical processes in the catalytic converter that are required to ensure that unburned methane is destroyed as much as possible – and hence does not produce an undesirable greenhouse effect. As a result, the team came up with a catalytic concept that significantly reduces methane emissions. This allows gas engines to meet the stricter requirements of the next emissions standard (Euro 7).

COMPREX CHARGER FOR GAS ENGINES

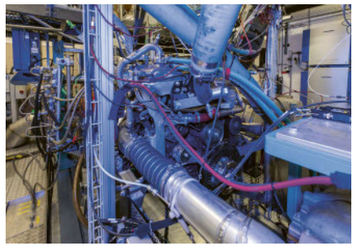
The Comprex supercharger, like the turbocharger, is a Swiss invention. The Comprex uses pressure waves in direct contact of the exhaust gas with fresh air for supercharging, while a turbocharger couples two flow machines (a turbine and a compressor).



In the 1980s, Comprex superchargers were used in diesel passenger cars by Opel and Mazda. But the supercharger had drawbacks: During cold starts, it was difficult to build up the pressure wave process, and temperature-related effects during load changes led to higher emissions and efficiency problems.

Meanwhile, engineers from the Swiss company Antrova AG have further developed the Comprex supercharger: Supported by an electric motor, it works smoothly in all conditions, and a new design of the so-called cell rotor completely solves the difficulties caused by temperature changes. Empa researchers, in collaboration with a commercial vehicle manufacturer and the Comprex manufacturer, have built a natural gas engine with such a "Comprex 2.0" supercharger and have been able to demonstrate that the new Comprex design works perfectly well in cold start conditions as well as under warm and dynamic

Photos: Empa



operation. In contrast to its turbo counterpart, the engine delivers enormously high torque practically from idle speed, which on the one hand improves drivability and, in combination with so-called Miller operation and an adjustment of the transmission ratio, helps save fuel.

At the same time, the catalytic converter warms up six times faster than in a turbocharged engine, which ensures better exhaust gas values. Finally, the Comprex enables a high engine braking effect – truck drivers would have to use the mechanical brakes much less frequently.

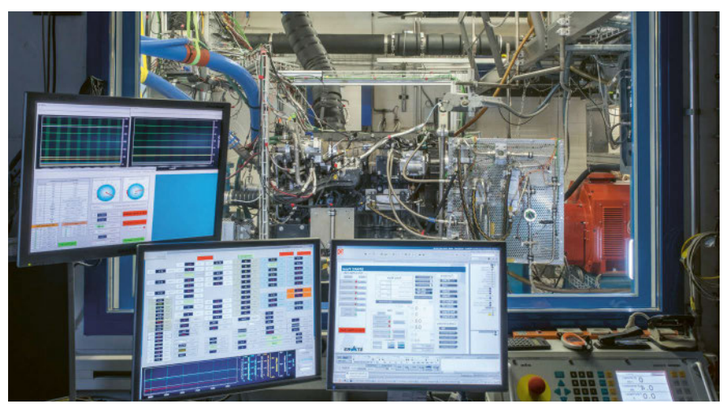
TWELVE-STROKE OPERATION

In recent years, Empa researchers have developed a fully variable electrohydraulic valve control system called FlexWork, which can be used for internal combustion engines and other thermal/pneumatic machines. Fully variable means that the valve lift as well as the opening and closing timing can be freely adjusted – even from one cycle to the next. When used on an internal combustion engine, this flexibility provides new degrees of freedom for optimization. For example, the load on gasoline engines can be adjusted without a throttle valve and from one cycle to the next, the full load can be optimized and the engine can be adapted to different fuels "by software".

The Empa team has built the valve train on a gasoline engine and is now exploring the possibilities offered by this new technology. One variant of load control is cylinder deactivation. This means that, in the partial load range, individual cylinders are operated at high load, while others are switched off completely by keeping all valves closed. However, the sudden transition from an operation with all cylinders to an operation with some cylinders shut down would result in undesirable torque peaks, so the transition must be smooth. In systems on the market today without a fully variable valve timing, such cylinder deactivation is triggered by ignition interventions that greatly reduce efficiency. With Empa's fully variable valve control system individual cylinders can be shut down without any loss of efficiency.

Just as it is possible to shut down cylinders completely, it is also possible to fire them less frequently. This turns a four-stroke operation into an eight- or twelve-stroke operation. Compared with a throttled four-stroke engine, such an engine operates much more efficiently. ■

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



EXPERT VIEW
Silvain Michel and Erwin Hack (right) examine the fuselage panel of an Airbus A350.

IN-FLIGHT DIAGNOSIS

Together with teams from England and Germany, Empa researchers developed a monitoring system for aircraft components. In the future, minor damage could be detected and monitored during flight without the aircraft having to go into the hangar for maintenance. This will reduce operating costs and increase safety at the same time.

Text: Rainer Klose

The pressurized cabins of commercial aircraft, as well as their wings and tail units, are inspected for cracks and damage at regular intervals. Every six to ten years, each jet has to undergo a D-check in a hangar for one to two months. There, it is largely disassembled, even the paint is removed. Together with the lost operating time, such a D-check can easily cost several million Swiss francs.

Couldn't it be simpler? Couldn't the stressed parts of the aircraft structure also be monitored permanently, i.e. during the flight, and any damage that occurs be specifically monitored? As part of an EU-funded project called DIMES (Development of Integrated Measurement Systems), an international research consortium has been investigating this idea. Besides Empa, the project partners are Airbus, the University of Liverpool, the companies Strain Solutions Ltd. from Great Britain and Dantec Dynamics GmbH from Germany.

WHERE IS IT? HOW BAD IS IT?

"We applied for the project in February 2018, which was launched as part of the EU's Clean Sky 2 program," explains Erwin Hack, the project manager at Empa. The question was an exciting one: Using components that were as robust and inexpensive as possible, the researchers were to monitor the metallic wing of an Airbus A320 and carbon fiber composites in the cabin panel of an Airbus A350. Hack: "The sensors were to answer several questions at the same time: Is there any damage? Where is the damage? What is the nature of the damage? How serious is the damage, and how long will the component last?"

Photos: Empa

The consortium was awarded the contract, and Empa played no small role: On the one hand, Hack is a specialist in optical monitoring of components, thermal imaging measurements and monitoring using strain gauges and Bragg gratings. All these methods were to be used on the aircraft parts at the same time. And secondly, Empa has the required infrastructure to clamp in the parts and selectively bent them thousands of times in succession. Hack developed his test strategy together with Silvain Michel from Empa's Mechanical Systems Engineering laboratory. Airbus supplied the approximately seven-meter-long wing segment of an Airbus A320-111 from Filton/UK, which had been damaged in a crash in 1988.

FOUR METHODS AT ONCE

In November 2019, the wing section was clamped in place at Empa, and the tests began. Hydraulic presses were used to bend the wing 70,000 times while the researchers collected data and analyzed the results. As expected, the bending tests enlarged the fractures the wing had suffered in the crash and led to new cracks.

The researchers "felt" the overall condition of the wing with strain gauges and fiber-optic Bragg sensors. They observed the immediate vicinity of the damage with cameras and infrared cameras – because the bending tests generate heat in the damaged wing section. Where heat is generated, it's important to look particularly closely.

PANDEMIC AS A CHALLENGE

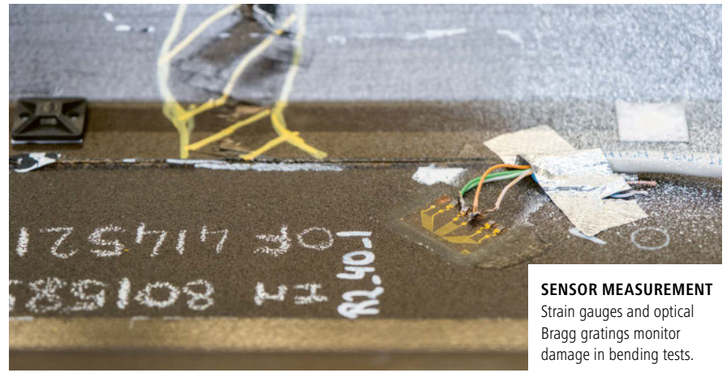
The next step was to adapt the testing methods from metal wings to carbon fiber structures of an aircraft: Airbus in Toulouse provided the cockpit of an Airbus, and Empa received fuselage panels of an Airbus A350 from Hamburg. Both parts are stressed primarily by the cabin pressure, which is built up during each flight and released again during each landing.

But then came Corona. Now the research teams in Chesterfield and Liverpool, in Ulm and Dübendorf, could no longer meet or travel to their test objects, which were in the laboratories in Dübendorf, Toulouse and Filton. The researchers solved the problem by developing a special communication system for mechanics, consisting of a helmet camera, head- and microphone. Thus equipped, a specialist in Toulouse was able to mount the module in the cockpit structure – guided remotely by experts in England, Germany and from Empa. The method worked so well that an aeronautics research laboratory in Ottawa, Canada, eventually joined the project. There, an aircraft wing was fitted with the monitoring module without the need for a single long-distance flight to the research object.

FIRST USE IN STRUCTURAL TESTS

The result of the project is a small module made of commercially available, low-cost components that can simultaneously handle four monitoring methods: strain measurements with measuring strips and Bragg sensors, optical monitoring and thermoelastic stress analysis. The data from the sensors is collected in a minicomputer and can be read out remotely.

Initially, the module will not be allowed to fly in aircraft yet, but will prove what it can do during structural tests in Airbus development labs. As the technology matures, it could play a key role in improving aircraft safety while reducing maintenance costs. The next generation of airliners could also be built somewhat lighter and thus more fuel-efficient than today thanks to such structural monitoring. ■



SENSOR MEASUREMENT
Strain gauges and optical Bragg gratings monitor damage in bending tests.

Further information on the topic is available at:
www.integratedtesting.org

SILENCE ON THE TRACKS

Noise barriers or improved wheel systems and brakes that are less noisy are not the only ways to reduce railway noise for close-by residents. An inconspicuous component under the tracks is a source of hope for a research team including Empa scientists.

Text: Norbert Raabe

ENVIRONMENTAL PROBLEM
Switzerland's dense railway network causes unacceptable nuisance in many places.

Photo: iStockphoto

Railway noise is unhealthy. Hundreds of millions of Swiss francs have already been invested in noise barriers, quieter braking systems and other measures with the goal to protect at least 80 percent of the Swiss population from emissions by the year 2025 – but because railway traffic will continue to increase, a lot remains to be done.

To further reduce noise pollution, researchers at Empa and the Vaud School of Economics and Engineering, under the leadership of colleagues from EPFL, are relying on an inconspicuous component of the rail system: "rail pads" made of elastic plastic, which are inserted between the rails and concrete sleepers. They serve to protect the highly stressed track made of compacted ballast and concrete sleepers by allowing the rails to move just a tiny bit – like a guitar string that is pressed onto the fingerboard at several points at once. But it is precisely this minute movement of the rails that makes them "sound" louder – and this noise is the decisive factor at frequent speeds of between 60 and 160 km/h.

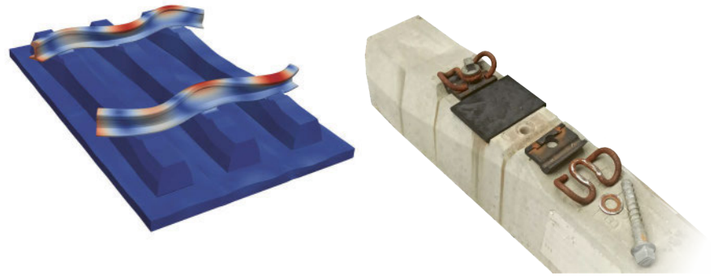


Photo: HEIG-VD

SIMULATION AND HARDWARE
The graphic on the left illustrates the deformation of the rail. Right: Grey rail pads protect the sleepers from high loads.

TAILOR-MADE COMPOSITE MATERIAL

In Switzerland, rail pads are usually made of the hard polymer ethylene vinyl acetate (EVA). It is true that a softer material would protect the tracks even better – but at the price of a higher noise pollution. This is a dilemma that the team commissioned by the Federal Office for the Environment (FOEN) wants to solve with a composite material. The idea: hard shell, soft core. More precisely: a shell made of EVA and a core made of the soft material polyisobutylene, whose damping is precisely tuned to the frequency range from about 200 to 2,000 Hertz, at which vibrations are particularly noise-intensive.

Uncharted territory, in other words. That's why the experts designed dozens of variants: sandwich structures made of flat layers – with and without a "lid" made of EVA. Zigzag-shaped PIB fillings, surfaces with incisions and all sorts of other things. But in order to find out in the laboratory what effect each type of construction has, extensive preliminary work was necessary.

The complex interaction between rails, sleepers and ballast was simulated by a "three-sleeper unit cell": a piece of track, just under two meters long, equipped with a "shaker" that generates defined frequencies and a probe that measures the sound intensity. Although this measuring cell does not reproduce the real behavior of a railroad track, it does allow precise comparisons to be made under varying conditions.

At the same time, researchers led by Bart van Damme of Empa's "Acoustics / Noise Control" lab developed a simulation of the system using finite element methods that matched the results of the experiments very well: the basis for eventually extrapolating the behavior to a longer railroad track.

With these tools of the trade, the researchers took a close look at their rail pad designs. Results: Sandwich structures, which can be easily bent thanks to indentations, were unsuitable for protecting the track bed and reducing noise at the same time, van Damme said. Zigzag-shaped infill made of PIB also did not bring any advantages. The best solution proved to be a PIB content of over 50 percent, inserted in a "shell" made of the harder EVA.

TESTS ON REAL RAIL TRACKS

A simple structure, then – with advantages for tests that will take place on a rail track in Nottwil starting next March. "These rail pads are easy to manufacture. We will need almost 400 of them on the 100-meter track," says van Damme, which is why a company is on board to manufacture the patented components.

Measurements of noise, vibration, deformation and other characteristics will show how the rail pads perform. "We hope that they will cause audibly less noise and at the same time protect the ballast better than the conventional hard intermediate layers," says van Damme.

In any case, there is optimism among the researchers. "The models developed in the project allow targeted optimization of the sometimes contradictory requirements," says Empa lab head Jean-Marc Wunderli. And: "Since no significant additional costs are expected for the production of the intermediate layers, I hope they will be used on a large scale and thus make a significant contribution to reducing railway noise." ■

Further information on the topic is available at: www.empa.ch/web/s509

SPEED LIMIT 30 – LESS NOISE?

Kurt Heutschi, a senior scientist in Empa's Acoustics / Noise Control lab, explains what noise does and why we perceive sound so differently.

Interview: Radka Laubacher, Radio SRF1 for the radio progam "Forum"

Mr. Heutschi, can noise actually be measured?
Noise is the term used to describe unwanted sound. In this context, unwanted means that it depends on a person's judgment whether a sound signal is noise or not. A sound measuring instrument cannot make this classification, i.e. noise is not measurable.

We perceive a buzz saw as annoying, but a rushing stream as pleasant. Why is that?
When evaluating sounds, humans tend to perceive natural sounds as less annoying or even as pleasant and enriching. Technical sounds tend to be rated as more unpleasant. The buzz saw is particularly extreme because its sound contains a very distinct tone, that is, a specific, dominant sound frequency. Street noise is more of a hissing sound, i.e., less annoying than the buzz saw at the same sound intensity. It is interesting to note that personal attitudes also have an influence on the evaluation. If, for example, I have shares in a company producing or operating wind turbines, their noise bothers me much less, since it signals that I am earning money.

Is traffic noise more acceptable in a city?
I think we have accepted in society that our need for mobility leads to noise. If we feel that this noise is unavoidable, we are much more likely to accept it. Where our acceptance quickly vanishes, however, is with posers, i.e., when cars are intentionally driven at extra loud levels. This does not satisfy a need for mobility, but rather personal passions are acted out.

ARTIFICIAL NOISE
In Empa's «AuraLab,« a test subject assesses her perception of rail travel noise.

Photo: Empa

How does the speed limit of 30 km/h compare to the speed limit of 50 km/h in terms of noise?
It depends on the type of vehicle, i.e. car, delivery vehicle or truck, plus the driving style also plays a role. But on average, a car emits about 5 dB less noise at 30 km/h compared to 50 km/h. This can be seen by comparing the maximum noise levels, i.e. when the vehicle passes at the shortest distance. However, if we look at the total amount of noise while a vehicle is passing us – or a resident – then the noise is reduced by only about 3 dB at speed 30. The reason for this is that the slower vehicle is significantly quieter, but it also takes longer to pass us.

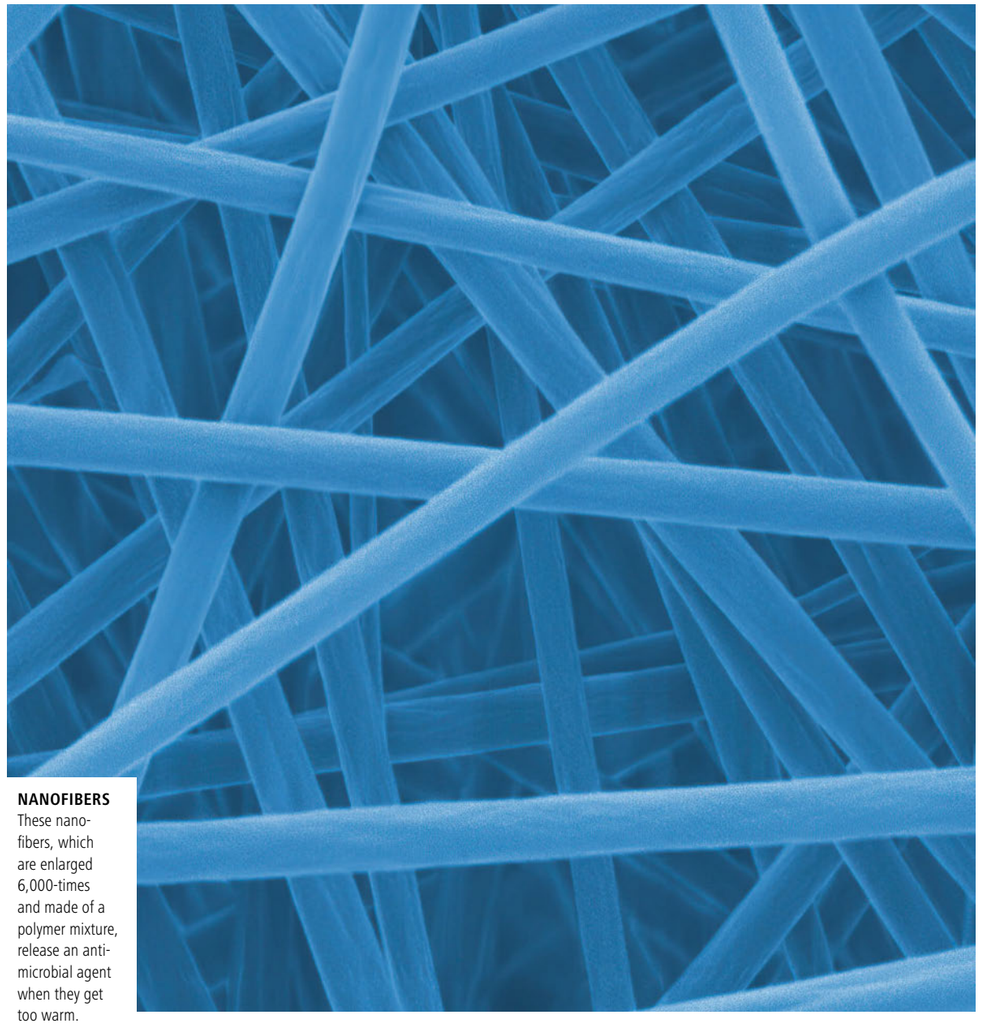
Do we perceive noise differently during the day and at night?
The reduction of 5 dB in the maximum level plays a role primarily at night, since potential sleep disturbances particularly depend on the maximum level. During the day, when many vehicles are on the road, a constant noise level builds up – you could call it a sound carpet. At 30 km/h, this sound carpet is 3 dB lower than at 50 km/h. This is a noticeable improvement, but nowhere near as noticeable as at night. Of course, a 30 km/h zone only has an effect if everyone adheres to the speed limit. Even a few speeding drivers would generate large and highly annoying noise peaks. ■

Further information on the topic is available at:
www.empa.ch/web/s509

IN THE HEAT OF THE WOUND

A bandage that releases medication as soon as an infection starts in a wound could treat injuries more efficiently. Empa researchers are currently working on polymer fibers that soften as soon as the environment heats up due to an infection, thereby releasing antimicrobial drugs.

Text: Andrea Six



NANOFIBERS
These nanofibers, which are enlarged 6,000-times and made of a polymer mixture, release an antimicrobial agent when they get too warm.

Photo: Empa

It is not possible to tell from the outside whether a wound will heal without problems under the dressing or whether bacteria will penetrate the injured tissue and ignite an inflammation. To be on the safe side, disinfectant ointments or antibiotics are applied to the wound before the dressing is applied. However, these preventive measures are not necessary in every case. Thus, medications are wasted and wounds are over-treated.

Even worse, the wasteful use of antibiotics promotes the emergence of multi-resistant germs, which are an immense problem in global healthcare. Empa researchers at the two Empa laboratories Biointerfaces and Biomimetic Membranes and Textiles in St. Gallen want to change this. They are developing a dressing that autonomously administers antibacterial drugs only when they are really needed.

The idea of the interdisciplinary team led by Qun Ren and Fei Pan: The dressing should be "loaded" with drugs and react to environmental stimuli. "In this way, wounds could be treated as needed at exactly the right moment," explains Fei Pan. As an environmental stimulus, the team chose a well-known effect: the rise in temperature in an infected, inflamed wound.

SIGNS OF INFLAMMATION AS TRIGGERS

As early as in the ancient world, the Greek physician Galen described the signs of inflammation. The five Latin terms are still valid today: dolor (pain), calor (heat), rubor (redness), tumor (swelling) and functio laesa (impaired function) stand for the classic indications of inflammation. In an infected skin wound, local warming can be as high as five degrees. This temperature difference can be used as a trigger: suitable materials change their consistency in this range and can release therapeutic substances.

PERFECT MIXTURE

Now the team had to design a material that would react appropriately to this increase in temperature. For this purpose, a skin-compatible polymer composite was developed made of several components: acrylic glass (polymethyl methacrylate, or PMMA), which is used, for example, for eyeglass lenses and in the textile industry, and Eudragit, a biocompatible polymer mixture that is used, for example, to coat pills. Electrospinning was used to process the polymer mixture into a fine membrane of nanofibers. Finally, octenidine was encapsulated in the nanofibers as a medically active component. Octenidine is a disinfectant that acts quickly against bacteria, fungi and some viruses. In healthcare, it can be used on the skin, on mucous membranes and for wound disinfection.

SHATTERING GLOVE

"In order for the membrane to act as a "smart bandage" and actually release the disinfectant when the wound heats up due to an infection, we put together the polymer mixture of PMMA and Eudragit in such a way that we could adjust the glass transition temperature accordingly," says Fei Pan. This is the temperature, at which a polymer changes from a solid consistency to a rubbery, toughened state. Figuratively, the effect is often described in reverse: If you put a rubber glove in liquid nitrogen at –196 degrees, it changes its consistency and becomes so hard that you can shatter it like glass with one blow.

The desired glass transition temperature of the polymer membrane, on the other hand, was in the range of 37 degrees. When inflammation kicks in and the skin heats up above its normal temperature of 32 to 34 degrees, the polymer changes from its solid to a softer state. In laboratory experiments, the team observed the disinfectant being released from the polymer at 37 degrees – but not at 32 degrees. Another advantage: The process is reversible and can be repeated up to five times, as the process always "switches itself off" when it cools down.

THE SMART DRESSING

Empa researchers are working in interdisciplinary teams on various approaches to improve medical wound treatment. For example, liquid sensors on the outside of the dressing are to make it visible when a wound is healing poorly by changing their color. Critical glucose and pH values serve as biomarkers.

To enable bacterial infections to be contained directly in the wound, the researchers are also working on a polymer foam loaded with anti-inflammatory substances and on a skin-friendly membrane made of plant material. The cellulose membrane is equipped with antimicrobial protein elements and kills bacteria extremely efficiently in laboratory tests.

Moreover, digitalization can achieve more economical and efficient dosages in wound care: Empa researchers are developing digital twins of the skin that allow control and prediction of the course of a therapy using real-time modeling.

Following these promising initial tests, the Empa researchers now want to fine-tune the effect. Instead of a temperature range of four to five degrees, the smart bandage should already switch on and off at smaller temperature differences.

SMART AND UNSPARING

To investigate the efficacy of the nanofiber membranes against wound germs, further laboratory experiments are now in the pipeline. Team leader Qun Ren has long been concerned with germs that nestle in the interface between surfaces and the environment, such as on a skin wound. "In this biological setting, a kind of no man's land between the body and the dressing material, bacteria find a perfect biological niche," says the Empa researcher. Infectious agents such as staphylococci or Pseudomonas bacteria can cause severe wound healing disorders. It was precisely these wound germs that the team allowed to become acquainted with the smart dressing in the Petri dish. And indeed: The number of bacteria was reduced roughly 1,000-fold when octenidine was released from the smart dressing.

"With octenidine, we have achieved a proof of principle for controlled drug release by an external stimulus," said Qun Ren. In future, she said, the technology could be applied to other types of drugs, increasing the efficiency and precision in their dosage. ■

TAKING A SAMPLE
Empa researcher Fei Pan is working on a membrane made of nanofibers that releases medication only when the material heats up. Such a membrane could, for example, become active in a bandage as soon as an inflammation starts.

Photo: Empa

Further information on the topic is available at:
www.empa.ch/web/s404

ECOLOGICAL COATING FOR BANANAS

Empa and Lidl Switzerland have jointly developed a cellulose protective coating for fruit and vegetables. The novel coating is made from so-called pomace – squeezed fruit and vegetable peels. The innovative project can reduce packaging and prevent food waste.

Text: Mathias Kaufmann, Rainer Klose

Plastic packaging in grocery stores protects fruits and vegetables from spoilage, but also creates significant amounts of waste. Together with the retailer Lidl Switzerland, Empa researchers have now developed a protective cover for fruit and vegetables based on renewable raw materials. For this project, Lidl chose Empa as a partner because Empa had decades of research experience with cellulose products.

KEEPING FRUITS FRESH AT HOME

In Empa's Cellulose & Wood Materials laboratory, the researchers then spent more than a year developing a special protective cellulose coating that can be applied to fruits and vegetables. The result: Coated fruits and vegetables stay fresh significantly longer. In tests, the shelf life of, for instance, bananas was extended by more than a week. This significantly reduces food waste. "The big goal is that such bio-coatings will be able to replace a lot of petroleum-based packaging in the future," says Gustav Nyström, head of the Empa lab.

Photos: Manifesto Films / Lidl Schweiz

PRODUCTION FROM PRESS RESIDUES

The idea is to process so-called pomace into fibrillated cellulose. Pomace is the solid residue left over after extracting the juice from fruit, vegetables or plants. Previously, this plant leftover was disposed of in biogas plants or directly on the field; in the future, it will be used to create a protective coating for fresh fruit. The coating is either sprayed onto the fruit or applied to the produce as a dip and is easy to wash off. As it is harmless to the consumer, it can also be consumed without harm. The potential of cellulose coatings is by no means exploited yet; there is the possibility of adding additives such as vitamins or antioxidants.

THROUGHOUT THE COUNTRY

In summer, the highly promising preliminary study, which has been ongoing since 2019, was successfully completed and the main study launched. The cellulose layer developed at Empa will be tested and further improved over the next two years together with Lidl Switzerland and a fruit and vegetable supplier. The project is supported by Innosuisse, the Swiss innovation agency. The aim is for the new technology to be used in all 150 Lidl stores throughout Switzerland following the successful main trial. ■

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

ECO-PACKAGING
Empa researchers Kevin DeFrance (left) and Gustav Nyström (right) worked with Corina Milz of Lidl Switzerland to develop the sustainable cellulose protective layer for fruits and vegetables.

BUILDING LEAN PAYS OFF

Superinsulating materials such as aerogels are expensive. At the same time, they offer a powerful advantage: the thinner the insulation of a building, the larger its sable area. An Empa research team shows when and where, even today, the use of aerogel is already economically viable and ventures an optimistic forecast.

Text: Stephan Kälin

CREATING SPACE
Profitable use of aerogel: thanks to superinsulation, an additional 30 square meters of usable space were created in the new building on Hohlstrasse in Zurich.

Photo: zimmermannfotografie, Jürg Zimmermann

Swiss real estate prices have been rising for months, shattering many a dream of home ownership. Especially in cities like Zurich, Geneva, Lugano and Basel, prices per square meter are among the highest in Europe. A square meter of floor space is therefore hard cash – in Zurich, the average price is around 12,700 Swiss francs. Anyone who builds cleverly – and above all economically – thus tries to maximize the usable building space as much as possible, both in a new building and in a renovation.

Superinsulation materials such as aerogels can play an important role here. For the same insulating effect, such materials require half or even only a quarter of the thickness necessary with conventional insulating technologies. On the other hand, such high-performance insulations are many times more expensive. In their latest study, a team led by Empa researcher Jannis Wernery pondered the question: When does the use of superinsulating materials pay off? In other words: When is the financial benefit of the additional floor space greater than the additional cost of the more expensive insulating material that leads to this gain in floor space? "For this purpose, we derived a simple equation that can also be used in the future by planners to decide on the appropriate insulation material early in the process," explains Wernery.

POTENTIAL IN EUROPE, NORTH AMERICA AND ASIA

It is obvious that the use of superinsulation is particularly worthwhile in the context of dense construction in cities. For their analysis, the researchers looked at the 25 most expensive cities in Europe, North America and Asia. In all three regions, they identified great potential: In an initial analysis, building with aerogel instead of mineral wool is worthwhile wherever the price per square meter is above 8,000 Swiss francs. In Europe, this applies to the 15 most expensive cities – including the four Swiss cities mentioned above. In North America, it's the 14 most expensive cities – from New York to Waikiki. And in Asia, it's the ten most expensive cities.

A real-life example on Hohlstrasse in Zurich shows how lucrative the use of superinsulation materials can be. The mixed residential and commercial building in the city center was built between 2015 and 2019 and is considered to be the first building in Switzerland to be insulated almost entirely with aerogel. The building is the last piece of a perimeter block development. The building's exterior perimeter therefore had to correspond with the existing buildings and left no wiggle room. "To maximize interior usable space, a wood aerogel façade was used that is just 14 centimeters thick," says Wernery, who served as a scientific advisor during the building's design and construction phases. "By comparison, a façade with conventional insulation material would have been around 20 centimeters thick," adds the Empa researcher.

Extrapolated to the entire building, the use of the superinsulation material thus created around 30 additional square meters of usable space. At a price tag of 12,700 Swiss francs per square meter, this comes down an added value of 381,000 Swiss francs. Deduct from this the additional costs of aerogel compared to conventional insulation, and you end up with a profit of around 247,000 Swiss francs.

"That's where we are today," Wernery says. "It gets even more exciting when you take a look into the future." The use of aerogel in construction is still rather new. At the same time, there are major research efforts – among others at Empa – to simplify the production process of aerogels and thus make the material more affordable. "Compared to today's production methods, the best-case scenario is a halving of production costs for aerogel granules," says Wernery. If this happens and real estate prices continue to rise, it will soon no longer be just the world's most expensive cities where the use of aerogel is financially viable. ■

FROZEN CLOUDS
Aerogels are the lightest solids known. They provide excellent insulation and are easy to recycle.

Photo: Empa

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

PREFABRICATED AEROGEL WOOD ELEMENTS IN THE NEST UNIT SPRINT

Together with the companies AGITEG AG and ERNE AG Holzbau and supported by Innosuisse, Jannis Wernery's Empa team developed prefabricated aerogel wood elements that are suitable for new buildings and upward extensions as well as for renovations. The elements consist of OSB boards with aerogel-filled gaps. At a thickness of just 15 centimeters, the elements achieve a U-value (heat transfer coefficient) of 0.2 W/(m²K). For an initial field test, the new elements were installed in the NEST unit Sprint, which was opened at the end of August 2021 in the Empa and Eawag research and innovation building. The Sprint unit was built almost entirely with reused components and scrap materials. Following this maxim, offcuts and scrap material from the production of aerogel sheets and granulate were also used for the aerogel wood elements. The function of the façade elements is now being continuously analyzed by means of monitoring.

PLAYING FOR CLIMATE PROTECTION

If Switzerland wants to achieve its goal of being climate neutral by 2050, there are still many hurdles to overcome. As part of the St. Gallen City Challenge for the Swiss Digital Day 2021, a new simulation game developed by Empa and partners immersed participants in problems, opportunities and quandaries – a lively inspiration for a sustainable future.

Text: Norbert Raabe

Today they will stop global warming: Bertrand, a food engineer, and Stephi, a biochemist with a PhD and a soft spot for environmental issues. Ariane and Salomon, two experts in sustainability, as well as Patrick, instructor for teachers, Marcel, an Empa scientist, and Tamar, a spatial planner. Between 41 and 56 years old, they bring a diverse range of skills and a lot of experience. And curiosity as to whether they will reduce greenhouse gas emissions in Switzerland to net zero – in half a day?

Saturday, 23 October, 1:30 p.m.: "postfossilCities" at Empa St.Gallen. "We're about to take off and accelerate!" says Markus Ulrich, a simulation game professional who helped develop it. With Empa researcher Andreas Gerber, he explains the simulation, which is based on several years of studies (see infobox). From now on, Bertrand is an investor, Stephi represents the general population, Ariane is a planner, and Salomon is an energy supplier. Patrick becomes a niche player, Marcel a politician and Tamar an industry representative.

Seven roles, equal rights – a climate federal council, so to speak. To make the simulation feel real, the rules of the game specify several goals. On the one hand, success in the struggle for less greenhouse gases and "a good life for all," on the other hand, pure self-interest. In other words, the politician should promote his popularity, the niche player new technologies; and industry wants to maximize its profit.

PUBLIC SPIRIT AND STUBBORNNESS

Warm-up round to the future: 2021 to 2024. Thank goodness there are no dice rolls in climate. Instead, the seven are each allowed to select three of their action cards: Climate protection measures ranging from cautious to radical. They look skeptically at their options, ponder, murmur. The investor, for example, can invest money in hybrid vehicles, possibly a transitional technology – and the politician could try to ban internal combustion engines for private vehicles altogether.

The consequences of each action can be read off the cards. The effect on the climate as well as the influence on one's own "role strength": Those who assert their interests may use more action cards – and thus have more room to maneuver. And last but not least, "de-blockers": other players who have cards that can be used to strengthen the effect of their own card. If you want to win, you have to forge alliances.

Second round: 2024 to 2027. Around the game table in the center, the seven form groups, split up, look for new alliances, compare their cards. Planner versus politician: First "renovate for a better climate" or immediately a strict building law to establish a "zero or plus energy standard"? Or better "urban self-determination" in advance, so that neighborhoods in the Swiss city help shape climate protection? Planner Ariane herself works on sustainable projects with citizen participation and wished for more action cards with such ideas. "Politics needs participation, too, doesn't it!" she says.

"30 seconds left, 10, stop!", Markus Ulrich's voice echos through the room. Andreas Gerber records the cards he has put down one by one on the computer in the game software. "Ah, you've been doing urban planning: Planning for short distances," he says, "huiij, also a drastic measure: banning combustion engines!" What did all this achieve? Andreas projects diagrams on the wall: four players are tied for the lead. The curve of greenhouse gas emissions by the year 2100 has lowered, but: "There is still a lot of potential in some areas," he says, "food and industry, for example."

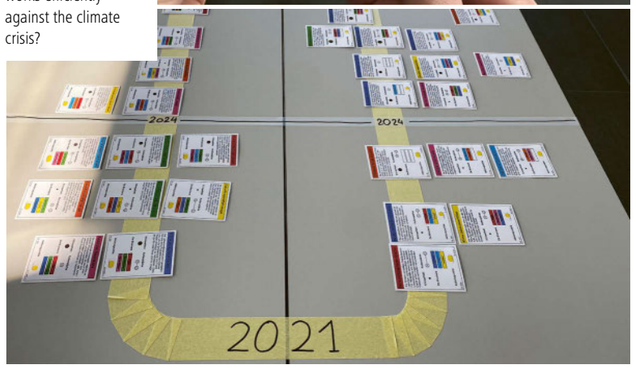
THE CLOCK IS TICKING

Third round: 2027 to 2030. Only five minutes to reflect – after all, time is running out for climate protection, too. Nevertheless, Stephi remains level-headed. Drastic action may not be necessary for her "population," she hopes. And black-and-white decisions like "Nuclear power? No thanks"? Better to wait and see.

Photo: iStockphoto

PRACTICING THROUGH PLAY
Effective strategies for climate protection are not created in a quiet room. Empa has developed a climate game that works well in teamwork to bring out ideas. ▶

SPOILT FOR CHOICE
Which «action card« works efficiently against the climate crisis?



Negotiate again. Groups of three, four and five, proposals, compromises. The game gets faster and also more intense. "He just won't budge on CO_2 capture and storage!", grumbles niche player Patrick about a colleague and leaves the group. "Vested interests versus collaboration," says Andreas Gerber with a satisfied smile, "now everyone is really in the middle of the game!"

A metronome starts ticking: one minute to go. And then another drastic directive. "Ban fossil heating systems," Andreas reads out. Energy consumption by refrigerators, stoves and other appliances will also be reduced, but the projection shows: The greenhouse gas emission curve slides only minimally downward as a result. Household appliances thus do not play a major role for the greenhouse gas balance.

JOINT CONCLUSION INCLUDED

"On balance, an effective round. But our emissions are still three times the available carbon budget," the game leader sums up. Much remains to be done, but at shortly before 4 p.m. time is running out, because the debriefing, which is part of the game, is still to come – aborting the exFercise. Disappointed expressions here and there. "Leave your roles," says Markus Ulrich all the same, "return to the year 2021!"

Coffee, chocolate, time to breathe – already thoughts are swirling through the round like leaves in a storm. "Coordination is important," says Stephi, "but sometimes you just have to take a decision and then see what happens. Very exciting!" Planner Ariane also found the game inspiring. "More topics from areas like biodiversity or health would be nice," she adds. And Solomon? "You're happy when a coup succeeds," he says, grinning, "but in the game, of course, there are only 'good' measures – no antagonists like 'climate Taliban' as opponents."

THE GAME

"postfossilCities" is a simulation game, in which players test the transformation of a fictitious Swiss city to climate neutrality. In addition to role-playing elements, the game also includes a new dynamic computer model that contains data on the material flows of the entire Swiss economy. This model makes it possible to spontaneously calculate various scenarios – the basis for estimating the impact of around 200 decision options ("action cards") on greenhouse gas emissions in various sectors. Because of its complexity, the game is not available in stores – it is designed for guided workshops and is aimed at current and future decision-makers such as managers, students and other interested parties. There is also a version for virtual game occasions. The game was developed as part of a project within the National Research Program "Sustainable Economy" (NRP73) at Empa in St. Gallen with partners Ulrich Creative Simulations, the University of Zurich, the University of Applied Sciences of Eastern Switzerland and the Norwegian University of Science and Technology.

WHO WON IN THE END?

No word on that, nor any question. The seven are simply not interested in who came out on top in the end – a quiet piece of advice, perhaps, to politicians, companies, investors and everyone else who plays a real role in climate protection. ■

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

Photos: Empa

PLASTIC SNOWFALL IN THE ALPS

In a large-scale fundraising campaign, popular YouTubers like Mister Beast and Mark Rober are currently trying to rid the oceans of almost 14,000 tonnes of plastic waste. That's about 0.15 percent of the amount that ends up in the oceans every year. But it's not just our waters that are full of plastic. A new study shows that the spread of nanoplastic through the air is a more widespread problem than previously thought.

Text: Noé Waldmann

ALPINE RESEARCH
The Sonnenblick Observatory in Austria's Hohe Tauern mountains has been in existence since 1886.

Photos: ZAMG / SBO

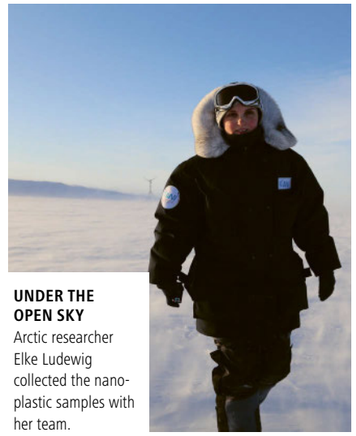
In a new study, Empa researcher Dominik Brunner, together with colleagues from Utrecht University and the Austrian Central Institute for Meteorology and Geophysics, is investigating how much plastic is trickling down on us from the atmosphere. According to the study, some nanoplastics travel over 2,000 kilometers through the air. According to the figures from the measurements about 4.3 trillion miniature plastic particles land in Switzerland every year. Researchers still disagree on the exact number. But according to estimates from the study, it could be as much as 3,000 tonnes of nanoplastics that cover Switzerland every year, from the remote Alps to the urban lowlands.

The study is uncharted scientific territory because the spread of nanoplastics through the air is still largely unexplored. The result of Brunner's research is the most accurate record of air pollution by nanoplastics ever made. To count the plastic particles, Brunner and his colleagues have developed a chemical method that determines the contamination of the samples with a mass spectrometer.

EXTREME CONDITIONS

The scientists studied a small area at an altitude of 3,106 meters at the top of the mountain "Hoher Sonnenblick" in the "Hohe Tauern" National Park in Austria. An observatory of the Central Institute for Meteorology and Geodynamics has been located here since 1886. The observatory is run by meteorologist and Arctic researcher Elke Ludewig. Since research began here in the late 19th century, the observatory has only been non-operational on four days. The research station also served as a base for the study on the spread of nanoplastics in remote areas.

Every day, and in all weather conditions, scientists removed a part of the top layer of snow around a marker at 8 a.m. and carefully stored it. Contamination of the samples by nanoplastics in the air or on the scientists' clothes was a particular challenge.



UNDER THE OPEN SKY
Arctic researcher Elke Ludewig collected the nanoplastic samples with her team.

In the laboratory, the researchers sometimes had to remain motionless when a colleague handled an open sample.

The origin of the tiny particles was traced with the help of European wind and weather data. The researchers could show that the greatest emission of nanoplastics into the atmosphere occurs in densely populated, urban areas. About 30 percent of the nanoplastic particles measured on the mountain top originate from a radius of 200 kilometers, mainly from cities. However, plastics from the world's oceans apparently also get into the air via the spray of the waves. Around 10 percent of the particles measured in the study were blown onto the mountain by wind and weather over 2,000 kilometers – some of them from the Atlantic.

NANOPARTICLES IN THE BLOODSTREAM

It is estimated that more than 8,300 million tonnes of plastic have been produced worldwide to date, about 60 percent of which is now waste. This waste erodes through weathering effects and mechanical abrasion from macro- to micro- and nanoparticles. But discarded plastic is far from the only source. Everyday use of plastic products such as packaging and clothing releases nanoplastics. Particles in this size range are so light that their movement in the air can best be compared to gases.

Besides plastics, there are all kinds of other tiny particles. From Sahara sand to brake pads, the world is buzzing through the air as abrasion. It is as yet unclear whether this kind of air pollution poses a potential health threat to humans. Nanoparticles, unlike microparticles, do not just end up in the stomach. They are sucked deep into the lungs through respiration, where their size may allow them to cross the cell-blood barrier and enter the human bloodstream. Whether this is harmful or even dangerous, however, remains to be researched. ■

Further information on the topic is available at:
www.empa.ch/web/s503/team-modelling

DENISE MITRANO WINS MARIE HEIM-VÖGTLIN PRIZE

Denise Mitrano, former postdoctoral researcher at the Environmental Risk Assessment and Management Group, led by Bernd Nowack, and now Assistant Professor of Environmental Chemistry of Anthropogenic Materials at ETH Zurich, was awarded the Marie Heim-Vögtlin Prize by the Swiss National Foundation (SNF). She is the 13th winner of the prize which honors outstanding young women researchers and is endowed with 25,000 Swiss francs. Mitrano's research focuses on tracking the spread of micro- and nano-plastic particles throughout the environment. These tiny particles, formed by the weathering and degradation of plastic items, are by now ubiquitous and one of the defining features of the Anthropocene, the epoch representing significant human impact on the earth's ecosystem and geology. Tracking the spread of tiny plastics allows Mitrano to assess the potential harmful effects that micro- and nanoplastics could have on various ecosystems, develop analyt-ical methods to better identify these particles and interpret the risk for humans and the environment.

www.empa.ch/web/s506

AWARD WINNER
Denise Mitrano conducted research at Empa for several years and is now an assistant professor at ETH Zurich.

"SALON PUBLIC": WISE MINDS EXPLAIN THE WORLD

VISIONARY
Peter Richner talks about the future of living at the «Salon Public« in Bern.

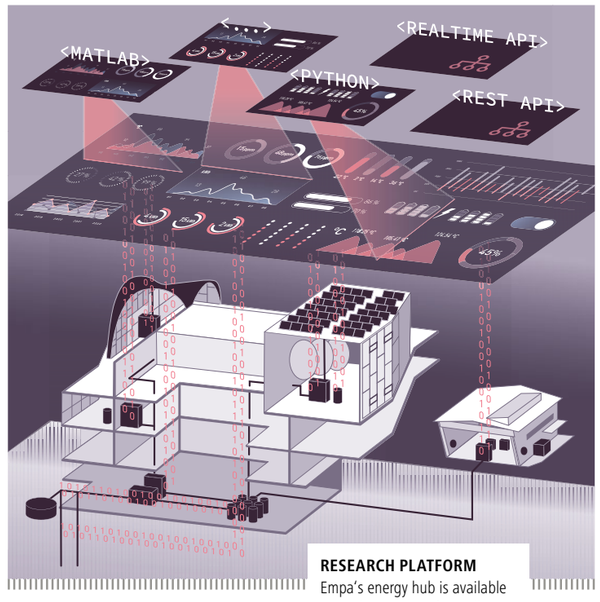
The «Salon Public« is the largest «science festival« in Switzerland. The four-part science festival took place on October 16 in the Kursaal Bern and on October 23, 2021 in Lausanne. At each event, four renowned speakers present a topic. Peter Richner, deputy director of Empa, showed in Bern how broadly the interpretation of an «intelligent building« can be applied and ventured a view far beyond today's building standards. In addition to Richner, the organizers had invited a number of other illustrious speakers, including former German Foreign Minister Joschka Fischer, solar visionary Bertrand Piccard, ETH Board President Michael Hengartner and philosopher Richard David Precht.

www.salon-public.ch

Photo: Aroma, Cornelia Vinzens

Grafic: Hug & Dorfmüller Design AG / Empa

LEARNING TO STORE GREEN ENERGY



RESEARCH PLATFORM
Empa's energy hub is available to working groups from all over the world.

Energy storage is one of the major challenges in the current transformation of our energy system. The European Green Deal is intended to help make Europe climate-neutral by 2050. Storage systems play a central role in this. In the recently launched Green Deal project «StoRIES«, numerous research institutions and industrial partners throughout Europe are working together on solutions for storing energy. Empa is participating in this project with its research and demonstration infrastructures NEST, move and ehub, as well as its know-how on life cycle analyses in the «Technology and Society« research lab.

www.eera-energystorage.eu/stories.html

EVENTS

(IN GERMAN AND ENGLISH)

20. JANUAR 2022
NABEL-Tagung: Luftqualität und Gesundheit
Zielpublikum: Industrie und Wissenschaft
www.empa-akademie.ch/nabeltagung
Empa, Dübendorf und online

02. + 03. FEBRUAR 2022
Onlinekurs:: Additive Fertigung von Metallen
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/addfert
Empa, Dübendorf

24. MÄRZ 2022
VERT-Forum: Best Available Technology in Emission Reduction
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/vert
Empa, Dübendorf

20. MAI 2022
Kurs: Elektrochemische Charakterisierung und Korrosion
Zielpublikum: Forschung und Industrie
www.empa-akademie.ch/korrosion
Empa, Dübendorf

01. JULI 2022
Kurs: Hightech-Keramiken
Zielpublikum: Industrie und Forschung
www.empa-akademie.ch/ht-keramik
Empa, Dübendorf

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

THE PLACE WHERE INNOVATION STARTS.