Empa Quarterly

RESEARCH & INNOVATION II #70 II JANUARY 2021

FOCUS

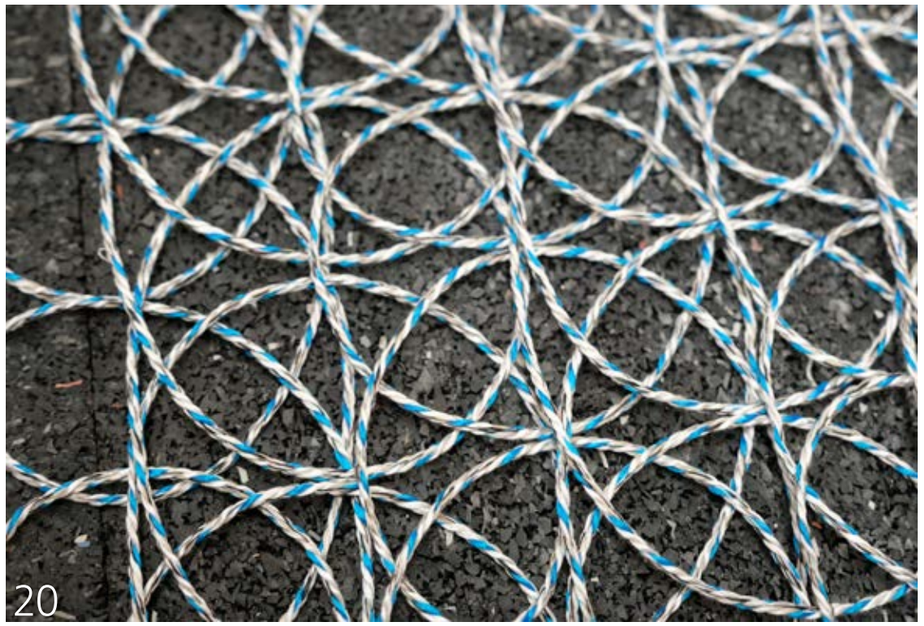
CLEAN NEW CAR WORLD

CARS ARE LEARNING TO SEE
HOUSES HOARDING ELECTRICITY
ROBOTS KNITTING ROADS

www.empaquarterly.ch

[CONTENT]

[FOCUS: CLEAN NEW CAR WORLD]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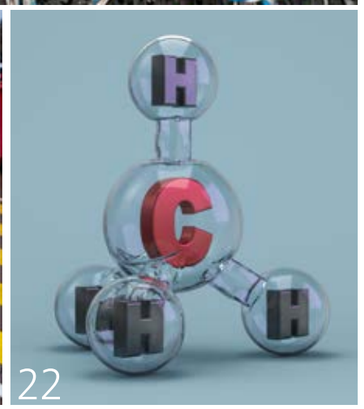
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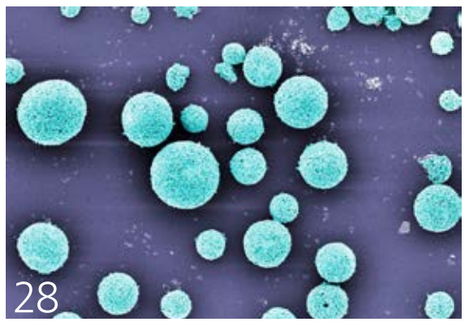
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Photos: iStockphoto, Empa

[COVER]

How well can self-driving cars see? Empa's test vehicle has a laser scanner on board that produces highres images like this. Additionally the system uses cameras and radar scanners. Empa wants to find out how accurately these sensors recognize the world. Page 17.

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IN PRAISE OF CONTRADICTION

Dear Readers,

Wherever you look these days, one conjecture comes to mind: we have forgotten how to deal with contradiction. Instead of dealing with counterarguments in a factual way, we are quick to play tough in controversial discussions. This rarely pans out well; just look at the furious Viking-shaman in the U.S. Capitol...

A glance at science might be useful here. Science thrives on contradiction. The Austrian-British philosopher Karl Popper considered it one, if not THE high road to acquiring new knowledge. Everything can be thought, said and asserted. But every hypothesis, assertion or theory, as soon as it has been put into the world, has to be met with critical scrutiny. If it can be refuted, it is thrown overboard and a new thesis is to be developed – which in turn ... I think you get it.

It is thus hardly surprising that sometimes, when the state of knowledge is still patchy, different scientists favor different ideas. The public often perceives this as "cacophony" and disunity within the research community. In fact, however, we merely see scientists at work and observe how they check their own and other people's ideas for disagreements.

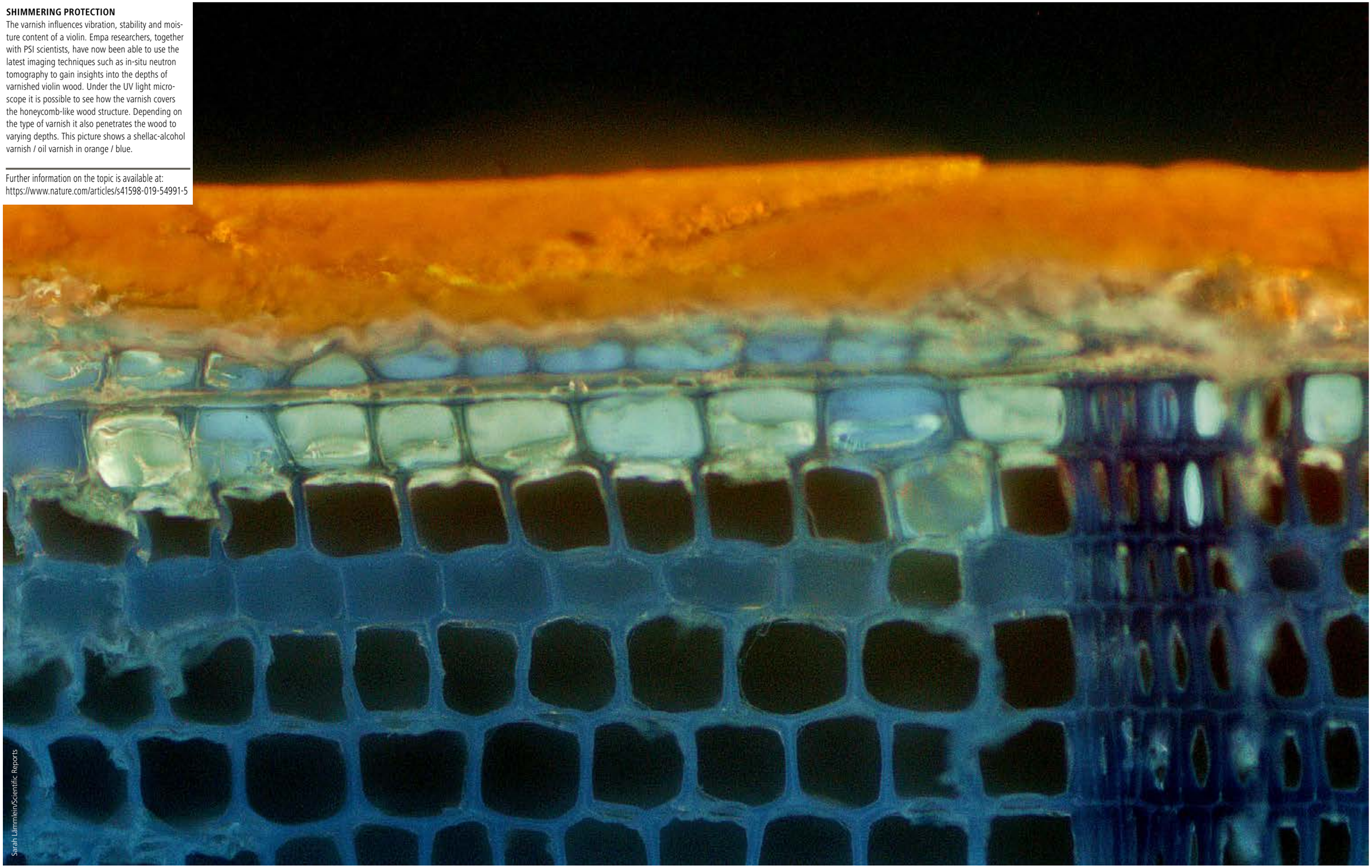
We could take an example from this way of working in future social and political debates. However, this means we have to be prepared to question our very own convictions, not just those of our counterparts.

Enjoy reading!

Your MICHAEL HAGMANN

SHIMMERING PROTECTION
The varnish influences vibration, stability and moisture content of a violin. Empa researchers, together with PSI scientists, have now been able to use the latest imaging techniques such as in-situ neutron tomography to gain insights into the depths of varnished violin wood. Under the UV light microscope it is possible to see how the varnish covers the honeycomb-like wood structure. Depending on the type of varnish it also penetrates the wood to varying depths. This picture shows a shellac-alcohol varnish / oil varnish in orange / blue.

Further information on the topic is available at:
https://www.nature.com/articles/s41598-019-54991-5



Sarah Lämmlein/Scientific Reports

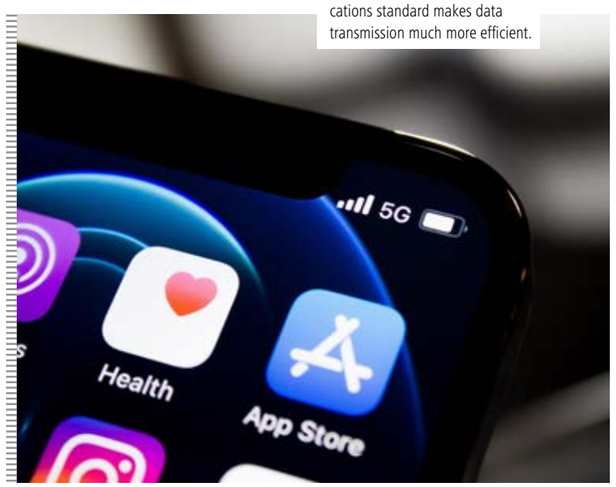
STEP2 – NEW UNIT AT NEST

INNOVATIVE
The two-story STEP2 unit will be built on the top platform of the NEST building.

A spiral staircase in the shape of a spine from 3D printing, a ribbed filigree ceiling that requires around a third less material, and an energy-efficient building envelope that ensures optimum comfort: a new Unit is being planned at NEST. STEP2 – as it is called – brings together innovations in the fields of circular economy, industrial and digital fabrication, and building envelope and energy systems. The two-story unit will be built on the top NEST platform and is scheduled for completion in summer 2022.

www.empa.ch/web/nest/step2

DATA CURRENT
The new 5G mobile communications standard makes data transmission much more efficient.



HOW DOES 5G AFFECT THE CLIMATE?

Researchers at Empa and the University of Zurich have been mandated by the swisscleantech trade association and Swisscom to study the impact that the 5G mobile communications standard will have on greenhouse gas emissions. The study shows that the expansion of the 5G network can significantly reduce environmental impacts. One reason for this is greater energy efficiency. Added to this are savings due to intelligent power grids or more targeted use of fertilizers and pesticides in agriculture.

www.empa.ch/web/s604/5g-netz

Photos: James Yarema für Unsplash, ROK Architekten

GLUE FOR WOUNDS

The first prize of the 2020 «Empa Innovation Award» went to a novel tissue adhesive technology that promises faster and safer wound healing. It was developed by researchers from Empa's «Particles-Biology Interactions» lab together with ETH Zurich's Nanoparticle Systems Engineering Lab. Unlike previous wound adhesives, which consist mainly of the body's own protein fibrin, the technology is based on a combination of inorganic nanoparticles. The adhesive particles bind particularly well to bone or soft tissue. Accelerated coagulation improves the treatment of external and internal wounds.

www.empa.ch/web/s604/empa-innovation-award-2020

START-UP
Sebastian Loy and Tino Matter (right) developed the new tissue adhesive and founded the startup company Anavo.

DURABLE
The concrete beam reinforced with a steel lamina has been supporting a load of just over six tons since 1970.

BY HOOK OR BY CROOK

Since 1970, Empa has been running a globally unique test to investigate the long-term behavior of bonded steel reinforcements on a concrete beam. Investigations like this have contributed to the fact that bonded reinforcement is now state of the art as a strengthening method, and engineers have confidence in this construction method.

www.empa.ch/web/s604/biegekriechversuch

Photos: Empa, anavo

THE "BLACK GOLD"OF MUSHROOMS

Empa researchers have succeeded in extracting the pigment melanin in large quantities from a fungus. The gigantic Armillaria fungus in the service of science is one of the largest and oldest living organisms in the world. Potential applications for the "black gold" range from wood preservatives to the construction of water filters and historic musical instruments.

Text: Andrea Six

DESTRUCTIVE
Like a sponge, the watery porling grows on wood surfaces and attacks its structure even in the depth.

Photo: Empa

Its properties are astonishing and its applications manifold: the pigment melanin, which, for instance, protects human skin from harmful UV light (and gives us a summer tan), is a veritable treasure trove for new materials and technologies. Although the miracle substance occurs naturally, the complex biopolymer can only be produced artificially at an industrial scale through expensive and complex processes, during which some of the compound's properties are lost. To date processes for extracting natural melanin from microorganisms only have low yields.

It is therefore not surprising that the substance is many times more expensive than gold. Empa researchers have now developed a method to produce the "black gold" in a simple and highly scalable process. "Melanin is extremely stable when exposed to environmental influences and is interesting not only as a pigment, but also far beyond for the development of innovative composite materials," says Empa researcher Francis Schwarze from Empa's "Cellulose & Wood Materials" lab.

In their quest for simpler, cheaper processes for the production of natural melanin in large quantities, Schwarze and his team came across a fungus, which is actually a common saprophytic fungus that grows in the forest: Armillaria cepistipes. Its amazing metabolism enables the fungus to bind heavy metals, make wood glow in the dark – and produce melanin on a massive scale. "We have selected a promising strain of A. cepistipes, that allows us to produce around 1,000 times more melanin than with other fungi" says Schwarze. The trick: A. cepistipes is cultivated in a nutrient fluid, and, in the presence of a precursor, tyrosine, the fungus releases melanin into the environment. "In this way we have developed a sustainable production method, which no longer requires time-consuming extraction steps used in previous microbiological processes," explains the Empa researcher. In three months A. cepistipes produces around 20 grams of melanin.

The scalable and sustainable production of melanin now enables Empa researchers to advance projects to develop innovative materials for a range of industrial applications. These include, for example, a system for water purification: since melanin is able to bind heavy metals, it can be used to develop new types of water filters. "We have integrated melanin into artificial polymers such as polyurethane," explains Empa researcher Anh Tran-Ly. Using electrospinning, the polymer mixture was spun into ultra-fine fibers to form membranes. The Empa team found that these melanin-based composite membranescan remove up to 94 percent of lead from polluted water.

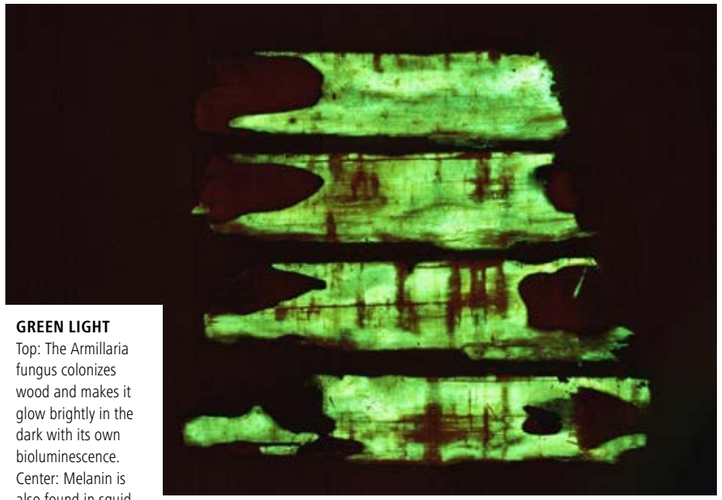
A PIGMENT AGAINST ENVIRONMENTAL STRESS

"Melanin" is a generic term for a large group of pigments. The pigment melanin gives our hair, eyes and skin its color. It is found in bird feathers, sheep wool and in the ink of squids. Plants, fungi and even bacteria also produce the miracle substance. Its task: to protect the organism from environmental stress. The darkening of the skin when exposed to the sun is but one example. Fungi, on the other hand, have an even more amazing ability: thanks to melanin, they can even use radioactivity to generate energy in their own metabolism.

AS BLACK AS EBONY

In nature, fungi use melanin to protect themselves against other organisms that compete for nutrients and space in the environment. With the new technology, the pigment can now also be used to protect much larger communities from human influence: melanin can be used to conserve tropical forests where highly priced and much sought after ebony grows.

Tropical ebony wood is particularly precious because of its unique dark color. A sustainable method that upgrades native Norway spruce wood to a visually equally attractive product allows vulnerable tropical forests to breathe a sigh of relief. "When spruce wood is impregnated with a melanin suspension, a deep dark wood can be produced that is comparable to ebony," says Empa researcher Tine Kalac.



GREEN LIGHT
Top: The Armillaria fungus colonizes wood and makes it glow brightly in the dark with its own bioluminescence.
Center: Melanin is also found in squid ink.
Bottom: An Armillaria fungus network is protected by melanin and can be several square kilometers in size.

Photos: Empa, unsprash

To enable the black melanin to penetrate the wood, the researchers used another "helper" from their fungal trick box: Physisporinus vitreus – the white rot fungus – is also a saprophyte that colonizes wood, thereby enhancing wood permeability. It grows sponge-like on trees and preferentially decomposes lignin within wood. With the help of a method developed at Empa, the wood is now first treated with the white rot fungus for six weeks to allow the melanin suspension to penetrate deeply into the wood, without altering the wood's stability.

SERPENTINO – THE LITTLE SNAKE AMONG INSTRUMENTS

Since Armillaria fungi use melanin as a weapon against competitors, it is only logical to use melanin to protect wood from fungi. In order to develop a melanin-based wood preservative, Empa researchers are participating in a recently launched interdisciplinary project supported by Innosuisse, the Swiss Innovation Agency. The goal is to reconstruct a historical wind instrument, the Serpentino (in English: small snake).

Together with the University of Applied Sciences and Arts Northwestern Switzerland and the Basel Historical Museum, the industrial partner in the project is the company SBerger Serpents in Le Bois (JU), which is responsible for the practical implementation of the research project. Company founder Stephan Berger is enthusiastic about the rebirth of this rare instrument: "The Serpentino was used over 400 years ago and was the godfather of modern instruments such as the saxophone and the tuba," he explains. Although it is a technical challenge for musicians to master the instrument, the sound is incomparable, enthuses Berger. "The Serpentino creates sounds that are rich in overtones and deeply touching". Originally, the wind instrument was used in churches to support singing because it covers the registers of the human voice and can thus "carry" a choir, the passionate instrument maker explains.

Although today's trend towards historically informed performances means that the Serpentino is in great demand, Berger is unable to supply its customers with instruments: the peculiarly curved original instruments have become rare. Because the snake-shaped instrument made of walnut wood not only creates an incomparable sound – there is also a war raging inside the "little snake": condensation from the musicians' breath creates a humid microclimate that provides excellent conditions for the growth of all kinds of microorganisms. Thus the conditions for bacteria and fungi are favorable for the decomposition of the centuries-old instruments gradually destroying the last original specimens.

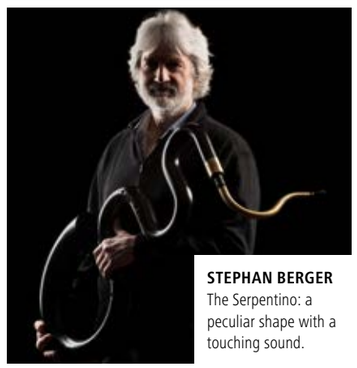
The research project's faithful serpentino replicas are to be protected from this damage. This is where Empa's melanin comes in: "If we can use a melanin-based wood preservative, not only the newly built serpentinos can be protected against decay," says Berger.

Other woodwind instruments built today using domestic, less resistant woods could also benefit from such an environmentally friendly wood treatment. Thus, the collaboration with the Empa team is exciting in more ways than one. ■

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

Photos: Empa, Xavier Voirol

AS BLACK AS EBONY
Empa researcher Tine Kalac applies melanin as a varnish to Norway spruce wood.



STEPHAN BERGER
The Serpentino: a peculiar shape with a touching sound.

A MOST GIGANTIC FUNGUS

The honey fungus is one of the most amazing organisms on Earth. Inconspicuously, it lives and grows in forest soils and colonizes wood debris and trees with its rhizomorphs. The fruting body is mushroom-shaped with cap, stipe with ring around the stipe, like a bracelet, which gives the fungus its latin name «Armillaria».

Much more impressive, however, is his network of black strands, which grows over the wood and in the soil. Mushroom threads join together to form thick bundles several meters long, surrounded by a black protective layer containing melanin, and colonize new habitats and food sources. These so-called rhizomorphs can also penetrate tree roots as parasites, ascend the trunk and decompose their host from within. With a size of several square kilometers, the largest living organism in the world, an approximately 2400-year-old Armillaria network, is expanding in the US state of Oregon. In Switzerland, the largest fungus in Europe is loacted at the Ofen Pass. This Armillaria covers an area of 50 soccer fields. It owes its age of around 1000 years to the pigment melanin, which protects the black fungal threads from environmental damage and competitors.

[SUSTAINABILITY]

ECO-ENERGY WITHOUT LIMITS?

Even a sustainable circular economy doesn't run without energy. Solar panels and wind farms, tidal and geothermal power plants: they all divert energy from energy fluxes that had remained untapped since time immemorial. The question is therefore: what part of these energy fluxes can mankind use for its own purposes without damaging the Earth's energy system? Empa researchers have developed an approach to estimate this.

Text: Harald Desing

The Earth has its limits. We are becoming more and more aware of this in view of the climate crisis, the increasing extinction of species and the littering of the oceans (and even space) as a result of human activity. In response, governments and institutions the world over are championing the concept of a circular economy. By closing material cycles, the environmental impacts associated with the extraction of raw materials shall be avoided and the waste problem solved. This approach is, however, not sufficient to build a sustainable society in and by itself, as it leaves the questions open of how much and how quickly materials can be cycled and what energy is used to power these cycles. After all, in a truly sustainable society, not only material flows but also energy flows must remain within the limits set by our home planet.

ENERGY FOR "RUNNING" THE EARTH

A key question is thus: is there enough renewable energy available globally to sustainably manage material flows without violating planetary boundaries? This question is being investigated by a team led by Harald Desing from Empa's Technology and Society lab. If we look at Earth as a system, it only exchanges energy with space. By far the largest part of the energy brought into the Earth system is solar radiation, supplemented by minor contributions from planetary motion and geothermal energy. These energy fluxes had always been used entirely by the Earth itself. They have powered its many subsystems, such as the oceans, atmosphere and forests, but also reflective ice surfaces.

Most of these subsystems convert the incoming energy into further renewable energy fluxes, for example wind and water currents or biomass production. In these conversions, free energy, called exergy, is extracted from the incoming energy fluxes. Regardless whether energy conversions are taking place in the natural Earth system or in the technosphere created by humans, all the energy is ultimately radiated back into space.

SOLAR PARKS MAY ALSO CHANGE THE CLIMATE – IT'S A MATTER OF SCALE

As humanity increasingly diverts renewable energy fluxes to its activities, the parts available to the Earth system are reduced. The Earth system can compensate for such disruptions to a certain extent. However, if they are too large, the risk of exceeding so-called "tipping points" increases. This would result in rapid and irreversible changes in the Earth system, such as the melting of the polar ice caps, which in turn would accelerate climate change. In order not to exceed these tipping points, the size of the land area occupied must not exceed the planetary boundary. Beyond the scale, the way in which the land is used is also crucial: solar plants instead of forests, for example, disrupt biodiversity, evaporation and thus the water cycle, the radiation of heat back to space, and much more.

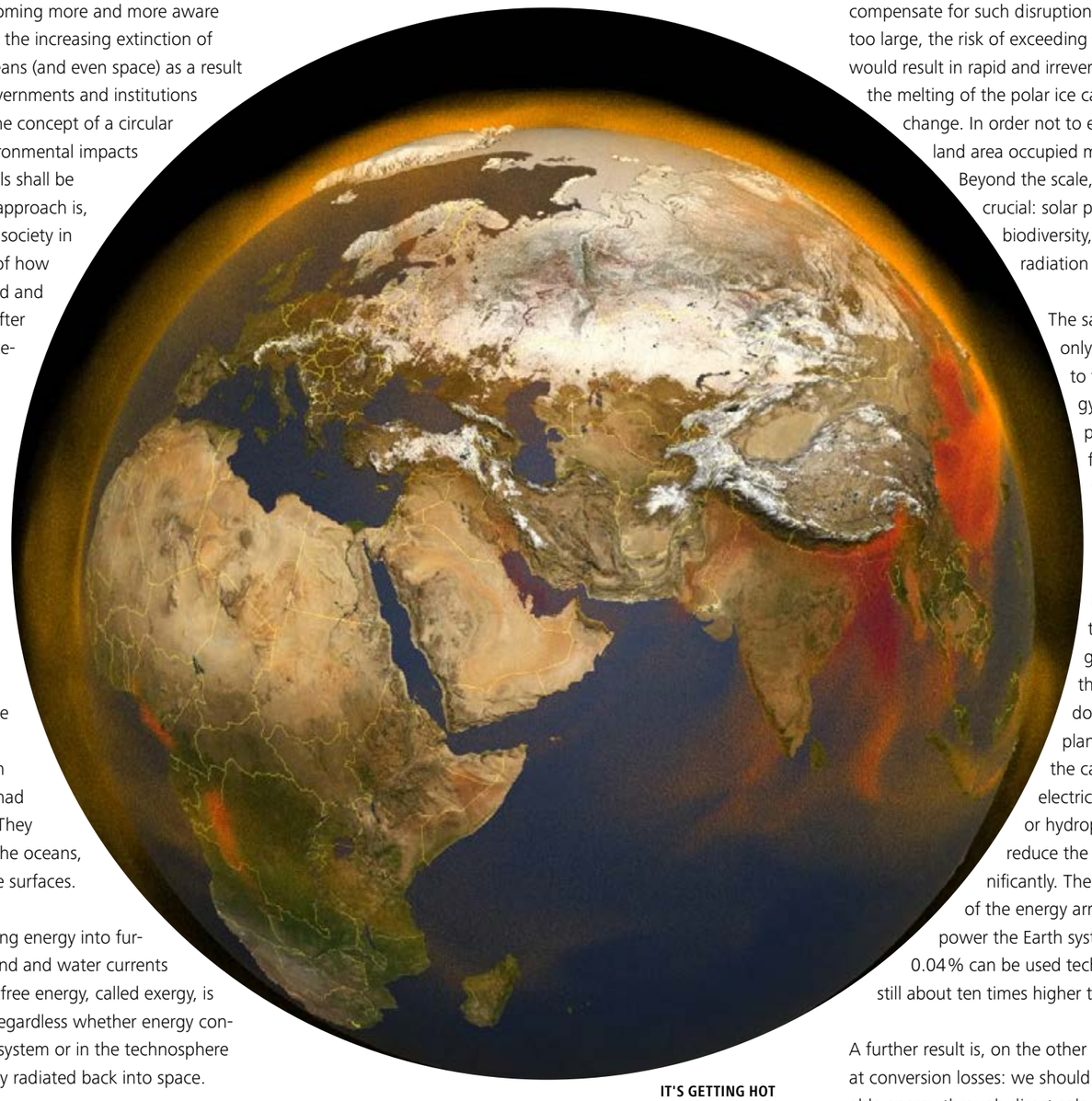


Photo: Nasa

IT'S GETTING HOT
NASA uses this image to illustrate global methane emissions. Methane is the second most important greenhouse gas, after CO_2.

The same upper limits for land occupation not only applies for direct solar energy use but also to the harvesting of so-called chemical energy - that is, to agriculture and forestry, which produce food and fodder, heating materials, fuels, and building materials. The production of technical energy competes with food production on many surface areas.

ELECTRICITY AS "UNIVERSAL CURRENCY"

In order to be able to compare or add up the various potentials for renewable energy, the Empa researchers have converted them into electrical energy equivalents. To do this conversion, efficiencies of power plant technologies available today are used in the calculations. It makes a difference whether electricity is generated from solar energy, wood or hydropower. These conversion losses further reduce the possible harvest of some potentials significantly. The result of the study is surprising: 99.96% of the energy arriving on Earth from space is needed to power the Earth system and food production, therefore only 0.04% can be used technically. Nevertheless, this potential is still about ten times higher than today's global energy demand.

A further result is, on the other hand, hardly surprising when looking at conversion losses: we should prefer to harvest and use the available energy through direct solar energy conversion. After all, almost all renewable energy resources – including wind, hydro power and biomass production – are ultimately powered by the sun. Direct use of solar energy means fewer conversion steps and thus fewer losses.

"Wind power, hydropower and biomass production are also powered by the sun – but there are losses in the process. It is better to harvest energy directly, with photovoltaics."

PHOTOVOLTAICS ON ALL SEALED SURFACES

Much of the sun's energy could be harvested from a small portion of the Earth's deserts, but this is technically and logistically challenging. The research team of the "Technology and Society" Lab therefore considers solar energy harvested on desert areas as a global energy reserve in case all other harvesting possibilities are exhausted.

As a consequence, we should start using already sealed surfaces worldwide, e.g. building roofs and facades, but also roads, railroads and parking lots. This area would be sufficient to power a global 2000-watt society.

However, if one would like to raise the global energy demand to the level of today's demand per capita in Switzerland, desert areas would also have to be used. All other energy potentials (e.g. from wind or biomass) are orders of magnitude smaller than the direct use of solar energy – and some resources are already overused. Nevertheless, they can play a significant role locally, especially because they can reduce the need for storage capacity – a problem that has not been considered in the study.

DESERT REGIONS AS A RESERVE

Simply building solar plants en masse and the energy problem is solved? It's not quite that simple, of course. In their study, the Empa team only looked at the first step – calculating the available energy potential. The actual amount of energy available will be smaller: limiting factors include the availability of raw materials, but also financial and human capital, environmental impacts during raw material extraction or production, operation and disposal of the plants, and the need for additional infrastructure for energy distribution and storage.

Currently, the research team is exploring how such a pathway from a fossil to a solar society might look like. The solar energy system must not only be large enough to meet global demand, but must also be able to replace the fossil fuel system quickly enough to avert the climate catastrophe in time. ■

Further information on the topic is available at:
www.empa.ch/web/s506

EMPA SHOWS THE WAY
Harvesting solar energy on all roofs and facades is possible. The NEST unit Solace does not have a roof. It only harvests electricity and heat through its turquoise façade.

Photo: Roman Keller, istockphoto

VOLTAGE FROM THE PARQUET

Researchers at Empa and ETH Zurich have made wood flexible and turned it into a micro-generator. When it is loaded, electrical voltage is generated. In this way, the wood can serve as a bio-sensor – or generate usable energy.

Text: Stefanie Zeller

FULL OF ENERGY
Modified wood can generate electricity through deformation. Is a tango enough for dim light?

Ingo Burgert and his team have proven it time and again: wood is so much more than "just" a building material. Their research aims at extending the existing characteristics of wood in such a way that it is suitable for completely new ranges of application. For instance, they have already developed high-strength, water-repellent and magnetizable wood. In a recent study, his team, collaborating with the research group led by Francis Schwarze, has shown how electricity can be generated by some kind of "wood sponge" using a simple chemical process. This is where the so-called piezoelectric effect comes into play.

VOLTAGE DUE TO DEFORMATION

Piezoelectricity means that an electric voltage is created by the elastic deformation of solids. This phenomenon is mainly exploited by metrology, which uses sensors that generate a charge signal, say, when a mechanical load is applied. However, such sensors often use materials that are unsuitable for use in biomedical applications, such as lead zirconate titanate (PZT), which cannot be used on human skin due to the lead it contains. It also makes the ecological disposal of PZT and Co rather tricky. Being able to use the natural piezoelectric effect of wood thus offers a number of advantages. If thought further, the effect could also be used for sustainable energy production. But first of all, wood must be given the appropriate properties. Without special treatment,

wood is not flexible enough; when subjected to mechanical stress; therefore, only a very low electrical voltage is generated in the deformation process.

FROM BLOCK TO SPONGE

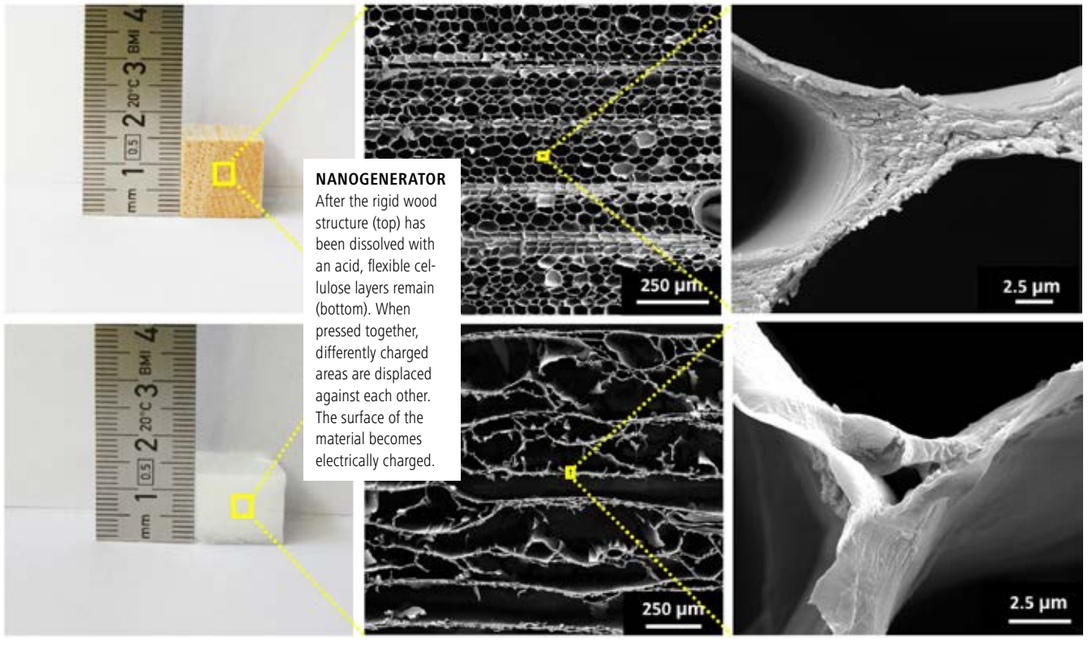
Jianguo Sun, a PhD student in Burgert's team, used a chemical process that is the basis for various "refinements" of wood the team has undertaken in recent years: delignification. Wood cell walls consist of three basic materials: lignin, hemicelluloses and cellulose. "Lignin is what a tree needs primarily in order to grow to great heights. This would not be possible without lignin as a stabilizing substance that connects the cells and prevents the rigid cellulose fibrils from buckling," explains Burgert. In order to transform wood into a material that can easily be deformed, lignin must at least partially be "extracted". This is achieved by placing wood in a mixture of hydrogen peroxide and acetic acid. The lignin is dissolved in this acid bath, leaving a framework of cellulose layers. "We take advantage of the hierarchical structure of wood without first dissolving it, as is the case in paper production, for example, and then having to reconnect the fibers", says Burgert. The resulting white wood sponge consists of superimposed thin layers of cellulose that can easily be squeezed together and then expand back into their original form – wood has become elastic.

ELECTRICITY FROM WOODEN FLOORS

Burgert's team subjected the test cube with a side length of about 1.5cm to about 600 load cycles. The material showed an amazing stability. At each compression, the researchers measured a voltage of around 0.63V – enough for an application as a sensor. In further experiments, the team tried to scale up their wooden nanogenerators. For example, they were able to show that 30 such wooden blocks, when loaded in parallel with the body weight of an adult, can light up a simple LCD display. It would therefore be conceivable to develop a wooden floor that is capable of converting the energy of people walking on it into electricity. The researchers also tested the suitability as a pressure sensor on human skin and showed that it could be used in biomedical applications.

However, there is still a long way to go before the "piezo" wood can be used as a sensor or even as an electricity-generating wooden floor. But the advantages of such a simple yet renewable and biodegradable piezoelectric system are obvious – and are now being investigated by Burgert and his colleagues in follow-up projects. ■

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



NANOGENERATOR
After the rigid wood structure (top) has been dissolved with an acid, flexible cellulose layers remain (bottom). When pressed together, differently charged areas are displaced against each other. The surface of the material becomes electrically charged.

Photos: Empa

TEST DRIVE
The radar- and laser-equipped Lexus does its laps on the Empa campus. Dejan Milojevic (left) and Miriam Elser designed the driving tests.

Photo: Empa

VISION TEST FOR AUTONOMOUS CARS

Cars that autonomously navigate from A to B are expected to be a common sight in a few years from now. But road approval is still a long way off. One important aspect: how can we tell a self-driving car has become "blind" with age, i.e., its sensors would need to be replaced? An Empa team is looking for a solution.

Text: Rainer Klose

The five meter-long Lexus RX-450h leads a rather contemplative life at Empa. It never takes long trips. Instead, the SUV dutifully does its laps on a special track just 180 meters long in a secluded backyard of the Empa campus. The scenery is not particularly spectacular: the Mobileye camera behind the windshield sees freshly painted lane markings on aging concrete; the Velodyne lidar scans the window front of always the same lab building at every turn, and the Delphi radar behind the Lexus' radiator grille routinely measures the distance to five tin trash cans set up to either side of the course.

AT THE SAME TIME, IN CALIFORNIA ...

Thousands of miles to the west, on the U.S. Pacific coast, things look a bit more dramatic. "Wow, I didn't think the car could do that," says Sam Altman. He's the head of OpenAI, an artificial intelligence company, in which Elon Musk and Microsoft have stakes. Altman watches a video with Kyle Vogt. Vogt is CTO and co-founder of Cruise LLC, which is now part of General Motors. The video is also available on Youtube and shows how a Cruise test vehicle drives through San Francisco for 75 minutes, mastering all inner-city driving situations with very little intervention from programmers. It overtakes waiting garbage trucks even when oncoming traffic is already in sight, and can turn left independently at small intersections even when pedestrians want to cross the lane at the same time.

The Tesla fan community also published euphoric videos in late October 2020. Some beta testers of the Tesla software have received a pre-release version that allows the car to navigate autonomously through residential areas. A Youtuber by the name of TeslaRaj underpins his enthusiastic video with violin music and shows how his car stops at red lights, strictly obeys speed limits and autonomously maneuvers around parked cars.

TRUST IS GOOD, CONTROL IS BETTER

If the Californians have already come this far, what sense does it make to drive around in a backyard in Dübendorf? Miriam Elser explains why. She works in Empa's Automotive Powertrain Technologies lab and is leading the project with the Lexus. Empa is breaking new ground with this project: previously, she and her colleagues had been working on powertrains, renewable fuels and exhaust gas purification, as well as vehicle operation. Now, for the first time, the Empa team is also looking at self-driving cars.

"We are investigating how these sensors work in different environmental conditions, what data they collect and when they make mistakes or even fail," says the researcher. "Every human driver has to pass a vision test before getting a driver's license. Professional drivers must repeat this test on a regular basis. We want to develop a vision test for autonomous vehicles so they can be trusted even when they're several years old and have thousands of miles on the clock."

> "We are studying how these sensors work in snow and rain, what data they collect, and what mistakes they make."

The topic has not received a lot of attention so far: among the more than 1,000 research papers published on autonomous driving in the past five years, only about 20 deal with the quality of sensor data. The processing of the data literally happens in a black box. The know-how is worth a lot of money and is carefully kept by Google, Apple, Tesla, Cruise LLC and the other major manufacturers developing autonomous vehicles. They don't let anyone look into their cards

THE NEEDLE IN THE DATA HAYSTACK

Sensor quality plays an important role in the eventual approval of autonomous cars for public transportation. The operational safety of such vehicles falls within the remit of the Swiss Federal Roads Office (FEDRO), which is providing financial support for the research at Empa. FEDRO wants to be able to assess the functionality of autonomous systems at regular intervals – and independently of the manufacturers. The authority's experts also want to make it possible to conduct a kind of "witness interview" if an autonomous car has been involved in an accident. The problem is that each second the sensors collect enormous amounts of data. Analyzing this flood of raw data would be unreasonable for accident investigation authorities. At some point in the future, therefore, the law will have to specify which data must be stored in the car and made accessible for investigations.

Moreover, FEDRO is preparing the approval of field tests with self-driving vehicles on public roads. But how can we judge if and when it becomes dangerous? When do sensors fail, and when do they make serious mistakes so that the test would have to be aborted or modified? Even for monitoring such field trials, it is necessary to be able to quickly and accurately assess the vision and the "judgment" of autonomous cars.

The project is part of a digitalization initiative of the Swiss Competence Center for Energy Research – Efficient Technologies and Systems for Mobility (SCCER Mobility), co-funded by Innosuisse, FEDRO and industry partners. While Empa is investigating commercially available sensors in practical use, the Swiss Federal Institute of Metrology (METAS) is analyzing the same sensors in a laboratory environment. The next generation of vehicle sensors is also already the subject of research. This part of the project is being undertaken by the Institute for Dynamic Systems and Control Engineering at ETH Zurich.

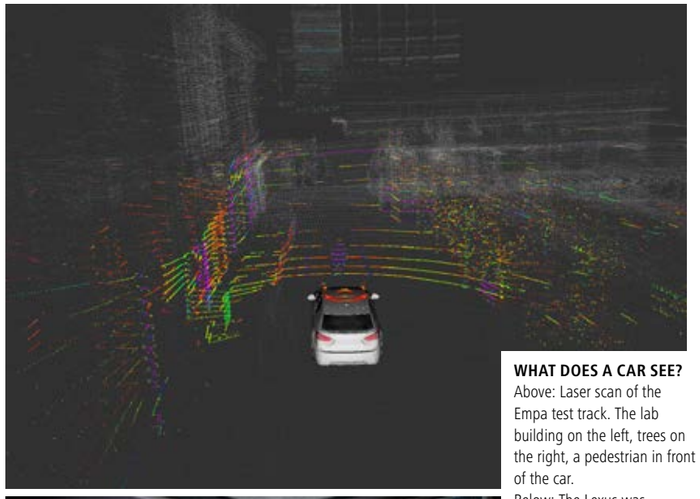
AVOIDING ACCIDENTS

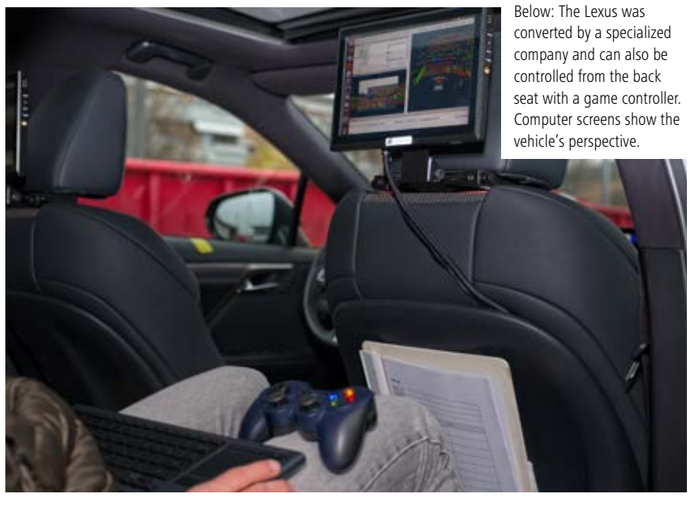
There is not much time left to develop the scientific basis for evaluating and assessing autonomous cars. The competition around self-driving cars is enormous, and the automotive industry could soon be equipping its vehicles for this purpose.

Whether self-driving cars will in future be able to avoid accidents and traffic is the subject of ongoing research. An appropriate legal framework is crucial. But the trend toward vehicle software that increasingly supports driving is unstoppable. ■

TECHNICAL PROFILE OF LEXUS RX-450H TEST VEHICLE

- Hybrid powertrain
- 3.5-liter V6 gasoline engine 183 kW/249 hp
- Two electric motors with 123 kW and 50 kW
- Acceleration (0–100 km/h): 7.8 s
- Top speed: 200 km/h
- Conversion kit to self-driving vehicle from autonomoustuff.com
  Gas pedal, brake, steering, transmission, horn, turn signals and driving lights can be switched remotely
- Self-driving vehicle starter kit from autonomoustuff.com
- "AStuff Nebula" driving computer, Velodyne lidar, Mobileye camera, Delphi Aptiv ESR radar and Robot Operating System (ROS)





WHAT DOES A CAR SEE?
Above: Laser scan of the Empa test track. The lab building on the left, trees on the right, a pedestrian in front of the car.
Below: The Lexus was converted by a specialized company and can also be controlled from the back seat with a game controller. Computer screens show the vehicle's perspective.

Photos: Empa

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

Youtube-Video: https://youtu.be/SHwQyKMxHpY

KNITTING ROADS

Empa scientists are investigating how roads could be reinforced with simple means and recycled easily after use. Their tools are a robot and a few meters of string.

Text: Stefanie Zeller

CONNECTED
The "Rock Print Pavilion" in Winterthur demonstrated how a stable construction made of loose stones and strings can be created by the "hand" of a robot.

Photos: Empa, Gramazio Kohler Research / ETH Zürich / Martin Rusenov

A robotic arm lays out a string in a mandala-like pattern on a bed of gravel. What appears to be a contemporary art performance is basic research that explores new ways in road construction. On the one hand, robot-assisted construction techniques for road building are being tested that have so far only been used in structural engineering. On the other hand, a new type of mechanical reinforcement is intended to change the typical structure of the road surface and thus to help save valuable resources in future or even to recycle road surfaces altogether.

AN IDEA FROM STRUCTURAL ENGINEERING

The idea originates from a project of the Gramazio Kohler Research lab at ETH Zurich. Here the project was actually raised as an art and research project. Pillars piled up purely from strings and gravel demonstrated that outstanding stability can be achieved by simply interlocking the gravel with a thread – without any cement as a binder! Laboratory tests showed that gravel pillars with a height of 80 cm and a diameter of 33 cm can withstand a pressure of 200 kN, which corresponds to a load of 20 tonnes.

Asphalt also consists of rocks of various sizes and a binder, bitumen. Thus Martin Arraigada and Saeed Abbasion from Empa's "Concrete & Asphalt" lab transferred this concept to road construction: "We want to find out how a recyclable pavement could be produced in the future. To do this, we are using digitalized construction methods in road construction for the first time," explains Arraigada.

A string-reinforced road surface that does not require bitumen promises a number of advantages. Since bitumen is extracted from crude oil, air pollutants are released during production and also later during use. What's more, it makes asphalt susceptible to cracking and deformation and, on top of that, impermeable to rainwater – this too could be overcome. For the researchers, it is also conceivable that rock could be used that is otherwise not suitable for road construction, but is less rare. Last but not least, the process allows for a rollable and recyclable pavement.

A STRING AND LOOSE GRAVEL

The two Empa researchers are using various experimental setups to test solutions for the above-mentioned aspects. The robotic arm plays a central role. It places the string in a programmed pattern on the layers of gravel stacked on top of each other. For the mechanical tests, five of these layers of gravel and thread are placed on top of each other in a test box, with the floor of the box covered with a rubber mat that fixes the whole package to the ground. It simulates the deformable bed, to which the pavement is applied. The fact that the string is exactly the same as the one used by every Swiss citizen for bundling waste paper shows that Empa researchers are breaking completely new (and cost-effective) ground here.

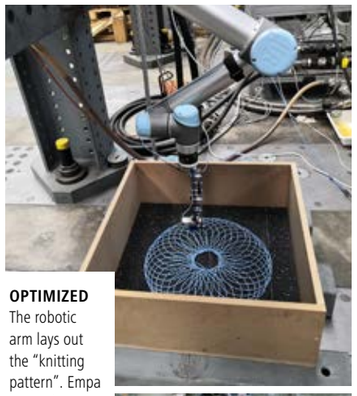
TESTS AND COMPUTER MODELING

The gravel-thread package is then loaded with a rotating plate and with pressure. This load test shows: by entangling the individual gravel stones with the thread, the package can withstand a pressure of 5 kN – half a tonne – without the stones moving much. Normally, the binder bitumen performs this task in asphalt. Dynamic load tests with rolling pressure, similar to the extreme conditions road pavements have to withstand, are soon to be carried out.

In parallel to their lab experiments, the researchers model everything in 3D on the computer using the Discrete Element Method (DEM). This should reveal the displacement of individual stones and the tensile forces acting on the thread – something that cannot be investigated in the lab. In addition, different patterns and mesh widths and their effects on the stability of the pavement will also be examined in more detail.

The research of Martin Arraigada and Saeed Abbasion has not yet resulted in a final product that is ready to be used in road construction. However, their research provides a lot of innovative potential to get closer to a recyclable and possibly rollable road pavement with simple means. ■

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



OPTIMIZED
The robotic arm lays out the "knitting pattern". Empa researchers are investigating different patterns in a number of test series.

SAVING THE CLIMATE WITH SOLAR FUEL

Produced in a sustainable way, synthetic fuels contribute to switching mobility to renewable energy and to achieving the climate goals in road traffic. In the mobility demonstrator "move" Empa researchers are investigating the production of synthetic methane from an energy, technical and economic perspective – a project with global potential.

Text: Stephan Kälin

ECO TRANSPORT
By 2030, the retailer Lidl Switzerland will switch from fossil natural gas to liquefied renewable gas to operate its trucks.

Photo: Lidl Schweiz

Mobility analyses show: only a small proportion of all vehicles are responsible for the majority of the kilometers driven. We are talking above all about long-distance trucks that transport goods all over Europe. If these continue to be fueled with fossil energy, it will hardly be possible to sufficiently reduce CO_2 emissions in road traffic. Synthetic fuels from surplus renewable electricity can make a significant contribution to such frequent driver applications. With electric mobility, hydrogen mobility and synthetic fuels, Empa's future mobility demonstrator, "move", is investigating three paths forCO_2 reduction in road traffic against the background of a rapidly changing energy system. "All these concepts have advantages and drawbacks in terms of energy, operation and economics. In order to use them in a smart way, we need a deeper understanding of the overall system," says Christian Bach, Head of Empa's Automotive Powertrain Technologies lab. "Together with our ‚move' partners, we are working to develop knowledge that can be put into practice."

The latest project focuses on the production of synthetic methane from hydrogen and CO_2 – the so-called methanization. Such fuels, produced synthetically with renewable energy – thus called synfuel or syngas –, can be transported via conventional routes and made available through the existing infrastructure. This is of interest for Switzerland as well as globally, because it opens up an enormous potential for renewable energy.

METHANIZATION MADE BY EMPA

The basic chemical process of methanization has been known for over 100 years as the Sabatier reaction. In "move", another process developed further at Empa will be used: the so-called sorption-enhanced methanization. Empa researchers hope that this novel process engineering concept will lead to simpler process control, higher efficiency and better suitability for dynamic operation.

Methanization works as follows: methane (CH_4) and water (H_2O) are produced by catalytic conversion from carbon dioxide (CO_2) and hydrogen (H_2). The water is causing problems with conventional processes, however: to remove it, serial methanization stages are typically required – with condensation areas in between. Due to the high reaction temperatures, a proportion of the water is converted back into hydrogen by the so-called water-gas shift reaction. The gaseous product of the methanization reaction thus contains a few percent hydrogen, which prevents direct feeding into the gas grid; the hydrogen must first be removed.

CO_2 AND WATER FROM THE AIR

CO_2 for the methanization as well as water for hydrogen production is taken directly from the atmosphere with a CO_2 collector from the ETH spin-off Climeworks. The system sucks in ambient air and CO_2 molecules remain attached to the filter. Using heat – around 100 °C – the CO_2 molecules can be released from the filter. Empa researchers see further potential for optimization in the heat required for this CO_2 desorption. "Both hydrogen production and methanization continuously generate waste heat," says Bach. "By means of a clever heat management, we want to cover the heat requirements of the CO_2 collector as much as possible with this waste heat". In addition to CO_2, the Climeworks plant also extracts water from ambient air, which is used for hydrogen production in the electrolysis device. This means that such plants are also conceivable in regions without water supply, for example in deserts (see box).

In addition to new knowledge about technical and energetic aspects, insights about the economic efficiency of synthetic methane are one of the project's prime goals. "In order to ensure this holistic perspective, the project consortium consists of partners who cover the entire value chain – from Empa researchers to energy suppliers, filling station and fleet operators and industrial partners in the technology and plant sectors," says Brigitte Buchmann, member of Empa's Board of Directors and strategic head of "move". The project is supported by the Canton of Zurich, the ETH Board, Avenergy Suisse, Migros, Lidl Switzerland, Glattwerk, Armasuisse and Swisspower.

Currently, Christian Bach's team is concentrating on the investigation of water adsorption on porous materials and the process control of the catalytic reaction. Construction of the plant is planned for mid-2021. "About a year later, we want to refuel the first vehicle," says Buchmann. "With methane from solar energy. ■

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

SYNTHETIC FUELS FROM THE DESERT?

When converting our energy system to renewable sources, there is a major challenge: renewable sources such as sun or wind are not always available everywhere. In winter we have too little renewable energy, in summer there is too much – in the northern hemisphere. In the southern hemisphere it is the other way round. But there are also areas with almost continuous sunshine – the so-called sun belt, in which the large deserts of the Earth are located. "From a global perspective, we do not have too little renewable energy worldwide, but 'merely' an energy transport problem," says Christian Bach. Synthetic energy carriers could help solve this problem.

Smaller plants in Switzerland can make a valuable contribution to the national energy system by harnessing surplus summer electricity and connecting different energy sectors. However, large plants could exploit their full potential above all in the Earth's sunbelt. This is illustrated by a simple calculation: in order to cover Switzerland's energy needs during winter not covered by hydropower as well as all long-distance domestic traffic exclusively with (imported) synthetic energy sources, a solar power plant would be required in a desert with an area of approximately 700 km^2; that is 27 x 27 km or, in other words, 0.008 % of the area of the Sahara. The water and CO_2 needed for production could be extracted locally from the atmosphere (see main text). "Existing trade mechanisms, transport infrastructures, standards and expertise could simply be used further", says Bach. So could the plant in "move" soon be a model for a gigawatt plant in the desert?

ENERGY HOUSE-KEEPING

Energy management in a house with a solar system is becoming increasingly complex: when do I turn on the heating so that it is nice and cosy in the evening? How much electricity can the hot water tank hold? Will there still be enough energy for the electric car? Artificial Intelligence (AI) can help solve the problem: researchers at Empa developed an AI control system that can learn all these tasks – and save more than 25 percent energy in the process.

Text: Rainer Klose

How simple it used to be: in the spring, when oil prices took a dip, one just filled the basement tanks, and all trouble was gone. There was gasoline at every corner. All around the clock. Fill up, drive on, that was it.

With the phase-out of the fossil economy life became much harder for smart spenders. Now energy prices no longer change annually, but hourly. Solar power is in abundance at lunchtime – in the evening the low sun hardly supplies any energy, while returning commuters are causing the demand for electricity to rise rapidly. The effect can be seen so clearly on consumption graphs that scientists have given it a name: the "duck curve". When the duck raises its head, it is getting expensive for everyone to buy electricity.

Eying the clock when drawing energy will thus be important for electric car drivers and homeowners. In future, those who want to use the available renewable energy in a cheap and at the same time environmentally friendly way will no longer be able to rely on permanently installed thermostats and manually operated buttons.

A MULTIFACETED PROBLEM

Bratislav Svetozarevic, a researcher at Empa's Urban Energy Systems lab, has recognized this problem. What is needed is an automatic control system that hoards energy when it's abundant and makes it available for expensive times of the day. The battery of one's car, for instance, which is attached to the charging station in the garage, could serve as a storage device. But Svetozarevic has to deal with a complex problem: every house is different, and so are its inhabitants. Depending on both weather and season, the power generated by the solar cells changes, as does the need for heating or cooling. An optimized energy control must therefore learn the daily rhythm of a house and its inhabitants – and should also be able to react flexibly during operation, for example when a sudden weather change upsets all calculations.

Photo: iStockphoto

WHAT'S THE PRIORITY? What is more important: a warm living room or a fully charged electric car? A smart house can manage both.

STEP ONE: THE THEORY

The solution to such problems is AI. The Empa researcher designed an AI control system based on the principle of reinforcement learning. When the system acts "correctly", it receives a "reward". Gradually the control system perfects its behavior in this way.

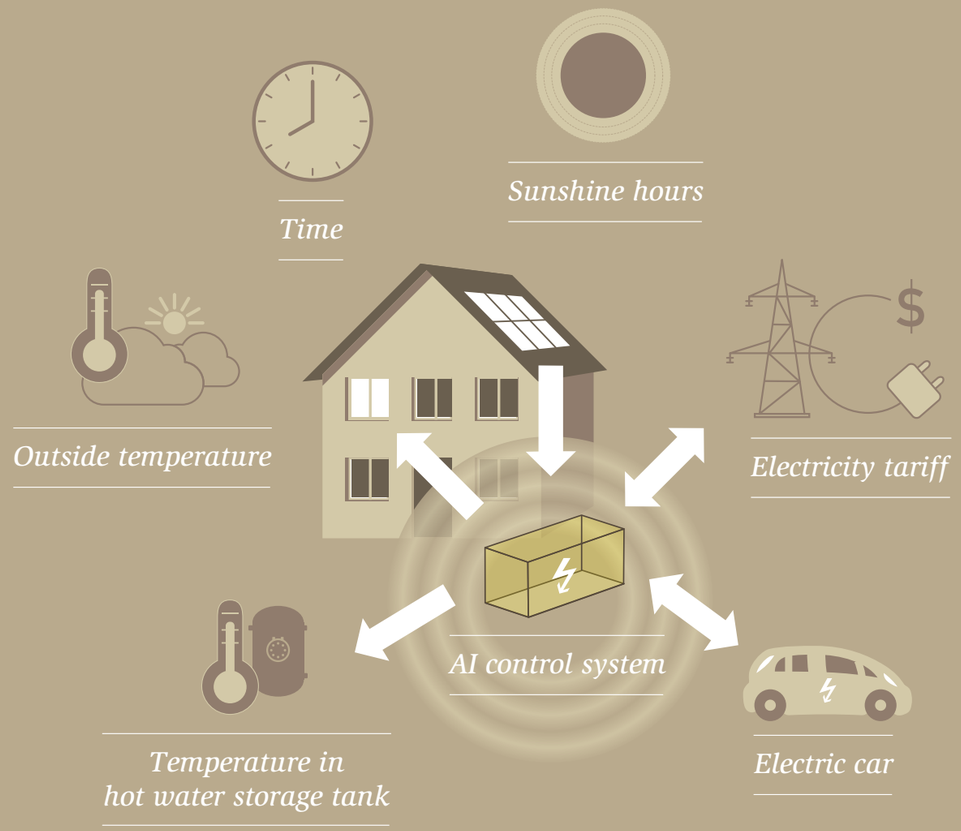
Initially, the control system was only simulated on the computer. The specifications: a certain room in a building had to be electrically heated to the desired temperature and maintain this temperature. At the same time, the system had to supply power to an electric car, which had to be at least 60 percent charged by 7 AM in the morning and be ready to go. In the evening at 5 PM, the electric car returns to the charging station with some residual charge and can supply electricity back to the house during the night. The control system was fed with weather data as well as room temperature data from last year and had to cope with two electricity tariffs: expensive electricity during the day between 8 AM and 8 PM, and cheap electricity during the night.

The result was amazing: the self-learning control system saved around 16 percent energy compared to a fixed-programmed solution and, in the theoretical test, also maintained the desired room temperature much more accurately.

STEP TWO: TEST IN A REAL BUILDING

Now the controller had to pass the reality check. Svetozarevic used the NEST research building on the Empa campus for this purpose. In the DFAB House unit, the AI algorithm controlled the temperature of a student bedroom for a week. At the same time, the 100-kWh-sized storage battery was used to simulate the battery of an electric car. This time, the result was even clearer: during a chilly week in February 2020, the AI control system saved 27 percent of heating energy compared to the neighboring student bedroom, whose heating was operated with a fixed-program (rule-based) control system. ▶

Distributing electricity in a smart way



Empa's AI control system distributes electricity from solar collectors in an optimized way. It does not need to be programmed, but uses AI to "learn" the needs of the occupants and adapt to the time of day and season. It can be used for buildings of various types and sizes.

When distributing energy, the occupants' thermal comfort is the top priority. The battery of the electric car is used as intermediate storage and and must provide enough range in the morning for the first trip of the day. Grid electricity is purchased when it is cheapest.

FORWARD-THINKING President of The Swiss Confederation Guy Parmelin opened the DFAB House in 2019. Now one of the rooms serveds as a research object.

Grafic: Empa / Photos: Nicolas Zonvi (2), Roman Keller

"The nice thing about our self-learning AI control system is that it can be used not only at NEST, but also in any other building", says Bratislav Svetozarevic. "It doesn't need an engineer to program the control system, nor someone to analyze the house beforehand and calculate a tailor-made solution".

WORKS EVEN WITH COMPLEX BUILDINGS

In a next step, Svetozarevic and his colleagues now want to determine how the system can be extended from one room to larger buildings. "In our first experiment we wanted to map a typical household of the future," says the Empa researcher. For the sake of simplicity, the team has limited itself to heating and vehicle charging. But the work is laying the foundation for much more: "Our AI control system can still cope when a photovoltaic system supplies electricity, a heat pump and a local hot water storage tank have to be operated – and the comfort requirements of the residents are constantly changing".

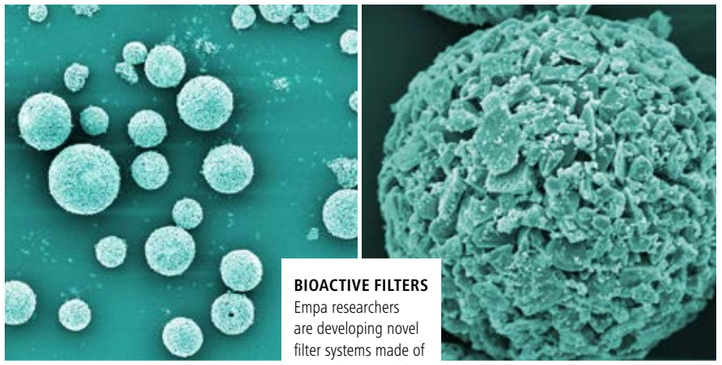
However, a new generation of electric cars is required to be able to use the AI system for optimal energy supply in the future. Today's standard models in Europe and in the US with the "CCS" quick-charging connection can only be filled up, but not supply electricity. Japanese cars with "Chademo" plugs, on the other hand, are designed for so-called bi-directional charging. The Korean company Hyundai announced in December that it would equip its new electric car platform E-GMP for bidirectional charging, too. This could help homeowners save energy in the long term and at the same time stabilize the electricity grid. ■

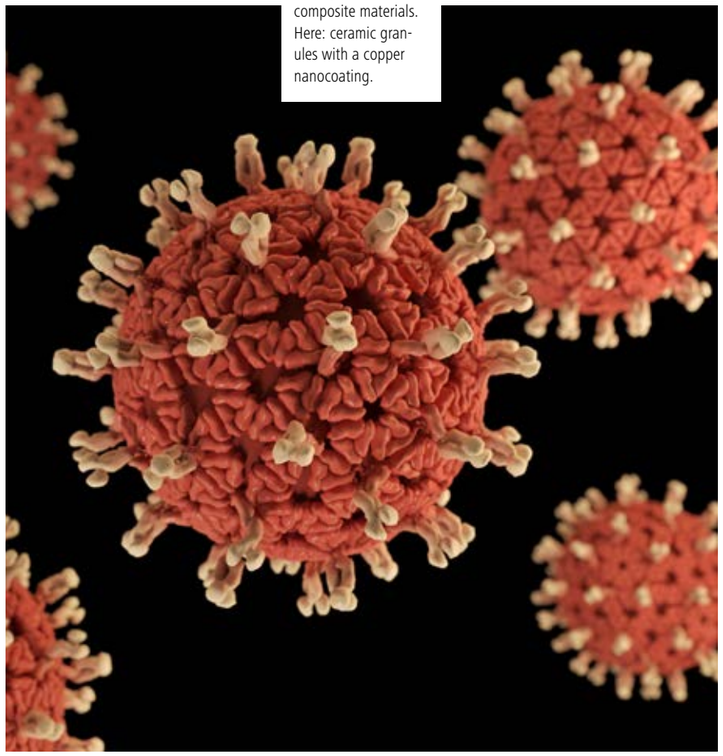
Further information on the topic is available at: www.empa.ch/web/ energy-hub

HEAVY CHARGE AGAINST WATER GERMS

Removing pathogens from drinking water is especially difficult when the germs are too tiny to be caught by conventional filters. Researchers at Empa and Eawag are developing new materials and processes to free water from pathogenic microorganisms such as viruses.

Text: Andrea Six





BIOACTIVE FILTERS
Empa researchers are developing novel filter systems made of composite materials. Here: ceramic granules with a copper nanocoating.

Photos: CDC / Unsplash, Empa

Water is life, biology teaches us. Reality teaches us something different: water contaminated with pathogens causes hundreds of thousands of deaths each year in places where water treatment is lacking or poorly functioning. To put an end to this, the availability of clean water for all mankind has been included in the United Nations (UN) Global Sustainability Agenda since 2015. In accordance with this goal, Empa researchers, in collaboration with their colleagues at Eawag, are developing new materials and technologies to remove pathogens from drinking water, which until now could hardly be eliminated with conventional measures, or only with expensive and complex processes.

TINY PATHOGENS

The researchers are aiming at the smallest of germs: tiny pathogens that – unlike the currently circulating coronavirus Sars-Cov-2 – are spreading via contaminated water and thus cause various water-borne diseases such as polio, diarrhea and hepatitis. Among these pathogens is the rotavirus, which is only about 70 nanometers in size. "Conventional water filters are ineffective against rotaviruses," explains Empa researcher Thomas Graule from Empa's High Performance Ceramics lab in Dübendorf. However, it is precisely these tiny germs that are among the most common pathogens causing gastrointestinal infections. According to the World Health Organization (WHO), in 2016 around 130,000 children worldwide died from rotavirus infections. The researchers have now developed strategies for filtration technologies based on new materials that cleverly circumvent the problem of minuteness. This is because one property of the virus particles can be used for a new type of filter: the negative electrical charge of the virus particles. Based on this idea, the researchers began to develop suitable materials that allow the adsorption of negatively charged virus surfaces. Until now, it has been difficult to create easily regenerated positively charged surfaces with high adsorption capacity, and systematic experimental studies have been scarce.

> "We were able to show how virus particles attach themselves to positively charged surfaces."

For their investigations, the researchers therefore chose a model virus that is even smaller than the rotavirus: the bacteriophage MS2, which is only 27 nanometers in size – a virus that attacks bacteria but is harmless to humans. Using this model virus, the scientists were able to show that viruses in water adsorb to the filter surface to varying degrees depending on the water's pH. "This must be taken into account when developing new water treatment and filter technologies," says Graule.

POROUS NANOCOATING

In order to develop filter technologies that can capture viruses at the nanometer scale, Graule is focusing on composite materials that are functionalized in such a way that they specifically bind viruses. "In water, the surface of the virus particles is negatively charged. We were able to show how the virus particles attach themselves to positively charged surfaces," he explains. For example, the researcher is working in an international team on ceramic granules made of aluminum oxide, whose fine granules are coated with nanometer-thin layers of copper oxide. "Together with the ceramic, the highly porous copper layer forms a composite material with a positively charged and immensely large specific surface," says Graule. The researchers were also able to coat tiny multi-layer carbon nanotubes with copper oxide, thus enabling virus elimination.

In order to develop a cost-effective and sustainable filter technology, the researchers specifically utilize materials that can be recovered after use in the sense of a closed material cycle. It is also important that no filter components are washed out into the purified water. To this end, analytical methods for nanosafety still need to be developed so that the most suitable composite material can be determined. At the end of the project, a filter technology is expected to be available that is also suitable for water treatment in developing countries with their particularly high numbers of rotavirus and other water-borne diseases. ■

PATHOGENS IN DRINKING WATER

Worldwide, around 3.4 million people, mostly children in structurally underdeveloped countries, die every year from water-borne diseases. Among the pathogens are single-cell parasites, such as amoebae and lamblia with a size of up to 40 micrometers. Bacteria such as salmonella, which cause typhoid fever, E. coli germs and cholera pathogens are significantly smaller (0.5 to 6 micrometers), but equally potent pathogens. With a size of 25 to 80 nanometers – about 100 to 1000 times smaller – viruses are the most difficult pathogens to filter out of water. In developing countries the contamination of drinking water with rotaviruses is particularly widespread, followed by other viruses such as the pathogens that cause hepatitis and polio.

Further information on the topic is available at: www.empa.ch/web/s201.

TAILOR-MADE POWER GRIDS

In her PhD thesis, Empa researcher Crisitina Dominguez is developing a computer model, which can be used to plan electricity grids in developing countries. To collect data, she travelled to Kenya to get an idea of how people live without electricity and what developments access to the power grid can trigger.

Text: Stefanie Zeller

The fact that electricity not only provides the luminous displays of our numerous gadgets, but also enables healthy, clean living spaces or even access to education in large parts of the world is easily forgotten in our highly digitalized world. Many developing countries are stuck in a vicious circle of poverty with their low electrification rates. Without lighting at home, there is a lack of opportunities for value-adding work besides agriculture. Children can no longer do their homework or learn to read in the evening. Moreover, there are health problems, often caused by smoking fireplaces in the house or sooty kerosene lamps. Access to clean energy is generally considered a springboard to generate a higher income and thus escape poverty. This is why it has been identified as one of the 17 UN goals for sustainable development.

NO POPULATION DATA

To help achieve this goal, Cristina Dominguez, a PhD student at the Institute of Building Physics at ETH Zurich and in Empa's Urban Energy Systems lab, is developing a computer model that will provide project developers in rural areas with estimates of household electricity requirements. This should enable accurate and therefore sustainable planning of the electricity grid. In developing countries, electrification projects often fail because reliable data for determining the needs of often widely scattered households is hardly available. Data collection in particular is a major cost factor that makes project developers hesitant to invest. If an electricity grid is then planned too large, for example, this is passed on to electricity prices, making electricity unaffordable for the poor population. Ultimately, electricity grids must be tailored to provide long-term benefits to the people on the one hand and to

Photo: Empa

CLEAN LIGHT
LED lamps are replacing open fires and kerosene lamps in Africa.

QUALITY OF LIFE
Without lighting, dark living spaces like this one in the village of Got Osimbo in western Kenya are barely usable. Kerosene lamps produce toxic soot and endanger health. Moreover, kerosene is expensive. Some households are already using small solar lights to escape these problems.

offer developers an attractive and realistic investment opportunity on the other.

To collect data, Dominguez chose an area in sub-Saharan Africa, the region with the lowest electrification rate worldwide: “In addition to political problems, the areas here are extremely sparsely populated, and the small settlements are very widely scattered. This makes electrification much more difficult – and of course more expensive”, says Dominguez. As part of her PhD thesis, she determined the energy use and requirements of around 250 households in eastern Kenya. In order to make her model applicable worldwide, research institutes in Guatemala and Pakistan support her and provide her with equivalent data sets from these countries.

ANALYSING DEVELOPMENT

Dominguez’s fieldwork in Kenya collected data from households without access to electricity and from those that had been connected to a power grid within the last six years. She was concerned not only with recording existing energy sources and their requirements, but also with the change in use after electrification had been completed. The Empa researcher also used diaries, in which the residents recorded their activities, which they had followed throughout the day, in order to get to know their everyday lives and needs and to anticipate changes, which would set in after electrification and which would then be reflected in the demand for electricity. In Kenya, for example, kerosene is an important source of energy to light up the dark mud huts. To get the kerosene, it is often necessary to walk long distances to the dealership. Time that could perhaps be invested in value-adding work at home in the future – if a source of electricity were available.

ENERGY LETS DREAMS COME TRUE

And once the power supply is available, people start to act accordingly; they buy electrical appliances such as TVs, and power consumption increases accordingly. But how long can the power grid continue to function if demand continues to rise? Dominguez wants to incorporate these dynamics into her model: “In our local surveys, we asked people which appliances they would buy after the first year or second year with electricity. We then compared this with households that had already gone through this process.” In this way, Dominguez wanted to find out how people would handle energy when it was available to them. Dominguez knows from her research that engineers are often unable to assess this correctly: “There are great biases here, which often result in power supply systems being designed too large.”

TAILOR-MADE POWER GRIDS

To make accurate predictions and recognize consumption dynamics, Dominguez applies machine learning algorithms and data mining techniques. To create the models, the researcher combines global data sets from organizations such as the World Bank with data from project development companies so that she can incorporate additional consumption patterns such as seasonal fluctuations. These are then validated for the three priority regions using field data from Kenya, Pakistan and Guatemala. Mini Grid companies have also provided data on electricity consumption in return for the opportunity to test their model on the basis of local conditions.

Photos: Empa, ETH

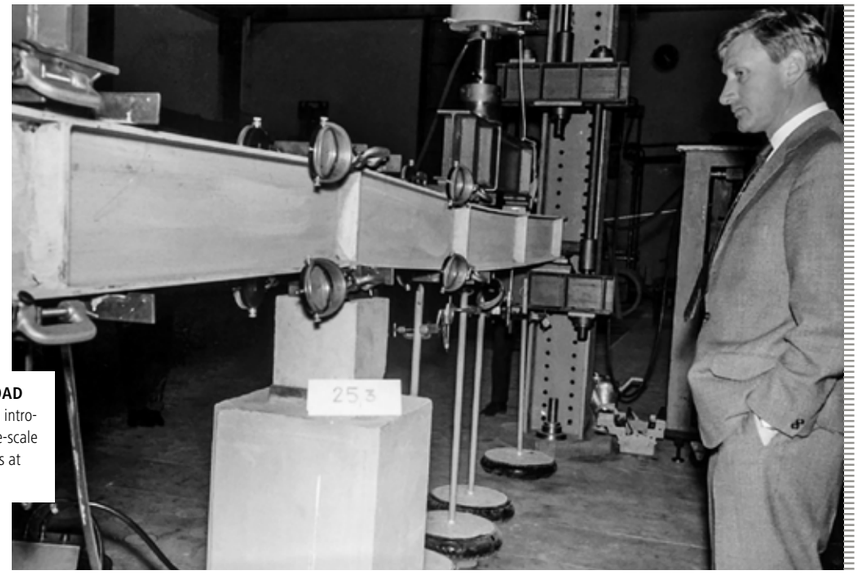
FIRST HAND
While collecting data in Kenya, Cristina Dominguez (right) got support from helpers on the ground.

> “What appliances do people buy first when electricity comes into the house?”

Cristina Dominguez’s approach highlights the problems facing developing countries with hardly any infrastructure: although technical possibilities for electrification exist and have become cheaper with solar technology, investments in a weak economic environment must be made with careful consideration. Otherwise, there is a serious risk of over-indebtedness on the part of electricity users and, in the worst case, also on the part of the operating companies – which could well exacerbate poverty and deter others from investing in these areas. Dominguez’s computer model has the potential to overcome at least one hurdle to electrification and thus provide the impetus for a way out of poverty. ■

Further information on the topic is available at:
www.empa.ch/web/s313

CONGRATULATIONS! EMPA PIONEER TURNS 100



HEAVY LOAD
Alfred Rösli introduced large-scale experiments at Empa.

Alfred Rösli celebrated his 100th birthday on December 7. The civil engineer joined Empa immediately after completing his studies at the ETH and, apart from a research period in the USA, remained at the research institute until the end of his career. Here he implemented his innovative ideas in the field of structural dynamics, for which he received worldwide recognition. The large-scale tests for complex structures, which continue to take place at Empa to this day, are Rösli's legacy.

www.empa.ch/web/s604/avenir

REMOTELY CONTROLLED
Empa researchers advise Airbus technicians via livestream as they install DIMES sensors on the cockpit of a jet.

SENSORS FOR THE AIRCRAFT HULL

In the Clean Sky 2 research project DIMES, Empa is working with Airbus, the University of Liverpool, Dantec Dynamics GmbH and Strain Solutions Ltd to develop sensors for monitoring aircraft structures. Initially, the sensors will be used in stress tests on the ground. Later, they will fly with the aircraft and provide real-time data to detect cracks on the jet. This technology could make aircraft lighter in the future and thus save fuel.

www.integratedtesting.org

Photos: Empa

COVETED PRIZE FOR RESEARCHER

AWARDED
Dorina Opris researches novel polymers.

The European Research Council (ERC) has awarded one of the coveted «ERC Consolidator Grants» to Empa researcher Dorina Opris. Thanks to the award, which is endowed with around 2 million Euros, the researcher will be able to further expand her research group in the field of novel polymers for energy conversion over the next five years. These innovative polymer materials can, for example, change their shape in response to an electric field - and thus act as "artificial muscles," they could generate electricity when stretched, cool, for which they require extremely little energy, or convert heat directly into electricity.

https://www.empa.ch/web/s604/erc-grant-opris

Photo: BM PHOTOS on behalf of the SNF

EVENTS

(IN GERMAN AND ENGLISH)

05. MÄRZ 2021
Kurs: Tribologie
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/tribologie
Empa, Dübendorf

26. MÄRZ 2021
Kurs: Klebetechnik für Praktiker
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/klebetechik
Empa, Dübendorf

28. MÄRZ 2021
Kurs: Elektrochemische Charakterisierung und Korrosion
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/korrosion
Empa, Dübendorf

15. SEPTEMBER 2021
Kurs: Additive Fertigung von Metallen
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/addfert
Empa, Dübendorf

08. OKTOBER 2021
Kurs: Energy Harvesting
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/harvesting
Empa, Dübendorf

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

THE PLACE WHERE INNOVATION STARTS.