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The magazine for people shaping the future

Lighter Materials:
Climate neutrality from new buildings to renovations

Seeds of Hope

New possibilities in the fight against bacteria

Dr. Winterberg and Dr. Dahlmann (right), Fraunhofer ITEM

Fraunhofer Wins 2024 Deutscher Zukunftspreis
German President Frank-Walter Steinmeier presents country's most important award for innovation

"We Can Do More!"
An interview with Minister-President Stephan Weil

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TRANSFER for Our FUTURE 2025

Editorial

From Knowledge to Value Creation

By Prof. Holger Hanselka

Prof. Holger Hanselka

We are living in volatile times. Now, at the end of a tense year in 2024, we find ourselves looking ahead to the new year. The Fraunhofer motto for 2025 is "Transfer for our future." If we are to forge a successful path into that future, it will not be enough to keep to the tried and true old ways practiced in Germany and across Europe. As we position ourselves with an eye to the future, we need to focus on innovation, now more than ever. At Fraunhofer, we are committed to doing our part to work with companies to develop these innovations and move them into broad application, in alignment with our mission.

As always when things get tough, it is important to focus on our strengths and to pool our resources and direct them to where they will do the most good. That is the situation for Germany, and Europe as a whole, after the U.S. elections. And it is also Fraunhofer's situation. To be able to maintain an agile position where we are able to take action in global competition now and into the future, we need to focus on our core business. Our model, with its balanced composition of industrial revenue, competitively raised public-sector revenue and base funding, forms the basis for our success, as it guarantees that our research will be rigorously aligned toward the market. Ideas, applications, developments, bringing technologies to the world: That's our mission.

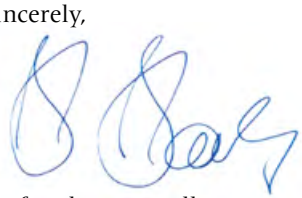
While the political discourse about transfer focuses much too often on start-ups, Fraunhofer takes a much broader view. Contract research is among the most vital drivers of innovation for value creation, jobs and Germany's standing as an industrial powerhouse — not just for us but for our entire society. This environment gives rise to whole new opportunities in their own right. That might sound like theory, but in fact, it is definitely practical. Take generative AI, for example. Artificial intelligence will open doors to a new world that we will experience in every situation in life — and, of course, across every sector of the economy, from materials research and science and mechanical engineering to energy and mobility. And what do we see happening? Germany seems fainthearted in the face of the American tech giants, their market potential and market power.

And yet, our strength will lie in exactly the things Google cannot do. Bigger isn't always better. Being smaller can also mean being more efficient, using less energy, operating at lower cost. If we can empower our medium-sized business sector to take part in the generative AI revolution and develop business models with international appeal, we can also establish our value system, the European value system, as a standard. At Fraunhofer, our goal and ambition is to build capabilities of our own and thus support our medium-sized business sector as an innovation partner. What we offer is the creation of customer-specific protected communities with a focus on applications. At Fraunhofer, we have learned that our business partners want to maintain their autonomy. They know that the more difficult the increasing tension between America and Asia becomes for us in Europe, the more valuable it will be to be able to trust in the security of our data.

And speaking of trust, let me make a personal note now, as we approach the holidays and the start of a new year. Amid all the dissatisfaction that certain actors who stand to benefit stir up, especially in an election year, let us make sure we do not lose sight of our strengths. Let's seize the opportunities that come our way.

And let's trust in our future.

Sincerely,



Prof. Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer/Stefan Obermeier

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International studies have found that up to 50 percent of antibiotic treatments are not performed appropriately. These drugs are prescribed in the wrong dosages and for the wrong amounts of time, for example — both key reasons resistance is on the rise.

50 %

Front and back cover photos: Jonas Ratermann, Biophoto Associates/Science Photo Library (2) and Marko Priske; Content photos: Michael Löwa, Jonas Ratermann, CNRI, Dennis Kunkel/both from Science Photo Library, Marko Priske, Eva Häberle, Sebastian Weingart/DML-BY, spacejunkie/Photocase

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Brief report

The 2024 outdoor strawberry harvest was about 25 percent lower than the previous year, which was already poor.

Local Strawberries, Even in Winter

A team of researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT is working to develop AI-controlled year-round indoor production of berries as part of the inBerry project. To achieve this, the scientists are using indoor vertical farming, a resource-efficient, space-saving and local method of growing plants right where they are needed. This technique has previously been used mainly for lettuce and herbs. Now, the inBerry team plans to expand its production range. "In cooperation with vGreens Holding GmbH, a company that specializes in data-based, AI-controlled production of strawberries, we are working on a berry production method that really takes things to the next level by using optical sensor technologies to determine quality," explains Volkmar Keuter from Fraunhofer UMSICHT.

Yields of strawberries and other berries have been declining for years due to factors such as increasingly severe weather events, which have a significant impact on all kinds of fruit, including berries. Interest in alternative indoor growing systems is booming as a result. ■

Sustainable Packaging with Reeds

Are peatland plants a good raw material for new bio-based packaging? A team of researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV worked to find the answer. In the PALUDI project, the researchers studied the potential of reeds, sedges and reed canary grass and tested relevant manufacturing processes. Peatland plants contain less lignin than wood, which allows for lower chemical use during the pulping of plant fibers. Further tests showed that the papers produced from these materials had good processability. Additives such as starch and sizing agent further increased the tensile strength, elasticity and water-repellent properties of the papers. They also proved to be suitable for processing methods such as folding, gluing and printing. Using fiber-molding and deep-drawing processes, the researchers were able to produce sturdy paper jars and trays from reed fibers. The team developed a laboratory unit specifically to produce the demo packaging. ■

Plants from rewetted peatlands are a good alternative to wood, 80 percent of which is imported in Germany these days.

How often does a famous person appear on a TV show? An AI-based software tool provides fast results.

Measuring Media Presence

An AI-based software program called InsightPersona developed at the Fraunhofer Institute for Digital Media Technology IDMT identifies faces and voices in large media archives and databases. In just seconds, it can produce analyses of the presence of certain people, groups of people and discussion content. This makes it possible to quickly determine how well women are represented on certain TV shows, for example, or how much of the time they are the ones to speak. It is also possible to put together news segments with audio and video clips of suitable people in near real time. Search results can be visualized on a customer-specific basis.

"Combining audio-based and visual recognition technologies allows us to produce highly meaningful, high-quality search results. This is especially helpful when the information is complementary, such as when someone is speaking in a media segment but does not appear onscreen at the same time," explains Uwe Kühhirt, a video analysis expert at Fraunhofer IDMT. Displaying the intelligibility of speech can also help make media content more accessible. This could allow media archives, streaming services and communication service providers to offer value-added options for their customers, for example by providing alternative audio with optimized intelligibility. ■

Resource-Efficient Avalanche Monitoring

Researchers at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR are working to use passive radar to detect whether avalanches have in fact been triggered by controlled detonations, even in remote areas. This was previously done using helicopters, wires that break when an avalanche starts or active radar technology, in which electromagnetic energy is bounced off of objects.

Passive radar, by contrast, does not actively emit radiation. Instead, it uses radio or mobile signals. Since it does not require a transmitter antenna or transmission license, this technology is cheaper, plus it saves electricity. The Fraunhofer team is relying on signals from the OneWeb and Starlink satellite mega-constellations, which — because they are so numerous — permit continuous radar visualization of the earth's surface. As soon as one satellite passes over the horizon, another appears.

The idea was tested at a former basalt mine near Remagen, where "landslides" occur when an excavator dumps a load into a hole. The researchers found that passive radar using signals from satellite mega-constellations can reliably confirm that an avalanche has started. ■

Avalanches can plunge downhill at speeds of up to 300 kilometers per hour.

Photos: MarcoFood, Gearstd, Sjo (all from istockphoto), picture alliance / imageBROKER / Werner Wulf

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Using AI to Find Parking

There is a shortage of some 40,000 truck parking spaces along Germany's highways.

An innovative AI-supported forecasting tool from the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI aims to make it easier for truck drivers to find parking. The solution, which was developed in the SOLP project, is intended to streamline the occupancy of existing parking spaces, thereby helping to prevent accidents and improving the flow of highway traffic.

The system supplies color-coded information on available parking. The AI-supported digital recommendation tool is built into either an app or an on-board unit, where it displays parking lot occupancy along a driver's route using color coding. Red stands for a fully occupied rest stop, yellow for tolerated parking, and green for available rest stop space. Forecasts are updated every 15 minutes for the next two hours. The AI is trained with information on the location and features of parking spaces within the highway network, with traffic flow data from induction loops and telematics and parking lot occupancy data. To produce a forecast, the current information is then analyzed and linked in real time with the routes traveled by truck drivers. ■

An Agent for the Heating Transition

How can we make sure the heating transition is a success in our cities and towns? From the historic city center of Freiburg to Kassel and Berlin's Prenzlauer Berg neighborhood, action is urgently needed all across Germany when it comes to heating. To help advance the energy transition, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE is using "urban twins" — digital twins for urban planning and energy optimization.

"We use existing geodata, statistics, laws, regulations and data collection," explains project manager Helen Ganal from Fraunhofer IEE. This process culminates in the creation of AgentHomeID, a tool that helps with planning processes by displaying the supply of local and district heat. Calculations for entire neighborhoods have already been performed at the institute. Fraunhofer IEE's models make it possible to take emissions and existing heating technologies into account and develop targeted suggestions for optimization. The goal is to help developers, renovation companies and investors make sound long-term decisions. ■

AgentHomeID helps with investment decisions relating to the heat supply.

Editorial notes

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Icicles form when heat escapes through the roof.

Small Contribution, Big Impact

How can heating systems be adjusted optimally to the buildings where they are operated? Researchers at Fraunhofer IIS have an idea.

Winter's chill can be enough to make your blood boil. Dr. Andreas Wilde, chief scientist at the Fraunhofer Institute for Integrated Circuits IIS, explains why: "Inefficient heating can unnecessarily add up to 30 percent to the heating bill for an average single-family home, night after night." Wilde aims to help homeowners and tenants save money. His project is called SHANGO.

Wilde, who holds a doctorate in physics, sought out divine assistance for his work: "Shango is the Yoruba god of thunder, lightning and fire. And SHANGO is much easier to say than the full name of the project, which is Smart Heating System Optimization," Wilde says with a smile.

Optimized heating management can cut energy costs by as much as one-third, he notes. SHANGO uses artificial intelligence (AI) and machine learning to analyze operating data and identify areas where optimization is possible. A test rig was set up at the institute's location in Dresden to simulate the most common operating errors and devise solutions for users. Improper installation and hidden wear and tear can also impair the efficiency of heating systems.

Resource efficiency is important to Wilde, and not just in terms of heating costs: "We're only looking at the measurement options and settings that are already present in the system. There's no need to install anything extra." Ever down to earth, Wilde also keeps his long-term objectives in mind: In the future, buildings should move beyond merely consuming energy to store it as well, which will help compensate for fluctuations in wind and solar power, at least in part. ■

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Building On KNOWLEDGE

Sustainability

Fungal mycelium as a construction material, ecofriendly concrete and smart recycling solutions pave the way for climate neutrality.

By Kathrin Schwarze-Reiter; Photographer: Marko Priske

Fungal mycelium as adhesive: Dr. Henrik-Alexander Christ (left) and Dr. Steffen Sydow research innovative construction and insulation materials at Fraunhofer WKI.

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Everyone knows the story of the three little pigs. Each of them wanted to build himself a house. The first little pig was a bit lazy, so he built his house out of straw. The second was a harder worker, so he used wood. But the third little pig went to all the effort of using brick. In the fable, which dates back to 19th-century England, the big bad wolf comes and blows down the houses made of straw and wood, calling out, "Then I'll huff and I'll puff and I'll blow your house down." But the wolf is no match for the brick house and ultimately ends up getting burned in the chimney. The three little pigs live happily ever after, safe and sound in the third house.

But what does all that have to do with this article? Well, from the story we learn that it is worthwhile to put some effort into building — and that brick is a very dependable construction material. Similar materials have been used in Germany for generations. Of the more than 19 million homes in Germany, the majority are built out of natural stone, brick or concrete. It is a tradition that dates back to antiquity, as sturdy walls afforded protection from storms, fire and invaders. German builders still emphasize stability and durability to this day. Besides that, stone also has natural heat-insulating properties, so it reduces energy consumption.

"Fungus has impressive capabilities that can be harnessed through biotechnology."

Lina Vieres, Fraunhofer UMSICHT

But it also has its drawbacks. Both natural stone and cement can sometimes contain substances that harm the environment or even human health. Water-soluble chromates in cement can trigger allergies, for example. Cement is also highly alkaline, which can irritate the skin and mucous membranes. Some kinds of natural stone, like granite, contain radioactive substances such as uranium, thorium and radium. At high activity concentrations, these substances release small amounts of radon, a radioactive gas that is considered harmful to health and increases people's risk of developing lung cancer. On top of that, natural stone is often treated with chemicals to polish or protect it from weathering. Some of these sealers and surface treatments release volatile organic compounds (VOCs), which can reduce air quality inside enclosed spaces.

Climate-neutral construction — a herculean task

As part of the new German Federal Climate Change Act (Klimaschutzgesetz, KSG), the German federal government stipulated that all existing buildings in Germany be made climate-neutral by 2045 — a massive project, but also a source of tremendous opportunities in terms of the future viability of German industry. Construction and use of buildings has been responsible for about 30 percent of CO_2 emissions in the country to date. The construction industry is facing the challenge of rethinking and reshaping the entire process, from the use of materials through to disposal.

Meeting climate targets requires fundamental change in a form just as complex as construction itself. On the journey toward climate neutrality, sustainable construction materials and intelligent recycling concepts are two factors that could revolutionize the industry. Numerous Fraunhofer institutes are researching these key technologies, which combine to empower a climate-neutral building sector. The Fraunhofer institutes offer solutions for the entire building value chain, from raw materials to the final product and from new construction to renovations.

"Conventional construction products use a lot of energy in the manufacturing process, plus they are often made from petroleum, which is a finite resource," says Dr. Henrik-Alexander Christ from the Fraunhofer Institute for ▶

The super powers of fungus: Lina Vieres prints noise absorbers at Fraunhofer UMSICHT. Fungus makes them lighter in weight and reduces their environmental impact.

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Valuable ash: Dr. Sebastian Dittrich and his team at Fraunhofer IBP use ash and slag to make concrete less resource-intensive.

Wood Research, Wilhelm-Klauditz-Institut, WKI. "Disposal and recycling are also difficult with these products. In many cases, incineration is the only option, but it also releases large amounts of carbon." Experimental sustainable construction materials are a promising answer to the environmental challenges facing the construction industry. These innovative materials are designed to lower carbon emissions, conserve resources and minimize waste.

The super powers of fungus

When it comes to fungus in the walls, most people tend to think of unsightly and potentially harmful mold and mildew. Christ and his colleague Dr. Steffen Sydow aim to change that. They are researching fungal mycelium, which they hope to use as a bio-based adhesive for hot-pressed construction and insulation materials. Fungal mycelium consists of long, thin cells that form a complex three-dimensional network. The network works its way through the substrates used, which can include substances like woody residue from hemp plants, wood chips and other plant fibers, and turns them into composites with favorable technical properties. "Mycelium is like a biological form of glue, if you will, making it an alternative to conventional petroleum-based products," Christ says. To intensify the natural bonding properties of the fungus, the mycelium is inactivated during hot pressing and the material is reinforced and dried.

But even beyond that, fungus also has true super powers when it comes to building: Mycelium is often lighter in weight than many traditional construction materials, plus it is extremely adaptable and can be molded into almost any shape. It also has high compressive strength and thermal and acoustic insulating properties. In tests, its thermal conductivity was similar to that of wood fiber insulation board. "Fungus has impressive capabilities that can be harnessed through biotechnology," says Lina Vieres, a research scientist in the Product Development department at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. Knowing that fungus can take fantastic shapes with extreme stability, she and biodesigner Julia Krayer started researching fungus-based materials five years ago.

In the FungiFacturing project, they cooperated with a team from the Fraunhofer Institute for Building Physics IBP to inject a paste of residual materials with a fungus growing through it. Working in their fungus lab, the researchers used a ceramic 3D printer to process the mass into sound absorption materials. Sawdust, brewer's grains from beer production or straw, all plant-based residues, serve as the nutrient-rich substrate for growing the fungi. The fungal mycelium grows inside an incubator, hardening the printed object until it is rock-hard. "Not all fungi are suitable for this. Fungi that break down wood, such as bracket fungi and tinder fungus, are especially good candidates."

To acquire this knowledge, Vieres worked extensively with the mushrooms. She is scheduled to do a continuing education course for certification as a mycology specialist next year. "My friends are no longer surprised to find me crawling off into the bushes looking for interesting mushrooms," Vieres says. She is certain of one thing: "The super powers of fungus can be used on a much more far-reaching basis than before."

The concrete transformation

Even with all its benefits, there is one important construction material that fungal mycelium cannot fully replace: concrete. No other materials have yet been ▶

> "Limestone is burned at high temperatures. That requires a lot of energy, uses up fossil fuels like coal or natural gas and releases chemically bound carbon dioxide."
>
> Dr. Sebastian Dittrich, Fraunhofer IBP

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able to match its high stability and compressive strength, which are needed for load-bearing structures, or its durability and fireproof properties. The issue is that concrete is not especially ecofriendly, primarily because cement production is CO_2-intensive, generating about eight percent of worldwide greenhouse gas emissions. "Limestone is burned at high temperatures," says mineralogist Dr. Sebastian Dittrich, Group Manager Processing and Recovery at Fraunhofer IBP. "That requires a lot of energy, uses up fossil fuels like coal or natural gas and releases chemically bound carbon dioxide." Producing concrete also consumes huge volumes of sand, gravel and limestone, which adversely affects natural ecosystems and jeopardizes biodiversity: Trees are cut down, rivers polluted and animal habitats destroyed in the process of extracting these materials.

To address these issues, various Fraunhofer institutes are working on more-sustainable versions by finding substitutes for the materials used to make concrete. Researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS and the Fraunhofer Institute for Electron Beam and Plasma Technology FEP are putting their hopes in bacteria. They are working on a biogenic construction material based on cyanobacteria as an alternative to concrete. These tiny organisms multiply in a nutrient solution and use photosynthesis to bind aggregates such as sand or basalt into solid structures reminiscent of stone. Unlike conventional concrete production, the process generates no harmful carbon emissions. Instead, the material actually binds the gas inside, where it cannot contribute to climate change.

Christina Haxter from Fraunhofer WKI, for her part, is taking a different tack involving woven materials. Natural fibers derived from flax, a well-known material in Germany, are woven together on a huge loom at Fraunhofer WKI and used to reinforce concrete. Potential uses include floor slabs in buildings or applications in road construction. "The conventional steel rebar used in concrete can corrode, but flax can't," Haxter says, pointing out just one advantage. What is more, the bio-based version of the reinforcing material is lightweight, sturdy and resilient, making it an ideal material for long-lasting and yet also sustainable construction projects.

"It's a really exciting material, but only 26 percent of the building material and 56 percent of the expanded polystyrene used for packaging is recycled in Austria."

Dr. Patrick Taschner, Fraunhofer Austria

Other scientists are taking still other approaches. Dr. Sebastian Dittrich and his team at Fraunhofer IBP are working on a new formulation for concrete in the BAUSEP joint research project. To that end, they are using secondary raw materials such as ash from household waste incinerators and slag from steel mills. The particular properties of concrete are maintained even when the materials used to make it are changed.

The ash undergoes ultrasonic cleaning to remove any clinging foreign materials, and glass is sorted out. The new formulations make it possible to reduce the proportion of primary raw materials used. "The approach we have developed can help significantly reduce resource consumption in the construction industry," Dittrich says. The project is still in the testing phase; the team has produced some 150 square meters of paving stones so far. "We firmly believe the new concrete will have its uses in road and building construction and in civil engineering," Dittrich notes. ▶

Throw expanded polystyrene away? No way! Dr. Patrick Taschner from Fraunhofer Austria collects, cleans and recycles old expanded polystyrene to make new insulation boards.

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Circular economy and recycling as keys to sustainability

Industrial waste materials aren't the only thing that can be reused in new construction, either; mineral construction and demolition debris can, too. Each year, Germany produces about 220.6 million metric tons of these materials, a large portion of all the waste generated in the country. Reuse and recycling are important in order to conserve natural resources and use less energy. Many projects in progress at various Fraunhofer institutes are looking at recycling in the construction sector. For example, Fraunhofer IBP is producing construction materials from recycled materials such as concrete, brick and asphalt. These secondary raw materials can then be reused in building construction. This reduces waste while also lowering the use of primary raw materials, thereby extending the life cycle of construction materials. Another project, BauCycle, is developing a method of sorting construction debris by dividing it into valuable recycling materials and secondary raw materials for use in construction — one route to circularity in the building sector.

Expanded polystyrene (EPS) is another of the construction and demolition materials that are generated in large volumes but have thus far mostly been simply thrown away. Commonly used in insulation, EPS is 98 percent air, which gives it extreme insulating properties. It also does not require much energy to produce or transport. "It's a really exciting material," says Dr. Patrick Taschner from Fraunhofer Austria, "but only 26 percent of the building material and 56 percent of the expanded polystyrene used for packaging is recycled in Austria." To tackle this imbalance, Taschner and a consortium from the EPSolutely research project, consisting of 13 partners, worked together to devise a concept for efficiently collecting, processing and reusing old expanded polystyrene nationwide. Some 5,000 collection bags with QR codes have already been distributed to partner companies. Construction firms use an app to quickly and easily send a message when the bags are full and ready to pick up. "Then we can grind it up, clean it and use it to make new insulation board." The process emits 80 percent less CO_2.

> "Renovations could be completed about ten to 15 percent faster, and the gray energy of these material streams could be cut in half through bio-based materials and other approaches."
>
> Dr. Simon Schmidt, Fraunhofer IBP

If the construction industry and all existing buildings are to be made climate-neutral by 2045, we also need to change the way we think about renovation and refurbishment. "These processes are often lengthy and resource-intensive," explains Dr. Simon Schmidt, head of the Hygrothermics department at Fraunhofer IBP. Researchers from seven Fraunhofer institutes aim to change that in the BAU-DNS flagship project. Schmidt explains: "Renovations could be completed about ten to 15 percent faster, and the gray energy of these material streams could be cut in half through bio-based materials and other approaches." A faster pace would be made possible, for instance, by systemic and functional development of sustainable renovation and rehabilitation modules, one of the areas of focus for BAU-DNS. The modules are to be industrially prefabricated and assembled on site, which will also help construction firms cope with the shortage of skilled workers. Schmidt knows what he is talking about, as he comes from a family of tradespeople and apprenticed as a carpenter himself. Now, as a structural engineer, he is focusing on the needs of construction companies. He views sustainability as especially important. "This is the only way to take the construction sector into the future." ■

Speeding up the renovation process: In the BAU-DNS Fraunhofer flagship project, Dr. Simon Schmidt from Fraunhofer IBP is developing sustainable renovation modules and ecofriendly solar panels.

"This is the only way to take the construction sector into the future."

Dr. Simon Schmidt, Fraunhofer IBP

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Sweet Temptation

Sugar tastes good — and, in large amounts, makes people sick. Researchers from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME are working to develop a healthy alternative. Their secret? Sweet proteins derived from tropical plants.

By Yvonne Weiss

In cubes or granulated form, added to mulled wine, coffee or tea, sugar sweetens many of the things we eat and drink — and our daily lives. The average German consumed more than 33 kilograms a year in 2023. That works out to about 91 grams a day, almost quadruple the 25 grams recommended by the World Health Organization (WHO). Potential consequences include obesity, type 2 diabetes and cardiovascular disease.

Dr. Stefan Rasche, head of the Plant Biotechnology department at Fraunhofer IME, is researching a healthy alternative to conventional industrially produced sugar. In the Novel Sweets project, he is working with industry partners Candidum and metaX, studying proteins found in a number of tropical plants that have a naturally sweet taste. The researchers are using these proteins' sequence, a blueprint of sorts, as a model for their lab-produced sugar substitute.

"The proteins we're developing are extremely sweet, like the natural version derived from plants: up to 10,000 times sweeter than table sugar," explains Rasche, who is in charge of managing the project. "That means we only need a fraction of the amount for our foods. Depending on the product, this will allow us to replace a large portion of the original sugar — all of it, in some cases." And that, he explains, also cuts a lot of calories, even as the end product stays just as sweet, with no change in taste.

Natural sweetness with no aftertaste

One aspect that sets the new proteins apart from existing sweeteners is that they offer more options, for example with regard to structural changes. This makes it possible to adjust factors such as taste, Rasche says: "Some sweeteners, like stevia, have a very particular flavor, so they depend on a person's individual sense of taste. This is one aspect we are tackling with the goal of completely eliminating aftertaste from our products."

Rasche explains that within their group of substances, the sweet-tasting proteins are also naturally relatively stable during processing. For example, they can briefly be heated to temperatures of up to 80 degrees Celsius without losing their sweetness. The new sugar alternative can also withstand lower pH values, which Rasche says is crucial to ensuring that the proteins remain stable — and sweet — in soft drinks like soda, along with other products. "We definitely have to take factors such as heat and pH value into account along with the taste and mouthfeel. We have a ways to go there so we can expand the range of uses for our product down the road."

The researchers are using various modeling and bioinformatics methods in the lab to test how the protein connects to sweet taste receptors in the mouth; for example, they are exploring which factors are responsible for aftertaste and how they can be targeted and overcome. The team then adjusts the protein sequence accordingly, including sampling the results.

The researchers are currently working on a cocoa beverage made partly with the new sugar substitute. They add the sweet-tasting proteins in powder form. As far as results go, Rasche says the taste is already impressive. The team is still dialing in the sweetness, though, since right now it still lingers on the tongue for several minutes. There are already plans for other foods and beverages, like soft drinks.

Beverages and chocolate sweetened with the protein brazzein are already available in the United States. However, Rasche notes that they use the original protein sequence, the "wild type" sequence, which has not yet been optimized in terms of flavor profile. As far as his lab-created version is concerned, Rasche is optimistic as a result: "I'm confident that our improved product will hold its own on the market, thereby helping to reduce excessive sugar consumption and the associated health conditions." ■

More than

33 kg

of sugar per capita

was consumed in Germany in 2023.

Like a kid in a candy store: A sugar alternative could make Germany healthier.

Photo: Jan von Holleben

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Interview

"We Can Do More!"

Automotive industry, energy, government crisis... we're coming to the end of a difficult year. Minister-President Stephan Weil holds a 20 percent stake in Volkswagen through the state of Lower Saxony, and he is successful at building political coalitions. What can we learn from him for 2025?

Interview: Josef Oskar Seitz

Stephan Weil has governed the state of Lower Saxony as the head of different coalitions since 2013. Now, ahead of his 66th birthday on December 15, he has already announced that this term, his third, will also be his last.

Mr. Minister-President, have you heard the one about the world's biggest golf course?
No, I definitely haven't.

It's in Wolfsburg! Get it, *Golf*? But dad jokes probably aren't your favorite tool for fighting the aspect you've identified as a systemic disadvantage for Germany: bad mood.
No, it's true, I tend to agree with Ludwig Erhard, who served as Germany's economics minister and later as chancellor. He said 50 percent of economic policy was psychology. We have objective difficulties right now. But the general bad mood is further exacerbating things, especially when it comes to investment.

You present yourself as a sort of attorney advocating for the economy. Hildegard Müller, President of the German Association of the Automotive Industry (VDA), puts it more in terms of a challenge. She says the German economy is competitive, but overall conditions in Germany are not — which boils down to how policymakers portray Germany as an industrial powerhouse in their dealings with the business sector.
The part about me being an attorney advocating for the economy is only partly true. I'm aware that we need a strong economy for a strong society. But my primary interest isn't in big profits. As for what Ms. Müller — and I really appreciate her otherwise — had to say, we definitely need to take action on overall conditions, but in some areas the root causes of lack of competitiveness also rest with the business sector itself. When we look at investment in digital technologies, for example, we can see that Germany is definitely not a leader compared to other countries. But the digital transformation is one of the key drivers of future growth, so many companies are rightly wondering what else they can do themselves. But to get back to overall conditions, energy costs are too high. Large swaths of German industry are thinking seriously and fundamentally about their competitiveness in Germany. It's absolutely clear that to truly be attractive as a location to do business, we need competitive energy costs. And we're nowhere near that right now.

You're thinking of the costs of expanding the grid?
Yes. We still have ten, 15 years of heavy investment in grid modernization ahead of us. Right now, we're simply passing the investment through to consumers. So thus far, more investment means higher energy costs. If we don't change that, it would be a clear signal to existing and future companies that they can't get to where they need to be in Germany. Important parts of the future economy will be highly energy-intensive. Just think of the big data centers or production of battery or solar cells.

"We can be proud of our non-university research landscape."

Stephan Weil

So, energy is one topic that's obviously on your mind. What do you think about bureaucracy? Does Germany need its own Elon Musk to declare war on regulations and regulators?
No.

I'm not all that surprised to hear you say that.
Well, let's just wait and see where this whole experiment with Musk as a government reformer goes. Personally, I have grave concerns. I'm not in favor of eliminating the role of government. But I am very much in favor of our government being smart about limiting its role and being cooperative and friendly to customers. We're too complicated. And because we're too complicated, processes take too long. Because processes take too long, things get even more expensive in the end.

That's a neat and tidy list: 1, 2, 3.
And the solution is just as simple. 1, 2, 3: We need to simplify, which will also make us faster and reduce costs.

You're not exactly new to the role of minister-president. Why is it so hard to cut red tape? Everyone agrees that it's the right thing to do.
There are good intentions behind every regulation. But what gets us bogged down is the sum of all those good intentions. Of course, we need to differentiate in many areas in the interest of ensuring that administrative actions are as appropriate to the circumstances as possible. But if that means everything comes to a standstill and the whole system isn't working, then the harm to society is greater than the benefit to individuals. ▶

Photos: Michael Löwa

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Cheery disposition

"When I started school, I didn't know yet what I wanted to be when I grew up," Stephan Weil says.

From Hamburg to Hannover

Weil was born in Hamburg on December 15, 1958. The family moved to Hannover in 1965.

Emblems of office for a lifetime

Weil went from city treasurer to lord mayor of Hannover in 2006. He called himself a "lifelong citizen" in his role as the city's chief executive.

Partnerships across the political spectrum

Weil and his wife, Rosemarie Kerkow-Weil, presumably voted for the Social Democratic Party (SPD) in the 2013 state parliamentary elections. Weil remains minister-president — albeit with changing coalitions.

So would you say we're drowning in good intentions?
That's going too far, I think. But we do need to take action. There are just so many regulations. We need to be smart about trimming them down. And that's easier said than done, unfortunately.

Where have you succeeded in cutting red tape?
Take a look at the new building code for Lower Saxony. We trimmed a lot of fat out of it. A number of other states seem to be looking to our changes for guidance right now.

And where have you been unsuccessful?
We're still in the middle of the process. But we do find ourselves struggling for a long time to come up with streamlined solutions in some cases. We have so many programs that require extensive documentation to be filled out for relatively small amounts of funding. And then it takes a lot of work to review all that documentation and do the calculations. We're working on simpler approaches now.

Would you say you haven't lost your optimism?
A politician who lacks confidence should change jobs.

You've been in politics for almost 45 years now.
Yes, if you count from when I joined the Social Democratic Party (SPD), which was in 1980. I'm a late bloomer as a professional politician, though.

Did that help you?
Yes. I was elected lord mayor of Hannover at 47. By then you have a rough idea of what life is really all about. There are risks to a more straightforward career in politics, so straight from the lecture hall to the assembly hall.

Are there things about politics that still upset you after all these years?
More and more, yes! *(laughs)* The main thing those of us in politics really need to watch out for is that as a result of ongoing internal competition and the close ties between government and the media, there's a risk that everything that seems important to us right now is also communicated to the public as supposedly important. But a lot of the things that politicians think about are only indirectly related to the actual issues people are facing in our communities. And that's the benchmark that people use when they look at politics: What are they doing to solve my problems, anyway? If the answer is unsatisfactory, people start to feel alienated. And that is something you can't afford in politics.

But that also means politics is becoming more and more of a sprint, and people are losing their endurance for the marathon aspect.
Sadly, yes. As Mark Twain once said, "Having lost sight of our goals, we redouble our efforts." That's definitely a very real risk.

As a young man, you did your civil service in a psychiatric institution serving adolescents and young adults instead of serving in the military. Did you learn something during that time for your career in politics?
Yes, I learned a lot. I might even go so far as to say I learned more in those 18 months than at any other time in my life. After a sheltered upbringing in a middle-class home, I was facing behaviors I hadn't even known existed before that. It definitely helped me a lot. Especially in politics, it's a huge advantage if you can keep your cool in the face of unusual behaviors. I also met my wife while I was working there. So that was a lasting and very positive effect, as you can see.

Your wife was the president of Hochschule Hannover University of Applied Sciences and Arts. My question to you from that perspective is: How do you think Germany is doing in terms of education?
You hear a lot of criticism about the quality of education in Germany. And not without reason, either, if you look at international comparisons. On the other hand, a lot of our higher education institutions are doing good work. We can also be proud of our non-university research landscape. I want to go on the record as making that compliment.

What do you think should be done to speed up the pace of innovation moving into the business sector and becoming reality?
We have room for improvement in higher education when it comes to focusing on industry and practical application. There are many impressive examples, but also some institutions that just aren't all that engaged. In Lower Saxony, our goal is to emphasize this aspect even more in the agreements we put in place with our higher education institutions going forward.

That brings me back to the big picture. You said Germany is in a weak phase.
Yes, it's plain to see. Just look at our GDP compared to that of other industrialized countries. We've been treading water economically for

three years in a row now. Other countries' economies are growing. And that means we're falling farther and farther behind.

Help me out for a moment: Which party was it, again, that gave us the chancellor during those three years?

With all due respect, that's a bit of a cheap shot. This government first came into office right when the war in Ukraine was starting. And as we know by now, the government was formed by three partners that didn't fit together. That's one of the reasons the last 18 months in particular have felt like torture to many people.

How should we build fresh strength?

Where should I start? Using more technology in our schools and teaching our kids how to navigate a digital future, controlling immigration and successful integration. We need to find ways to take our highly successful industry into a new era. And all that will require an active government.

That makes me think of two current news items. Berlin is cutting six million euros in funding for quantum technologies. And Germany and Europe more broadly are at risk of being left behind by China and the United States when it comes to technology leadership in green hydrogen. Do those two reports, which I happened to see, fit with the picture of a government that is too passive, as you're saying?

I could add more examples. I find it very concerning that research funding for battery development has been slashed on a massive scale. And to return to the industry I know really well, a lot of people underestimate how important the German automotive industry — our key industrial sector — is to research and development in this country in general. Cuts to research are cuts to our future. We can't afford that. Of course, we do have to turn a critical eye to some things, because obviously, the state just doesn't have enough money. But I personally wouldn't make cuts to research.

"I personally wouldn't make cuts to research."

Stephan Weil

We're certainly glad to hear it. Does that bring us to the famous debt brake?

We don't want to rack up debts for their own sake. I don't want that myself. I spent ten years as the city treasurer, and I know it's no fun to take out loans. You have to repay them with interest. On the other hand, we have a huge need for investment, and we will only be able to serve that need if our government is more capable of taking action, including financially. So for that reason, I do think we need reform when it comes to the debt brake.

What makes you hopeful?

We're still the world's third largest economy. We shouldn't downplay our role. We have a lot of companies, especially medium-sized ones, that haven't lost any of their innovative strength. But I don't like the body language I'm seeing from some of our business leaders these days. I'm seeing some really drooping shoulders. I'd like to see people hold their heads up, be straight talkers, and say we can do more.

Do you still drive an old VW Golf as your personal vehicle?

Yes. We drive a Golf. It's 11 years old now. It just refuses to give up the ghost. And my wife is so happy with it that all my efforts to start making the move to an electric car have been unsuccessful so far. The discussions around our house aren't much different than in many other German families on that point.

You aren't hesitating because you have doubts about electric mobility, in other words. The delay is just because your old car simply works too well.

Doubts? No. Quite the opposite. I've definitely done my research on it. And I know an electric vehicle can be highly worthwhile, including for personal use. We could put a nice solar array on the roof of our garage and generate our own power for charging. It would be greener and much cheaper.

Let's go from your good old Golf to current figures from the transportation industry. Ford has announced plans to cut 4,000 jobs. The automotive arm of Bosch is talking about 3,500. And Volkswagen is grappling ▶

Weil enjoys the ride...

Weil, former German economics minister Sigmar Gabriel (left) and VW chief Martin Winterkorn (right) pose in a 1956 Beetle. But all is not well beneath the surface: 2015 brings the start of the diesel emissions scandal for VW.

...until he doesn't

From the diesel emissions scandal in 2015 to the threat of plant closures in 2025, VW is always political in Lower Saxony. The state holds 20 percent of voting rights, giving it a blocking minority in the group, which has 120,000 employees at Volkswagen plants in Germany. The stake dates back to the VW Act of 1960. VW is a source of a lot of ups and downs for the minister-president.

Summer, sun, sand and Stephan

Well protected from the sun by a cap, the minister-president enjoys his downtime at the Carolinensiel resort on the North Sea. He likes to keep his personal life private. Except for one thing: A staunch Catholic, he left the church — "because I didn't agree with the ban on birth control."

Photos: Michael Löwa, @Instagram/stephan.weil.spd; Holger Hollemann (2), Frank May, Jochen Lübke, Rainer Jensen, Mohssen Assanimoghaddam (all from dpa)

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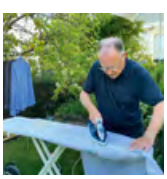
A red-letter day

Reelected! Weil wins a new mandate in the state parliamentary elections in 2022. After a coalition between Weil's party, the SPD, and the Greens (until 2017) and then another with the Christian Democrats (until 2022), the minister-president forms a fresh coalition with the Greens for his third term.

Wide open spaces

Weil has an unusual picture hanging behind his desk in the state chancellery. Its title? *Shy Beauty*. The "beauty" in question is leaving the scene, and all that is left of the cow is a slice of her rear end at the edge of the picture — and a trail of cow patties in the field. Weil thinks irony is dangerous in politics but makes an exception for his wall.



A sneak peek at retirement?

At the end of his vacation in July 2024, the minister-president puts in an appearance doing some ironing under an apple tree. "Duty calls," he writes to explain his preparations. He plans for this term to be his last in office.

with three plants and 30,000 employees. Didn't the automotive industry shift too far toward electric cars and lose sight of its customers' needs?

No, I disagree. Volkswagen didn't focus exclusively on electric mobility. But prioritizing this kind of drive system was the right move. Brussels has told us point-blank how much carbon we're allowed to emit between now and 2035, and when hefty fines will start to apply. That's the real reason for what you see playing out at many automotive companies, including Volkswagen.

So that means Brussels is at fault?

No, there are good reasons for these EU rules. Climate change is having a noticeable impact, including here. The trend toward electric mobility was organic and growing in Germany. And then the federal government decided to yank all the subsidies. So sales collapsed. That was a huge policy error. People are very good at telling whether the government practices what it preaches.

I ask you once again, which party gave us the chancellor for the past three years?

My answer hasn't changed. Politicians make mistakes, too. The interesting question is how they deal with those mistakes.

How do you think they should deal with them?

First, admit it: Yes, that wasn't the right thing to do. And second, fix the problem. The old coalition government made a proposal for how to get to a higher proportion of electric vehicles in corporate fleets, which account for about half of all sales. Plans call for using the declining balance method of depreciation. But then that should also be extended to private households as well, for example through tax credits or other incentives.

***Die Zeit*, a major weekly newspaper, congratulated you for being the big businessman among German politicians: Volkswagen, Stahlwerk Salzgitter, Meyer Werft. Is it right for government to hold such massive stakes in industry?**

That was a backhanded compliment. The fact is that these are really different circumstances. In the case of Meyer Werft, we have committed 200 million euros as a temporary crisis intervention. Our goal is to help a company with high potential and a big backlog of orders get over the hump into the future. In the case of Salzgitter and, of course, Volkswagen, the state is involved in the long term. We've held a stake in Volkswagen for 75 years. Over that time, Volkswagen became a successful global company.

"Are there things about politics that upset you?" "More and more, yes!"

Stephan Weil

Is government effective in business?

Yes.

Has that been your experience with VW as well?

Speaking for Lower Saxony, I would say we're doing it right.

In your role as minister-president, you can work with the Greens and with the Christian Democrats. You've proven both of those things through your coalitions. So, my question for you going into the 2025 election year is, what makes for successful politics in times of difficult majorities?

Oh, that's simple. It has to be based on shared content and as many shared goals as possible. It has to be about facts on the ground. Posturing of all kinds just isn't helpful. Rigor and dependability are important. That might make politics a bit boring at times, but it also makes it more persuasive. And my feeling is that we've managed very well in that respect in Lower Saxony over the past 11 years.

You were kind enough to show me the gallery of minister-presidents of Lower Saxony in the corridor outside your office and tell me a little about the paintings. You've said this term as minister-president will be your last. What do you want the picture you leave for posterity to look like?

With everything we've been talking about, I'm sure you understand I haven't had the chance to think about it yet. And I'm not even close to the end of my term.

But you do already know where the picture will be hung.

Way down at the end, behind the coat rack. ■

Photos: Michael Löwa, Bernd von Jutrczenka, Holger Hollemann (both from dpa), @Instagram/stephan.weil.spd

“Getting People Excited About the Future!”

An LED matrix turns car headlights into a projector: The German president has awarded the Deutscher Zukunftspreis (German Future Prize) to a team of researchers from Fraunhofer and ams OSRAM.

By Josef Oskar Seitz

Better vision with less glare is something many drivers want, especially in the darker season of the year. Now, a team of researchers from Fraunhofer and ams OSRAM is much closer to making it a reality. And what’s more, their innovative LED matrix actually turns headlights into a projector. German President Frank-Walter Steinmeier finds the solution so groundbreaking that he awarded the implementation of this idea the Deutscher Zukunftspreis (German Future Prize) for 2024.

The Deutscher Zukunftspreis is given out for technology and innovation. It is the only prize awarded by the president of the Federal Republic of Germany. With 250,000 euros in prize money, it has been given out annually since 1997 in recognition of “outstanding achievements in the fields of technology, engineering and science that result in products that are ready for applied use.” This is the tenth prize of its kind for Fraunhofer. The prize is considered Germany’s most important innovation award.

Smaller, lighter, more efficient, smarter and more precise in illumination: those are the features of the revolutionary new technology, which was developed by a team of experts headed by Dr. Hermann Oppermann at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin and by Dr. Norwin von Malm and Stefan Grötsch from ams OSRAM. Unlike conventional headlights, the novel solution does not have just two light sources. Instead, it relies on 25,600 LEDs in a matrix of 320 x 80 points, each one of which can be controlled via a digital signal. In combination with a special lens, this creates a headlight that works much like a video projector. This makes it possible to adjust the light optimally to meet requirements and control the spatial distribution to avoid blinding oncoming drivers, but that is not all. It also requires just minimal installation space and is highly efficient to operate. Unlike in passive modulation, this solution does not involve generating the full amount of light and then blocking some of it, but rather only generating as much light as is needed. As an additional safety element, ams OSRAM and Fraunhofer also thought up something special: The light source can project warning signs onto the road to call a driver’s attention to things like dangerous black ice or the risk of wrong-way driving.

The possible future applications of the digitally controllable LED matrix go far beyond road traffic. For example, it could be used for optical data communication between computer chips at data centers for applications in artificial intelligence or for augmented reality (AR). Here, the light matrix could be used as a virtual monitor for AR glasses, where digital information is displayed in the user’s field of vision in addition to the real-world environment.

“You’re getting people excited about the future,” the German president, Frank-Walter Steinmeier, said at the awards ceremony held in Berlin on November 27. Fraunhofer President Prof. Holger Hanselka also praises the team for their achievement: “The Fraunhofer IZM team has clearly demonstrated the dedication, creativity, and pioneering research and entrepreneurial spirit that characterize the Fraunhofer-Gesellschaft and form the basis of our success.” ■

At the ceremony presenting the Deutscher Zukunftspreis (German Future Prize) for 2024 (from left): German President Frank-Walter Steinmeier, Markus Blume (Bavarian State Minister for Science and Arts), Dr. Norwin von Malm and Stefan Grötsch (ams OSRAM), Dr. Hermann Oppermann (Fraunhofer IZM), Fraunhofer President Prof. Holger Hanselka.

Photo: Deutscher Zukunftspreis / BILDSCHÖN / Maelsa

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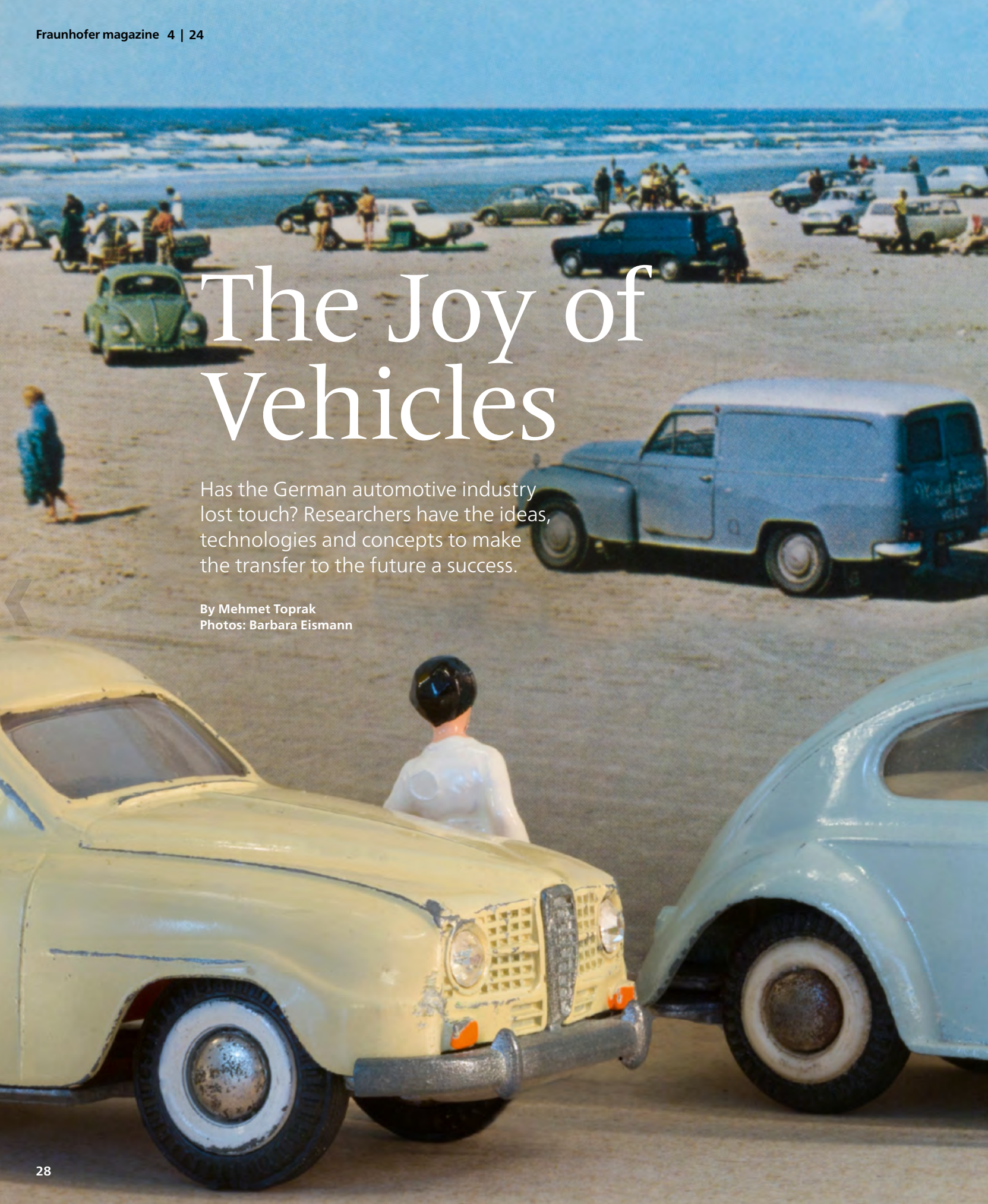

The Joy of Vehicles

Has the German automotive industry lost touch? Researchers have the ideas, technologies and concepts to make the transfer to the future a success.

By Mehmet Toprak
Photos: Barbara Eismann

A day at the beach — with lots and lots of cars. The vehicle of the future will look different, but the need for individual mobility isn't going anywhere. From the book *Kleine Autos, Grosse Welt* (Little Cars, Big World), published by Delius Fine Books, author: Veit Golinski

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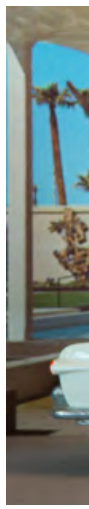
"We need a clear pledge of support for cars in both politics and society in Germany."

Prof. Thomas Bauernhansl, Fraunhofer IPA

Dr. Gerald Rausch started his driver training at 17 so he would be able to get his license and drive his dad's car just as soon as he turned 18. His first car of his own was a red Opel Kadett. With a gasoline engine, four cylinders, 53 horsepower, and four gears, it was one of the best-selling cars in Germany until the mid-1980s. Each year, thousands of them rolled off the assembly line. Still a gearhead today, Rausch is now the spokesperson of the Automotive Working Group of the Fraunhofer Transport Alliance. Cars have changed, too. "The vehicle architecture, the components, the drive, the mobility behaviors, the image of cars and the market — everything has changed," Rausch says. But the big German automotive manufacturers are obviously having a hard time adjusting. Summer and fall brought almost daily bad news about dwindling sales, plans to close plants and job cuts. Many experts believe the German automotive industry, once a leader, has lost touch, especially compared with others internationally.

Rausch is by no means nostalgic as he looks back on the Kadett's success and the golden age of German automotive manufacturing. "The applied research sector has a wealth of concepts and technologies in the pipeline that can put German automotive manufacturers back at the head of the pack," he says. A walk through the labs and development centers at Fraunhofer's institutes reveals pioneering innovations for every area of the automotive sector, from fast-charging batteries to concepts for smart charging management, hydrogen technology, sensors and computer chips for autonomous driving and beyond to creative interior concepts, lightweight bodies and modular production. And circularity and carbon-neutral manufacturing are baked in as well.

The car of the future is ready. All it needs now is to be built.



Underestimating the competition

But why does the German automotive industry seem to have stalled out right now in comparison to competitors from the U.S. and China?

Prof. Thomas Bauernhansl is the executive director of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and a member of many different committees and working groups focusing on industry and manufacturing. In his role as a member of the Expert Group on the Transformation of the Automotive Industry convened by the German Federal Ministry for Economic Affairs and Climate Action (BMWK), he also advises the German federal government. His diagnosis? "In Germany, we underestimated the speed at which companies like Tesla in the U.S. and competitors from Asia would be able to modernize their production operations and implement new technologies. The U.S. is well ahead of us in terms of the digital transformation, and Chinese manufacturers have taken the lead in battery technology for electric cars. They also build very

Good Technology Makes for a Good Ride

From ecofriendly vehicle bodies to safe batteries and climate control features for the interior: 11 selected Fraunhofer projects that make driving a car sustainable, safe and comfortable.

Combined power — cars as energy storage on wheels: In the future, plans call for electric cars to function as energy storage on wheels. The battery will do more than just consume energy and then need to be recharged, instead feeding unneeded energy into the power grid. Researchers from the Fraunhofer Institute for Energy Economics and Energy System Technology IEE are working on a multifunctional, bidirectional charging and drive unit that also saves space and reduces weight. The German Federal Ministry for Economic Affairs and Climate Action (BMWK) is providing a total of 4.19 million euros in funding for the project.

Sleek lines: Large cast parts made from aluminum substitute for many individual pieces of sheet metal, enabling ecofriendly production of high-quality vehicle bodies.

A zippy little thing: Streamlining regulations on the political side could significantly accelerate the pace of innovation in Germany.

low-cost cars. The German automotive sector is not competitive on those points right now."

Prof. Steffen Ihlenfeldt, Chairman of the Fraunhofer Automobile Production Alliance, takes a similar view: "Fluctuating markets and increasingly stringent requirements for environmental sustainability pose new challenges, especially for production." He calls for "a faster pace of innovation in both products and production in Germany."

Bauernhansl says government regulation is putting the brakes on creative solutions. As an example, he points to safety technologies in self-driving cars. "Even when the car is in autonomous driving mode, regulations require the driver to keep their hands on the wheel at all times, or a warning signal will sound. If not for that rule, manufacturers would find innovative solutions, such as an interior camera that observes the person and waits to issue a ▶

Sustainable body concepts: A group of eight Fraunhofer institutes aims to achieve greater efficiency in processes and technologies for the sustainable construction of high-quality bodies for electric vehicles. To reach this goal, they plan to incorporate various elements, such as highly integrated large cast parts made from aluminum instead of many individual pieces of sheet metal. The research teams are also focusing on enhancing repairability and collision safety. "In the case of electric vehicles, the body is the second biggest source of carbon emissions aside from battery production. Since sustainability requires considering the entire life cycle, we are working on holistic solutions and methods of evaluating and developing sustainable body concepts," says Prof. Stephan Krinke, head of the Sustainability Management and Life Cycle Engineering department at the Fraunhofer Institute for Surface Engineering and Thin Films IST.

Modular production with the open-source factor: Intelligent production with versatile robots and machines that can be planned individually for each job is the goal for the SWAP-IT production architecture. The software-based concept combines automation, connectivity and greater flexibility of means of production. It is intended to help modularize manufacturing. This will also make it easier to produce small unit volumes.

The centerpiece of SWAP-IT is a description language for machines, processes and products in which the production system autonomously issues commands to the individual machines or robots. Ten Fraunhofer institutes pooled their expertise in the SWAP flagship project, whose results are now available on an open-source basis. This allows many players in the manufacturing sector to design their own scenarios and adopt modular production practices in the future.

For more information, see:

CombiPower
https://s.fhg.de/combipower-En

Body concepts
https://s.fhg.de/karosserie

Modular production
https://s.fhg.de/swapit

Bauernhansl photo: Fraunhofer IPA / Rainer Bez

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Worry-free travel: EV chargers in public parking lots or in front of supermarkets would be a nice service.

warning until they have been looking away from the road for too long." Policymakers need to create the overall conditions for these and other innovations now, he cautions.

Safety for self-driving cars

Ideas and technologies for safety in autonomous vehicles come from research. For example, the Predictive Autonomy Lab at the Fraunhofer Institute for Experimental Software Engineering IESE studies how well human operators react when they need to retake the wheel of a self-driving car after resting for a while. Researchers there use eye trackers and sensors to measure vital indicators such as heart rate (for more information on the projects described here, see the gray box below). "Ultimately, the goal is to build a digital twin of a human driver. Automotive manufacturers or providers of driver assistance systems can test and refine their systems in the Predictive Autonomy Lab," explains Ralf Kalmar, Head of Business Development at Fraunhofer IESE.

Connected, autonomous cars of the future require tremendous computing power. Fifty to 100 small computer units are already built into cars today. As part of the CeCaS joint research project, researchers from the Fraunhofer Institute for Photonic Microsystems IPMS are working on a system architecture in which a computer platform manages many electronic components centrally. They transmit their data via a fast Ethernet backbone and have updates performed by Wi-Fi as needed. This empowers connected, real-time-capable control of the car.

Fear of a dead battery

Bauernhansl and Rausch agree that battery technology is especially crucial to success. At the Fraunhofer Project Center for Energy Storage and Management Systems ZESS, researchers are working on a solid-state battery as an alternative to traditional

For more information, see:

Battery enclosure
https://s.fhg.de/coolbat

Solid-state battery safety
https://s.fhg.de/festkoerper

CO_2-saving battery enclosure: The COOLBat joint research project is pursuing the goal of a long-range battery that charges quickly and is climate-friendly to manufacture. One key component in this is the enclosure. Researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU are working together with partners on a next-generation battery enclosure. They are focusing on lightweight construction materials such as fiber-reinforced plastic composites. Thoughtfully designed structures in frames, lids and base plates help to distribute the load, conduct heat outward and protect the core of the battery from damage in a collision.

Improved safety in operation for solid-state batteries: Lithium all-solid-state batteries (ASSBs) offer greater energy density and lower weight than conventional lithium batteries that use liquid or gel electrolytes. The solid-state batteries use a solid that enables ion transport between the electrodes. The solid-state electrolyte also offers great advantages when it comes to safety in operation, as the risk of leaks and fires is minimized. The Fraunhofer Center for Energy Storage and Systems ZESS is conducting research and development toward this aim, working on a prototypical and flexible production chain extending from the raw materials to the finished battery cell.

lithium-ion batteries with liquid electrolyte. Greater safety, less weight and longer ranges are the advantages. Fraunhofer researchers are working on using robots to accelerate and automate production of the complex fuel cells as much as possible as part of the H2FastCell project.

In the COOLBat project, experts are optimizing the battery enclosure. Using special plastics and thoughtfully designed structures in the enclosure makes the battery lighter and draws heat away quickly. The core of the battery is also better protected in a collision.

The CombiPower project is rooted in an idea that is both surprising and obvious. A bidirectional charging and drive module ensures that the battery in an electric vehicle not only charges quickly but also returns unneeded energy to the power grid. Cars used to be standalone machines. In the future, they could be an integral element of power and energy networks, doing their part to stabilize power grids when peak loads occur, for example.

The public charging network, which has been the subject of much discussion, encompasses more than just setting up as many charging points as possible as fast as possible. Rausch hopes that going forward, more and more companies will install charging stations in their parking lots, so employees can charge their batteries during the working day and find them fully charged when it is time to leave. Rapid chargers at shopping mall and supermarket parking lots would also be a nice service.

50 to 100

small computer units
are already built into cars today.

And greater convenience during charging would be a plus as well. For example, the user's smartphone could automatically transmit information on the car when the charging cable is plugged in. Then, once the battery is charged, the owner could receive a notification via the app.

"All these solutions will help take away people's fear of their battery dying when they're halfway to where they're going," Rausch says, looking to the future.

Efficient production for individual cars

In addition to battery technology, production is another major route to success. One forward-looking concept is modular production, which could replace the somewhat dated platform approach. The SWAP-IT production architecture calls for largely automated production using versatile robots and machines assigned to perform individual assembly tasks for ▶

PEM fuel cells — lightweight and powerful: A number of Fraunhofer institutes are working with proton-exchange membrane (PEM) fuel cells for sustainable mobility. Their high power density and compact structure make these types of fuel cells perfect for use in vehicles. Production of membrane electrode assemblies (MEAs) is one area of focus here. The MEA converts hydrogen to electricity, heat and product water inside the MEA. The scientists at the Fraunhofer Institute for Solar Energy Systems ISE are especially active in this research.

Rapid production of fuel cells: A team of researchers from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA teamed up with Campus Schwarzwald in the H2FastCell project to develop a robot cell that produces fuel cells automatically and at very high speed. A robot picks the bipolar plates up off a conveyor belt and stacks them up. A second robot stacks membrane electrode units. It takes just 13 minutes to complete a stack of 400 fuel cells. Cameras scan the dimensions and condition of the bipolar plates to ensure quality and high accuracy in production. In this way, the technology enables efficient mass-production of fuel cells, especially for heavy goods transportation.

For more information, see:

PEM fuel cells
https://s.fhg.de/pem-wasserstoff

Fuel cells made fast
https://s.fhg.de/fastcell

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"Individual mobility isn't going anywhere, and the future of cars will be diverse."

Dr. Gerald Rausch, Head of the Fraunhofer Automotive Working Group

each job. The results are available on an open-source basis. This means many players in the manufacturing industry can design their own scenarios for modular production. Open-source availability and this kind of community approach will be increasingly important to the mutual success of German automakers and automotive suppliers.

Modular production also makes it possible to offer a wider range of different features in cars and other mobility concepts going forward. Experts believe there will be much greater variety among cars in the future, including individualized models, cars designed for specific regions or applications and produced in small unit volumes, cars with new interior concepts like that of an "office on wheels," and cars that actively function as part of a complex transportation network. In the future, people will be able to use a single app to plan an entire trip with multiple means of transportation. They might take a high-speed train to the next big city, where they find a driverless taxi or car sharing vehicle waiting for them at the train station, use that to get to a nearby small town and then transfer to an electric scooter for the last mile or two.

Rekindling the spark

Production that comes as close as possible to zero carbon and uses resources sparingly, combined with a circular economy mindset, could also help rehabilitate cars' image as sources of pollution and waste. But what about the spark, the fun of driving? "It's sure to come back, but in a different form. Instead of having these souped-up powerhouses that roar down the road, we'll see compact, intelligent and connected vehicles with cool designs that learn for themselves as systems, adjusting to the driver's needs as the key to ensuring the maximum in mobility," Rausch says. "Individual mobility isn't going anywhere, and the future of cars will be diverse," he predicts.

Bauernhansl, Ihlenfeldt and Rausch don't doubt for a second that Germany's automotive manufacturers have a good chance of regaining their lead and successfully creating value in Germany as an industrial location. "We're in the early days of a painful but productive learning process. We need to let go of the past so we can move into the future," Rausch says with conviction. Ihlenfeldt comments: "Production in Germany has always been more expensive than in the rest of the world. But through human-centric automation, robust processes and the resulting outstanding quality of our cars, we can make up for that in a lot of ways."

Bauernhansel is also optimistic: "We need a clear pledge of support for cars in both politics and society in Germany." "The engineers of the German automotive industry have done an excellent job over the past 60 or 70 years. They can keep on doing that in the future, too. We just have to let them do their thing."

And maybe then there will once again be a car like the Opel Kadett that Rausch once drove: A small, solid and low-priced car that takes new drivers off into a mobile future. ■

For more information, see:

Self-driving vehicles
https://s.fhg.de/autonomy-En

Bessere Sicht
https://s.fhg.de/lidar-En

How well do humans interact with autonomous vehicles? Assistance systems in vehicles can take over part or all of the task of driving. But how do drivers perform when they are asked to retake the wheel themselves after a defined time interval?

Researchers at the Fraunhofer Institute for Experimental Software Engineering IESE are using a driving simulator at their Predictive Autonomy Lab (PAL) to test how people navigate the change from taking a break to taking over steering a vehicle, along with how well they deal with driving situations, some of them critical, after taking the wheel. Inside the simulator, a human operator sits inside a car. The surrounding traffic appears via 180-degree panoramic projection as a virtual environment three meters wide. There are also digital exterior and rear-view mirrors. A realistic driving experience is ensured by 5.1 surround sound and a motion system.

Better visibility even in fog, darkness and snowy conditions: A team of researchers at the Fraunhofer Institute for Photonic Microsystems IPMS is developing a "scanning eye" made from MEMS (microelectromechanical systems) scanner mirrors used for high-resolution 3D vision. These are combined with LiDAR (light detection and ranging). The laser-based LiDAR technology measures distances and maps the surrounding area in 3D. It detects obstacles on the road, even in conditions of poor visibility.

Fun to drive: Intelligent vehicles with cool designs and individual interior concepts are being developed to make driving fun again.

Photo of Gerald Rausch: Fraunhofer IFAM

How 3D audio is changing the driving experience: Autonomous driving leaves vehicle occupants free to work, relax or enjoy entertainment. At the same time, acoustic interactions between humans and vehicles are growing more important. The Fraunhofer Institute for Digital Media Technology IDMT offers a 3D audio technology called SpatialSound Wave that comprises solutions for entertainment, driving safety and acoustic human-technology interaction. This central audio platform enables holistic sound management inside the vehicle, along with controlling all audio-capable functions. This creates 360-degree perceptions of the vehicle's surroundings. Dangers like an approaching train or a vehicle in the car's blind spot are represented in real time and with precision spatial accuracy as audio objects. For example, if a train is approaching from the left rear of the vehicle, a train sound is made in the back left part of the vehicle's interior.

DressMAN keeps car interiors comfortable, even in the winter: Comfortable interior temperatures are beneficial to the wellbeing of vehicle occupants and to safety while the vehicle is in operation. But the energy needed to power heating and cooling processes can reduce the range of electric vehicles in particular. The DressMAN measuring mannequin developed at the Fraunhofer Institute for Building Physics IBP can be used to record the overall thermal conditions inside the vehicle, along with human perceptions of comfort. The researchers are using this information to develop thermal comfort models and heating and cooling concepts for vehicle interiors.

For more information, see:

3D audio
https://s.fhg.de/Spatial-En

DressMAN
https://s.fhg.de/Dressman-En

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Controlled Collision

German companies are having a hard time in the automotive market right now. But when it comes to safety, Germany still leads the pack. Fraunhofer researchers have developed the world's first crash test using X-rays — and with it, a fresh selling point.

By Yvonne Weiss

A loud crash splits the air. But that's just as it should be. To find out what happens to a car and its occupants in an accident, automotive manufacturers send their cars hurtling into obstacles under controlled conditions. This has been the practice since 1959, when Mercedes-Benz performed the world's first crash test. The same manufacturer is now using safety as a selling point — and using Fraunhofer technology to do so.

"We've developed the world's first crash test that uses X-ray technology," explains Dr. Malte Kurfiss, a physicist and head of the crash center at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI. "We can look inside the vehicle at a rate of 1,000 images per second, allowing us to observe things that had previously been hidden from view." These findings can help manufacturers make crash simulations even better, which in turn contributes to safe, efficient vehicle development.

For the first X-ray crash test that the Fraunhofer EMI researchers performed in cooperation with Mercedes-Benz, Kurfiss and his team replicated a scenario devised by the Insurance Institute for Highway Safety (IIHS), a nonprofit based in the U.S.: A piece of equipment weighing 1.9 metric tons with a collision barrier rams the left side of a Mercedes C-Class sedan at a speed of 60 kilometers per hour. A crash test dummy is sitting behind the wheel.

Like in a conventional crash test, high-speed cameras record the collision on video from outside, while numerous cameras inside record what happens in the vehicle's interior. The dummy is also equipped with sensors; this makes it possible to determine whether the head hits the car door, for example. The issue is that the data can be used to make indirect inferences about what might have happened — but it is not always possible to observe in detail what actually did happen. Airbags that trigger inside the vehicle also block part of the view.

After the crash test: Dummies show how safe a vehicle is.

Photo: Mercedes-Benz AG

This is where Kurfiss and his team come in: "The crucial structures in the vehicle that protect occupants in an accident are not parts that are readily visible from outside, like the fender, but internal load-bearing structures or airbags. They absorb the impact energy but are hidden inside the car," he explains. "Our X-ray technology lets us look inside and see exactly what takes place at the moment of the accident."

To perform the tests at the crash center, the researchers place an X-ray source above the roof of the car: a specially modified linear accelerator. On the ground underneath the vehicle is an X-ray detector provided by the Fraunhofer Development Center for X-ray Technology EZRT at the Fraunhofer Institute for Integrated Circuits IIS. It records the images, showing not only what happens to the dummy during the tests but also how the events unfolded.

"Our measurement method gives us answers for issues that are especially hard to observe," Kurfiss says. "In addition to the dummy, we also observe what happens mechanically to the protective structures in a collision."

Thanks to the X-ray images, for example, it is possible to determine in detail how the car door deforms in a crash, meaning which door structure crumples inward in what position, potentially causing greater risk to areas such as the legs or rib cage of people inside the vehicle. This information can help the manufacturer's developers during the structural design and configuration and crash simulations.

Other carmakers aside from Mercedes-Benz are already relying on X-ray crash tests from Fraunhofer EMI. Kurfiss and his team are currently fine-tuning precision 3D measurements. The researchers are also focusing on electric mobility and observing how batteries behave in a collision.

Kurfiss is excited about the technology: "Transportation is a basic need in our society. I think it's fascinating that with our test, we can provide a wide range of information, optimize simulations and thus help keep people safe in an accident." ■

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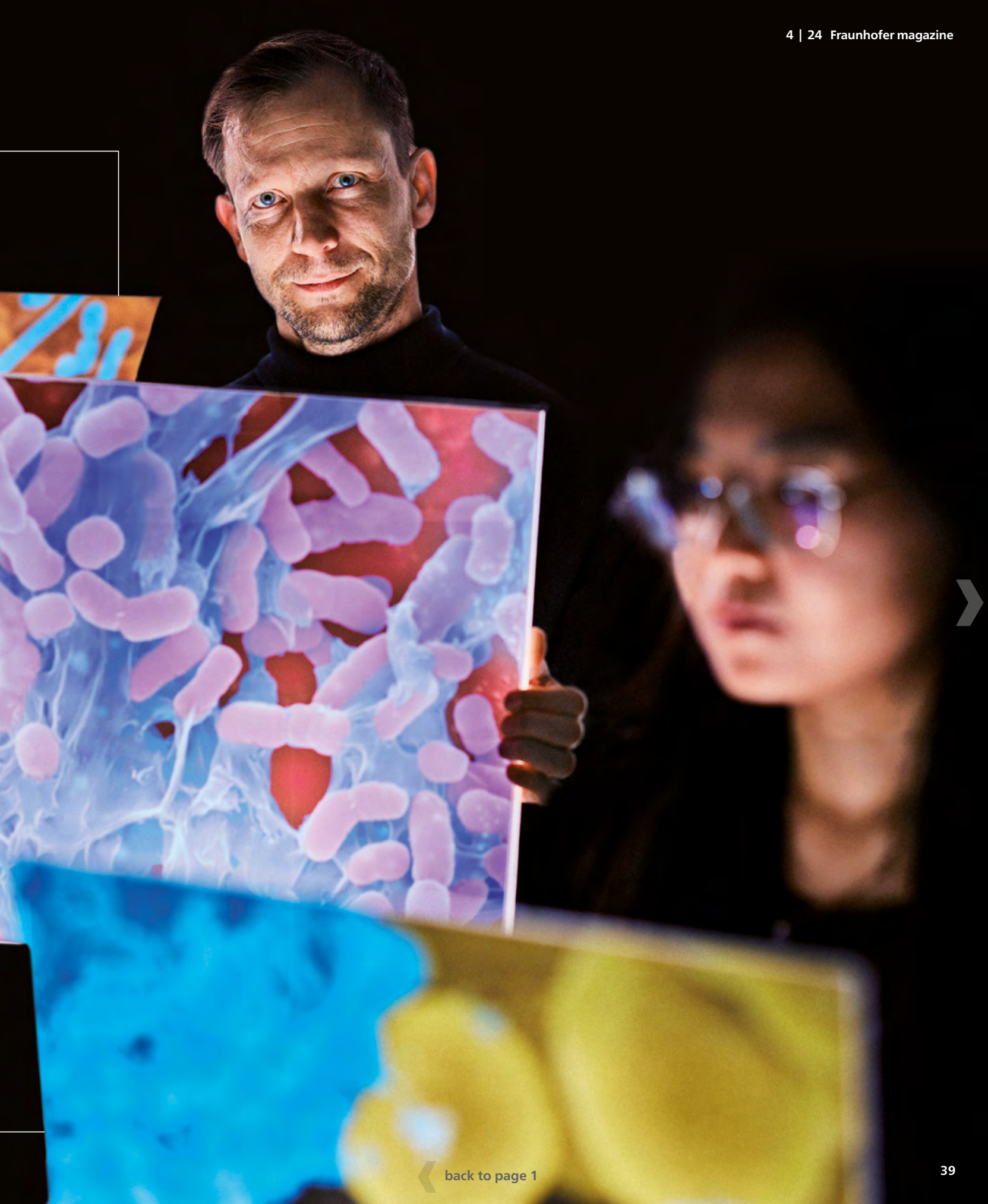
Multidrug-resistant germs

A Race Against Time

The weapons available for fighting dangerous bacteria are losing their edge, and life-threatening infections are increasingly resistant to treatment. There are hardly any substitutes available so far, making it high time someone took action.

By Dr. Sonja Endres;
Photographer: Jonas Ratermann

Beautiful but worrisome: problem germs visualized with a scanning electron microscope. Prof. Till Schäberle from Fraunhofer IME plans to fight them with a new drug.



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Prof. Till Schäberle used to do his fighting against the international karate elite as part of the German national team. These days, his opponents are much smaller but equally fearsome: bacteria that have become resistant to antibiotics.

The World Health Organization (WHO) estimates that each year, 1.3 million people worldwide die from antibiotic-resistant infections. A detailed study published in the influential medical journal The Lancet in September 2024 predicts that if the current situation continues, the death toll will reach more than 39 million between now and 2050. The authors make an urgent plea to the research world to work on finding new antibiotics.

Schäberle, who heads the Natural Products department at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen, has already identified one promising candidate: darobactin. This substance is formed by Photorhabdus, a genus of bacteria living in the digestive systems of nematode worms. These worms infect insect larvae and use the microorganism as a deadly weapon: Once injected, the larvae die due to toxins released by the bacteria as they multiply. "To protect their source of nutrients, the bacteria produce darobactin, which kills competitors — other bacteria for which the nutrient-rich larvae are also attractive as a food source," Schäberle explains. Darobactin's target is different from those singled out by conventional antibiotics: a vitally important protein called BamA, which is present in the outer membrane of gram-negative bacteria — that is, exactly the problem germs for which scientists are urgently looking for new drugs. "The targets for commonly used antibiotics are relatively limited. There hasn't been much progress on that front since the 1960s. Having a new target means the drug is also effective against multidrug-resistant bacteria — that's a huge opportunity!" Schäberle explains.

And that makes darobactin more than just an essential helper for nematodes. It could also become a key ally for humans in the fight against life-threatening microbes.

Bacteria are masters of adaptation, which is why they can survive in even inhospitable places like hot springs, the deep sea and highly radioactive environments. Every time antibiotics are used, it encourages resistance: Sensitive bacteria are killed off, while others find a way to survive, reproduce and change their genetic makeup so there is no longer a target for the antibiotic. That is why drug-resistant pathogens are especially common in places where a lot of these medications are used, such as hospitals.

With darobactin, though, there is hope: "Our studies show that bacteria that have changed their target to elude darobactin are less dangerous," Schäberle explains. He and his team are now working to optimize the substance known as the molecular lead: "Nature did not develop this substance for use in humans. We need to make it more active against the pathogens that affect us while also ensuring there are no toxic effects." However, Schäberle also says it is clear that a single new drug will not be enough to overcome the current antibiotic crisis. "We need a whole toolbox — many different solutions that can and should be combined to fight life-threatening infections successfully." Biodiversity offers many possibilities, he says. "We need to throw everything we can at it," Schäberle emphasizes.

Medicinal toxins

One possibility that has been little explored in the field of antibiotic research to date is animal toxins. Schäberle's colleague Dr. Tim Lüddecke, who also does research at Fraunhofer IME, where he leads the Animal Venomics working group, wants to change that. Lüddecke explains: "Animal toxins hold a wealth of potential for new drugs. A number of important medications are based on them, like captopril, a drug widely used to lower blood pressure that contains a slightly modified toxin derived from the terciopelo, a venomous South American snake."

In August, he and his team discovered that individual components of the family of toxins found in house pseudoscorpions are highly effective against one of the most common — and dangerous — germs found in hospitals: methicillin-resistant Staphylococcus aureus, or MRSA. Twenty to 30 percent of people have this pathogen on their skin or mucous membranes without becoming ill from it. But if it enters the body, for instance through a surgical incision, it can cause infections that often end up being severe. MRSA lacks sensitivity to a broad range of antibiotics.

Lüddecke and his team are focusing their research on poisonous and venomous animals found in Germany, like the house pseudoscorpion (Chelifer cancroides), which averages just three millimeters in size and tends to prey on the booklice that cluster inside books. Worldwide, there are some 3,000 different species of pseudoscorpions, also known as book scorpions. "Compared to true scorpions, they do not have a poisonous stinger. Instead, they deliver their venom through pincer-like structures called pedipalps, which makes them really unusual," Lüddecke explains. They use their venom to immobilize their prey, which also includes mites and fruit flies.

But how do people get the toxin out of these tiny creatures? "Oh, it's a lot of work," Lüddecke says with a laugh as he describes the process. The Fraunhofer IME team built an intricate apparatus to "milk" the toxin ▶

"But the really key thing is its high efficacy against MRSA."

Dr. Tim Lüddecke, Fraunhofer IME

The toxin in a pseudoscorpion's pincers paralyzes prey — and can also neutralize dangerous germs found in hospitals, as Dr. Tim Lüddecke discovered.

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Somewhat reminiscent of Christmas ornaments: phages clinging to a bacterial cell wall. Dr. Dorothee Winterberg (left) and Dr. Franziska Dahlmann from Fraunhofer ITEM are confident in the therapeutic potential of these bacteria-eating viruses.

from the pseudoscorpions. "It took forever to collect enough venom for our chemical analysis. But luckily, we only had to go through the procedure once," Lüddecke recalls. Once the toxin cocktail has been decoded, it can be synthesized chemically or made using biotechnology. "That's not only true of pseudoscorpion venom. The same goes for all the animal poisons and venoms we work with," says Lüddecke. These substances are typically complex compounds of many different toxins. "There are spiders whose venom consists of as many as 3,000 individual substances," Lüddecke explains. The tiny pseudoscorpion is an arachnid, just like spiders. Its venom might not contain quite as many active ingredients, but it does have one that packs quite a wallop: checacin, the name Lüddecke and his team gave to one toxin that is highly effective in fighting MRSA. It also targets other common germs found in hospital settings, like E. coli and Pseudomonas aeruginosa, along with a number of pathogenic yeasts like Candida. "But the really key thing is its high efficacy against MRSA," says Lüddecke.

He and his team are still in the early stages of their research, and the exact properties and mechanisms of action of checacin are not yet clear. "Before the toxin can be considered as a drug candidate, we need to study aspects like whether the molecules remain stable in blood serum or break down quickly." If that is the case, it will prove unsuitable for use as an antibiotic. For now, it will be faster — because there are fewer obstacles and less time and cost are involved — to use it in antimicrobial coatings. MRSA is frequently transmitted via medical instruments and equipment. This could be an especially helpful way to lower the risk of immunosuppressed patients becoming infected with the dangerous bacteria while in the hospital.

Viruses that kill bacteria

Once infection has already occurred, there is another promising treatment option for MRSA and other problem pathogens: bacteriophages, which literally "eat" bacteria. These viruses use bacteria as hosts, replicating inside them until they burst. A team at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM aims to harness them for pharmaceutical use.

Although phage therapy has existed for over a century now and is widespread in Russia and elsewhere in Eastern Europe, there have been no scientifically sound studies to date proving its clinical efficacy, which also means there are no phage medications approved in the EU or U.S. After scientists in the United States discovered a way to mass-produce penicillin, in 1943, the West focused on antibiotics. Compared to phages, antibiotics are simpler in clinical terms and promise better outcomes. They are broadly effective at fighting bacteria, while phages can be picky, infecting only certain strains of a particular species of bacteria. Selecting appropriate phages therefore requires detailed study of the exact pathogen causing the infection before treatment begins. Unlike with antibiotics, a course of treatment cannot be started based on mere suspicion. This is cumbersome and more expensive, but at the same time, it can also be an advantage, as phages leave the healthy bacteria of the human microbiome intact, whereas antibiotics make no distinction. This often leads to side effects ranging from diarrhea to a weakened immune system.

Tbilisi, the Georgian capital, is home to the largest collection of phages in the world. It is held at the George Eliava Institute, founded in 1923. The institute receives many inquiries from patients with infections that are resistant to antibiotics. Phage therapy is their only hope. But the phages they receive do not meet the safety and quality requirements set by European drug laws, so treatment can be risky.

Safely producing phage cocktails

Researchers at Fraunhofer ITEM are working on safe alternatives. In the Phage4Cure project, they are working with the Leibniz Institute DSMZ — German Collection of Microorganisms and Cell Cultures GmbH and Charité — Universitätsmedizin Berlin to demonstrate the efficacy of phage therapy and bring the first-ever phage-based drug to market in the EU.

> "Producing phages is challenging, since no two are alike."
>
> Dr. Sarah Wienecke, Fraunhofer ITEM

The cocktail of three different phages fights Pseudomonas aeruginosa bacteria, which frequently infect the lungs, causing severe inflammation. Most strains are resistant to a large number of antibiotics. Dr. Sarah Wienecke and Dr. Imke Korf, both experts on biotechnological production methods and phage biology, achieved a breakthrough at the Braunschweig location of Fraunhofer ITEM: They not only identified phages with therapeutic potential but also produced their phage cocktail under GMP conditions, a key prerequisite for drug approval. GMP stands for "good manufacturing practice," a body of stringent requirements ▶

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relating to quality assurance, for example in relation to drug purity and safety as well as accurate and detailed documentation of all process flows.

"Producing phages is challenging, since no two are alike," Wienecke explains. The bacteria-eating viruses have their individual preferences for factors such as temperature, culture medium and oxygenation. As a result, the three phages used to fight Pseudomonas aeruginosa are not produced together but rather in separate processes. They are then combined at a later stage. The scientists have developed a production platform that can also be used for other phages when individual adjustments are made. "The infrastructure for phage production is in place. We now know where to make adjustments to create ideal conditions for each phage. And the more phages we produce, the more experience we gain, which also translates to greater process acceleration," Korf explains.

But before doctors could administer the phage cocktail to the first test subject at Charité, preclinical studies were needed to test for aspects such as undesirable side effects and toxicity and to determine the dose-response relationship. Dr. Dorothee Winterberg, head of the Preclinical Toxicology department at Fraunhofer ITEM in Hannover, comments: "The preparation is inhaled. We were able to show that this is safe because in the animal model, the phages did not go anywhere but where they were supposed to: the lungs. They did not migrate to the blood or other organs." And that means there is no concern about side effects here, either. No negative effects were observed from high concentrations or daily inhalation of the substance for up to 14 consecutive days.

> "The infrastructure for phage production is in place."
>
> Dr. Imke Korf, Fraunhofer ITEM

On the whole, the study results were so good that the German Federal Institute for Drugs and Medical Devices (BfArM) greenlit the start of clinical trials at Charité, which have been under way since the fall of 2023. The trials started with healthy volunteers and are now being conducted with patients suffering from chronic Pseudomonas aeruginosa infection of the lungs. Initial results are scheduled for publication in the fall of 2025.

But phages are not simply an improved version of antibiotics; bacteria can develop resistance to them, too. This means combining the two may be the ideal route. "We treated infected lung sections with our phage preparation and antibiotics and saw that it works much better than using just one or the other," says Dr. Franziska Dahlmann, Group Leader Infection and Immunology. In the future, she hopes it will be possible to mix and administer phage cocktails on a targeted basis to kill off bacteria that have mutated to elude antibiotic therapy.

"Compounding" at pharmacies would be an ideal way to connect people with these substances, her colleagues Wienecke and Korf say: The cocktails could be customized and prepared individually there for each patient. This would eliminate the need for costly, time-consuming clinical trials while allowing for fast responses to emerging resistance and flexibility in adjusting the composition of the phage cocktails. In the PhagoFlow project, they teamed up with the pharmacy, microbiology and surgery departments at the Bundeswehr Hospital in Berlin and with the Leibniz Institute DSMZ to test this approach — with good results. The pilot project was financed by the German Federal Joint Committee. "What I can tell you at this point is that the phage preparations were very helpful for individual patients at the Bundeswehr Hospital. We're happy about every single case. When you spend this long researching something, it's really nice to see that you've been able to make an impact." But before this solution can enter widespread use, there needs to be a way to provide pharmacies with much larger volumes of phages for the different species of bacteria. After all, just like a bartender needs a variety of ingredients to do their job, a compounding pharmacist will also need access to a wide range of phage preparations to make customized cocktails for their patients. The phage production platform from Fraunhofer ITEM has created the conditions for large-scale mass production, but GMP requirements are too stringent to be able to speed things up much more at this point. "It would be important to agree on minimum requirements going forward so the production process can be streamlined and sped up to the degree needed," Korf says.

Wastewater as treasure trove

Dr. Belinda Loh from the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig agrees that we cannot afford to continue to ignore phages in the fight against multidrug-resistant germs. With that in mind, she and her research group have teamed up with hospitals in central Germany to work on developing phage-based treatments as well.

To identify bacteriophages that are effective against common problem germs, Loh and her team make ▶

Dr. Belinda Loh hunts phages at wastewater treatment plants — and finds them. Her collection at Fraunhofer IZI has grown to 200 different phages. About half of them are effective against Klebsiella pneumoniae, a much-feared germ found in hospitals (colored orange here).

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regular visits to wastewater treatment plants. "The dirtier the water, the better," she says. After all, to find phages, you have to go where their hosts — bacteria — are clustered. "It's a process of coevolution. You can't find one without the other," Loh explains. "It's not exactly one of my favorite jobs. The water is so dirty that in some cases it isn't even really liquid anymore, and the smell is truly awful," she admits. But the effort is worthwhile, since the wastewater has proven to be a true treasure trove. By now, she has a collection of about 200 phages, about half of them effective against Klebsiella pneumoniae, a much-feared germ found in hospitals that can cause severe pneumonia or even sepsis (blood poisoning) in vulnerable patients. It is increasingly resistant to commonly used antibiotics and can also contribute to further infections. Loh has also discovered phages that are effective at fighting other problematic pathogens such as Pseudomonas aeruginosa and multidrug-resistant enterococci.

> "But simplifying the drug approval process is much more important."
>
> Dr. Belinda Loh, Fraunhofer IZI

In addition to the use of the phages themselves, Loh and her team are also researching therapeutic uses for individual phage proteins. She explains: "A phage is made up of DNA inside a protein envelope. It also produces further proteins that can kill off bacteria. To destroy the bacteria, we use certain phage proteins that poke holes in the cell wall and cell membrane." Loh likens an individual bacterium to a water balloon full of water, which is then pierced with ultra-thin needles: "At some point, it bursts." The advantage of this method is that antibacterial proteins are not limited to highly specific strains of bacteria, instead having broader effects. "But simplifying the drug approval process is much more important," Loh says. This is because unlike viruses, the therapeutic proteins can be produced as what are known as biologics. They could be used like chemical antibiotics. The issue, Loh says, is finding suitable proteins: "So, I look closely at every single phage and identify all the genes that could be of interest. Then I produce the proteins separately in bacteria and test them."

But although phage research is currently gaining momentum, it will still likely be some time before the first preparations hit the market. Until then, it is even more important to curb the spread of dangerous pathogens and minimize the number of infections, especially in hospitals and nursing homes. To that end, a team of researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart had a simple yet highly effective idea that has already been tested successfully at two hospitals: antimicrobial wall paint that reliably kills bacteria and viruses. Dr. Christina Bauder, head of

Express diagnostics the size of a postage stamp

Whether phages or antibiotics are used, successful treatment depends on rapid diagnostic systems, which ideally identify the pathogen causing an infection, along with any resistance, right there at the hospital. A team at the Fraunhofer Institute for Cell Therapy and Immunology, Bioanalytics and Bioprocesses institute branch IZI-BB in Potsdam is working on this. Emily Mattig, a technical employee in the Point-of-Care Technologies working group, explains: "The traditional method of detection through a blood culture takes anywhere from five to seven days. Our goal is to do it in four hours." Cutting the time involved can save lives in cases of severe infection, especially sepsis, also known as blood poisoning. The trick: Mattig and her team detect the bacteria based on their DNA instead of incubating the blood sample in special culture media and waiting for potential microorganisms to slowly grow so they can be identified. To achieve this, the researchers first isolate the bacterial DNA, reproduce it and then deposit it onto a microarray — a chip pre-loaded with numerous DNA counterparts from various bacteria.

"If the DNA binds to one of these counterparts, which we call probes, we've found the pathogen," Mattig explains.

the Applied Coating Technology team, explains: "We added photocatalytically active pigments to the paint. They are activated by natural light or artificial indoor light, at which point they form radicals that react with the surfaces of the germs and destroy them." The pathogens do not even need to come into direct contact with the wall surface, either; it is sufficient if the air circulation brings them into the immediate vicinity. "The nice thing about our method is that the chemical reaction continues indefinitely. The photocatalyst isn't used up," Bauder points out. That is because it uses oxygen and water from the air inside the room to produce radicals that are harmless to humans. And that means the paint remains effective permanently, unlike other antimicrobial coatings that gradually release substances to kill germs. "Once those substances are used up, the protection wanes. That can't happen with our method. Even in darkness, our photocatalyst has residual activity lasting at least 24 hours," Bauder says. The results of the field tests conducted at the Oberschwabenklinik medical center in Ravensburg and at Kantonsspital Graubünden hospital in the Swiss city of Chur are impressive: The paint was highly effective, and swabs taken by researchers showed that the walls were nearly germ-free.

Even with all these approaches and potential solutions, the antibiotic crisis is still very dangerous, as there is a particularly acute issue: Antibiotics are not lucrative. Prices are low, development costs high. "We should actually be able to do more about this creeping pandemic, as Lothar Wieler, former president of the Robert Koch Institute, once called it," says Dr. Dorothee Winterberg from Fraunhofer ITEM. There are many research initiatives, she says, but unfortunately not enough money. Winterberg sighs: "It's enough to drive you crazy at times." Prof. Till Schäberle from Fraunhofer IME agrees. "The market isn't going to solve this on its own. The state needs to step in," he adds. He has high hopes for large global funding initiatives like CARB-X, whose supporters include the Bill & Melinda Gates Foundation, the U.S. and Canadian governments and the German Federal Ministry of Education and Research (BMBF). Schäberle is firm in his prediction: "It is necessary, so we will see action on this front." ■

Emily Mattig does research at Fraunhofer IZI-BB on diagnostic systems for rapid detection of life-threatening pathogens like Pseudomonas aeruginosa (in blue) and drug resistance.

She and her colleagues have succeeded in developing modified probes to cover resistance as well: "In the case of resistance, it's not enough to simply detect the gene. We need to find specific point mutations in the gene. But we can identify them, too." The microarray is tiny, holding 5,000 probes in an area of only about three square centimeters. The entire diagnostic system would fit into a hospital exam room with no problem. And that means in the future, there might be no need to involve external labs, a time-consuming process.

Photos/Tableaus: Dennis Kunkel (3), NIOH, Steve Gschmeissner, Biophoto Associates (2), CNRI, Jürgen Berger/all Science Photo Library

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Safety in a Winter Wonderland

A new body scanner from the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR helps to keep everyone safe at Germany's bustling Christmas markets.

By Laura Rottensteiner-Wick

Christmas markets are a beloved tradition: mulled wine, sweet treats, the holiday spirit — and sadly, like any event that draws a crowd, a certain amount of safety risk as well. Not one but two suspected plots to attack Christmas markets were uncovered at the start of the holiday season in 2023, one in Lower Saxony and the other in North Rhine-Westphalia. From holiday crowds to any other setting packed with people, a new body scanner from the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg could help enhance safety in the future — without dampening the festive mood.

"Violent incidents have repeatedly shown that unfortunately, there is a great need for preventive safety measures in public settings, but those measures also need to be practical and not disrupt the natural flow or infringe people's privacy rights," says Patrick Wallrath, 3D Signal Processing Group Manager at Fraunhofer FHR, describing the challenging situation. "Established systems require people to be wearing lightweight clothing and standing still, so they don't work for broad-based, light-touch detection of dangerous objects." Working as part of the DEXTER (Detection of EXplosives and firearms to counter TERrorism) flagship initiative of the NATO Science for Peace and Security (SPS) program, Wallrath and his team have now devised a solution that could make it easy to monitor safety in crowded settings: an innovative body scanner that uses an array of radar antennas and receivers to scan passersby, including those in motion, for relevant shapes to detect knives, guns, and other dangerous objects. "The material the objects are made out of isn't the main factor, although metal does show up a bit brighter in the images," Wallrath explains.

Imaging while people are in motion is made possible by an innovative arrangement of MIMO (multiple input, multiple output) radar systems: With 352 transmitters and 528 receivers, images of people can be generated even if they are moving. The principle is that radar waves penetrate the person's clothing and bounce off of objects such as knives and other weapons. Each measurement yields about 80,000 signals, which are used to reconstruct multiple images in real time. To achieve this, the Fraunhofer Institute for Algorithms and Scientific Computing SCAI in Sankt Augustin implemented the reconstruction algorithms from Fraunhofer FHR on a graphics card. The system compensates for the speed of the person depicted while the image is being captured. The scanner generates five images a second. These images are then analyzed in real time using artificial intelligence, an element of the system supplied by ONERA, a partner based in France. The scanner can be placed discreetly so it does not attract attention.

"Choosing the right frequency range is challenging. There are two main factors to consider. The higher the frequency, the better the image resolution. But lower frequencies improve penetration, which is necessary to discover objects hidden under the thicker layers of winter clothing, for example," says Dr. André Froehly, a research scientist at Fraunhofer FHR. "We use radar waves ranging from 6.5 to 10.5 gigahertz, which means even thicker clothing is not an issue." There are two advantages to this approach. First, the scanner transmits in a range that poses no health concerns, like that of a mobile phone. Second, people are not individually identifiable in the images, so there are no concerns from a privacy standpoint.

"The intended use case is crowded public spaces," Wallrath says. "We've already had specific inquiries from security agencies." A prototype of the scanner was already tested at a metro station in Rome, with good results. However, shading can appear in the images, so the scanner does need to be positioned appropriately. "The perfect spot is a narrow point where people are moving in single file, like on an escalator. If there are multiple scanners in a row, it is also possible to monitor a number of parallel passages, like those found at a Christmas market entrance." The scanner can currently cover an area 80 centimeters wide. To expand its functionality, the team is now aiming to extend that to about two meters. "The goal is definitely within reach," Wallrath says with optimism. "Right now, we're looking for suitable partners for further development so our scanners can be used on a broad basis down the road, improving safety for as many people as possible." ■

Photo: Sebastian Weingart/DMI, BY

"The intended use case is crowded public spaces."

Patrick Wallrath, Fraunhofer FHR

For a worry-free holiday season, Christmas markets (photo: Striezelmarkt in Dresden) need to be secure, like other places.

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Fraunhofer start-ups:
Applying research in industry

Cultural Heritage Goes Digital

A mobile 3D scanning system from Fraunhofer spin-off Verus Digital helps museums make the jump to the digital age. Law enforcement agencies are also interested in the high-end technology.

By Beate Strobel

For posterity: COO Martin Schurig digitizes a Roman sword from the collections of the Museum of Cultural History in Oslo.

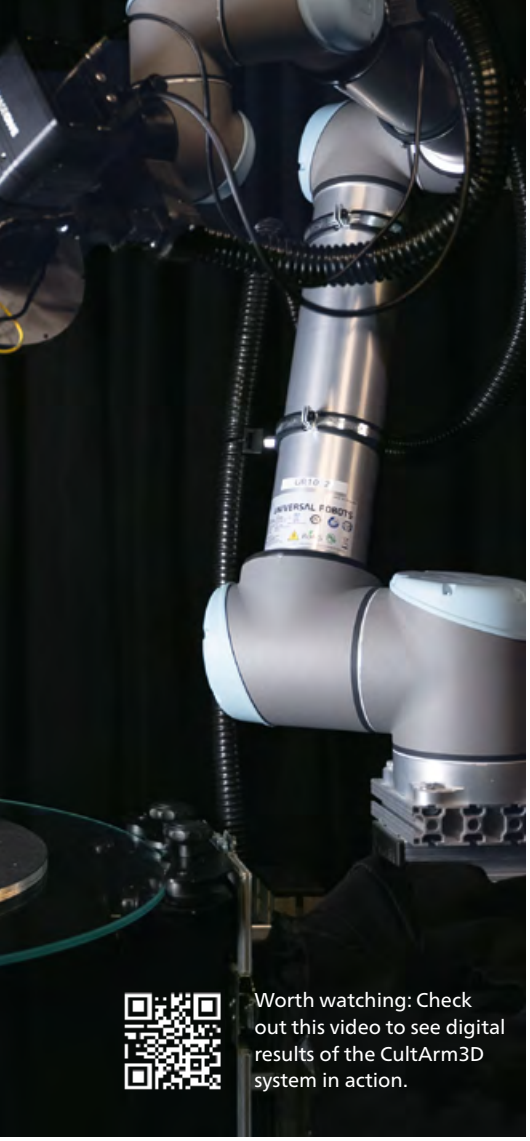
The true treasures held by German museums aren't on display but hidden away. Only about three percent of a museum's full holdings are actually exhibited. The lion's share of all this cultural heritage is stored in basements, archives and warehouses. Wouldn't it be wonderful to be able to make these works accessible to the global public as well? Maybe even without their having to make a special trip to the museum and be guided through the storage facilities?

Digitalization is the solution to this dilemma. From taking inventory to managing collections and from research to exhibition concepts and allowing the populace to engage with cultural heritage, digital technologies can make museums' work easier — although they also pose significant challenges in terms of expert knowledge and execution. "Most museums and cultural institutions have limited access to IT and 3D experts in-house," explains Matevz Domajnko. An engineer originally from Slovenia, Domajnko spent several years doing research within the Cultural Heritage Digitization department at the Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt, where he worked on technologies for scanning even fragile artifacts. The team won several innovation and culture prizes with the CultLab3D system, which was developed for this purpose. The system comprises two scanning units connected by a conveyor belt. It scans objects fully automatically from all sides within ten minutes, generating digital images at resolutions in the sub-millimeter range.

However, at eight meters in length, the CultLab3D system is too large for mobile use at museums around the globe. To solve this problem, Domajnko and his Fraunhofer colleagues Reimar Tausch and Martin Schurig developed an alternative called CultArm3D: a combination of robot arm and 3D scanner that scans all of an object's visible surfaces fully autonomously at the touch of a button and uses the data to generate a digital twin that is "web ready," meaning that it can be used on the internet and for VR and AR applications. These scans can also be used as a source of data for 3D printing.

Detailed, true-to-life visualizations

"Three factors were especially important to us in developing the CultArm3D: the safety of the object, the speed of scanning and the quality of the 3D model,"



Worth watching: Check out this video to see digital results of the CultArm3D system in action.

Photo: Verus Digital

Domajnko points out. After all, only if the technology supplies absolutely consistent results can the digital model be used for scientific analysis and simulations in addition to being presented in the museum or online.

The system was also designed to be as simple to handle as possible. "All the curator has to do is place the object. The system automatically learns the most important parameters, meaning aspects like size and shape, so the arm does not inadvertently destroy the artwork during scanning," Domajnko explains. This simplicity means museum staff can operate the CultArm3D after just a brief training course.

The digital transformation at museums and other institutions has only just begun. There is still a lot to be done. That is why the three researchers soon became excited about the idea of advancing this technology and launching it on the market as a spin-off of Fraunhofer IGD. The trio founded a start-up called Verus Digital in 2023 with Domajnko as CEO, Tausch in the role of VP of Engineering and Schurig as COO. The team has now grown to eight people, partly because the range of applications for CultArm3D has been expanded to forensics. Domajnko views this as a logical next step in scaling the business: "When it comes to things left behind by suspects or crime scenes, the goal is to digitally document the potential evidence, which may also have to stand up in court, with maximum accuracy and consistency. The 3D model gives law enforcement the option to perform a simulation without having to use the real object." Right now, Verus Digital is working with the police in the German state of Hesse, who want to use the CultArm3D technology to digitize their evidence storeroom for efficient analysis and improved presentation. The team is already considering expanding the use of the system for state criminal police authorities and the German national criminal police.

"Our goal for 2025 is to refine the technology, set standards and establish ourselves as the top player worldwide."

Matevz Domajnko,
CEO of Verus Digital

Strong connection to Fraunhofer remains

For help getting Verus Digital off the ground, the team turned to the Fraunhofer AHEAD program, which acts as a kind of business incubator, validating business models and providing workshops and coaching to prepare potential entrepreneurs from the field of research to survive in the free market. The expertise of Fraunhofer Venture, the spin-off and shareholding management arm of the Fraunhofer-Gesellschaft, was also highly important to the team as they got their start in the business world. Fraunhofer IGD has been a shareholder in the start-up from the very beginning and continues to provide support in the further development and refinement of the technology: "Our connection with Fraunhofer is still very strong," Domajnko says.

Working in tandem with two external business angels, the founders have already identified new use cases, such as collaboration with geological institutes for digitization of rock formations. Another potential avenue is working for auction houses to allow them to give their worldwide clientele a detailed view of the available items. 3D printing of works of art, including paintings, is another interesting possibility, as CultArm3D can be used to scan and process not only shapes but also colors accurately and in detail. Domajnko shows a 3D-printed painting in which each and every brush stroke is identifiable: "You can't tell the difference from the original at all."

For now, though, Verus Digital plans to focus on heritage and forensics. "Our goal for 2025 is to refine the technology in these fields, set standards in these areas and establish ourselves as the top player worldwide," Domajnko explains. The team is also hoping things settle down a bit in their day-to-day work, since in retrospect, the years since the idea first germinated have been something of a roller coaster. "We often had these spurts where there would be as much activity in two days as in two months before." His key takeaway for other entrepreneurs? If you have a good business idea, don't wait around. Just go for it: "The longer you wait for conditions to be perfect, the likelier you are to miss your time window." ■

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A voice from the business world

Marie-Christine Ostermann is the head of Rullko, a family company with some 200 employees and 91 million euros in sales.

Innovation Requires Freedom and Confidence

Less government regulation, bolder investment in our future — that could get the German economy rolling again.

An opinion column by Marie-Christine Ostermann, President of Die Familienunternehmer e. V., a nonprofit dedicated to family businesses.

Do you recall the last time you heard about a big state-sponsored invention or achievement? They certainly have existed — take the moon landing the U.S. set out to achieve, and then did in fact accomplish, under President John F. Kennedy. That was a literal "moonshot," and one that created progress and laid foundations across a wide variety of fields. But ultimately, successful science projects in which government calls the shots are very rare. Too often, they merely serve short-term political goals or to build prestige. Even the moon landing itself, however much of a catalyst it was for many different industrial sectors, was a project with ulterior motives. It speaks volumes that adequate funding for NASA dried up almost immediately after the U.S. declared victory in the "Space Race."

But how many innovations come from inventors, tinkerers, engineers or free spirits who start out on their own? And how many more could there be, especially here in Germany, if it weren't for stifling government regulations? How often do I hear from family businesspeople that they can't put solar panels on the roof because the array will be too big, because the grid isn't adequate, because legal obstacles mean it doesn't pencil out?

How often do government regulations get in the way? How often do people lack the equity needed to take risks because the tax burden in Germany is so heavy compared to other countries that the only investments possible are in replacements, not expansion? According to a survey of family businesspeople, only 18 percent can or wish to invest in expanding their business these days. A whopping 49 percent of companies have no plans for any investments at all, not even in replacements.

I read the latest news about the Starship rocket system from SpaceX in the U.S. via Google News on my iPhone and write op-eds about it in Microsoft Word. As I do, I wonder: Where is the German Musk, Page, Brin, Jobs or Gates? Where are the German geniuses, the unicorns? They must exist, since our country is rightly known for its inventive spirit. But can they become successful here? No, because the conditions simply aren't right.

Private financing through venture capital — exactly what innovation requires — is incredibly rare here. This is because in Germany, bold entrepreneurial risks are always treated as suspicious, which is also why German politicians look on private equity as a resource with disdain or at least as involving greed. If it must exist, it should be taxed, at least from the perspective of the rampant "nanny state." But used in the private sector? To be successful? And maybe even earn a profit? Shock, horror! And so, the German stars of tomorrow would rather go where the opportunities are: abroad.

"We need a tax system that accepts courage and does not punish profits."

Marie-Christine Ostermann

- has been a partner in Startup Teens GmbH and deputy chair of STARTUP TEENS Netzwerk e. V., whose mission is to get young people excited about entrepreneurship, since 2015.
- joined the Free Democratic Party (FDP) in 2013 and became a member of the presidential council of nonprofit Die Familienunternehmer e. V. that same year; she has been president since April 2023 and is the first woman to hold this position since the lobbying organization was first founded, 75 years ago.
- worked first as a division head at Aldi Süd in Munich before joining Rullko Grosseinkauf GmbH & Co. KG., a grocery wholesaler founded by her great-grandfather in 1923, in the role of managing partner in 2006
- was born in Hamm in 1978. After finishing high school, she enrolled in a vocational training program to become a management assistant in banking in 1997 and earned her certification in 1999. She went on to study business administration at the University of St. Gallen and completed her degree in 2004.

Even our longstanding family businesspeople would like to take more risks, but they run into the same issues as start-ups. In Germany, we have high incidental wage costs — unfortunately, not much of which ends up in my employees' pockets on a net basis — high energy costs, heavy tax burdens, incredibly high bureaucratic costs, a sluggish digital transformation and inefficient administration.

And in spite of all these costs, we use the returns on the investments we do make to keep our businesses running. We entrepreneurs invest what we can to stay competitive. But it doesn't leave us with much for the big swings, to experiment, even at risk of failing. And then, many of the things we might want to try run into bureaucratic hurdles. Take our labor law, for example. It is so restrictive that entrepreneurs have reason to worry if a couple of enthusiastic employees might want to hang around after work and play around with a bright idea. This is no way to produce innovation.

Instead of despair, we need confidence and freedom. Freedom to do business and build equity, and freedom to take the plunge and follow an idea or try something new. We need a tax system that accepts courage, allows for investments and periods of loss and does not punish profits. After all, there's no point in investing if you have no chance of ever making a profit, and innovation is no exception.

But above all, we need a paradigm shift. Across society, we need to take a more tolerant view of failure, acknowledging and respecting those who try new things instead of judging them for making mistakes. We need a state that unleashes our free spirits, engineers and entrepreneurs and gives them room to try new things instead of arrogantly claiming it knows better or deciding for us what the future should be like. Innovation requires freedom — at every level. ■

Photo: Anne Grossmann / Die Familienunternehmer e. V.

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Safety First

Cancer treatment is expensive and time-consuming. Researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA are developing a method of producing immunotherapy drugs at much lower cost — entirely without a cleanroom, and yet still under sterile conditions.

By Yvonne Weiss

When it works, cancer treatment can achieve near-impossible feats, fully curing even aggressive forms of cancer such as leukemia. Advanced gene therapies and immunotherapies like CAR T-cell therapy are highly effective. But these kinds of treatment come at a price: A course of treatment with the drug KYMRIAH costs about 300,000 euros per patient, for example.

A lower-cost solution that is accessible to more people is what Fraunhofer researchers are working toward in the SteriDoc project: "Our goal is to optimize an expensive step in the production of immunotherapy drugs, which would lower the costs of treatment," explains Michael Pfeifer, an expert on technology and device development at Fraunhofer IPA.

For patients with leukemia, for example, blood samples are taken first, and then the immune cells are extracted. The cells naturally present in the body are then genetically modified, multiplied millions of times over and reintroduced to the body, where they fight malignant cancer cells effectively.

To date, a highly complex process has been used to separate and purify the isolated cells, genetically modify and reproduce them, and then concentrate them for use. To ensure patient safety, the process takes place inside hermetically sealed containers connected by tubes. The process itself is done at specialized facilities, where it is largely automated. It can take as long as two weeks. Substances are added from small vials at various points along the way. To ensure sterility, the closed system must not be opened at these times. The additional substances allow the cells taken from the body to attack the tumor when they are reintroduced later on.

> "It may even be possible to cure diseases that are currently incurable. "We're really motivated by the idea of contributing to that."
>
> Michael Pfeifer, Fraunhofer IPA

The existing process calls for the transfers from the vials into the closed tube system to be performed by hand under absolutely sterile conditions: "So far, the modified cells have been transferred in a cleanroom setting, following stringent rules," explains expert Richard Rösch. "The reason for this is that unlike the human body, the cell culture does not have an immune system of its own. If germs were to get in, there would be nothing stopping them from growing along with the rest."

Together with their colleague Markus Schandar, Rösch and Pfeifer are working to find a way to connect the vials to the closed systems automatically, eliminating the expensive and time-consuming step involving connecting them in a cleanroom and replacing it with a lab device. "Once an effective form of treatment that a lot of people need is found, it also has to be affordable, so it's accessible to the general public. That's where we are trying to help," Pfeifer explains.

The researchers' idea involves using a special needle to safely transfer the modified cells between two closed systems. The needle has a silicone outer coating that can be heated inductively. Before the needle penetrates the sealed vial containing the

Absolutely sterile: CAR T-cell therapy is an efficient method of fighting certain kinds of cancer, like leukemia.

cell culture, the silicone "sheath" is heated to kill any germs that may be present.

Then, once the needle has cooled down, the vessel is rotated. The reagents can then be extracted with negative pressure through the needle. This same method can be used to add different substances at various points to modify the body's natural cells as needed. Once the culturing process is complete and the modified cells have been prepared, they wind up in the tube system and can later be administered to the patient.

Pfeifer, Rösch and Schandar are currently fine-tuning the process of producing the needle and the outer coating. The material used must be both biocompatible and capable of induction heating. A technology demonstrator already exists, so the Fraunhofer researchers have demonstrated its functionality.

They are optimistic about the opportunities this technology may offer for various treatment methods in the future: "It may even be possible to cure diseases that are currently incurable," Pfeifer says. "We're really motivated by the idea of contributing to that."

Rösch is also excited about forging ahead with the project: "The market is still open. There are no production standards yet. It's fun to do pioneering work in this field." ■

Photo: Tek Image/Science Photo Library

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Replacing Mice with Models

Nearly one in two people in Germany will develop cancer at some point in their lives. To find out how best to fight tumor cells, Fraunhofer researchers are now relying on an artificial microsystem instead of animal testing — and modeling human organs out of plastic in the process.

By Yvonne Weiss

Soft and spongy, the human lung weighs about 800 grams and is vital to our survival. The airways branch out, ending in more than 300 million tiny sacs called alveoli. When malignant tumors develop in the lungs, it is generally in the cells of these sacs. Researchers from the Fraunhofer Institute for Material and Beam Technology IWS and the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM partnered with the University of Regensburg in a project to study how tumor cells spread in the lungs and how new medications can fight them more efficiently.

Instead of animal testing, they are relying on a special microsystem: The researchers create a model of a human lung out of plastic and then use human cells to visualize physiological and disease processes in the model. "The goal of our system is to simulate various aspects of the body as realistically as possible," explains Prof. Armin Braun, Division Director of Preclinical Pharmacology and Toxicology at Fraunhofer ITEM.

Model human organs

The system is used to test new approaches to treatment. While conventional tumor therapies harm not only malignant cells, but also healthy ones, the idea is for new active ingredients to bolster the immune system and remove any blocks that tumors may have put in place to impede its effectiveness. These blocks make it impossible for the immune system to attack a tumor.

Braun says testing the efficacy of the new treatments calls for a system that is more similar to the human body than the body of a mouse, for example. It also takes several days to test the new medications. The scientists have to keep the tumor cells and immune cells that are being studied alive during that time.

Florian Schmieder, Group Manager Micro and Biosystems Engineering at Fraunhofer IWS, and his team simulate human organs out of several layers of plastic. Equipped with channels and chambers, pumps and valves, the model is about the size of a smartphone. Inside the system, the researchers culture human cells on a chip about as large as a business card. The cells were taken from a lung with a tumor, so the sample contains living immune cells and tumor cells alike.

"Inside the body, our organs are embedded in a physiological environment," Schmieder explains. "Our model realistically simulates that environment. We also control factors such as oxygen concentration, pH value, and CO_2 levels." Schmieder simulates heart and lung functions electrically, using a pump. A nutrient solution similar to blood takes the place of the body's natural circulation and keeps the cells alive.

Tests on the affected tissue samples show that new medications do in fact remove the blocks imposed by the tumor, thereby strengthening the immune system. The microsystem offers a good way to observe how safe and effective a medication is inside the human body, even at a very early stage of research. The new approach would also mean significantly less animal testing in the long run.

Technology helps fight other diseases

The technology also offers opportunities for testing other medications. For example, the researchers are currently using the microsystem to study how to fight viral infections such as parainfluenza, a type of flu-like illness for which there are no vaccines or medications at present. Braun says having a human test system is crucial, especially when it comes to viral infections.

He is optimistic about what the future holds: "By developing this system, we're creating a tool that lets us do something to benefit all of humanity. It can help to develop new medications faster, with better safety, and that's especially helpful in unusual situations such as a pandemic." Schmieder is also fascinated by the possibilities the microsystem may open up in the future: "Our system can artificially keep tissue alive for a long time. And that brings us a critical step closer to the artificial organs we will have available one day." ■

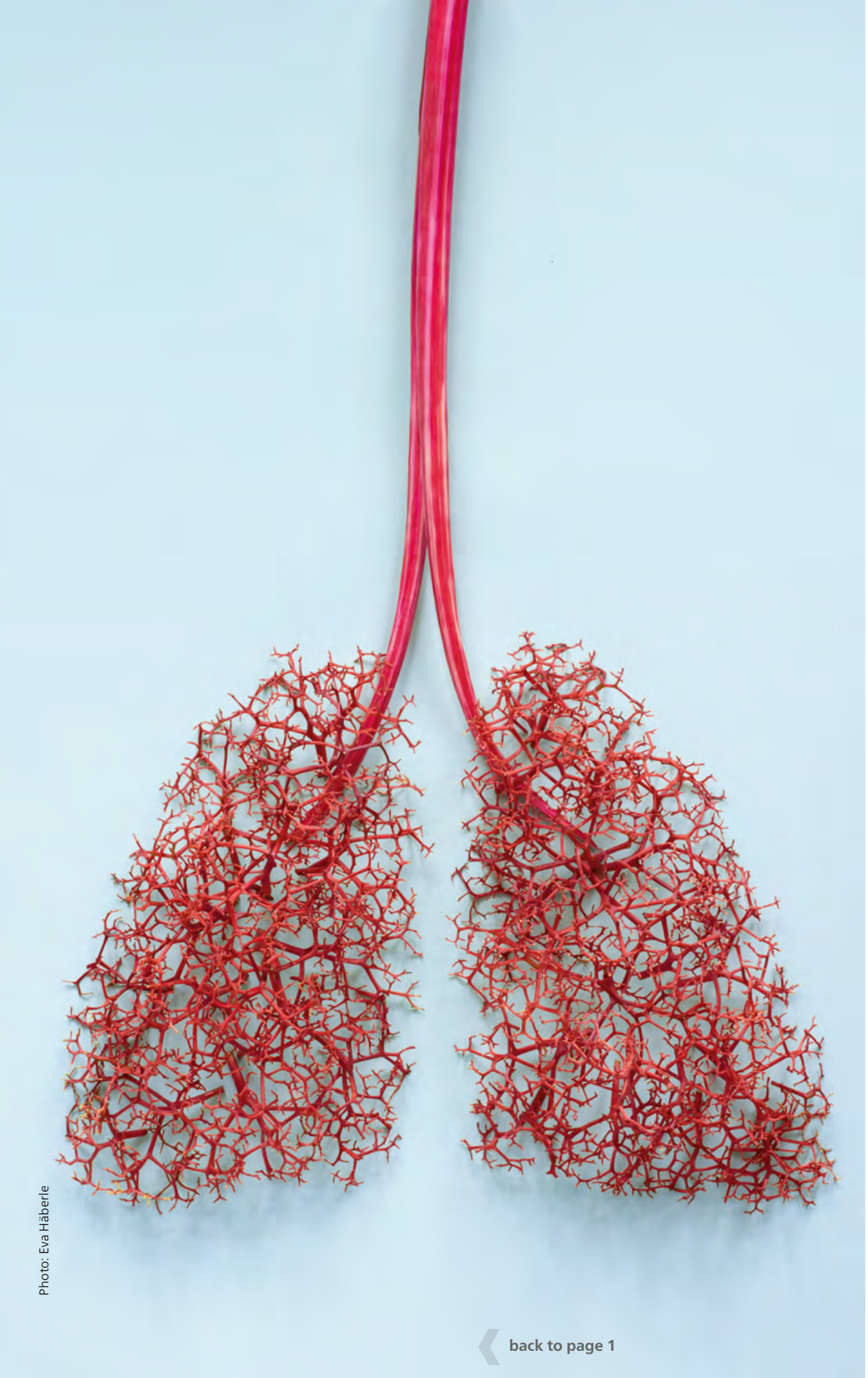

Photo: Eva Häberle

The airways branch out, ending in more than

300

million tiny sacs called alveoli.

Vital nutrients: The lungs supply the blood with oxygen through branching blood vessels.

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When AI Negotiates Contracts

A contract is "signed" by AI — is it legally valid?

By Dr. Janine van Ackeren

The use of artificial intelligence for legally binding documents is a legal gray area.

Regional court of Südlingen, August 8, 2024. In courtroom 123, the defendant and his legal counsel rise along with the plaintiffs and their own lawyers as the judge enters the room, accompanied by two lay judges assigned to the case. The case has to do with delivery of roller bearings. The defendant argues that the purchase agreement is void. He was on vacation when the contract was signed, and there is evidence to prove it. That means the contract must be invalid, and the defendant is therefore obviously not obligated to take delivery of the goods he supposedly ordered. What makes this case unusual is that the contract was signed not by human signatories, but by artificial intelligence (AI). Is a contract that no human was involved in signing still legally binding?

The Regional Court of Südlingen doesn't exist, but courtroom 123 does, at the Regional Court of Frankfurt am Main. The lawyers and judge are real, but the case is fictitious — with potentially far-reaching ramifications. American retail giant

Walmart is already piloting the use of a chatbot for purchasing operations.

So, how much legal certainty does a contract signed by AI instead of human employees actually provide? Will it stand up in court? Researchers from the Fraunhofer Institute for Material Flow and Logistics IML, the Fraunhofer Institute for Software and Systems Engineering ISST, the Institute of Legal Informatics at Saarland University and the Horst Görtz Institute for IT Security at Ruhr University Bochum explored these issues in the Industry 4.0 Legal Testbed project. "Our primary goal was to recommend actions that policymakers and companies can take to establish new legal standards," says project manager Benjamin Korth from Fraunhofer IML.

To be able to do that and lay a technological foundation, the researchers first developed a digital testing ground for automated business processes: the "legal testbed" of the project's name. The new environment can run through the entire transaction process automatically, from contract negotiations to signing and execution, a capability found nowhere else to date. "We looked at two scenarios as examples," says Philipp Hagenhoff, a researcher at Fraunhofer ISST who worked with other project members to advance these use cases. He was responsible for design and conceptual aspects. "The first is a transportation scenario, in which goods are to be delivered to a logistics service provider, and the second is a production scenario, in which a certain number of roller bearings are to be produced and delivered on a recurring basis."

Contract negotiations: software agents do the haggling

The first step is to negotiate a contract, including all the relevant points: prices, delivery date, when items will be called off. There are many different issues to consider. Take the delivery date, for example: If the goods are delivered before they are needed, the recipient has to store them in the meantime, which adds costs for moving them in and out of storage. This means it can be a good idea to invest more to make certain the transportation service provider will reliably provide a driver on the desired date. Before the AI tool can approve a contract, it also has to check whether the other party is trustworthy. Does that party meet the requirements the company has set for its contracting purposes? Are there any reasons not to work with this potential partner? Plans call for a form of digital self-disclosure in which companies provide information on their legal form and where they are headquartered, along with certificates such as IT security certificates or ISO 9001 certification for a standardized quality management system. Only if all of the pre-established conditions are met does the tool open negotiations.

Before the AI tool can approve a contract, it also has to check whether the other party is trustworthy.

But can machines be taught to negotiate in this way? "We've written algorithms that simulate different negotiation strategies," Korth explains. The researchers used a software agent that tends to take an accommodating approach to negotiations by starting with a high price and quickly dropping it, along with a more hardline one that sticks to its position for a long time. Once all the terms have been negotiated, the actual contract is drawn up. All of the terms are drafted in a legally valid form and confirmed by both sides. Unlike with human negotiators, however, the text of the contract alone is not enough. The data model and machine-readable logic are also recorded. Hagenhoff explains why: "Both parties can use this information to trace the steps taken by the AI with full transparency." The tool stores all events that are important to the contract's execution on the blockchain. All of the data is kept in a list, with new items simply being added when new events occur, like when the goods are sent out and received. This means the entire chain of actions is stored in a tamper-proof format. "Capturing this all in a single logical form was a big challenge," Korth recalls. "The content on the blockchain can be highly individual, depending on the contract. Take disruptions, for example, which can involve ▶

American retail giant Walmart is already piloting the use of a chatbot for purchasing operations.

Photo: Andrey Popov/istockphoto

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AI in logistics: Is it allowed to negotiate and approve contracts?

added fees: When a truck driver arrives at the agreed location at the appointed time to pick up the goods, but they are not yet ready, the driver cannot continue their route as planned. Who is considered to be responsible for this delay and any charges that may be incurred as a result? "The smart legal contract analyzes the information on incidents like these and updates the blockchain with contract status and the obligations involved," Korth says.

As useful as blockchain technology is for tracking purposes, it is also problematic in terms of data privacy and protection of trade secrets. After all, trade secrets — including which contracts have been signed and with whom — must not be allowed to fall into competitors' hands. The team found a way around this issue by choosing Hyperledger Fabric as the blockchain framework. It offers separate channels, which means the stored data can only be viewed by authorized nodes. This means a separate blockchain is created for each contractual relationship, and no one other than the parties to that contract receives access.

A way for companies to explore options

The project has been concluded, and the legal testbed is available to companies free of charge online (https://s.fhg.de/industrie40-rtb (site in German)). They can use it to run through various automated negotiation scenarios — including determining in advance which parameters the software agents are supposed to negotiate and which aspects to emphasize. "This gives companies a way to get their feet wet with automated contracting, so to speak, and see for themselves what the process might be like," Korth explains. He believes this technology will be adopted in stages, with certain segments leading the way. The first applications are likely to be concentrated among transportation services and recurring orders, he says. "But contracts are sure to be signed by humans for quite some time whenever there are individual negotiations that require highly detailed specifications."

The verdict is in: a contract is a contract

But to return to the courtroom, how well do these automatically signed contracts stand up in court? The judge brought in an expert to scrutinize the method used, right down to the source code. The verdict, based on the expert's opinion? A contract is a contract, whether it is signed by a human or AI. And that means contracts signed automatically can be viewed as legally valid. ■

Photo: steffi.go/Photocase

Fraunhofer

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How Can AI Be Made Sustainable?

Artificial intelligence requires vast amounts of energy. Is there any way to change that?

By Dr. Janine van Ackeren

Photo: Felix Wong Photo/Newscom/picture alliance

The future in sight: Improving training data can optimize AI models from an energy perspective.

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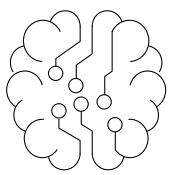
Artificial intelligence is a true "energy hog." The International Energy Agency (IEA) estimates that AI applications use 500 terawatt-hours of electricity per year worldwide — significantly more than all the power consumed across Germany in 2023, at 467 terawatt-hours. And AI's thirst for energy is even forecast to more than double between now and 2026. In response, Microsoft is planning to recommission Pennsylvania's notorious Three Mile Island nuclear power plant, which was taken offline after a partial meltdown incident in 1979. From an environmental standpoint, all this does not exactly show artificial intelligence in a good light as a transformative technology. How sustainable is the use of AI in reality?

"Sustainability is more than electricity use," says Dr. Paulina Prantl, a department head at the Fraunhofer Institute for Integrated Circuits IIS. "In addition to the environmental side, there are also economic and social aspects to consider, for example when a technology has a positive impact on society." And that means the answer to the question of sustainability lies in the details of the specific use case. After all, AI can definitely be sustainable, even when energy use is considered, such as when it is used to lower the energy consumption of production lines or logistical operations by optimizing processes.



AI applications are estimated to use

500

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of electricity per year.

The training phase: boosting data quality

But why does artificial intelligence use so much energy in the first place? Two aspects are responsible for most of this: the training phase and the use phase. Depending on the use case, one or the other of these phases may use more energy over the model's life span. During the training phase, large volumes of data and high complexity or poor, imprecise data can combine to push energy needs higher. In the use phase, the size and complexity of the models that have previously been trained are major factors. Prantl and her team are digging deeper on training in particular.

To make AI more sustainable, the researchers at Fraunhofer IIS are looking at the data side as one aspect. "Our approach is known as data-centric AI. It involves exploring ways to enhance data quality so less training data is needed and the model is smaller — which reduces the time, effort and expense companies have to put in along with energy consumption during the training phase," Prantl explains. One way to do this is by "labeling" the data: associating individual data points with information relevant for AI analysis purposes. These kinds of labels are not commonly used in production environments. While a wealth of process data is collected in most cases, the finished component is not always checked in the end due to cost reasons. "When that happens, the data is like a diamond in the rough. Polishing and cutting it, so to speak — so, for example, knowing whether the component was approved during quality assurance or flagged for disposal — would make it easier to analyze the data and save energy during training," Prantl explains.

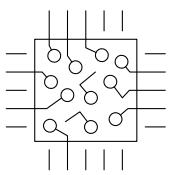
As one potential approach, researchers at Fraunhofer IIS are therefore automatically labeling the data in order to boost efficiency and increase the amount of information available and thus save energy for training the models. Initial solutions for automatic labeling are already available on the market, but they generally still need to be tailored to the specific application. The Fraunhofer IIS team of researchers did this, for example, in the project titled ARGOS — How Digital Eagle Eyes Find Brownfields. Germany is home to a great deal of developed land, so it is very difficult for industrial firms to find completely unused tracts of land to develop from scratch. Instead, they generally need to use "brownfields," or previously developed and possibly now disused land, for new construction projects. In many cases, however, there is a lack of information about whether these properties have been abandoned or are still in use. The team of researchers used existing data that had already been annotated to train an AI tool to act as an assistant in the annotation process. The tool made it possible to automatically annotate a large volume of further image data in a process known as pseu-

do-labeling. The data can now be used to train AI models sustainably, with minimal work and expense involved, so that they can find valuable brownfield sites that can be reactivated for new construction projects.

The researchers also discovered that it makes a big difference which data point is used in which order for the training process. "With the right data points, it is easier and faster to achieve good performance, even with less data. In active learning, the algorithm selects the data that offer the biggest gain in terms of information," Prantl explains. The team has already optimized the training data for a mechanical engineering firm. Originally, people had to assess each component, take automatic measurements and then use image processing software to manually trace and mark up any defects in order to generate training data. This meant that employees not only had to check which components had faults but also see which of the faults supplied enough additional information to make the laborious and time-consuming annotation process worthwhile. The automated process, on the other hand, aims to check all of the components, but ultimately have humans step in to annotate only the ones that add value for the model. This way, unnecessary time, effort and expense for manual digital annotation of data can be eliminated and models can be trained energy-efficiently using a smaller pool of more relevant data.

Use phase: smaller models and post-training

So, artificial intelligence just needs to be developed one time and then it works, right? Not quite. Like any other system, AI requires maintenance and, at times, repairs — post-training, in other words. Does the material have a somewhat different sheen than before? Is there a slight buildup in the pipes that has caused a minimal pressure change? "Even small changes like these can make it necessary to restart the AI training process all over again," Prantl says. With that in mind, the researchers developed an employee-efficient, energy-saving approach for Siemens Digital Industries. The company has several production sites for soldered circuit boards. The boards are very similar to each other, but different enough to push AI to its limits if one and the same program is used for quality assurance. This would require separate training for each system. But not for the automated solution from Fraunhofer IIS: "Multiple different models are stored in it, and the one that is optimal for the specific use case is selected automatically from those," Prantl says. These kinds of solutions can even use energy consumption as one of the selection criteria. "A solution like this makes sense anywhere that a model is needed repeatedly in different versions or needs to be adapted on an ongoing basis due to environmental changes."



"Sustainability is more than electricity use. In addition to the environmental side, there are also economic and social aspects to consider."

Dr. Paulina Prantl, Fraunhofer IIS

One-time use of AI uses much less energy than training, but it is possible to achieve savings there as well. Selecting the AI models that are used is an especially important way to do that: Depending on the use case, deploying large models like deep neural networks can be overkill. They use considerably more energy, but do not necessarily produce better solutions. "This means if possible, we rely on smaller models like decision trees. They are simpler, easier to understand and less energy-intensive," Prantl explains.

So what does Prantl, an expert in the field, think of the general chances of sustainable artificial intelligence? "We know from ChatGPT what kinds of surprises there can be in terms of quality and output, and it's certainly conceivable that we may be surprised when it comes to sustainability, too. Even so, right now I see conscious use of AI as the biggest source of leverage. Not every issue requires large generalized models. Specific specialized small models tailored to certain applications can be much more sustainable," Prantl says, explaining the bottom line. "On the flip side, there's no way around AI, since many companies simply can't find qualified specialists these days." And that is another way that AI, while not always sustainable itself, is contributing to sustainability. In addition to being one way to help optimize energy use in processes, it is also filling the gap left by the shortage of skilled workers, thereby contributing to the social and economic aspects of sustainability. ■

Illustration: istockphoto/ Valentin Amosenkov

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Researchers are working on smart prostheses to simulate the sense of touch found in human hands.

Feeling the Way Forward

Thanks to neural interfaces, smart prostheses can restore patients' sense of touch — right up to the fingertips. Researchers at the Fraunhofer Institute for Reliability and Microintegration IZM are studying how the microchips needed to achieve this work inside the body over a period of decades.

By Yvonne Weiss

The challenge is a raw egg. When a patient with a prosthetic forearm tries to pick up the egg using their thumb and forefinger, there is a risk that it will break — that is, unless sensors at the end of the prosthesis register the contact and transmit an electric signal to the brain via the implant and nerves. The patient's brain can be trained to decode this tactile feedback over time and perceive it as touch, restoring the ability to feel with the artificial hand.

Every year, some 60,000 people in Germany lose an extremity, and the figure for the U.S. is about three times as high. Amputation is a last resort when someone is severely injured in an accident, but it may also be necessary for those with diabetes, vascular disease or cancer.

Researchers are studying how smart prostheses can revolutionize the everyday lives of affected patients as part of the NerveRepack project, which was co-initiated by the European Union and involves 27 institutions from ten countries across Europe, with IMT-Bucharest as the coordinating research institute. Their aim is to use neural interfaces to make artificial hands, legs and feet feel more like part of a person's own body, so patients can regain their sense of touch, for example.

"The idea is for a prosthesis to permit an intuitive user experience and simulate the way a person's own hand feels," explains Dr. Joshua Wilson, a research scientist within the Technologies for Bioelectronics working group at Fraunhofer IZM. This could restore fine motor control in patients who have lost it for a variety of reasons.

"In the project, we're working on technologies intended to restore everyday mobility to people with amputations, paralysis of the extremities, or spinal cord injuries," he adds. The scientists plan to develop two exoskeletons for people with paralysis of the legs and a forearm prosthesis. Wilson and his colleagues are working on special housings to accommodate the necessary electronics, so the implants can work safely and effectively inside the human body for decades without any further surgical interventions.

> "Our innovation could help with certain types of paralysis and motor disorders that cannot be treated with existing drugs."
>
> Dr. Joshua Wilson, Fraunhofer IZM

An implant placed inside the patient's stump allows the forearm prosthesis to communicate in two directions: The brain transmits an impulse to move to the prosthesis, which in turn sends a signal back to the brain on contact, simulating touch.

For the technology to be a success, it will be crucial for the implants to work in the long term inside a constantly changing body. Conditions inside the body are not exactly favorable. Water and salts can damage electronic components, in the worst case even causing them to fail. This makes one thing important above all: the right packaging.

In the past, ceramic housings have been an especially prevalent way to provide dependable protection for implanted devices such as cardiac pacemakers. But they are relatively large and rigid, so they cannot be used close enough to the target tissue — and that, in turn, requires leads or cables, which are prone to issues of their own.

With this in mind, Wilson and his team are focusing on housings that combine ceramic and polymer layers, even while they are thinner than a single strand of human hair. "Thanks to their thin coating, our biocompatible housings offer significant advantages for the implant. Their small size reduces the risk of potential immune reactions. Making the entire implant smaller also means it can be placed right near the target tissue, so we don't need any leads or cables, which are vulnerable to malfunctions."

Before safe implantation in human patients is possible and the technology enters real-world use, Wilson and his colleagues are working on a number of other elements, including test systems that can be used on the coatings. They are developing individual components and testing the materials to ensure biocompatibility. Wilson is eager to see what patients have to say about the new technology and excited about its potential: "Our innovation could help with certain types of paralysis and motor disorders that cannot be treated with existing drugs. In the long term, our intelligent prostheses should enhance quality of life for millions of people with amputations, paralysis of the extremities or spinal cord injuries, improving their social and financial independence." ■

Photo: Martina Meier/plainpicture

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Birch, beech or poplar? Tree recognition software with AI has been trained for each type of wood specifically. It already has hardwoods down pat.

Photo: Robert J. Ross/World Nature Photography Awards

Photo & Fraunhofer

Seeing the Forest for the Trees

Amid the thicket of EU regulations, a new issue has taken root: The EU Deforestation Regulation (EUDR) requires companies that process wood to begin declaring the types of wood used in 2025. What's more, they will also have to prove that the wood is of legal origin. And for good reason: Illegal logging is one of the main reasons for deforestation around the world. Well over half of the forest clearing taking place worldwide is estimated to be unlawful.

Determining the type of wood used and its origin is relatively simple when it comes to furniture. But with other types of wood products, such as particle board, paper and cardboard, the process is highly time-consuming and involved. First, the wood cells are separated from the material, dyed and then positioned on a slide. Finally, they are analyzed individually under a microscope and classified based on their appearance.

To make the process more efficient in the future, researchers at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern are working with the Thünen Institute of Wood Research in Hamburg to develop analytical software with the goal of streamlining this laborious process through automation. In the KI_Wood-ID project, they are training neural networks on reference preparations from the Thünen Institute's collection. The goal is to get the artificial intelligence to the point where it is capable of independently identifying the characteristic features of a particular species and comparing the findings to the type of wood that has been declared.

An initial prototype can already distinguish eleven types of hardwood based on high-resolution microscope images; the next step in the learning process will involve softwood. In the long term, the AI-based image recognition tool is to be rolled out to support institutes and government agencies worldwide in monitoring the wood trade. And that will mean people really can see the forest for the trees.

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Hydrogen Meets Heat Pump

Using renewable energy to produce green hydrogen also produces oxygen and heat as usable byproducts.

By Mandy Bartel

Hydrogen is viewed in Germany as the key element in the energy transition. According to the German federal government's hydrogen strategy, 30 to 50 percent of the gas of the future should be produced domestically by 2030, with imports making up the rest. Hydrogen produced using renewable energy is an especially hot commodity. But producing "green" hydrogen from renewables is still very expensive, plus it has not been incorporated effectively into the further value creation process.

At a new test facility in Zittau, a team headed by Dr.-Clemens Schneider from the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG aims to find ways to make the process known as PEM electrolysis more cost-effective through energy systems integration. In this method, water is split into hydrogen and oxygen using electricity derived from as high a proportion of renewables as possible. A polymer electrolyte membrane (PEM) is used to separate the two molecules, allowing only hydrogen molecules to pass through. This produces waste heat, which is to be captured and processed by a heat pump so it can be used in the municipal district heating network.

Energy systems integration is key

"The outlet temperature on the electrolyzer is 55 to 60 degrees Celsius, but we need about 90 degrees for the district heating network," explains Schneider, the project manager. "A heat pump is used to make up the difference so we can feed the heat into the district heating network and thus supply households with heat energy." For every kilowatt of electricity that the heat pump requires, three to four times as much heat can be produced.

30–50

percent of the gas of the future is to be produced domestically by 2030.

In the IntegrH2te project, the researchers are working with project partner Linde GmbH to study how the different systems interact, meaning the connections between PEM electrolysis, heat pump and heat network but also the electricity and gas sectors. The operating method and parameters change depending on whether the

Twice as sustainable: The waste heat from hydrogen production can be used in district heating networks.

"Thanks to the connection to the district heating network in Zittau, we can test the system under living lab conditions with different temperatures and demand for heating in winter and summer."

Dr. Clemens Schneider, Fraunhofer IEG

focus is on using excess green energy, conserving fossil fuels or optimal hydrogen production. The project team is now using the new system to test the concepts they developed in recent years in practice. "Thanks to the connection to the district heating network in Zittau, we can test the system under living lab conditions with different temperatures and demand for heating in winter and summer," Schneider says. The researchers are also looking at the link with electricity prices as a factor in their scenarios: How does the system work if it runs exclusively at low prices, meaning that as much wind and solar energy as possible is available in the grid?

Using oxygen for biological water treatment

In addition to the waste heat, the oxygen produced through electrolysis can also be used — provided it is sufficiently pure. After all, for every two molecules of hydrogen, the process also produces one molecule of oxygen. It can be used for applications such as biological water treatment or for the fourth stage of treatment, in which advanced water treatment plants use ozone to filter substances such as hormones and drug residues out of the water. Other potential areas of application for the oxygen produced using this method include the chemical industry, fish farming and healthcare.

Schneider says the big challenge here is a coherent safety concept: "If there is a disruption due to unequal pressure in the process and that causes the oxygen to be contaminated with hydrogen, it not only lowers the O_2 value, but can also cause an explosive mixture to form," he explains. "That's why the oxygen produced during electrolysis has hardly been used at all so far. Instead, it has been released into the air. At the Zittau facility, we plan to monitor purity and safety by incorporating sensors, containers and recombiners so the oxygen is usable."

The Fraunhofer IEG test facility is scheduled to come online in the spring of 2025. Going forward, other industry-related processes could be tested and validated there for manufacturers and operators as well, including methanation of carbon dioxide, closed carbon cycles, oxygen concentrators and hydrogen compressors as well as hydrogen burners, along with other components for the use of the primary and secondary products of PEM electrolysis. In this way, the facility will not only help grow the hydrogen sector and ensure a sustainable energy supply but also bring about structural transformation in the region of Lusatia. ■

Photos: Grigorev Vladimir/istockphoto, Fraunhofer IEG

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EUROPE

Sustainable Microchip Production

A new method is making semiconductor manufacturing greener.

Significantly reducing the environmental footprint of semiconductor production is the goal for the EU's recently launched HaloFreeEtch project, in which the Fraunhofer Institute for Electronic Nano Systems ENAS is playing a major role. The researchers are developing an ecofriendly hydrogen-based etching process for silicon wafers that eliminates the need for halogenated compounds containing substances such as chlorine or fluorine, which pose considerable environmental and health risks. The new method, which is testing innovative metal catalysts among other substances, is to remain compatible with existing plant technologies for gas-phase etching. To capture information on cost-effectiveness and efficiency and optimize both factors, the researchers are combining process and sustainability models for the first time. As the first step, the many different material combinations are being analyzed using quantum mechanics simulation methods at the Center for Micro and Nano Technologies (ZfM) at Chemnitz University of Technology. The processes will then be evaluated using production equipment at Fraunhofer ENAS.

Flat, stretchable antennas allow robots to scan their environment more effectively.

BELGIUM

Intelligent Robot Skin

To help robots better perceive where people are located and what they are doing, researchers at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR have teamed up with six European partners from industry and the research sector to develop stretchable metasurface antennas that are much better at sensing their immediate surroundings than conventional antennas and can also predict movements. The goal of the EU project FITNESS, which is led by the belgian University of Louvian (UCL), is to enhance people's safety and make production processes more efficient. The innovative flat antennas are based on high-frequency-capable polymers with integrated electronics. These "metamaterials" enable precision control of electromagnetic waves and adapt flexibly to the robots' contours — much like an "intelligent skin."

Using truck cargo space more efficiently with AI.

AUSTRIA

Smart Logistics

E-commerce is booming, and with it, so is demand for transportation orders on shorter and shorter timelines, which are difficult to plan for. The result? Trucks traveling with less than full loads, which harms the environment and is not cost-effective. A team of researchers from Fraunhofer Austria has set out to change that. They are using an AI-based algorithm to combine shipments and make efficient use of remaining capacity based on real-time data with the goal of using existing resources sustainably and efficiently. The algorithm uses modular load cells in the cargo area, image-based measurement methods and data from the internet to combine internal and external streams of information about cargo volume, weight, remaining cargo space and orders along the route or freight exchanges and calculate the most efficient route based on the current weather and traffic situation, available capacity on the truck and the specific requirements relating to the cargo.

EUROPE

Global CO_2 Monitoring

What percentage of the carbon dioxide in the earth's atmosphere comes from human activity? The European Space Agency (ESA) plans to use high-resolution spectral measurements to study this starting in 2026. The Copernicus mission, which consists of a constellation of satellites, plans to map the CO_2 emissions from cities, countries and large industrial zones in detail. The Fraunhofer Institute for Applied Optics and Precision Engineering IOF produced an optical disperser for the infrared spectrometers used on the satellites. This component, which was specially developed for the requirements that apply in space, breaks down the light reflected off the earth into spectral colors and permits measurements at an accuracy of fewer than 100 CO_2 particles per billion air molecules. The disperser owes its extreme precision to a unique nanostructured optical grating used in combination with two prisms.

The Copernicus mission was launched to help meet the targets outlined in the Paris climate agreement.

SWEDEN

Calculating Climate Change with Greater Accuracy

Climate change is especially evident in the Arctic.

Collecting precise weather data for the Arctic for the first time and improving global climate models are the task for a small satellite that ESA launched into low Earth orbit in mid-August. It was developed and built under the leadership of OHB Sweden. Equipped with state-of-the-art microwave radiometer technology, the Arctic Weather Satellite is about the size of a home dishwasher. It contains four low-noise high-frequency amplifiers from the Fraunhofer Institute for Applied Solid State Physics IAF, whose high electron mobility ensures optimum signal receptivity and data quality. Their main function is to amplify weak microwave signals from the earth's surface while causing as little background noise as possible. This makes it possible to collect precise data on temperature, humidity and clouds on an ongoing basis, even under unfavorable weather conditions.

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All Packaging, Wrapped Up

Germany leads the pack when it comes to packaging waste in Europe. The country generates some 19 million metric tons of it a year — and that figure is rising. But because doing away with protective outer packaging is usually impossible, Fraunhofer researchers are looking to sources like fungi, algae, oils and starch for new solutions.

By Beate Strobel

Safe and sound: Christmas is a time for loved ones — and lovingly packaged items.

Christmas generates a lot of waste. One need only think of all the plastic mailers and glossy wrapping paper, plus the many ribbons and bows adorning all the presents under the tree. Experts estimate that the volume of packaging waste generated by German households jumps some 20 to 30 percent during the holidays. And that's on top of the fact that Germany is already well above the European average on this score, at 237 kilograms per capita each year as opposed to 189 kilograms. Per capita volumes of packaging waste have risen 26 percent in Germany since 2005, despite individual zero-plastic initiatives, reusable solutions, and stores making efforts to cut down on packaging.

"Packaging is extremely important, including for sustainability reasons," counters Dr. Jens Balko, a polymer physicist and head of the Processing Pilot Plant for Biopolymers Schwarzheide at the Fraunhofer Institute for Applied Polymer Research IAP. Extra layers of wrapping protect foods and other products so they do not have to be thrown away simply because they have lost some of their freshness in transit or have otherwise been damaged, so they can no longerbe sold, he points out. Of course, Balko is also bothered by things that are "overpackaged," meaning that more plastic, paper and/or other materials have been used to package them than strictly necessary for protection purposes. Christmas gifts may be something of an exception, but decorative packaging that serves no other purpose is an environmental nuisance in light of the fact that quite a bit of plastic waste winds up in the environment — some 52 million metric tons a year worldwide, as a study by the University of Leeds found.

The European Union has set its sights on packaging waste, announcing that it aims to lower the use of plastic packaging by 20 percent from 2018 levels between now and 2040. All packaging is to be made recyclable before then, by 2030. Lightweight single-use plastic bags used for purposes such as purchases of bulk produce at supermarkets will be banned at that point. For researchers, this represents both a challenge and an opportunity: How can things be packaged more sustainably in the future?

As is so often the case, there will not be just one solution. After all, Balko notes, "Sustainability means a lot of things." The goal here is to choose the type of packaging with the smallest environmental footprint for a given use case. And that, in turn, is affected by a number of different factors, including the choice of raw material, the form of production, the energy used for transportation and recyclability, to name just a few.

> "Packaging is extremely important, including for sustainability reasons."
>
> Dr. Jens Balko, Fraunhofer IAP

In Germany, the debate often revolves around ways to increase the recycling rate. But the notion of being able to recycle 100 percent of the plastics used for packaging one day is unrealistic. Some material is lost during production or to friction, so there will always be some amount that winds up in the environment. In the case of fossil-based plastics, that means microplastics that linger there indefinitely as pollution. These ultra-tiny particles enter our food and even the air we breathe. Biodegradable packaging materials, by contrast, break down over time. "Biodegradability as a sustainability factor for packaging materials is an aspect that has been underappreciated in the public conversation so far," Balko says.

Fungi could be a solution. At Fraunhofer IAP in the Potsdam Science Park, a team of researchers headed by Dr. Hannes Hinneburg is working to produce packaging using fungal mycelium. This kind of rootlike structure made up of branching threadlike elements is found in various fungi, from edible mushrooms growing in the ground to the oyster mushrooms and tinder fungus that grow on trees. Its job is to break down dead organic matter into substances that feed the fungus. "First, you mix water together with agricultural residues such as straw, wood chips or sawdust to form a mass. Once the moisture level and particle size have been established, and a heat treatment has been conducted to eliminate competing germs, the substrate is ready," Hinneburg explains. The substrate is mixed with the fungal mycelium, nourishing it for several weeks. As the metabolic processes continue, the substrate is penetrated by delicate interwoven "threads" of fungus. "This forms a compact three-dimensional network, enabling a self-sustaining structure to develop," Hinneburg says. Light is not needed for this process, which means production uses less energy.

Dense and stretchable or soft, elastic and fluffy? By skillfully varying parameters such as temperature, humidity, and substrate, researchers can focus on specific properties of interest to the packaging industry, tailoring materials to meet those needs. Hinneburg and his team are already working in collaboration with the Institute for Food and Environmental Research and Agro Saarmund e.G. to develop mycelium-based packaging trays from residues and raw materials sourced from agricultural and forestry activities. Plans call for production trials to be expanded to other mycelium-based materials as well soon, using an innovative prototype roll-to-roll method first developed for production of leather alternatives. But Hinneburg is already thinking ahead: "Production can be further improved ▶

Photo: spacejunkie/Photocase

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by using technologies like artificial intelligence to optimize the combination of residual materials and fungus species."

Paper could be another exciting approach. The challenge is that paper requires a coating to act as a barrier, for example in order to preserve foods hygienically for longer periods. This is why paper bags and boxes often have an ultra-thin layer of plastic inside that protects the contents from moisture, oxidation and other issues. But this coating — think of a paper bag with a layer of polyethylene inside — complicates the recycling process. The Fraunhofer Institute for Process Engineering and Packaging IVV in Freising, Bavaria, is addressing this by researching bio-based paper coatings such as proteins that block oxygen and waxes that can act as barriers to water vapor.

Nanocellulose as a coating material is the focus of another research project, CoatNanoCell. These particulate or fibrous nanostructures are made from 100 percent cellulose, a renewable raw material. Nanocellulose-coated paper is considered a mono-material, so it can be recycled just like regular paper. To achieve this, the researchers at Fraunhofer IVV are developing a method that allows for roll-to-roll application of the nanocellulose coating on paper. This extra layer is also intended to enhance the oxygen-blocking properties of paper packaging to the point that it is adequate for use with food and to provide good protection against mineral oil and grease, with the ultimate aim of increasing the use of recyclable paper in food packaging, which has been something of a rarity to date. In addition, another project, ACCEPT, is working on coatings based on algae.

Researchers at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig are taking a different approach in the BioPlas4Paper project, focusing instead on plant-based oils and bark extracts that already have a natural antibacterial effect. "So far, we have been using untapped plant substances with a high proportion of unsaturated fatty acids to make the paper hydrophobic, meaning it repels water," explains Martin Bellmann, a scientist at Fraunhofer IST. "To do this, we use atmospheric pressure plasma technology, where gas is excited with high voltage under ambient pressure to generate plasma — a particle mixture of ions, free electrons and, in most cases, neutral atoms or molecules — and cause a plasma discharge."

Adding nitrogen turns the plant-based substances into an aerosol that can be introduced into the plasma. The micrometer-sized particles join together to form plasma polymers, penetrating deep into the pores and fibers of the paper and making it water-repellent. The advantage of this complex technology is that depending on the precursor compounds used and the coating parameters, the layers can be optimized on a targeted basis, unlocking more and more potential use cases for paper as a packaging material — possibly even as an alternative to plastic.

But even plastic has true potential in terms of sustainability — that is, as long as it is based not on petroleum, a fossil fuel, but rather on renewable raw materials. One of the leading bioplastics is polylactide, or PLA, a synthetic polymer made from plant starch. When this starch is metabolized by certain microorganisms, the result is lactic acid, which is then polymerized to form granules. The granulate can then be converted into plastic products, a process that typically requires certain additives. Right now, PLA is the most important bioplastic in the packaging industry, where it is used to make transparent windows for sandwich boxes and takeout containers for cold dishes. The only issue is that PLA tends to be fairly brittle as a material, so it is not a good basis for flexible single-use packages like shopping bags — but those are a key source of single-use plastic waste. Certain additives can help make PLA more flexible, but they are not bio-based, some are even harmful to the environment and all of them make recycling more difficult.

Natural packaging: Tree nets are among the items that can already be made from bioplastic or cotton.

Photo: ddp images

In cooperation with an industry partner, chemist Dr. Antje Lieske and her colleagues Dr. Benjamin Rodríguez and André Gomoll from Fraunhofer IAP are tackling an ambitious goal: to develop a long-lasting, flexible packaging film made from PLA that is low in price and lends itself to efficient processing using commonly available machinery. "We went pretty wild at the start and just tried everything," Lieske recalls. The only thing they knew for sure was that polyether needed to be added to PLA as a plasticizer. But what kind of polyether? How much? And how can the additive be incorporated into the PLA so it does not migrate out of the material over time, leaving the bioplastic to re-harden? "As time went by, we started to get a sense for the basic parameters and what happens when you start tweaking this or that factor," Lieske recalls. "The improvements we made got smaller and smaller, but also more to the point."

> "There's a wealth of potential — not as a niche product, but for the mass market."
>
> Dr. Jens Balko, Fraunhofer IAP

The PLA granulate they developed underwent testing at the Processing Pilot Plant for Biopolymers Schwarzheide, which is operated by Fraunhofer IAP. Lieske still recalls the elation she felt when a nicely supple and consistent film was produced as part of this process for the very first time after some ten years of research: "It was awesome!"

The end result is a flexible PLA material that uses no migrating plasticizers at all and, unlike its petroleum-based counterparts, is at least 80 percent bio-based. It is also inexpensive to make using commercial raw materials and a simple synthesis process. SoBiCo GmbH, a subsidiary of industry partner Polymer-Group, has now installed equipment with an annual production capacity of up to 2,000 metric tons of the new bioplastic granulate and is aiming for a production volume of 10,000 metric tons per year in the long term. The researchers' next step is to fine-tune it to nearly 100 percent bio-based while improving PLA's recyclability so used PLA can be utilized to produce granulated plastic of the same quality as new material.

Aside from that, Balko is also focusing on another plastic: polybutylene succinate (PBS), which is made from succinic acid and butanediol. Both of these starting chemicals can be produced from plant cellulose (such as fallen timber or digestate from biogas plants) through fermentation. If this biopolymer ends up in the environment, it breaks down on its own in just a few years, leaving only water and carbon dioxide behind.

"While research on PLA has been ongoing for about two decades now, PBS is still viewed as a relatively new bioplastic, albeit one with great potential," Balko says. Compared to PLA, PBS has a number of favorable properties going for it: It is impact-resistant and flexible and can be shaped into many different forms, from rigid plastic parts to films. PBS also features greater temperature stability than PLA, so it is also suitable as packaging for hot foods and coffee to go.

In the RUBIO project, researchers from Fraunhofer IAP teamed up with companies and other research institutions to develop new types of PBS. The first marketable product was produced in collaboration with Polifilm Extrusion GmbH: mailers made from soft but durable PBS film. Water bottles for use in fitness and sports are another product segment that is under development, this time in cooperation with Sauer GmbH & Co. KG and Gramss GmbH Kunststoffverarbeitung. "The results are highly encouraging, and they open up ▶

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a whole range of other potential uses," Balko says.

Bio-based polymers currently hold a market share of less than one percent in the plastic packaging segment. Balko says there are a couple of factors at work here. First, they are still often too expensive for the extremely price-sensitive packaging industry. On top of that, he says, availability of raw materials from Europe is still too restricted. "However, in our role as an institute straddling the gap between research and industry, we are creating incentives in all directions as we aim to get industry excited about bioplastics. Progress is being made," he explains. "There's a wealth of potential — not as a niche product, but for the mass market." ■

One cucumber with everything, extra hot sauce

From hot dogs to hamburgers and pulled pork sandwiches, buns have caught on internationally as a way to package and hold different foods as fillings. But even a successful concept still has room for improvement: Why not cucumber instead of bread? After all, cucumbers are right on trend when it comes to healthy eating, with water content of up to 97 percent and hardly any calories, fat or carbohydrates. They can also be grown locally and have a significantly smaller environmental footprint than bread.

Cucumber to go: When an industry partner presented this idea to Christian Kaiser at a trade show they were both attending, Kaiser, a researcher at the Valley location of the Fraunhofer Institute for Building Physics IBP, was immediately fascinated: "They had been trying to scoop out the insides of the cucumber to make room for the filling. But that means a lot of the actual cucumber is lost, plus it takes a long time." There must be a better solution, he thought.

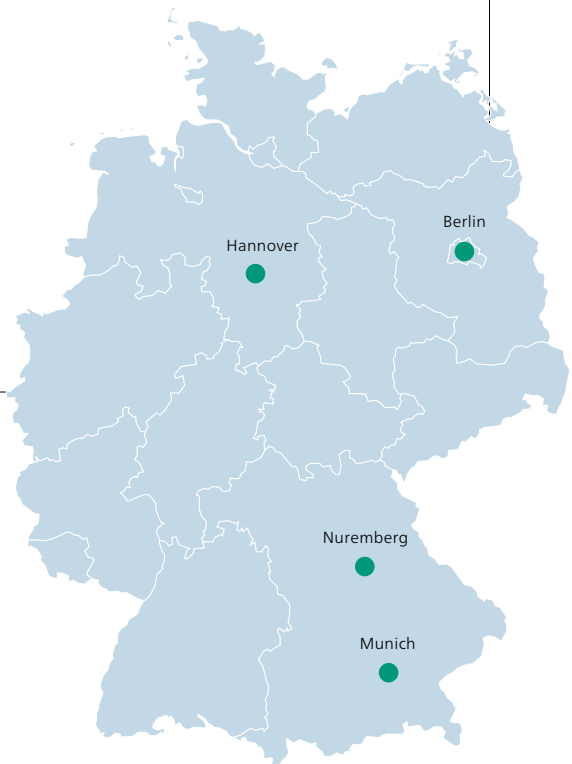
Back at work in Valley, in Upper Bavaria, Kaiser spent two days trying things out in the lab and landed on a better method: ultrasound, not drilling. "Instead of removing the insides, we insert something called an ultrasonic sonotrode and use it to burst the cells inside the cucumber," Kaiser explains. "This creates a smooth, even hollow space, and hardly any water comes out. The probe pushes the remaining flesh of the cucumber to the side, which packs the inside wall down and makes the cucumber easy to fill." The idea was a hit with his colleagues as well. A patent application for the "cucumber hollowing process" was submitted just a few days later.

The idea has now been further developed through Fraunhofer's internal AHEAD funding program to the point that there is no longer any obstacle to licensing it to the start-up that is involved. Fraunhofer IBP is currently developing a prototype to test different configurations. On this basis, Raeder Food GmbH has now commissioned the production of a cucumber machine to establish CUCOO® cucumbers as a healthy, versatile alternative to buns and a sustainable form of "packaging" in the fast food market. The researchers are still looking for an innovative solution for the noise of the cavitation process caused by the ultrasound: "Because the device is equipped with a soundproof outer casing, the machine sounds a bit boring, unfortunately. Maybe we should have our acoustics experts create a typical 'cucumber hollowing' sound for us," Kaiser jokes. Of course, what that might be like remains to be seen — or heard.

Although the Fraunhofer IBP team works with ultrasound to develop new construction materials, the researchers are in uncharted territory as they design the cucumber technology. "Unlike with cement, there's a lot more focus on emotional impact in the food segment." And that is why the researchers have abandoned the idea of hollowing out, peeling and filling the cucumber in a single production step: The subjects who tested the results felt that was too mechanical. In the first taste testing, they preferred cucumbers filled with chunky content by hand. Incidentally, döner kebab, a Turkish meat dish similar to gyros or shawarma, was by far the favorite filling. All of which means things are looking promising, and people may soon be ordering "one cucumber with everything, extra hot sauce."

Photo: Irina Gutyryak/istockphoto

Fraunhofer on the road



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