Fraunhofer
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Fraunhofer

The magazine for people shaping the future

2024 — Time to lighten up
Trends in lightweight construction

PFAS: The poison of the century

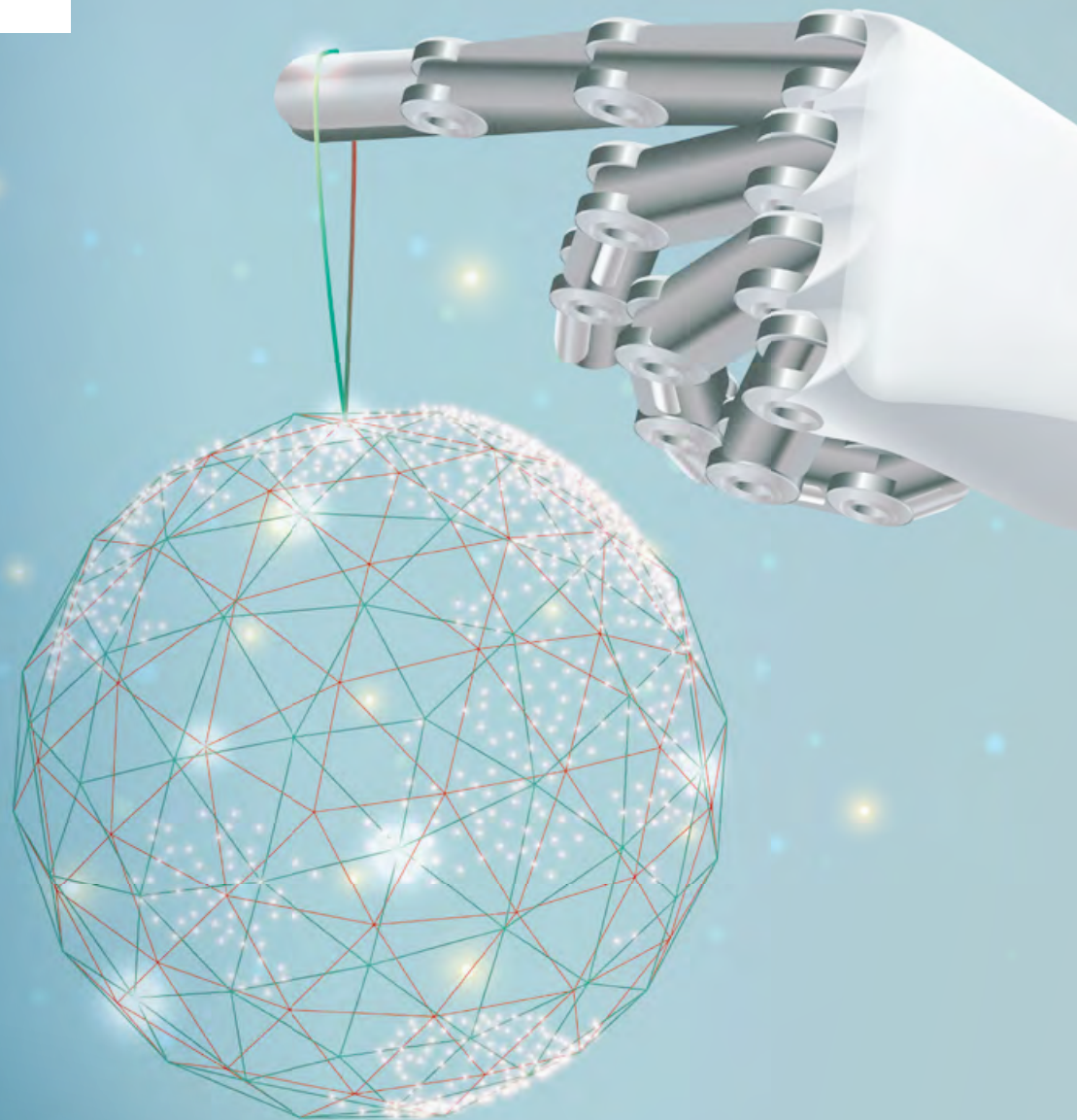
Ways forward for water, industry and the world

Dr. Georg Umlauf, Fraunhofer IGB, points the way toward clean water.

"Pragmatism trumps the sledgehammer approach"
An impassioned plea from Dr. Martin Brudermüller, BASF SE

"I feel like Krampus"
An interview with German finance minister Christian Lindner

Fraunhofer



Season's Greetings

Today's ideas.
Tomorrow's innovations.

Editorial

For industry and the future

By Prof. Holger Hanselka

Prof. Holger Hanselka

As Hildegard Müller said at my inauguration ceremony, "Fraunhofer is developing solutions to the central challenges of our time." Many warm words from that event have stayed with me, but this phrase in particular sticks out. It is not only a recognition of our Fraunhofer-Gesellschaft. It also gives us all a mission and motivation.

A key factor in the Fraunhofer-Gesellschaft's success is our consistent market orientation. Fraunhofer has a clear goal: to transfer knowledge to industry. As a non-profit organization, Fraunhofer supports businesses — particularly small and medium-sized enterprises, which make up more than half of its customer base — with developing new technologies, right up to launching them on the market. Our core business activities in this area are contract research with industry and granting licenses and patents; spin-offs also play an important role.

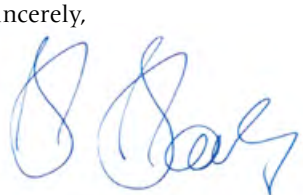
In 2022, Fraunhofer submitted 375 patent applications, registered 443 inventions and had 7,414 active patent families. These are figures that we and our more than 30,000 employees can rightly be proud of. Behind these figures, there is so much knowledge, so much skill, so much passion. But as well as that, there is what makes Fraunhofer so unique in Germany and across the world: the Fraunhofer model. With its balanced mixed of industrial revenue, revenue from public projects and base funding, the Fraunhofer model guarantees that our research and development work is market-oriented, and thus that we can make an impact.

I assure you that one of my areas of focus during my time as president will be driving the process of strengthening our industry. If we want the chance to build a future worth living in, we need a strong industrial sector in Germany and Europe. This means taking consistent steps forward that will add up to major progress. To give a specific example, if the European Chemicals Agency (ECHA) wants to ban the "forever chemicals" PFASs, that will be a huge goal. However, it has so far been almost impossible to replace the per-and polyfluoroalkyl compounds that are used in countless everyday products, as well as in future-oriented technologies such as heat pumps, batteries and medical engineering products. The cover story of this issue of Fraunhofer magazine reports on the many adjustments, both big and small, that Fraunhofer researchers are making to support industry through this difficult but important transition.

We will only be able to tackle future challenges if industry, government and research join forces. So, I am delighted that Dr. Martin Brudermüller, CEO of the world's highest-earning chemical corporation, BASF SE, (and alumnus of the Karlsruhe Institute of Technology (KIT)), has contributed to this Fraunhofer magazine to passionately advocate for a competitive chemical industry and greater openness to new technologies. And I am pleased to see this assurance from German minister of finance, Christian Lindner, in his interview: "I have no problem with using public funds — so long as they're being effectively invested in the future viability of this country."

Let us all work together: researchers, politicians and industrial leaders. With our research, we will carry industry forward into the future.

Sincerely,



Prof. Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer/Stefan Obermeier

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Guardian of the microbes

Fraunhofer IME is home to one of the largest collections of bacteria and fungi in the world — and it has huge potential for fighting diseases.

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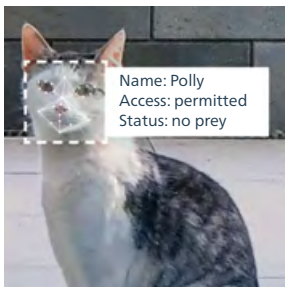
No more compromise for chocolate lovers

Researchers at Fraunhofer IVV are working on a dairy-free, melt-in-the-mouth chocolate.



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The Polly project

A smart cat flap means no entry for outsiders.

Over 1,500 locations in Germany are contaminated with PFAS; around 20 percent of these have been classified as hotspots under the Forever Pollution Project. This project collected and evaluated 100 data sets from across Europe. An important source for Germany: Fraunhofer IME's SumPFAS study.

20 %

Front and back cover photos: Jan von Holleben, Bernd Hartung, Der Tagesspiegel/imago-images; Content photos: Jan von Holleben, photothek/picture alliance, Bernd Hartung, luchschenF/AdobeStock, Jill Chen/Stocksy/F1 Online, Mareike Helbig

Brief report

Modern insulated windows are not only a barrier to heat and sun, but also to radio waves.

Better cell phone reception within buildings

Fraunhofer researchers have made insulated glazing more permeable to radio waves. To do this, they have used a laser to remove strips 50 micrometers in width from the heat-insulating layer. The resulting matrix, which is almost invisible, allows long radio waves pass through while reflecting the shorter waves of thermal radiation back into the building.

Scientists from the Fraunhofer Institute for Solar Energy Systems ISE have been using a prototype facade to test and evaluate different types and configurations of radio-transparent glazing. As a result, they found that the transmitted signal improved by a factor of between 100 and 100,000. The maximum LTE download speed increased by a factor of more than 50.

Their method can be used with thermal and solar control coatings in double and triple glazing in both the construction and automotive sectors. Fraunhofer ISE's industry partners, Arnold Glas and isophon glas, have already launched this product on the market. ■

Safe start for new life

In the future, a smart patch will allow continuous monitoring of embryonic development in the womb. This biocompatible, stretchable, flexible patch will be applied to the skin and allow finely tuned sensors to continuously record vital data and transmit it via Bluetooth to a device such as a smartphone.

Researchers from the Fraunhofer Institute for Reliability and Microintegration IZM have embedded electronics and sensors into this integrated patch; its base material is thermoplastic polyurethane (TPU), which means it will feel like a regular Band-Aid.

To ensure that continuous obstetric monitoring is comfortable for both pregnant people and their unborn children, the Newlife project researchers plan to integrate innovative MEMS-based ultrasound sensors directly into the TPU material. These miniaturized sensors will record data through direct skin contact. Stretchable conductors made from TPU will then transmit the information to the electronic analysis system and finally to a wireless interface, allowing doctors and midwives to view all relevant data in an app. In addition to ultrasound, the researchers are planning to integrate microphones, temperature sensors and electrodes. There are also plans to integrate the sensors into baby clothing in the future to improve the medical monitoring of newborns. ■

Conventional prenatal examinations only capture snapshots. Continuous monitoring can minimize risks.

From a state of emergency to the new normal

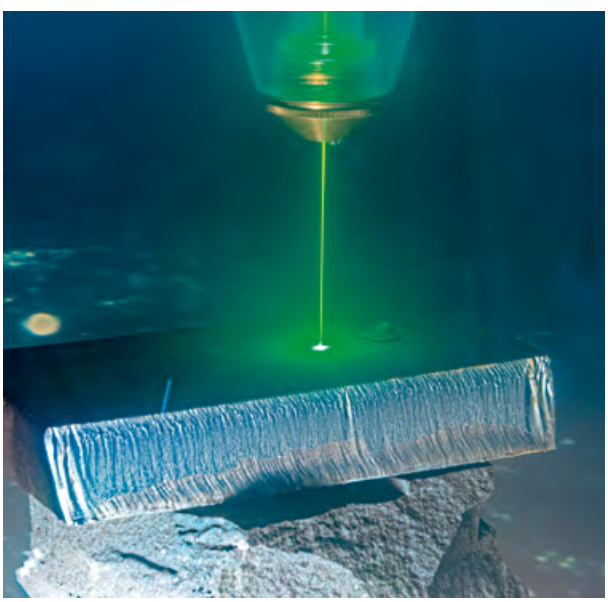
How has our working world evolved in the wake of the pandemic? This is the topic of a new study by the Fraunhofer Institute for Industrial Engineering IAO and the German Association for Human Resource Management (DGFP). The results showed that hybrid working has now become standard practice in German companies. In fact, almost one third of the 400 firms surveyed have scrapped any minimum attendance requirement, and flexibility in office organization and savings on the cost of office space have become par for the course. It is also becoming increasingly common to work remotely from other EU countries for German companies.

However, as a consequence of these types of hybrid working, there have been some negative developments, according to Dr. Josephine Hofmann of Fraunhofer IAO. She notes that the world of hybrid work hinders integration, networking and exchange of ideas among employees. To counteract this, she recommends that companies engage more strongly with their role of providing a "social place." A solid business community, along with measures for building company identity, are necessary for establishing long-term loyalty and a shared ability to innovate. ■

The complete study can be downloaded here:
https://s.fhg.de/hybrides-arbeiten

Everyday collaboration is not just governed by works council agreements, but by regulations set at the individual team level.

Underwater laser cutting



The short-wavelength green laser works in an efficient and environmentally friendly way.

Researchers from the Fraunhofer Institute for Material and Beam Technology IWS have successfully used green lasers with particularly short-wavelengths to work with steel and other metals underwater. Compared to today's common cutting methods that use saws, automatic saw wires and plasma cutters, the underwater laser cutting process requires comparatively little energy, and its power transmission is more efficient. New underwater manufacturing technologies are among the prerequisites for the rapid development of offshore wind energy.

The researchers use the water as a tool to exert pressure and expel the resulting melt from the kerf. Metal is usually cut with lasers in a dry environment using infrared or other long-wave laser radiation. In this process, auxiliary gases are used coaxially to the beam to remove the molten metal. There are different conditions to contend with in the ocean: Water scatters long-wave light in all directions. As a result, a large proportion of the laser output dissipates after a short distance. The auxiliary gas also requires complex piping systems, which this innovative solution from Fraunhofer IWS renders superfluous. ■

Photos: Daniel Ingold, Maskot/Westend61/both mauritius images, Drobot Dean/AdobeStock, Fraunhofer IWS

A 3D model of the seabed can easily be created with the help of a survey vessel.

Precise surveying of rivers and lakes

An autonomous survey vessel for conducting cost-effective, accurate mapping of rivers and lakes has been developed by researchers at the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Karlsruhe. This operational prototype has already been used to carry out successful testing on various lakes.

Watercourse maps need to be compiled and updated regularly by the relevant authorities, which is very costly. These surveys are currently carried out manually with the aid of experts on board specialized mapping vessels. An autonomous survey vessel can reduce the associated costs and time required for this task.

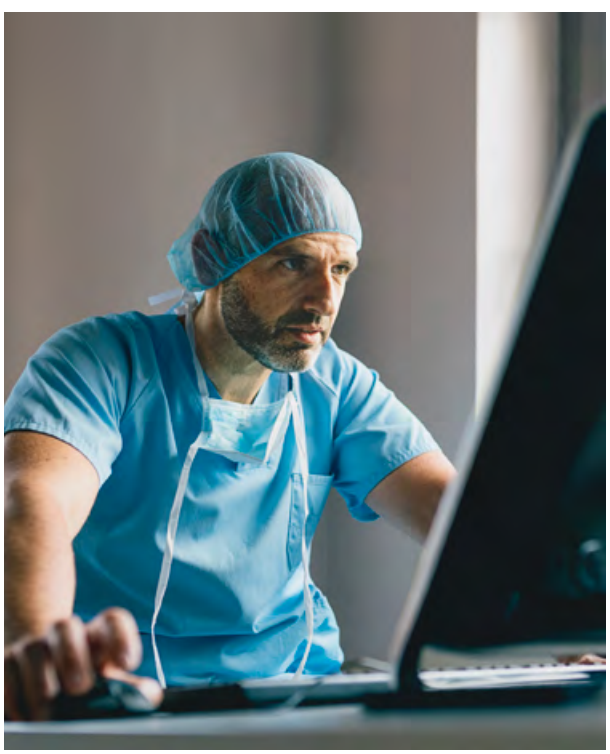
The boat, which is based on a commercially available unmanned surface vessel (USV), is connected to a land-based central control station and can take measurements both above the surface of the water and below, to a depth of up to 100 meters. It is equipped with GPS, acceleration and angular rate sensors, as well as a Doppler velocity log (DVL) — a sensor that enables the boat to feel its way along the bottom of the body of water. The data from the various sensors is merged to guide the semi-automatic navigation system. Laser scanners, cameras and mapping software developed at Fraunhofer IOSB are used to reconstruct high-precision 3D models of the surrounding area. Underwater mapping is carried out with the help of multibeam sonar, which is integrated into the sensor system. ■

Doctor's letters drafted by artificial intelligence

The "doctor's letter generator" being developed by researchers from the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS should free up more time for patient care. 150 million doctor's letters are written every year in Germany. This takes a lot of time away from doctors — time that they need for consultations, providing information and interacting with patients.

In the future, artificial intelligence could take existing documents and automatically extract important information such as medical history, suspected diagnosis and medication administered, and then include this in the doctor's letter issued to each patient on their discharge from hospital. Only the epicrisis — the summary of the hospital stay overall, test results and the recommended treatment — will still have to be written by the doctor.

The Healthcare Analytics Team at Fraunhofer IAIS are currently working with several university hospitals, among them the University Hospital of Essen, to develop various potential methods for extracting information. The doctor's letter generator should be on the market by the end of 2024. ■



Writing a doctor's letter takes an average of three hours.

Editorial notes

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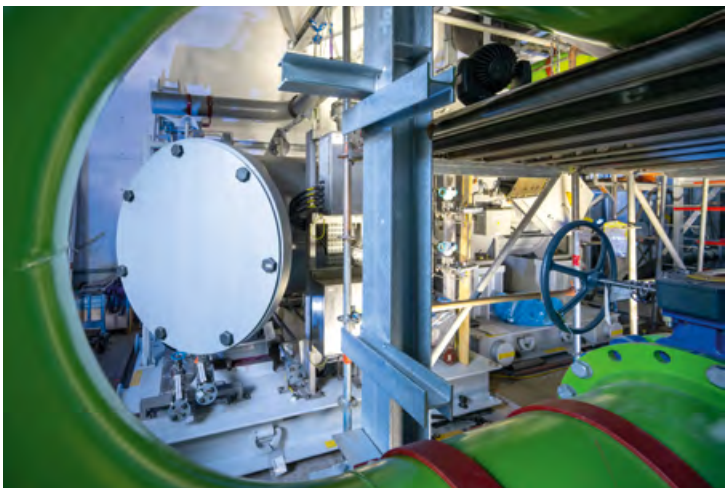

Large-scale heat pumps can tap into different green heat sources for large-scale use.

A giant push for the heating transition

By using heat pumps, in the long-term, Germany could supply all the heating it requires up to 200 degrees Celsius, a Fraunhofer study has revealed. Judicious further development of large-scale heat pump technology will be needed to achieve this.

The amount of heating that heat pumps could supply in Germany using environmental and waste heat exceeds the quantity required for buildings and industrial processes up to 200 degrees Celsius. This was the finding of the "Roll-out von Großwärmepumpen in Deutschland" (Roll-out of large-scale heat pumps in Germany) study carried out by the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG on behalf of Agora Energiewende. In total, the potential quantity of heat that these heat pumps can supply from carbon-free sources — without using heat from ambient air — amounts to around 1,500 terawatt hours. Potential heat sources include shallow and deep geothermal systems, lake and river water, industrial waste heat, coal mines and data centers. On the other side of the equation, Germany's annual heating requirement for temperatures up to 200 degrees Celsius amounts to just over 1,000 terawatt hours.

A lot of hopes are pinned on the large-scale heat pump. "It really is the sleeping giant among sustainable heat technologies," says Fabian Ahrendts of Fraunhofer IEG. Based on long-term scenarios created by the Federal Ministry for Economic Affairs and Climate Action (BMWK), the study shows that by 2045, large-scale heat pumps should be providing 70 percent of district heating, replacing the bulk of natural gas.

Fraunhofer IEG in Bochum has put an innovative pilot plant into operation to drive forward plans for large-scale heat pumps. During the summer, solar thermal energy heats the water in an already flooded mine to 60 degrees Celsius. When heating is later required in fall and winter, the mine water can serve as a heat source for a high-temperature heat pump, which feeds the heat into the local district heating network.

Fraunhofer IEG in Cottbus also has two test stations for large-scale heat pumps. The first measures the performance data of the system in realistic operating conditions for up to 1 megawatt of heating output and flow temperatures of up to 90 degrees Celsius; the researchers can use this data to optimize their heat pump prototypes. In the second station, a 500-kilowatt large heat pump is being tested - the model for a multi-megawatt heat pump that will supply Cottbus with district heating in the future. ■

Lightweight design

It's time to lighten up …

A little light matchmaking: Jana Gebauer, a researcher at Fraunhofer IWS, is searching for ways to marry metals and plastics.

… so we're making things lighter!

Lightweight construction as a future-oriented technology: A multitude of innovative approaches are set to not only reduce the weight of components and products, but also lower their costs and impact on the climate.

By Beate Strobel, photography: Bernd Hartung

Lighter materials: By using a pultrusion process, Michael Wilhelm at Fraunhofer ICT is hoping to make the monomer caprolactam suitable for use in sustainable lightweight construction.

Three wheels, a sturdy frame and a large cargo box: at first glance, the white delivery bike looks like any other cargo e-bike — like the sort people use these days to get their groceries, that parents use to bring their children to preschool or that couriers use to deliver goods. What's different about this bike, developed by the Fraunhofer Institute for Structural Durability and System Reliability LBF, is clear as soon as you start pedaling: Wow, how can a cargo bike be so light?

"Our goal was to develop a truly innovative cargo e-bike using lightweight construction methods — and to include as many different areas of expertise at Fraunhofer LBF in the process as possible," explains Dr. Saskia Biehl, head of the Fraunhofer project L-LBF ("Lasten-LeichtBauFahrrad" (lightweight cargo bike)). So, they bought a commercially available cargo bike with an electric motor, fitted it with sensors, loaded it up to maximum capacity and rode it through the city as well as through fields, forests and meadows to record it in operation under as many conditions as possible, while also identifying weak points. "Then," says Dr. Biehl, "we broke the wheel down into its individual parts to see how we could create a lighter design for the front end, with the goal of reducing the mass by at least 30 percent." By doing so, the team aims to show the huge potential for using lightweight construction methods for micromobility.

In L-LBF, the battery system is now hidden from sight — it has been integrated into the newly designed lightweight frame, rather than being attached externally in another box. The battery system in question is tubular and was developed specially for this bike; it has double the capacity of a commercial alternative. The steel hubcaps were replaced with aluminum variants with a wave design, and the cargo box can be made from either ultralight plastic, up to 100 percent natural materials or entirely from recycled materials. There are also sensor modules that monitor the position and distribution of the load in the cargo box, while also acting as connecting elements between the box and the frame. "More functions, more power — and yet even if we just take the front end, the L-LBF is 39 percent lighter than the original e-bike," says Dr. Biehl.

Lighting the way: The German Federal Ministry for Economic Affairs and Climate Action (BMWK) has highlighted lightweight construction methods as a key technology for the future. In July 2021, the German federal government agreed on a lightweight construction strategy. Lightweight construction is not just about making slight reductions in mass. This construction philosophy focuses on selecting materials, designing products and carrying out production processes in a way that conserves materials and makes products lighter, while also improving functionality and safety at the same time.

> "Lightweight construction technology helps to reduce many different industries' environmental footprints and to support the transition to a more sustainable industrial sector."
>
> Prof. Alexander Böker, director of Fraunhofer IAP

Heavy objects are a burden on the environment. If a car is made 100 kilograms lighter, its fuel consumption decreases by around half a liter per 100 kilometers. That doesn't sound like much, but considering cars in Germany travel 582.4 billion kilometers per year, it quickly adds up to an enormous amount. Reducing the weight of an Airbus 320 by 100 kilograms saves almost 10,000 liters of kerosene per year. The fact is, the consumption of raw materials globally has more than tripled since 1970 and around half of global greenhouse gas emissions now stem from raw material extraction and processing. Smart lightweight construction uses less material — which helps reduce the German industrial sector's dependence on raw material imports and lessens the financial strain on companies, as 43.2 percent of costs in the manufacturing sector come from material procurement.

"Lightweight construction technology helps to reduce many different industries' environmental footprints and to support the transition to a more sustainable industrial sector," says Prof. Alexander Böker. The director of the Fraunhofer Institute for Applied Polymer Research IAP believes that, when combined with digitalization and bionics, lightweight construction can open up new opportunities in emerging future markets, thus serving as a driver for increasing resource and energy efficiency.

However, for these industries, the transition to lightweight construction is not a step to be taken lightly; the transformation requires a whole new way of thinking. According to Prof. Böker, research has a vital role to play here: "In order to ensure that industry, particularly ▶

Light exercise: Dr. Saskia Biehl of Fraunhofer LBF and her team have done more than just optimize the mass of their cargo e-bike.

"The right material for the right price in the right place."

Prof. Holger Seidlitz, Fraunhofer IAP

Lighter production: Prof. Holger Seidlitz is working on designing fiber-reinforced plastics for lightweight construction — such as this automated fiber placement system.

the SME sector, can harness the huge opportunities for transformation offered by lightweight construction, we need to accelerate the process of transferring scientific knowledge to practical application."

Lightening the load… with smart material choices

"The right material for the right price in the right place": according to Prof. Holger Seidlitz, director of the Polymeric Materials and Composites PYCO division at Fraunhofer IAP, this is the formula for success when it comes to lightweight construction. The aim is to find materials and components that not only allow for lighter products, but also guarantee the required functionalities and levels of safety at an economically viable price.

In this respect, carbon fibers are the "black gold" of lightweight construction. First of all, they are incredibly light and yet extremely strong — this means they can be used as a substitute for metal, greatly reducing the mass of products. They can also be used in carbon fiber-reinforced plastics (CFRP), which can be molded into almost any shape while still making any product they are incorporated into rigid and strong. The drawback is that manufacturing these fibers is a highly complex, energy-intensive process. At the Carbon Lab Factory Lusatia, a joint initiative by the German states of Saxony and Brandenburg that involves close collaboration by the Fraunhofer Institutes IAP and IWU, the Brandenburg University of Technology Cottbus-Senftenberg and the Chemnitz University of Technology, the plan is to develop and produce "green" carbon fibers in the future. Could these fibers be spun from local, renewable raw materials? And how far can renewable energy sources go toward improving the environmental footprint of CFRP production? According to Prof. Seidlitz, the circular economy approach could also help transform carbon fibers from the "black gold" to the "green gold" of lightweight construction: "The longer we can keep carbon fibers in the cycle, the better it is for the environment."

As part of the TransHyDE project MUKRAN, Fraunhofer IAP is collaborating with five partners from science and industry to examine ways of optimizing the circular economy for CFRPs. Led by Prof. Seidlitz, the researchers have developed two types of spherical storage tanks for hydrogen. Just their shape alone helps to save mass: Due to the laws of physics, the walls of conventional cylindrical tanks need to be twice as thick as the spherical tanks. "Tanks made from pure steel also have many times the mass of those made from CFRPs," explains Prof. Seidlitz. This high mass also increases fuel costs, as the chassis and brakes of the vehicles that transport these tanks must be reinforced. And this will eventually raise the question as to whether hydrogen is actually an environmentally friendly solution.

To avoid using unnecessary quantities of expensive carbon fibers, researchers in the MUKRAN project are searching for ways to make hydrogen storage containers that are light, yet sturdy. To assist with this, the research team at Fraunhofer IAP develops technologies such as sensors that can be applied to the fiber-reinforced composite parts using printed electronics — "layer by layer, where possible, so that we can find out more about what happens inside the material when it is under stress," says Prof. Seidlitz. This information will be crucial for designing and constructing the containers efficiently. Later on, when the high-pressure tanks are put into operation, the sensors will also be useful for condition monitoring.

The tanks are being tested at locations such as the ZenaLeb (Zentrum für nachhaltige Leichtbautechnologien, "center for sustainable lightweight technologies"), a project group that involves collaboration between Fraunhofer IAP and the Brandenburg University of Technology Cottbus-Senftenberg, and is funded by the German state of Brandenburg. The aim of ZenaLeb is to develop efficient lightweight structures and bring them into mass production.

> "The CFRP door frame is not only significantly lighter, but also more economical, because we have implemented automated manufacturing processes that make efficient use of materials."
>
> Kevin Scheiterlein, Fraunhofer IGCV

Another innovation has already made the leap from the lab to implementation: As part of a wide range of aviation projects funded by the BMWK, researchers at the Fraunhofer Institute for Casting, Composite and Processing Technology IGCV have collaborated with the aviation supplier Premium Aerotec in Augsburg to develop new technologies for efficiently manufacturing structural components from CFRPs. The team ultimately succeeded in replacing the titanium frame of the door in an Airbus 350 with one made from CFRPs. "The CFRP door frame is not only significantly lighter, it's also more economical because we use automated manufacturing processes that make efficient use of materials, such as automated fiber placement," says Kevin Scheiterlein, group manager for Fiber Placement and Composite Molding at Fraunhofer IGCV. ▶

"Lightweight construction is an interdisciplinary field," says Prof. Seidlitz: In order to make the technology available for a wide range of industries, research findings from all along the value chain must be pooled and the relevant synergies must be harnessed. This approach has been wholeheartedly adopted by the Fraunhofer Research Field Lightweight Construction, a consortium of 14 Fraunhofer institutes. The consortium acts as an expert point of contact and support for industry, with services ranging from developing new materials and material combinations to efficient, automated manufacturing and joining technologies right through to sustainable construction methods and suitable testing processes.

The institutes participating in the Fraunhofer Research Field Lightweight Construction include the Fraunhofer Institute for Mechanics of Materials IWM, which focuses on testing technology — this sub-area of the lightweight construction field is key in determining how much material can actually be saved without risking functionality and safety. "The more I learn about a material and the more comprehensively I can characterize it, the closer I can get to the limit," explains Dr. Jörg Hohe, group manager for Composite Materials in the Component Safety and Lightweight Construction business unit at Fraunhofer IWM. His team is studying polymer, ceramic and metal matrix composite materials to determine their operational properties, with the aim of reducing costs in material and component development.

The problem is, even within the same batch, no two components are 100 percent identical — small fluctuations always arise during production. On top of that, many composite materials and solid foams have a particularly irregular microstructure and so their material properties can vary widely. However, for safety-critical components such as those used in the aerospace sector, the automotive industry, construction and hydrogen transportation, when it comes to selecting materials, researchers can't only look at the mean values — the whole scatter plot must be taken into account. So is it better to use a bit more material to be on the safe side? "That usually leads to 'oversizing' — and means the potential of lightweight construction is not being exploited to the fullest," says Dr. Hohe.

In order to predict the variance of material properties in a more accurate and cost-effective way, researchers at Fraunhofer IWM have developed processes for creating numerical simulations of composite materials and components. These simulations allow them to predict the expected range of the fluctuations. Dr. Hohe explains: "With the simulation, we obtain data that we can't directly measure though experiments — in inaccessible areas where we can't take measurements, for example."

However, anyone who works with natural-fiber-reinforced plastics (NFRPs) can only look on with envy at the range of fluctuation for CFRPs and the discussion around how far they can go in replacing petroleum-based plastics. It is difficult to apply existing models and processes to NFRPs for multiple reasons: "For one thing, they are less homogeneous, and for another, they also have special properties in terms of moisture absorption and thermal stability," says Dr. Christian Beinert, head of the Polymer Processing and Component Design department at Fraunhofer LBF.

In the BMWK-funded COOPERATE project, Fraunhofer LBF researchers are investigating how biopolymer composites can be used in lightweight construction. "The main focus of our research right now is motor vehicle components that are put under high levels of mechanical stress," explains project manager Georg Stoll. "We want to reduce CO_2 emissions — first of all, by replacing petroleum-based polymers with biogenic plastics, i.e., plastics made with linseed oil or other renewable raw materials." The researchers' second tactic is to use as little of this plastic as possible. "By combining these two approaches — substituting materials and using less material — we expect to see a reduction of 75 percent in our carbon footprint."

The researchers hope that newly developed digital modeling methods will help here: "We not only look at the component in its final form, but also how the component is filled with material during the production process, the direction of the fibers and the local material properties that occur as a result," explains Mr. Stoll. The design and production processes will be set up so as to make the material as sturdy and as rigid as possible — by ensuring that the fibers are positioned in the right way in the areas that experience the highest levels of stress. Developing the models required for this will be crucial for lightweight construction, adds Dr. Felix Dillenberger, deputy head of the Polymer Processing and Component Design department, who is in charge of the Mechanics and Simulation research field at Fraunhofer LBF. "The more effectively we can digitally map and optimize the production process and material properties, the more material we will ultimately be able to save." ▶

> "The more I learn about a material, the closer I can get to the limit."
>
> Dr. Jörg Hohe, Fraunhofer IWM

Vibro-acoustic metamaterials: For a lighter, quieter world

Contains metamaterials: A VAMM exhibit shows how this innovative idea can be put into practice.

In addition to its many advantages, lightweight construction also has one big drawback. While objects with a large mass usually do not vibrate much at all, a low weight means the opposite: there is often very significant vibration and high levels of sound radiation. In order to make a car as quiet as possible, the car doors — which are often just made from thin sheets of metal — will generally be fitted with sheets of sound insulation material. While this is understandable from an acoustic designer's perspective, it causes problems when it comes to lightweight construction objectives.

Researchers at the Fraunhofer Institute for Structural Durability and System Reliability LBF are looking to overcome this obstacle as they work toward building lighter structures: Vibro-acoustic metamaterials could help strike a balance between reducing mass and blocking out noise. "Metamaterials are artificially manufactured materials with properties that do not occur in nature," explains Heiko Atzrodt, a researcher at Fraunhofer LBF. The interactions between this material and the special structure applied to it can be used for tasks such as influencing light waves and guiding them around an item so that it cannot be seen. Was Harry Potter's Invisibility Cloak made from a metamaterial then? It's quite possible!

In MetaVib, part of Fraunhofer's internal PREPARE initiative, researchers at Fraunhofer LBF have developed a metamaterial with vibro-acoustic properties. "We create microstructure elements that can be integrated into the original material; this allows us to achieve virtual negative mass in certain frequency ranges," explains project manager Mr. Atzrodt. "Because it is not possible for vibrations to be created or sound waves to spread where there is no mass." The resonators that are used in this material must be arranged in a particular way to reduce sound: the spaces between them must be smaller than half of the wavelength of the oscillation that they need to reduce. Only then can they generate stop bands in the sound transmission — meaning the resonators can stop the airborne sound waves from spreading, convert them into structure-borne sound waves and finally absorb them.

One of the first projects to use vibro-acoustic metamaterials (VAMM) was Silent Running. The goal of this project was to develop a technology that can help minimize micro-vibrations in rocket components. In space travel, it is important to not only minimize weight, but also ensure minimal vibrations to avoid affecting measurements taken on board using optical instruments. In July 2023, the VAMM technology was awarded a prize for being among the best ideas to be submitted by a research institution to the INNOSpace Masters competition since it began. INNOSpace Masters is a competition initiated by the German Aerospace Center (DLR) to recognize innovations in space travel.

One advantage of vibro-acoustic metamaterials is that they are not limited to a certain material. "Wood, rubber, residual materials, recycled materials — anything is possible," says Mr. Atzrodt. "That means specific materials can be used that reduce not just the weight of a product, but its carbon footprint as well." In the MetaVib project, in addition to investigating how metamaterials can be used as sound insulation in car doors, researchers are developing other forms of VAMM with functions that can be individually customized. Mr. Atzrodt explains: "We now have a standard catalog that lists all the variations of resonators and materials we can use, which makes it easier to develop a solution for a specific case."

As part of a new project, Fraunhofer LBF is putting an innovative technology for glass sound barriers into application in collaboration with ASFINAG, the Austrian public corporation that manages the country's highways. These barriers will help to lower noise levels by up to 20 decibels. Reducing noise levels by just 6 decibels is enough to halve the amount of sound perceived by the human ear. The VAMM barriers will soon be tested on certain Austrian highways and expressways.

As part of the collaborative project LowCarboVan, Fraunhofer LBF is working on a very practical use for NFRPs: in the cladding of conventional motor homes. "As demands for comfort are increasing, these vehicles are getting bigger and their designs are becoming more elaborate," explains project manager Dr. Dillenberger. "So they're gradually heading toward the limit of what is allowed under a regular driver's license. That's why this industry is very interested in developing a lightweight version."

> "This industry is very interested in developing a lightweight version"
>
> Dr. Felix Dillenberger, Fraunhofer LBF

The aim of the research project is to develop technical solutions to reduce moisture absorption by the flax fibers used in the exterior cladding that is exposed to the elements. This development will be important for a multitude of other potential NFRP applications. The researchers' goal for 2024 is to create a prototype motor home that is lighter than conventional models and has natural fibers in its cladding — and to get it on the way to series production.

Lightening the load… with innovative production processes

How does a lightweight material become a lightweight component — i.e., a component that helps the manufacturing industry to easily swap its standard materials and processes for alternatives? One possible option is pultrusion, a process that can be used to efficiently and cheaply produce continuous fiber-reinforced plastic profiles that are light and very robust. This process involves impregnating glass or carbon fibers with plastic, before pulling them through a heated tool and then curing them. "It's a highly automated process that we can use to produce large batches, so it's also suitable for series production," says mechanical engineer Elisa Ruth Bader, a research scientist at the Fraunhofer Institute for Machine Tools and Forming Technology IWU.

In addition to manufacturing straight profiles, researchers at Fraunhofer IWU are now also able to produce curved profiles (radius pultrusion). These can be used to create many different shapes, from solid profiles to complex multichamber hollow structures. Fraunhofer IWU researchers are also looking into producing hybrid profiles — combinations of fiber-reinforced plastics and

Naturally lighter: At Fraunhofer LBF, Dr. Christian Beinert (left) and Dr. Felix Dillenberger are researching the use of biopolymer composites in lightweight construction — they are pictured here with a natural fiber-based organic sheet that can reinforce technical components.

other materials — and incorporating shape-memory alloy wires that can measure strain into the profiles, thus upgrading them by including sensor technology. Ms. Bader believes that "pultrusion is a process that holds great potential for lightweight construction."

In the lighthouse project ALBACOPTER, which is coordinated by the Fraunhofer Institute for Transportation and Infrastructure Systems IVI, six Fraunhofer institutes are bringing their expertise to the table to develop a particularly lightweight, sustainable, aerodynamic drone. As part of this project, the Fraunhofer Institute for Chemical Technology ICT has developed pultrusion profiles made from fiber-reinforced thermoplastic that will be used in the drone's frame. The researchers have chosen to use a mono-material sandwich structure for the drone's cargo box. "This enables the box to be recycled to an excellent degree at the end of its service life, as although the box is made up of several layers, including foam layers, we're only using a single type of plastic,"explains Michael Wilhelm, group manager for Structural Composites at Fraunhofer ICT. The idea is that this type of aircraft could some day perform tasks such as autonomously delivering goods in cities.

Mr. Wilhelm is also working on further advancements to the pultrusion process. His research is mainly focused on the monomer caprolactam, which is used to make polyamide 6. "This monomer is as fluid as water," says Mr. Wilhelm. "That means reinforcing fibers such as glass or carbon fibers can easily be soaked in it and impregnated to the maximum possible extent." In addition, the thermoplastic matrix allows parts to be shaped or thermally joined later. "And when the parts reach the end of their service life," Mr. Wilhelm adds, "the material can simply be ground down and put to use in a new application through injection molding. One advantage of this is that the properties of the material are almost as good as those of virgin injection-molded material. That allows us to create a very simple closed material loop."

However, this process comes with a challenge: Caprolactam's low viscosity means special tools and processing machinery are required. In the CaproPULL project, a consortium consisting of Fraunhofer ICT and several industry partners developed in-situ pultrusion as a method, whereby the monomer can be processed to form stable, durable profiles made from continuous fiber-reinforced thermoplastics. Mr. Wilhelm believes these types of profiles could be used to provide localized reinforcement for components in the automotive industry, for example. However, the construction sector could also be another potential field of application: "Unlike steel, the fiber-reinforced plastics don't corrode," the expert explains. "This could significantly extend the life span of structures such as bridges." ▶

Take the weight off: At Fraunhofer IWS, Andrea Berger has developed a process for manufacturing lightweight panels quickly and cheaply.

And what about 3D printing — could this be a game-changer for lightweight construction? After all, additive manufacturing is well suited to producing complex forms with hollow internal structures, which saves material and reduces mass. Along with other industry partners, researchers from the Fraunhofer institutes LBF and IWU are investigating this approach as part of the joint research project ECO_2-LInE. The goal of the project is to develop natural fiber-reinforced plastic components that could replace metal structures and that are suited to SEAM, a particularly fast method of additive printing. "In this way, we want to manufacture sustainable components to be used in internal and external vehicle structures — for cars, buses and trains alike," says Dr. Dillenberger of Fraunhofer LBF. "3D printing allows us a great deal more freedom in designing components than injection molding does, for instance."

However, sometimes there's no way around using metal. Does that have to mean a lot of mass? Since January 2023, Fraunhofer IGCV has been working with an international team of experts on the EU-funded project MADE-3D (Multi-Material Design using 3D Printing); the team is researching methods of manufacturing multi-material components that are strong but light.

"We want to join metals together using an additive process so that we can exploit their special properties to the highest extent possible," explains Christopher Singer of Fraunhofer IGCV. The concept of creating alloys, i.e., making materials from at least two elements, is crucial to lightweight construction, as the individual ingredients' "talents" can still be utilized, but with less weight. This means that expensive metals such as titanium need only be incorporated into products in places where their properties are needed. "In terms of processes, we are mainly looking into laser beam melting and laser material deposition — these are both additive technologies that can be used to manufacture unusual structures and that can also help to incorporate the individual metals into the alloy in a targeted way."

The use of machine learning will help researchers to design the ideal materials for specific areas of application. By using lighter metals and less material and customizing the material's functions, the weight of individual components could be reduced by up to 50 percent.

> "We want to join metals together using an additive process so that we can exploit their properties to the maximum extent."
>
> Christopher Singer, Fraunhofer IGCV

The Fraunhofer Institute for Material and Beam Technology IWS is focusing on joining metals to fiber-reinforced plastics. Simply gluing the two materials together is the wrong move, as Jana Gebauer, a researcher at Fraunhofer IWS, explains: "Not only do adhesives take a long time to harden, but they also age, which shortens the components' life spans." For this reason, researchers at Fraunhofer IWS have been working on alternative solutions for joining metals and FRPs. One of these methods involves applying a protective, functional layer of metal to a plastic composite using thermal spraying. According to Ms. Gebauer, the trick is to pre-treat the plastic: "A rough surface is not enough for components that are put under this kind of complex stress. We need to create structures with a laser so that we can make a reliable join between the hot metal and the cold FRP." First of all, pulsed laser radiation is used to very precisely the fibers in the plastic matrix, but without damaging them. The sprayed particles stick to these fibers. Additional indentations are then made that act like a clamp or a hook-and-loop fastener.

"As the thermal spraying process is suitable for a multitude of materials, this technology can be scaled up to be used for other applications and sectors," says Ms. Gebauer. In the CHIMERA project by the German Federal Ministry of Education and Research (BMBF), this process is currently being used to develop battery housing with electromagnetic shielding. The HPCi® technology for combining metals and plastics using direct thermal joining was also developed by Fraunhofer IWS. This technology has already been put into use as a joining tool in the manufacture of car bodies and aircraft.

Fraunhofer IWS is also responsible for another lightweight construction method: laser roll welding. "This enables us to manufacture lightweight panels quickly and cheaply — and they are especially durable and don't use any adhesives, which makes them easier to recycle," explains Andrea Berger, a researcher at Fraunhofer IWS. At the core of the sandwich panels, there is a light, metal structure with hollow chambers and thin metal sheets are fixed to each side. The internal structure is then rolled between two rollers, while a scanned laser beam heats the surface of the metal between the rollers from above and below; this is done at lightning speed and with high precision. The rollers press the sandwich elements together so tightly that they are permanently joined. "Because ▶

this involves a roll-to-roll process, we can achieve very rapid production," says Ms. Berger. "In addition to its low energy requirements, this speed makes the process very attractive to the manufacturing industry — for shipbuilding or metal building construction, for example."

Lightening the load… with smart design

The batteries in electric cars are heavy: In small cars, they weigh about 250 kilograms, while large limousine batteries can weigh as much as 700 kilograms. Larger batteries guarantee longer ranges, but they come with another problem: The bigger a traction battery, the larger its environmental footprint will be. Fraunhofer IWU wants to use smart design methods to unlock the potential for optimization here in terms of sustainability. In collaboration with the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, the Institute for Surface Engineering and Thin Films IST and the Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI, the IWU is working to design a new battery housing as part of CoolBat — a project funded by the BMWK. They are aiming to "accommodate all the required functions with fewer individual components and fewer joins — and the joins that are used will be easy to dismantle," explains project coordinator Rico Schmerler, a research scientist at Fraunhofer IWU. To do this, they will take steps such as integrating the temperature control channels into the support structures. Aluminum foam in the base plate, used in combination with phase-change material, assists with cooling the battery. At the same time, it provides protection if any accidents occur, as it can absorb the energy from the impact.

The goal of CoolBat is to increase the range and charging speed of batteries "while saving 15 percent of the CO_2 emitted per battery housing over the entire life cycle," explains Mr. Schmerler. The holistic approach is key to this project: "We test and assess all our ideas to see what CO_2 savings we can potentially achieve by making better choices in terms of materials, technologies, and manufacturing methods."

"The potential of lightweight construction technologies is far from being fully unlocked," says Prof. Alexander Böker, director of Fraunhofer IAP. "Developing new materials, manufacturing methods and applications can hugely increase efficiency and significantly reduce the environmental footprint." For some industries, the transformation toward lightweight construction will bring enormous challenges, such as high costs, safety requirements and the need to adjust existing production processes. "Regardless, lightweight construction is an important step toward a sustainable future," insists Prof. Böker. "And most sectors will need to move in this direction if they're going to stay competitive." ■

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For interested parties from industry
More about Fraunhofer Match
on page 79

The unbearable lightness of being photographed: To produce the photos for this article, Frankfurt-based photographer Bernd Hartung draped fiberglass roving around researcher Michael Wilhelm (left) and got Dr. Felix Dillenberger to jump on a trampoline (right). He made it look effortless — and his subjects weightless.

Impressive strength: Rico Schmerler of Fraunhofer IWU uses a powerful press to manufacture cleverly designed metal sheets for sustainable electric car batteries.

A voice from the business world

Martin Brudermüller, 62, wants to power ahead with a green transformation at BASF. Important drivers for this are the switch to green electricity and more climate-friendly production processes.

Pragmatism trumps the sledgehammer approach

Everyone agrees on the goal: Europe will become the first climate-neutral continent by 2050. However, there is still debate around how to achieve the great task of this century. One thing is clear, though: It cannot happen without a strong and competitive chemical industry.

Martin Brudermüller, CEO of BASF SE, offers his view

The chemical industry is undergoing the greatest transformation in its history. This industry, one of the most emissions- and energy-intensive, is aiming for climate neutrality. This demands not only ground-breaking innovations, but also suitable framework conditions and political pragmatism. BASF is backing the Green Deal. That is why we are doing our utmost to achieve net-zero carbon emissions by 2050. But what will the future of chemistry look like at BASF?

The chemical industry is everywhere. It is the "industry of industries" and supplies its products to almost every sector. Chemistry is the place where we most need to make things greener. Resins make wind farms weatherproof. Solar plants can only function with the help of electronic chemicals, while electric mobility is dependent on battery materials.

However, the chemical industry also generates a high level of CO_2 emissions. We are changing this. An important driver here is the shift in our electricity and steam supply from gray to green. For example, only a few weeks ago, one of the world's biggest offshore wind farms commenced operations off the Dutch coast with the participation of BASF — and without any subsidization. Around half of the green electricity generated there flows to our locations in Europe. Our new collaborative site, located in the southern Chinese city of Zhanjiang, will be powered by 100 percent green electricity from day one.

In addition, to reduce CO_2 emissions during production, we are developing and trialling new technologies in pilot projects — our primary focus here is on basic chemicals, the emissions-intensive fundamental building blocks that make up thousands of our products. For example, the world's first pilot plant for electrically powered steam cracker furnaces will commence operations in Ludwigshafen in early 2024. With this technology, we can reduce the CO_2 emissions generated during ethylene and propylene production by more than 90 percent. We are also testing the possibility of using water electrolysis on an industrial scale to replace the carbon-intensive steam reformation process in hydrogen production.

Reducing CO_2 emissions during production means we can in turn offer our customers products with a reduced carbon footprint, thus supporting them in achieving their own climate protection goals. We regularly calculate the carbon footprint of all BASF's 45,000 commercial products. On the basis of this information, we optimize our processes, increase our efforts to use low-carbon, renewable raw materials and expand our portfolio of low-carbon products.

We at BASF are willing to strive toward climate neutrality, and we are on the right road to achieve this. However, we are reliant on the government doing its homework too. They need to ensure that climate protection and competitiveness go hand in hand. There are four crucial elements here:

First — more pragmatism. Europe already has one of the world's most comprehensive and effective chemical regulation systems. With the Green Deal, this system is becoming even more extensive: It has already consists of some 14,000 pages. However, instead of using regulations as a sledgehammer, we need to introduce a set of guidelines that can be implemented pragmatically.

Second — more speed. Almost all climate-friendly technologies are based on green energy. We therefore need a greatly accelerated plan to extend the use of renewables throughout Europe. The suggested approaches for speeding up planning and approval procedures are promising. Now, these must become a reality, and quickly.

Third — more openness. Many technologies for achieving a climate-neutral future are as yet unknown to us. We must therefore remain open to new ideas, rather than hindering innovation by labeling some as off-limits. Unfortunately, we in Europe have a mania for discussing potential dangers and prohibiting new technologies — instead of conducting a rational risk assessment and exploiting the opportunities they present.

Fourth — more incentives for investment. Restructuring the industry in a climate-neutral way is a costly process. The problem is that investments often lack a business model. Despite this, we at BASF are still getting involved — out of entrepreneurial responsibility and in the spirit of the global innovation race. Nevertheless, living laboratories and non-bureaucratic support are needed to generate growth from innovative ways of thinking. What's more, pioneering work must be profitable. The USA has given an impressive demonstration of how incentive schemes can be used with the Inflation Reduction Act.

The goal of industry, government and society should be a green transformation that links climate protection, innovation and competitiveness in a pragmatic and effective way. This is the only way to make an ambitious vision into a success story for everyone. ■

"There's no sorcery to it: The green transformation will succeed through innovations in chemistry."

Dr. Martin Brudermüller

- is CEO of BASF, the largest chemical corporation in the world with over 110,000 employees in 91 countries.
- was born in Stuttgart in 1961. After studying chemistry at the University of California, Berkeley, USA, followed by a doctorate and post-doc position, he embarked on his career with BASF in 1988. His many years of research were followed by various functions and postings in Germany and abroad.
- has been a member of the executive board since 2006. He took on the role of chair in 2018.
- holds numerous honorary positions, among them president of CEFIC, the European Chemical Industry Council, member of the BDI presidential board and vice-president of the VCI (German Chemical Industry Association).

Photo: BASF SE

Interview

“I want us to look toward the future.”

There’s a 60 billion euro gap in his budget, he’s had to put an emergency stop to the debt brake and a new era is looming in the world of interest rates: In this interview, German finance minister Christian Lindner makes a case for investing in the future. As he puts it, the very fact that so much has been left undone is what “gives us such wide scope for shaping the future.”

Interview: Josef Oskar Seitz

German finance minister Christian Lindner will celebrate his 45th birthday on January 7, 2024.

Mr. Lindner, there's been a certain Christmassy feeling in the political sphere over the last few weeks: Everyone gets to make a wish. You enjoy sporting a snowy beard — do you feel like Santa Claus?
When I think of the creative wishes for tax increases, I feel more like Krampus.

In your time as finance minister, you have stubbornly defended the debt brake. But where does Germany need to step on the gas?
The need for action in Germany is plain for everyone to see. We must make investments in infrastructure, the digital transformation and education our priority. The public funds we have are enough to cover this, provided that we set sensible priorities. What's more, when it comes to economic competitiveness in particular, we can achieve great things without actually spending money — for example, by cutting back on red tape and accelerating planning and approval processes.

It's been an expensive few years for Germany: We've had Mr. Scholz's "double whammy" energy price brakes, a 180 degree shift toward rebuilding military power due to the war in Ukraine and a hefty rescue package back in the early days of the COVID pandemic. Do you have to skimp on Germany's future viability because in the past, we have been too focused on the present?
A combination of past crises and the insufficient level of investment in the future during the pre-COVID era is limiting our scope for action in this period of dramatic change in the interest rate landscape. I want us to look toward the future. Because the very fact that so much has been left undone is what gives us such wide scope for shaping the future.

There's a lot of rumbling about crises at the moment: Is there still scope for shaping the future beyond all that?
Crisis management goes hand in hand with efforts to shape the future. If we consider the major effects of the crisis — rising prices for fossil-based energy sources, ending our neglect of our armed forces — then we will see that these were tasks that we would have had to tackle in any case. Perhaps some people might wish we had more time to accomplish them. But for responsible politicians, these are not tasks that we can shirk.

How do you intend to ensure that Germany can make adequate investments in the digital transformation, climate protection and technology to secure its future?
As I explained earlier, we are already investing at a record level through the priorities we have set in our budget. That's what we can do in terms of public funding. However, we cannot afford to forget that this accounts for only 1 in every 10 euros of investment in Germany — so our primary focus must be on mobilizing private funding. This is why I am working to create better conditions for private investments — for example, through the Financing for the Future Act (Zukunftsfinanzierungsgesetz). With the Growth Opportunities Act (Wachstumschancengesetz) on the other hand, we're expanding fiscal support for research and development.

Let's take a concrete example: This Growth Opportunities Act, one of the showcase projects of your ministry, is in the pipeline as we speak. What effect do you hope it will have on Germany's position as an innovation location?
To keep things brief, I'll break this down into three points: The reduction of strain on small and medium-sized enterprises, the creation of more incentives for private investments and the provision of better conditions for industry in Germany.

What role will research have to play in Germany's future?
A big one. Because unlike in decades gone by, administration alone is not enough anymore. To safeguard our future viability, we need to tap into new sources of prosperity. We have the necessary know-how. What I — and my colleague, Bettina Stark-Watzinger — want to do is ensure that we also have the ideal conditions for this.

Let's talk about AI, to take just one example: Other domestic economies like the USA and China are supporting future technologies through massive investments. Can we afford to fall behind here in Germany?
No, of course we can't afford to do that. However, I believe that creating good conditions for research and industry is a more effective and sustainable measure than subsidizing individual sectors on a situational basis.

Is technology neutrality more than just a buzzword for you? ▶

Photo: Der Tagesspiegel/imago-images

1989: Digital native

Christian Lindner was born on January 7, 1979 in Wuppertal. Little Christian discovered his love of digital communication at a young age.

2000: An early start

Mr. Lindner entered the North Rhine-Westphalian state parliament for the FDP as the youngest representative at the tender age of 21.

2008: A late vocation

Mr. Lindner had refused to do military service for reasons of conscience. His decision to join the German Air Force as a reserve officer did not come until 2008, when he was general secretary for the FDP in North Rhine-Westphalia.

2018: Small balls

A passionate amateur golfer, Mr. Lindner is shown here raising money for good causes at the GRK Golf Charity Masters in Leipzig. Golf is not his only hobby. Mr. Lindner has a race driving license and a motor-boating permit for inland and maritime waters. He also likes to hunt.

If it were just a buzzword for myself and my party, we could have saved ourselves an awful lot of debates within the coalition. But because it isn't just a buzzword, we have acted on it decisively. In the 90s, it's unlikely that anyone — especially politicians — could have predicted the technological possibilities that we have today. Why should that be different when it comes to the next 30 years? This is why I am explicitly advocating against choosing one-sided solutions. Then, if certain technologies fail to become established, it's not a problem — but we shouldn't jeopardize our future prospects by becoming overly dependent on them.

Education is an important factor for the future: On the subject of child poverty, were you surprised by the outrage that resulted when you spoke out in favor of improving language development, integration, and schools and daycare centers "rather than putting more money into the parents' accounts"?

If we discount the shrill tone adopted by some media outlets, I found that a lot of people were in agreement with me. My opinion remains unchanged: I think our goal should be to bring people into employment and out of dependence on social security benefits.

Your party colleague, Bettina Stark-Watzinger, has been heading up the education and research ministry for two years. How do you think the collaboration between your ministry and the education ministry is working out?

We are working together closely and with a great deal of mutual trust. Our collaboration has given rise to some excellent initiatives, such as increased funds for education and improved financial education in Germany.

Has the FDP succeeded in preventing the parliament from having a noticeably liberal tone?

The goal of political parties is not to influence the parliament, but to implement good policies for the country on the basis of the knowledge available. For example, the German Federal Ministry of Education and Research (BMBF) has already implemented and launched important projects such as a reform of the German Federal Training Assistance Act (Bundesausbildungsförderungsgesetz, BAföG) and an excellence initiative for professional development (Exzellenzinitiative Berufliche Bildung). This strengthens the possibility of social mobility in Germany, which is a core element of liberal politics.

Two years in government — it's half-time for the coalition. What should our "team coach" Chancellor Scholz and his players bring to the field for the second half?

It's not my job to advise the coach, if we stick with your metaphor. The coalition must resolve challenges in areas such as migration. Getting our country back on track for economic success is no less important. This is the guiding principle for my actions.

Time for four short questions: What's your stance on raising the minimum wage?

This is a question that will not be answered by politicians, and for good reason — that's for the collective bargaining agreement partners working in the Minimum Wage Commission to decide.

And on wealth tax?

I am working to reduce the strain on our society's working middle class. This is where my focus lies. Taken as a whole, Germany as a country already has high taxation levels.

On the inheritance tax reform?

I believe that a further increase in the taxation of the substance of assets or inheritance would be wrong. In many cases, the assets in question are commercial, and many jobs in the SME sector depend on them. However, I do see a need for reform when it comes to the amount that is exempt from taxation. These figures were last set in 2009, and we have experienced significant inflation since then. That's why I'm open to the idea of a reform — one that increases the tax-exempt amount. However, to do this, I need to have the federal states on my side, because they are the beneficiaries of the tax revenue.

And on a sovereign wealth fund for more investments?

Our fund for investments is provided for in the federal budget. In any case, improving conditions for private investments is more important and more effective than new public funds.

Minimum wage increases, wealth tax, inheritance tax, sovereign wealth funds: These are all proposals by the Social Democratic Party (SPD), your coalition partners. How can you defend the future of your partnership when

members of your party are already referring to the "traffic-light" coalition as a "Punch and Judy show" or a "red-green lemon press" with your party getting squashed in the middle?
Parties exist to represent the purest form of their political ideals in a clear, emphatic fashion. We in the Free Democratic Party take advantage of our freedom to do just that. It is no surprise to us that the SPD and the Greens are on the left of the spectrum. It was clear from the outset that our task would be to keep the governmental strategy on a middle course. If you consider the actions this government has taken so far from an unbiased perspective, then you will see that we have succeeded in this.

You described working in the traffic-light coalition as follows: "We are a government where things really get hammered out. That means there's a lot of noise, but something still comes out of it in the end." Chancellor Scholz liked this turn of phrase so much that he started using it himself straight away. Of all the things that have "come out" of this government, what are you personally most proud of?
We have provided hundreds of billions of euros in financial aid for our citizens and our economy. Very few people would have thought our coalition capable of achieving this. The Inflation Compensation Act (Inflationsausgleichsgesetz) comes to my mind in particular here, as this law recognizes the struggles of our society's working middle class.

When all the wrangling over crises and budgets is finished with, what do you actually like spending money on as the federal finance minister?
You're swallowing a tall tale there. I have no problem with using public funds — so long as they're being effectively invested in the future viability of this country. And I think the best way to do that is to invest in the digital transformation, education and research.

And as a private citizen, what do you like spending money on — and if a nice meal comes to mind, will that still be the case when sales tax hits 19 percent in January?
My private life has been the subject of speculation often enough already, with varying degrees of accuracy. I would like to keep things that way. To answer your actual question: The reduction in sales tax for the food service industry was a temporary measure originally introduced during the pandemic. This measure was extended by a year at my instigation. But now we are returning to normality. ■

2020: Worn out…
… from being in the opposition? Christian Lindner was elected federal chair of the FDP in 2013 — making him the FDP's youngest party leader at 34 years of age.

2021: A rare proximity
It's become the stuff of legends: Volker Wissing, Annalena Baerbock, Christian Lindner and Robert Habeck took a selfie together to express their solidarity as the traffic-light coalition kicked off.

2022: Private happiness
Mr. Lindner married Franca Lehfeldt, then a reporter for RTL, in a church ceremony on the north German island of Sylt.

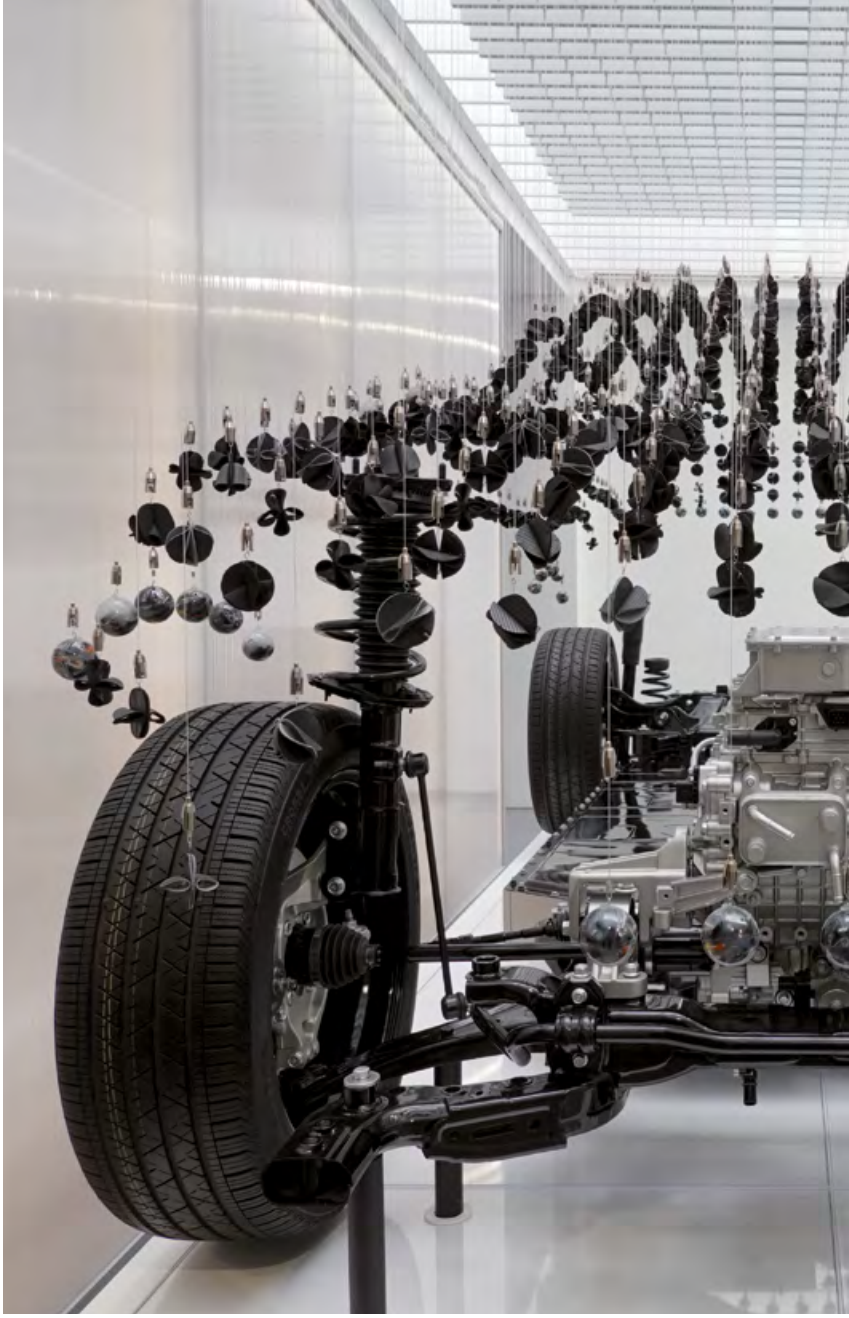
2023: Financial sucker punch
A 60 billion euro hole in the budget: The ruling by the German constitutional court utterly stunned minister for the economy Robert Habeck, Chancellor Olaf Scholz and finance minister Christian Lindner, leaving them scrambling for composure — and billions of euros.

Photos: Xander Heinl/photothek/dpa, private, DAVIDS/Schmidt, dpa (6)

Efficient? Try ultra-efficient!

Humanity urgently needs to conserve fossil fuels and renewable resources. Fraunhofer IPA believes ultra-efficient factories are the best response to this challenge.

By Dr. Janine van Ackeren



By August 2, 2023, it had happened again: This was the day when all of the natural resources that the Earth can produce in a year had been used up. Earth Overshoot Day highlights the fact that the global population is living off savings when it comes to our planet. And one day, these savings will run out too.

"We urgently need to counteract high levels of consumption," warns Dr. Markus Kröll, head of department at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. And that can be achieved not simply with "less," but also with "more." Ultra-efficient factories are efficient in production terms, but also take efficiency to the next level by making optimal use of energy, materials and human resources while minimizing emissions and costs — and all with the support of the ideal organizational structure. "The crucial thing is to look at the overall picture. If possible, an improvement in one field should not cause an additional burden in another," adds Kröll. The best way to explain how this looks in everyday factory operations is to take a few examples.

From a living lab…

Let's turn to the "Hybrides Zentrum für Ultraeffizienzfabriken" (Hybrid Center for Ultra-efficient Factories), a living lab at Campus Schwarzwald in Freudenstadt, where they produce and package nine men's morris travel games, including boards and pieces. But their attention is not on the games that roll off the production line, but on how to restrict the levels of consumption required to produce them. Sensors on the machines collect data about energy consumption, output, CO_2 emissions, waste, offcuts and much more. This data is sent to a digital control panel that allows the researchers to monitor and control the entire process some 80 kilometers away at Fraunhofer IPA — which is why the center uses the term "hybrid" in its name. For instance, the remote workers can use a 3D mode to take a virtual tour of the production hall and inspect the wood processing plant, press, injection molding system and packaging facilities, as well as a robot that will be responsible for assembly in future. The measured values obtained from the sensors are displayed in real time.

"The virtual control panel gives us an uninterrupted overview of the efficiency of the model production facility, and we can quickly detect any faults that could have a negative impact on energy consumption, for example," says David Koch, who has worked as a researcher at Fraunhofer IPA for several years. Algorithms from Fraunhofer IPA evaluate the collected sensor data and search

Maximum efficiency in production: The car industry (photo: installation by manufacturer Kia) could also benefit.

"Every company is unique, so there can be no standard way to achieve ultra-efficiency."

Dr. Markus Kröll, Fraunhofer IPA

Photos: letspicsit/Shutterstock, Lichtklick-Fotografie (Kraus)

for any correlations: How do changes affect the key figures? For example, how is energy consumption impacted if the machines are maintained more frequently or if the facility switches from alternating current to direct current? As the digital control panel is an open-source solution based on real-time data, it can also be used at real companies to gain an overview of the current production status and evaluate it accordingly.

As one example, the ultra-efficient factory has highlighted some major savings potential in relation to compressed air processes. "In Germany, there are around 62,000 of these systems in operation; the generation of compressed air is responsible for 7 percent of energy consumption in industry. By identifying and avoiding leaks, up to 30 percent of this energy can be saved," says Kröll. If facilities switch from alternating current to direct current, further energy savings of around 10 percent can be made — and not just in relation to compressed air processes. This is achieved through a reduction in conversion losses. Another benefit of direct current is that up to 98 percent of network incidents are avoided. Materials can also be conserved by implementing an additive manufacturing process rather than a machining process, or in other words by using 3D printers.

But the variables — which are easily accessible via sensors — are not the only important factor in ultra-efficient factories; the way in which processes are organized also matters. "We use the key figure of overall equipment efficiency, or OEE for short, to convert this into comparable figures that are then integrated into the optimization process," says Koch. As the human factor has a significant impact on the ultra-efficiency of a facility, the working conditions for staff also play a role. The researchers therefore measure noise levels, the indoor climate and other factors so that potential improvements can be identified. There are also plans to take workers' stress levels into consideration in the future. This will be monitored using wearables, sensors worn on the body by volunteers.

…to a factory for electric vehicle motors…

"Every company is unique, so there can be no standard way to achieve ultra-efficiency. Even when looking at the big picture, we need to examine every company individually, define the available ultra-efficiency potential in each case and develop a customized concept," emphasizes Kröll. This is exactly what the researchers are doing in the UltraELab (ultra-efficient factory innovation laboratory) project — and they are ensuring the ultra-efficient factory is a step closer to becoming a reality. Fraunhofer IPA, the University of Stuttgart and the Karlsruhe Institute of Technology (KIT) have designed and planned part of the production facility for electric vehicle motors ▶

at Schaeffler Automotive Buehl GmbH & Co. KG, with a focus on ultra-efficiency aspects. In the long term, the plan is for the results to be used in the same way as a living lab so that more facilities, production processes and companies can be transformed.

Now the second phase is set to begin and will receive ten million euros in funding from the German Federal Ministry for Economic Affairs and Climate Action (BMWK). This is where the real business starts: The production facility will be constructed in accordance with ultra-efficiency principles, and the effects of the measures will be compared and evaluated during ongoing operations. Will they deliver what the researchers expect? "One of the most important principles when implementing an ultra-efficient factory is to establish maximum transparency: What do the flows of materials and energy look like? What about the processes and activities?" says Kröll. This transparency is set to become a reality thanks to an ultra-efficiency management system that takes account of all the different dimensions of ultra-efficiency, namely the five fields of action of energy, materials, emissions, people and organization.

> "We want to shed light on this area of tension — and create valuable synergy effects by resolving conflicts of objectives."
>
> David Koch, Fraunhofer IPA

The researchers from Fraunhofer IPA are primarily interested in identifying specific areas of potential and deriving meaningful key figures by the time the project reaches completion in 2025/26. For example, a savings potential of ten percent is realistic when it comes to materials. Some research questions that the Fraunhofer team will be asking in the project include the following: What input variables are needed to ensure that these parameters can be calculated? How can the corresponding data sources, such as sensors, be connected, how can the data be processed and how can the key figures within this data be presented graphically for users of the management system? "Ultimately, the management system should help decision-makers at Schaeffler GmbH improve efficiency in all five fields of action," says Koch.

In another ultra-efficiency project, the researchers hope to investigate how the different ultra-efficiency measures influence each other. What types of interaction take place and what conflicts of objectives occur? For example, it may be the case that changes in a process enable materials to be conserved but cause an increase in energy consumption. "We want to shed light on this area of tension — and create valuable synergy effects by resolving conflicts of objectives. In other words, the change should improve all of the fields of action to a greater extent than would be possible through individual changes," says Koch. In this project, the researchers are still on the lookout for interested companies.

...and an entire industrial park

The researchers are broadening their perspective even further at the Fellbach industrial park near Stuttgart. "In this case, we are moving away from looking at ultra-efficiency simply at the level of an individual factory, and instead identifying the potential for an entire industrial park," explains Koch. The project is being run as part of the International Building Exhibition 2027. The first phase was recently completed; it took around six months and was funded by the Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg. The main challenge is to identify the mass flows and energy flows and reconcile the different demands. To this end, the researchers have started by carrying out surveys at the various companies. One of their results showed that while the farmers need a lot of water to irrigate their fields, a large number of businesses must pay a stormwater fee based on the size of the sealed area of land. If the farmers were to use the rainwater collected from the industrial park for irrigation purposes, considerable savings could be made: The farmers could conserve fresh water up to a value of 10,000 euros a year, while the businesses could make savings of up to 1,000 euros a year. This does not take account of the investment required — after all, the necessary infrastructure would need to be built first.

A second phase of the project involves developing a tool that enables a similar analysis to be completed for other industrial parks, and allows the measures to receive scientific support during implementation. With ultra-efficient factories, the researchers are therefore doing everything they can to gradually push back Earth Overshoot Day over the coming years and decades. ■

Knowledge relay

sustainability or security ?

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Knowledge relay

Prof. Büttner, what is more important when it comes to ***food supplies:*** ***sustainability or security*** and quality***?***

Knowledge relay, episode 10

Prof. Büttner, what is more important when it comes to food supplies: sustainability or security and quality?

Series:
Knowledge relay

The times we live in have raised **many questions — questions Fraunhofer researchers are working hard to answer.** A specialist **answers a question,** then poses a **question of their own** for the **next expert** to answer — it's a **"knowledge relay."** In this edition, **Prof. Andrea Büttner,** director of the Fraunhofer Institute for Process Engineering and Packaging IVV, answers a question posed by **Prof. Manfred Renner,** director of the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT.

To understand what is paramount, simply important or even irrelevant when it comes to food and nutritional supplies, we need to turn our attention to the general perception of supply security, or the extent to which this can be perceived.

We have seen how much of a challenge it can be for people and societies (even those that are highly developed technologically and those with high educational standards) to design and plan their supply security, especially under general conditions that might be considered unlikely or even unimaginable. Even in our country, where supply seems to be secured nationwide through supermarkets, we experienced a temporary shortage of goods to meet basic daily needs, such as toilet paper and certain food and luxury items. This left many people alarmed.

Historically speaking, the task of setting the frameworks for a secured supply of the population with basic necessities has always been seen as the government's primary mission.These necessities include water, food, clothing, accommodation and a basic energy supply. Today, the concept of supply is becoming increasingly fuzzy. The scale of basic supply conflicts with the narrative surrounding safeguarding economic prosperity: How

large does it need to be and could it be a little bigger?

In general, a strong economy is seen as a guarantee of security of supply. The question remains as to the role that the government plays: It sets the parameters for free, secure economic activity to safeguard the supply. Intrinsically, this includes — and must include — sustainability. You don't need a crystal ball to see that it takes a certain amount of work to secure supplies, whereby the essentials, the basic supply, must remain in focus. Securing basic supply must also take account of unforeseen and unexpected events and, if we exaggerate somewhat, even events that are unforeseeable and unthinkable.

The essential thought experiments

If we are to anticipate different futures in this way, we need to carefully assess various situations and scenarios and imagine a range of different circumstances. Only then can we derive potential measures and strategies today, including those that need preliminary and development work and cannot be implemented for another 5, 10 or 20 years. We need to plan for these now. In a true strategy process that ends in an uncertain future, these processes are the essential thought experiments; they are realistic and not — as is often thought-

Advocating for imaginative foresight: Prof. Andrea Büttner, director of Fraunhofer IVV

lessly assumed — pipe dreams or flights of fancy. This is why a coalition of the willing has come together in Fraunhofer with the aim of tackling these issues together.

I think this is exactly why human beings have been gifted with powers of imagination and not just reason. For me, this is the key factor behind our historically high level of resilience and our survival skills, because it is only through imaginative foresight that we can keep achieving the new forms of development and adaptation that we need. On a personal level, I can say that the past ten years have made me more contemplative than ever before. It is time to reflect on a possible rise in negligent, malicious and criminal behavior in our highly complex global food network — particularly when the system is under pressure. It is also high time that we all prepare for genuinely possible and conceivable situations, that we work together to consider possible futures and develop the necessary strategies, measures and technologies. We cannot keep satisfying ourselves with these two answers, which have become all too simple:

1. We need to achieve economic success today.
2. Who would have an interest in funding that?

My essential reason for joining Fraunhofer in 2006 was to work with others to answer the following questions — and in principle, they are still the same today: What needs to happen, what skills do we need to bring together, what processes do we need to launch in order to achieve what is such a distant goal for many people: a secure supply of high-quality and safe food. From my point of view, it is a question of strategy as well as culture and conviction. We need to jointly shape our vision, our mission — with the necessary foresight. This leads me to the knowledge relay question for the next edition of the Fraunhofer magazine. ■

It is time to *reflect* on a possible rise in negligent and criminal behavior in our highly complex global *food network* — particularly in times of *pressure.*

In the next issue:

How can we work together to achieve a *neutral mindset* when it comes to the *best solutions* — without *dominance by partisan interests* — in the face of current and possible *crises?*

Photo: Marc Dietenmeier

Title

PFAS

identification | replacement | removal

Toxic PFAS are endangering our water. Now there are plans to ban them in Europe. This presents the industrial sector with major problems because these “forever chemicals” are essential to many products and processes.

By Dr. Sonja Endres, photographer: Jan von Holleben

PFAS have always been essential to obtaining hydrogen for the energy transition. Now, Dr. Taybet Bilkay-Troni from Fraunhofer IAP is working on PFAS-free electrolyzers to split water into hydrogen and oxygen.

PFAS have been hailed as a magic bullet in the industrial sector for more than 70 years. But in early 2023, the European Chemicals Agency (ECHA) announced that their days were numbered. It has recommended that the European Commission place a ban on per- and polyfluoroalkyl compounds, and to do so as quickly and extensively as possible.

"Since the ECHA made its announcement, companies have been practically banging on our door," says Dr. Stefan Löbbecke, spokesperson for the Fraunhofer Chemistry Alliance. He reports that the number of inquiries regarding substitute chemicals and environmental and human toxicology assessments for various PFAS materials, as well as recycling, filtering and cleaning technologies, has increased exponentially in recent months. On serious note, Löbbecke adds: "I can understand companies' concerns and hardships, with some of them feeling a ban is a threat to their very existence."

PFAS can be found in everyday products like coated pans, pizza boxes and outdoor jackets, as well as in medical devices, heat pumps and batteries. As process chemicals, PFAS are used in the semiconductor industry to etch patterns in microchips, for example. They repel water, dirt and oil, they can withstand high temperatures and aggressive chemicals, and they are resistant to bacteria and light. Almost no other chemical substance can compete with them, so unique are their properties — and this explains why they are used so frequently. PFAS now come in many different variants, numbering around 15,000 substances according to the U.S. Environmental Protection Agency.

But while these colorless, odorless and tasteless substances can be used in a wide range of applications, they have also been found to be toxic in many cases. They can cause cancer and infertility and weaken the immune system. What's more, the industrially produced, extremely stable carbon-fluorine bonds characteristic of PFAS are not found in nature and cannot be decomposed. Once they are released into the environment, PFAS stay there forever, which is why they are often called "forever chemicals" in public debate. A study conducted by the German Environment Agency (UBA) in 2020 tested children between the ages of 3 and 17 and found PFAS in the blood of every test subject.

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Despite all of the risks, in many applications it would be impossible to stop using PFAS overnight. Nevertheless, researchers at Fraunhofer are working on a range of projects aimed at developing alternatives, reducing PFAS contamination in the environment over time and using improved filtering and cleaning technologies to ensure that fewer forever chemicals end up in watercourses, organisms and soil, where they can accumulate and spread.

Not all PFAS are the same: It is important that risk assessments differentiate between the individual compounds so that those that pose a particularly high risk potential to people and the environment are removed from circulation sooner. In the case of PFOS (perfluorooctane sulfonate), PFOA (perfluorooctanoic acid) and PFHxS (perfluorohexanesulfonic acid), this has already happened. They are only permitted for use in a small number of exceptional cases. Since February 25, 2023, restrictions have also been imposed on perfluorinated carboxylic acids — of which PFNA (perfluorononanoic acid) is the best known — affecting how they are placed on the market, manufactured and used.

The substances all belong to the class of PFAS, which are made up of long carbon chains. They accumulate in organisms along the food chain and are rarely excreted. Human beings come at the end of the food chain. The substances bind to the proteins in human blood, in the kidneys and liver, where they remain for many years and can have a harmful effect. During pregnancy, they are transferred to the unborn child through the placenta and even passed on through breast milk.

In many cases, the industrial sector has now switched to short-chain PFAS, which are made up of a maximum of six perfluorinated carbon atoms. These accumulate in the organism to a lesser extent but they are more mobile. They are not retained in the soil and quickly enter the groundwater, which is often used for the drinking water supply.

Identification

The Fraunhofer Institute for Toxicology and Experimental Medicine ITEM is working with 15 European partners in the ZeroPM project, which aims to identify the potential risks of different PFAS in drinking water. Dr. Annette Bitsch, head of section for chemical safety: "It is not a trivial thing to say that one substance is more dangerous than another. It is important to take a comprehensive view of the individual substances. A fundamental principle in toxicology is that the risk is calculated on the basis of the inherent danger posed by the substance and the degree of exposure, or how often you come into contact with it." To this end, she is analyzing study data and scientific publications. "In this

process, it becomes clear fairly quickly which substances are critical." She adds that it comes as little surprise, therefore, that the use of PFOS, PFOA, PFHxS and PFNA has been restricted first.

The European Food Safety Authority (EFSA) also focused on these four compounds in its most recent report from 2020 and defined a threshold value for the maximum weekly intake that is considered to be not harmful to health. This is 4.4 nanograms per kilogram of body weight. "This is equivalent to only around 0.00003 milligrams per person per day," explains Bitsch. The substances are most frequently found in drinking water, fish, fruit, eggs and egg products.

When it comes to the plan put forward by the European Chemicals Agency (ECHA) to apply the restrictions to all PFAS in the near future, Bitsch expresses her understanding: "That is a huge class of substances with many subcategories. It will take decades for them all to undergo thorough toxicology assessments. We can't wait that long." She adds that exceptions are still possible, such as if a substance is needed in certain medical applications, if an assessment of the benefits and risks suggests continued use is preferable, or if it has been scientifically proven that a substance is harmless. However, the burden of proof rests with the industrial sector, she says.

The urgent need for an EU regulation has also been confirmed by the most recent research findings from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME, which were published in January 2023. In the SumPFAS study carried out on behalf of the German Environment Agency (UBA), the researchers conclude that PFAS are much more widespread than previously thought. Dr. Bernd Göckener, head of department for Trace Analysis and Environmental Monitoring at Fraunhofer IME: "Even in smaller rivers, we found large quantities — including of lesser known PFAS. The problem is often no longer local but general. PFAS are simply everywhere."

Together with his team, he examined around 200 samples of suspended solids and sediment from 170 rivers and lakes across Germany and compared them with archived samples from the German Environmental Specimen Bank, which has been documenting chemical pollution in the environment and in human beings since the 1980s. The good news is that pollution of the watercourses with PFAS has reduced; the EU bans are working. The bad news is that when Göckener and his team used a modified analysis that includes precursors, they found that overall PFAS concentrations were up to 346 times higher than when conventional investigation methods were used. Once they are released into the environment, precursors oxidize to form conventional PFAS. Göckener: "From an analytical perspective, we will never fully understand these thousands of substances. We assume that the level of pollution is much higher than we are able to measure."

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Dr. Bernd Göckener, Fraunhofer IME

Göckener and his team found particularly high levels of PFAS downstream of large wastewater treatment plants and industrial facilities that produce or process PFAS. The forever chemicals enter rivers primarily through wastewater and eventually end up in the North Sea or Baltic Sea. "The oceans are the great reservoir for all PFAS around the world. This is where they will continue to accumulate," Göckener believes.

Replacement

That's unless alternatives to PFAS are successfully developed so that the continuous influx can at least be reduced. Dr. Jakob Barz at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is working on this very task. He is using plasma technology to functionalize different material surfaces in order to make them chemically stable or resistant to dirt, water and ice. Barz: "Strictly speaking, PFAS coatings are not needed in many applications. The only thing we haven't got right yet is a really effective oil-repellent function."

He adds different chemical substances to the plasma depending on the characteristic profile required. "The molecules are broken up. The individual fragments react on the surface of the material, where they form a polymer layer. The type of polymer created always depends on the substances I add to my plasma, and on the process conditions." One advantage of the plasma coating is that it can be applied in a very thin layer, like a film on the surface. Textures and pores are retained without being blocked, making this method ideal for coating solder stencils for computer circuit boards or membranes for use in wastewater filtration. These are both applications in which PFAS are used today.

For water-repellent coatings on outdoor fabrics, the researchers at Fraunhofer IGB use a biobased, sustainable substitute: chitosan. This forms a robust shell around the fibers, thereby improving the wear resistance. It can be obtained from various sources, including crustaceans. The EU sees around 250,000 tons of crustacean shell waste every year, over 6 million tons accumulate annually worldwide — a natural resource in abundance. Insect cuticles and exoskeletons, a common residue from animal foodstuff production, contain ▶

chitin, from which chitosan is made. "Chitosan is much more reactive than chitin. We use this to our advantage. We apply it to the fabric at the same time as water-repellent vegetable oils. With the application of heat and pressure, the substances bond to form an even and robust protective layer," explains Dr. Thomas Hahn, deputy head of the Bioprocess Engineering working group at Fraunhofer IGB. His colleague Dr. Achim Weber adds: "The ingenious thing is that our impregnation — which is based on natural products — can be easily reactivated after cleaning it in the washing machine by ironing the fabric or putting it in the dryer." Another advantage is that the formulation is simple to

"Chitosan is much more reactive than chitin. We use this to our advantage."

Dr. Thomas Hahn, Fraunhofer IGB

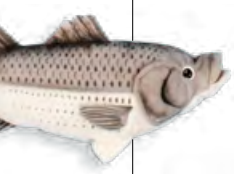
apply using the machines and production technologies already available in the textile industry. "Chitosan is also an effective solution for food packaging or coated boxes to protect washing powder from moisture and clumping, for example," says Weber. PFAS can be safely dispensed with in this case too, he says.

However, the forever chemicals have so far been indispensable to the energy transition. Whether used in electrolyzers to obtain hydrogen, or in fuel cells and batteries, membranes that contain PFAS can be found everywhere. They need to offer properties such as high chemical stability and special levels of conductivity and permeability. "The material requirements are extreme," says Dr. Taybet ▶

Dr. Bernd Göckener from Fraunhofer IME is searching for PFAS in German watercourses.

Bilkay-Troni, head of the Polymers and Electronics department at the Fraunhofer Institute for Applied Polymer Research IAP. Nevertheless, she and her team are looking for alternatives — and they have already succeeded. Together with the Center for Fuel Cell Technology ZBT, they have developed a new type of polymer and used it to produce membranes for anion-exchange membrane water electrolyzers (AEM-WE).

As Bilkay-Troni explains: "The membrane is at the heart of any electrolyzer. It is crucial to the reliability and effectiveness



> "The membrane is at the heart of any electrolyzer."
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> Dr. Taybet Bilkay-Troni, Fraunhofer IAP

of the electrolysis process, or in other words, the process of splitting water into hydrogen and oxygen using electricity." In addition to the membrane, electrolysis requires two electrodes (anode and cathode), a source of direct current and an electrically conductive fluid called the electrolyte. The positively charged hydrogen collects on the cathode, while the negatively charged oxygen collects on the anode. The membrane ensures that the negatively charged ions — or anions — are transported, and separates the anode and cathode chambers. The electrolyte is a weak lye, with electrolysis taking place at temperatures of around 60 to 80 degrees — operating conditions to which the membrane is continuously exposed. Nevertheless, it must not become brittle and should retain its flexibility and ionic conductivity.

The initial results in the electrolysis test cell are promising, with the PFAS-free membrane remaining stable. The new polymer that is used to make the membrane can also be processed very effectively.

Dr. Achim Weber (left) and Dr. Thomas Hahn want to use chitosan from crab shells to waterproof outdoor fabrics and replace PFAS coatings.

Another advantage is that there is no need to use costly electrodes made from rare-earth metals, such as those required in proton-exchange membrane electrolysis, which is commonly used today. In the future, the membrane could also be used in fuel cells.

"But before we get there, a few more development steps are needed," adds Bilkay-Troni. "We are just at the beginning of our research. Next, we want to work with our partner ZBT GmbH to test the membrane in a real-life environment over a longer period so that we can continue to improve the stability and conductivity." She believes the membrane could be ready for market in three to five years. "The demand is huge. But companies always prefer to have a finished product. We can't offer them that. The only way we can develop good solutions that meet their needs is to work together with the industrial sector."

Removal

As long as we are unable to replace PFAS completely, it is all the more important to capture them as effectively as possible and prevent them from spreading in the environment. To this end, Dr. Stefano Bruzzano from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT worked with Cornelsen Umwelttechnologie GmbH several years ago to develop a cleaning technology that has since undergone continuous modification. It is particularly efficient where there are high emission levels that are locally limited, such as when special foams are used to extinguish fires, or at landfills in which consumer goods containing PFAS slowly "bleed" and release the chemicals into the groundwater.

The PerfluorAd® cleaning system can be used on site in a mobile container to clean the polluted water. For this purpose, the water is pumped into the system vessel where PerfluorAd® is added; this is a biodegradable liquid agent to which the PFAS bind, causing them to settle at the bottom. The remaining water is chan- ▶

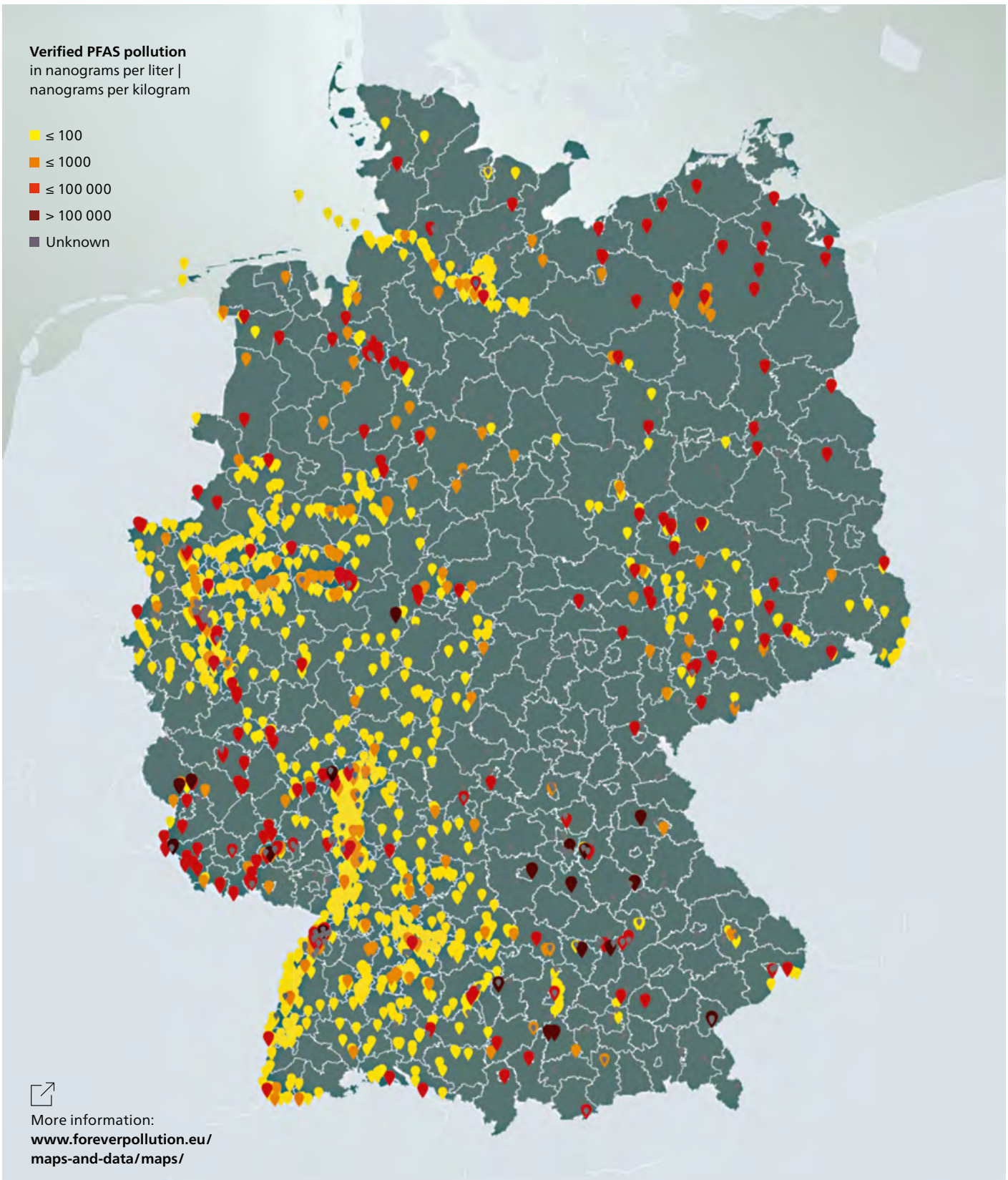

Diagram: NDR, WDR, Süddeutsche Zeitung

Fish can breathe a sigh of relief: Dr. Georg Umlauf from Fraunhofer IGB is removing PFAS from waste water.

neled through activated carbon filters, in which the few PFAS that were not captured in the first cleaning step are retained. The severely contaminated sediment is later disposed of appropriately in an incinerator at temperatures well in excess of 1,000 degrees Celsius. Bruzzano: "The strength of our process lies in the fact that it combines different methods." The activated carbon filters, which are already used in many water treatment plants, were not enough to provide a cleaning process that was both powerful and environmentally sound. At higher contaminations of more than 10 micrograms of PFAS per liter, they quickly became clogged. "It is important to analyze the polluted water in advance so that our process can be adapted to the PFAS and associated substances in the water, as well as the level of contamination," emphasizes Bruzzano. This determines how much PerfluorAd® needs to be added, and whether any other process additives are needed, such as flocculants to separate the PFAS.

Dr. Georg Umlauf from Fraunhofer IGB is going one step further. Instead of simply removing PFAS from the water, he wants to destroy their structures to render them harmless by using plasma technology, just like his colleague Dr. Jakob Barz. As Umlauf explains: "We ignite air plasma between two electrodes and the polluted water flows in between them and down a column. Since the plasma is a very energy-rich medium, we can break apart the PFAS molecule chains so that we can keep shortening the carbon chains. However, this requires the water to be pumped around a circuit multiple times because one-off, brief contact with the plasma is not enough. The end goal is to mineralize the PFAS, which is when they have more or less dissolved. Then there is no need to use an energy-intensive combustion process."

In the laboratory reactor, Umlauf successfully tested the plasma cleaning method with real samples from wastewater contaminated with PFAS. In the future, he would like to adapt the process to handle larger volumes. An improved analytical method should enable more accurate monitoring of the process and help to adjust the number of pump circuits required in individual cases. "However, there are still a few more challenges to overcome until we have a finished system that can clean tens of thousands of cubic meters of water per year. We are looking for partners from the recycling and industrial sectors to take part in the subsequent research." This would spell the end for forever chemicals.

But time is running out. The European Commission wants to reach a decision on the PFAS ban by 2025. There will have to be transitional periods and exceptions. The substances are too important to achieving a rapid energy and mobility transition, as well as to state-of-the-art medical devices and the semiconductor industry. This is why alliance spokesperson Löbbecke underlines the urgency of the Fraunhofer research: "We can limit PFAS emissions. But we cannot completely dispense with PFAS yet." ■

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For interested parties from business
More on Fraunhofer Match on page 79

AI made in Germany: Be bold!

The American tech giants are engaged in a fierce struggle for supremacy when it comes to generative AI. Amazon recently invested four billion dollars, and Microsoft ten billion. But what about Germany?

By Dr. Sonja Endres

A new era in AI began in the summer of 2020 with the release of the GPT-3 language model, which ChatGPT is also based upon.

The technological development of generative AI is proceeding at a breathtaking pace. Microsoft has already integrated its first AI features into its most important Office programs, while Google is increasingly adding them to its products and services. "We can no longer afford to drag our feet in Germany," believes Dr. Nicolas Flores-Herr, who heads up the OpenGPT-X project at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS. He and his team are working with the Fraunhofer Institute for Integrated Circuits IIS as well as ten partners from business, research and the media to develop a European alternative to ChatGPT, Google PaLM or Meta Llama. They are convinced that a European AI language model is essential to remaining independent — from a digital and market economy perspective — in the future. Flores-Herr: "In Germany, we have outstanding individuals who are working to great success in the field of generative AI. And there would be enough public and private money available. The only thing we have lacked until now is courage! That's why I welcome the recent AI action plan by the German Federal Ministry of Education and Research (BMBF) and the investments German companies are making in Aleph Alpha. But this can only be

the beginning. I'm advocating for greater determination so that more European initiatives and start-ups can be launched."

The OpenGPT-X team is training its AI model in 24 European languages, with German, Spanish and English making up the largest share with around 20 percent each. For the latest American models, only a small percentage of the training data is available in German, so the responses in English are much better. Language has a huge impact on the AI model, as language represents culture, with all its unique characteristics, norms and values. But this is not the only reason why a large European language model is needed. Many companies have significant reservations about sharing their data with American tech giants in order to keep using their AI services. Amazon, Microsoft, Google and others also offer models and standard solutions that are suitable for the general public but fall short when it comes to meeting the individual requirements of small and medium-sized enterprises in Europe. Flores-Herr: "Our model is completely open. This means that any company that wants to use it can do so. As it is open, it can be adapted to specific requirements with speed and flexibility. That could make OpenGPT-X extremely successful."

High-performance computing centers are a rarity

That's assuming things move quickly and the conditions for developing large models in Europe are established soon. Until now, it is a competitive AI computing infrastructure that has mostly been lacking. The OpenGPT-X team is using resources such as those at the Jülich Supercomputing Centre (JSC) and the Center for Information Services and High Performance Computing (ZIH) at TU Dresden — a real privilege. High-performance computing centers are a rarity in Germany, with capacity in great demand.

This will soon change, according to the authors of the LEAM feasibility study. They have investigated the conditions that must be met in Germany in order to remain competitive when it comes to the development of large AI models. The study was conducted by the German AI Association with the support of Fraunhofer IAIS, as well as other research institutions, trade associations and companies. It was funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). A key requirement of the LEAM initiative is to tap into the knowledge of experts to establish an AI supercomputing center in Germany and operate it on a long-term basis. The idea is for AI models to be continuously developed at this center and made available as open source solutions. It is estimated to cost around 350 to 400 million euros — a sound investment, thinks Jörg Bienert, president of the German AI Association. He says: "Only those who master the technology will be able to use their own judgment to determine how it is used."

> "We can no longer afford to drag our feet in Germany."
>
> Dr. Nicolas Flores-Herr, Fraunhofer IAIS

Although there are many potential applications for AI language models, and costs can be reduced while productivity and efficiency can be significantly increased, many German companies have so far been cautious. According to a recent survey by the IT industry association Bitkom, three out of five companies have not used the technology yet or cannot imagine using it. Flores-Herr thinks this is a risk: "If you are not already finding out about the potential applications in your own business, you may be steamrolled by developments in 18 months, rather than in 3 or 5 years."

Talking to the data

According to Flores-Herr, it makes sense to introduce generative AI in fields such as knowledge management. "Wherever there are large, unstructured quantities of data, generative AI is unbeatable because it can almost talk to the data, so it can extract relevant data in a quick and focused way," he explains. Instead of using a search engine and keywords as a laborious way to determine the reason for a machine fault, for example, employees will simply be able to use natural language to request advice from the AI in the future — in return, they will receive an explanation of how to rectify the fault based on all the available information about that precise machine. Flores-Herr thinks generative AI will become a kind of extra colleague who can learn new things very quickly. But this is not simply a matter of loading a large AI model onto the company server, he warns. The challenge will be to adapt it to the company's specific requirements and use it to develop some potentially complex applications, as he believes this is the only way to get the most out of what AI offers.

The OpenGPT-X consortium aims to launch its first, small-scale AI language model by the end of this year. It contains around seven billion parameters — these are adjustable values in a model that control the behavior of the model and are optimized through training. Much larger models are set to follow next year. Flores-Herr: "It is worthwhile investing in AI 'Made in Germany.' Waiting is the opposite of creating. We need to act now." ■

Photos: Andrey Kuzmin/Alamy Stock Photos/mauritius images, Fraunhofer IAIS

The problem with XXL waste

We want to obtain more and more electricity from wind energy. This means building new, more effective wind turbines — but what happens to the old rotors?

By Kathrin Schwarze-Reiter

From a distance, they look like the kind of pinwheels that a child might have stuck here and there in the ground. Their rotor blades rotate tirelessly, driven by a wind that sometimes blows softly and sometimes in stormy gusts. It is only when you approach them that you notice how huge they are: A single rotor blade can measure up to 75 meters in length. By comparison, an Airbus A380 has a wingspan of 70 meters — and that includes both wings. Wind turbines are the largest pieces of rotating machinery that human beings have ever built.

A great deal has happened in the world of wind energy since the first offshore wind farm was opened off the coast of Denmark in 1991. There are now nearly 30,000 turbines on the German mainland, and 1,500 at sea. But this is still not enough to meet the targets set by the Renewable Energy Sources Act: In order to slow down global warming caused by fossil fuels, wind energy needs to generate a minimum of 115 gigawatts by 2030. By the end of 2035 this figure needs to be 157, and 160 gigawatts five years later.

Almost no other piece of technical equipment is used as continuously as a wind turbine. The rotors are in constant motion, exposed to the elements. At sea, the salt in the air corrodes the materials. "Wind turbines are generally designed for a service life of 20 years. But this does not mean that they have to be decommissioned after this time," says Dr. Steffen Czichon, head of the Rotor Blades department at the Fraunhofer Institute for Wind Energy Systems IWES. He adds: "At many sites, the load placed on a turbine over its service life is lower than previously calculated. If its complete load history is known, its remaining service life can be predicted and old turbines

A single rotor blade can measure up to 75 meters in length.

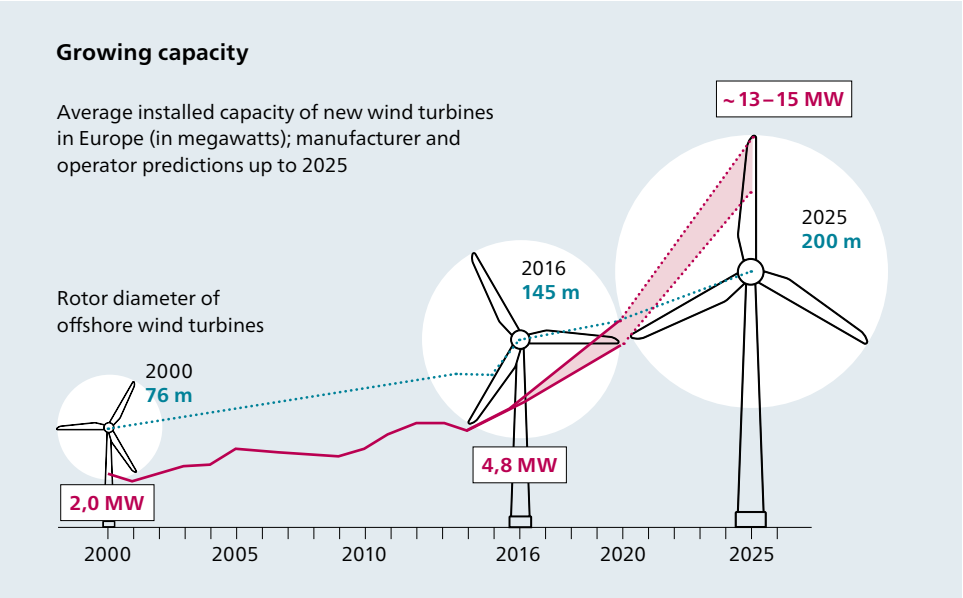
Photo: Grzegorz Michalowski/EPA/picture alliance

can be operated for longer." This reduces resource consumption and waste. Once they are manufactured and erected, wind turbines are virtually climate-neutral.

Keeping wind turbines alive with AI

Two projects are investigating how to extend the service life of wind turbines. In the KIWI project, a consortium of researchers from Saarland University, the University of Bremen, Fraunhofer IWES in Bremerhaven and external partners from industry want to use an AI-supported simulation to find out how the complete turbine (tower, nacelle, drivetrain and rotor) can last for longer. In the Bladaption project, researchers from Fraunhofer IWES are focusing solely on the rotor blades. "Specifically, it's about measuring rotor blades so that we can determine the deformation more accurately," says Czichon. "This is important when it comes to making precise estimates of the service life."

Computer simulations of fatigue loads require a great deal of time and computing power but remain inaccurate. Fraunhofer IWES has therefore worked with its partners to improve the simulation methods. Artificial intelligence is now helping to make the calculations faster and more precise. A study by the Fraunhofer Institute for Chemical Technology ICT predicts that another 72,000 rotor blades will need to be disposed of in the next three years in addition to 15,000 in 2024. "There is a scrapyard near Flensburg where thousands of rotor blades are waiting to be recycled so they can have a second life," says Peter Meinlschmidt from the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI. "While ▶



The race to build the largest wind turbines is clear when looking at their development over time.

there are tried-and-tested recycling methods for the steel and concrete used in the body and foundation, the rotor blades are still causing difficulty."

The large blades of the wind turbines are mostly made from glass-fiber reinforced plastic, as well as balsa wood stuck together with epoxy and polyester resin, and plastic foam. Steel would be too heavy and inflexible. For example, a rotor blade measuring 40 meters in length uses 24 tons of plastic, 1.3 tons of balsa wood and 0.5 tons of metal. Balsa wood is a very high-quality and lightweight wood that quickly grows back. The trees are ready to cut down after just six years. "They are grown in special plantations using sustainable production methods — so it would be a great shame to throw it away," says Meinlschmidt. However, most rotor blades are currently incinerated in refuse incineration plants or cement works in a process that requires a lot of energy.

Second life for rotor blades

Until now, there has been no way to reclaim wood from a disused rotor blade. But together with the Nuremberg Institute of Technology (Nuremberg Tech) and partner companies, researchers at Fraunhofer WKI have now built one: "One major problem was how to release the materials that are permanently attached. By using a spray lance strapped to a vehicle, as well as a mobile shredder, we were able to easily take the rotor blade apart and grind it up," reports project manager Meinlschmidt. The project team processes the shredded balsa wood to form a pressure-resistant wood foam containing no synthetic binders. This can be used as building insulation. "It isn't possible to do this yet on a large scale, but we hope to find a company in the near future that specializes in it." The goal is for the materials to be turned into thermal insulation straight from the recycling stage.

In the Research Alliance Wind Energy (FVWE), which includes partners the German Aerospace Center (DLR), ForWind — Center for Wind Energy Research and Fraunhofer IWES, some 600 researchers are working on the further development of the giant wind turbines. Their aims are to increase efficiency, accelerate the development of state-of-the-art turbines, optimize production and reduce the failure rate. In the HANNAH project, a team of researchers from Fraunhofer IWES is investigating innovative materials for rotor blades, including hybrid materials and nano-modified material systems. Computer models are then used to simulate the component load capacity and any possible damage.

State-of-the art wind turbines have very little in common with those used in the wind farm off the coast of Denmark in 1991. They are bigger and generate more electricity, because the taller the wind turbine is and the longer its rotor blades, the more capable it is of exploiting the available wind energy. "Moving from onshore to nearshore wind turbines was only a small step compared to offshore wind farms," believes Peter Meinlschmidt. "Securing them in the ground, the height of the towers and the significantly increased wind loads applied to the longer rotor blades — these are all a challenge. In that sense, it's impressive that the turbines are able to withstand the considerably harsher conditions at sea for so long." But he adds that dismantling the turbines and transporting them back will be just as difficult as building them in the first place. Meinlschmidt: "The longer usage periods and repair options that we are researching also benefit the profitability of offshore wind turbines. This means repowering will be delayed for as long as possible." ■

Source/illustration: Foundation OFFSHORE WIND ENERGY

Concrete with a heart of flax

Delicate flax fibers could be used in the future to reinforce concrete structures while also improving the building material's carbon footprint.

By Dr. Katja Engel

Flax is both attractive and useful.

When a field of flax is blooming in the Normandy summer, a sea of delicate, light blue blossoms and dainty stems sways in the wind. People used it for thousands of years to make clothes until it was displaced in the textile market by cotton — even though flax fibers are considerably more resistant to tearing.

Now this ancient crop could be set to make a comeback, though not in shirts or tote bags but as a textile structure inside concrete. With funding from the German Federal Environmental Foundation (DBU), researchers Jana Winkelmann and Christina Haxter from the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI have worked with Biberach University of Applied Sciences and industry partner FABRINO to investigate whether flax fibers are a sustainable alternative that can be used in high-performance concrete. "We wanted to show that natural fibers may contain materials that are suitable for reinforcing concrete," explains project manager Winkelmann.

From massive bridges to meter-thick walls and rough-textured buildings, mixtures of sand and cement need to be reinforced inside to ensure that concrete structures are strong enough. Until now, steel has mostly been used for this purpose, but it needs extensive protection against corrosion to ensure that the building does not rust inside. A textile made from carbon fiber or fiberglass represents a durable alternative, but its synthetic manufacturing process is extremely energy-intensive and is based on fossil raw materials. This exacerbates the carbon footprint of concrete, which is already depressingly large: Global production of concrete is responsible for around eight percent of the world's carbon dioxide emissions.

One of the main reasons why Jana Winkelmann is conducting research into flax as a potential natural fiber for use in textile-reinforced concrete parts is a desire to improve the carbon footprint in the construction industry. A textile made from high-strength flax could make it possible to build structures with a reduced concrete thickness, thereby saving considerable quantities of this climate-damaging building material.

> "Concrete with a natural fiber textile is a good alternative to steel-reinforced concrete."
>
> Jana Winkelmann, Fraunhofer WKI

The researchers first used digital tools to plan how a textile structure that is optimized for this purpose would need to look. When choosing an appropriate fabric, it is important to consider the way in which the yarns are crossed so that the fabric subsequently allows the least movement possible. Once the researchers had defined the structure on the computer, they could weave the fabric from flax yarn on the institute's own loom. To improve tensile strength, durability and bonding, the flax yarns were also coated — though not with the commonly used petroleum-based epoxy resin, but with a partially biobased impregnation.

Opportunities for new architectures

Multiple layers of the semifinished textile were then embedded in the concrete. The project partners at Biberach University of Applied Sciences tested how stable the sample unprocessed workpieces were when under load. Winkelmann: "The results were clear: Concrete with a natural fiber textile is a good alternative to steel-reinforced concrete or to concrete with synthetic fiberglass or carbon fiber." As part of the project, a number of models have been produced for larger concrete parts reinforced with natural fibers, such as a facade panel and an industrial floor with reinforcing flax fabric.

Plant fibers don't just improve the carbon footprint — they also allow more lightweight structures to be built while optimizing the future recycling process and opening up new architectural opportunities for sleek and freely designed structures. Jana Winkelmann now hopes that textile-reinforced concrete parts based on natural fibers will eventually be successful in the market — particularly in view of their considerably improved carbon footprint. The researchers at Fraunhofer WKI have proven that this innovative building material is fundamentally fit for purpose. In any case, by harnessing the potential of these plants with light-blue blossoms, it might be possible to cultivate a new generation of structural materials. ■

Photo: vkimages/istockphoto

Smart devices can make a home more secure — if they are used correctly.

“A lack of security is not a trivial matter”

Internet-enabled devices have become indispensable tools in most households. But how secure is the smart home? A new EU regulation is finally forcing manufacturers to prioritize the issue of security.

By Beate Strobel

These days, thieves don't have to pick a door lock or break a window. All they need to do is hack a digital thermostat and take control of other devices in a home network via a router. If the heating in your home is turned up remotely, you will soon be ready to pay the ransom so that you can take charge of your own house again.

Increasing your household IQ with a smart home has been one of the high-tech trends of recent years. In 2018, just 26 percent of Germans used smart home applications in their own four walls, but by 2022 this had risen to 43 percent (Bitkom Research 2022). From video surveillance to lighting, robot vacuum cleaners, fitness trackers and smart TVs, the number of internet-enabled devices in the home is growing. Some 74 percent of users want to use the devices to make their everyday lives safer and more convenient. But by the same token, the internet of things (IoT) can become a security risk.

"Every IoT device you add to your household increases the potential points of attack," says Nikolai Puch, scientist and cyber security researcher at the Fraunhofer Institute for Applied and Integrated Security AISEC in Garching. Since smart devices generally access the world wide web via a home router, criminals can use any device as a gateway to the internal network.

In the case of devices that are connected to a network (particularly the internet), it is almost impossible to avoid being scanned. If these devices have any security vulnerabilities, another party could take control of them using malware. Once a large number of devices have been captured in this way, they can be connected to form a network known as a botnet. "You can imagine scanning to be like a street, and the IP addresses of all the internet-enabled products are the house numbers. These automatic bots will knock on any door in the hope that it is open," explains Sebastian Peters, another cyber security researcher at Fraunhofer AISEC. If the network of infiltrated devices is large enough, criminals may then be able to paralyze specific websites and servers by flooding them with requests.

For this reason, IoT devices should only be connected to the internet when this is essential to their function. If this is the case, the maximum restriction should be placed on their communications (think of parental controls) and they should only connect to the internet via the router rather than automatically, as the central firewall provides better protection against external attacks. However, a possible security vulnerability may arise due to the optional UPnP (Universal Plug and Play) router setting, which not only enables any device from any manufacturer to communicate in the home network, but also permits requests from the internet to be sent to a home computer. The German Federal Office for Information Security (BSI) recommends disabling this function so that no IoT device can send uncontrolled communications to the outside world.

It is also possible that criminals may drive down a real street and check every Wi-Fi network for vulnerabilities: Is it only protected by a weak password or the out-of-date WEP standard? Or is it not protected at all? If the answer to any of these questions is yes, there is a serious risk that criminals could take control of devices via malware and scan sensitive data such as online banking logins to use for their own purposes. Or they may cause actual damage by breaking into a house because the infiltrated cameras show that nobody is home. And what about criminals tampering with virtual assistant technology so that they can buy goods online or even open a smart door lock?

"A password is like the lock on your front door," emphasizes Nikolai Puch. He says this is why you need to change the preset password for routers or internet-enabled devices immediately after installing them, but you should never use a phone number, date of birth or other readily available data. Puch adds that it is advisable to use combinations of eight digits or more containing uppercase and lowercase letters, numbers and special characters; words from the dictionary should be avoided. Where possible, the password can be backed up with two-factor authentication, giving the virtual front door an additional lock.

Puch also recommends segmenting the Wi-Fi network in the smart home, perhaps by creating a separate guest network for visitors, a network for IoT devices and a third network for your laptop, smartphone and other devices that contain particularly sensitive data. After all, in a real house you would only invite guests into the living room and would never give them immediate access to your desk drawers. ▶

"We want to use AI so that more attempted attacks can be detected at an earlier stage."

Dr. Matthias Meyer, Fraunhofer IEM

Photos: Viennaslide/Construction Photography/Photosh/dpa, Fraunhofer IEM

"Every IoT device you add to your household increases the potential points of attack."

Nikolai Puch, Fraunhofer AISEC

According to the experts at Fraunhofer AISEC, a significant risk arises when IoT products are not regularly loaded with the latest security updates. Peters says this is often not the fault of the user but of a large number of manufacturers who are not willing to offer updates beyond the legally stipulated warranty period of two years. From a security perspective, these devices have reached the end of their service life by this time. But who would throw out their games console, robotic lawnmower or smart TV just because they stopped receiving updates? "In this case, it can be helpful if you at least prevent these devices from communicating freely with the internet, and use them with maximum separation as part of the home network," recommends Sebastian Peters. He adds: "When you buy a new device, one of the important purchase criteria should be a guaranteed availability of security updates over a long period."

Ending software updates early is a consequence of price pressure in the technology industry, believes Dr. Matthias Meyer, head of the Secure IoT Systems department at the Fraunhofer Institute for Mechatronic Systems Design IEM in Paderborn. Many manufacturers look to save when it comes to software protection and updates. The Fraunhofer expert recommends that users inquire about the update provision when purchasing a device and search for information about new software versions on the manufacturer's website: "The manufacturer only takes the issue of security seriously if there is regular activity there," explains Meyer.

To make life easier for the less tech-savvy while also improving digital resilience throughout the IT value chain, the European Commission initiated the Cyber Resilience Act (CRA) in 2022. It is set to come into force in 2024 and will apply with a transitional period of two to three years for all IoT products (software and hardware) available in the European market. Under the CRA, manufacturers will be responsible for cyber security for a product's entire life cycle. Enshrining the principle of "security by design" in law will cause problems for many companies, predicts Matthias Meyer: "In many sectors, security expertise is not very widespread yet."

Both manufacturers and users see their laptops, tablets and PCs as a virtual platform for home banking or for saving passwords and treat them accordingly as security-critical devices, but other IoT devices are not seen as the mini-computers that they are. Who would stop and think that a toy with Bluetooth connection in their children's room, a toothbrush with associated app in the bathroom or a digital thermometer in the living room aquarium might be the target of a cyberattack? In addition, users are often unsure about what data is actually transferred; they don't know what servers the data is saved on or how it is backed up.

In a study carried out on behalf of the BSI, Fraunhofer AISEC analyzed potential hardware attacks on microcontrollers and outlined some corresponding countermeasures. As single-chip computers, microcontrollers are effectively the heart of any IoT device and are increasingly being used in consumer products and e-wallets. Although they often store highly sensitive data like cryptographic keys or login details, the industry prefers to use standard microcontrollers for cost reasons — an invitation for hackers. In this study, the researchers at Fraunhofer AISEC want to raise awareness of the problem among manufacturers of microcontrollers and encourage them to implement appropriate countermeasures.

In turn, Fraunhofer IEM is already supporting companies in the early development stage — in line with the principle of "security by design" — and is also analyzing existing security concepts for smart home devices. The IoT-ScuBA project (IoT security through cyclical, precisely interconnected threat analysis and attack detection) focuses on the secure development and operation of a networked robot vacuum cleaner from project partner Miele. In this context, the research team is also using AI methods for two reasons: firstly to register attacks — including those of previously unknown types — in the system at an early stage using anomaly detection, and secondly as a systematic way to feed these findings back into the further development of the products. "Attacks are currently detected by analyzing communication in the network," explains Matthias Meyer. "But we want to use AI to look at the software running on the devices so that more attempted attacks can be detected at an earlier stage."

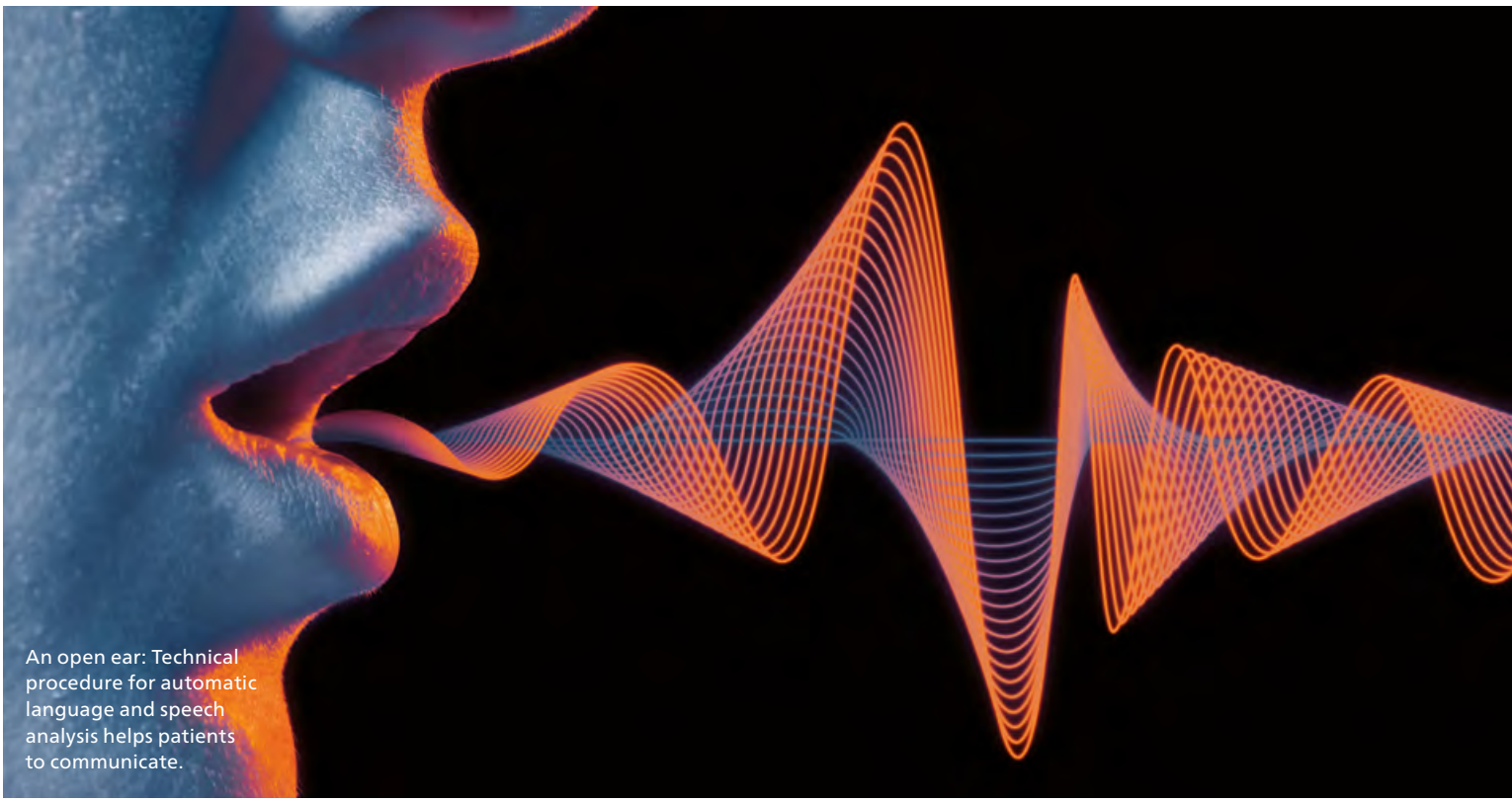
An innovative tool for IT security testing is being developed in the IntelliSecTest project involving four Fraunhofer institutes: the institutes for

Everything is under control: According to a Bitkom survey (2022), 85 percent of users control their IoT devices via a cellphone app.

Photo: Gpointstudio/Westend61/mauritius images

Mechatronic Systems Design IEM, for Applied and Integrated Security AISEC, for Open Communication Systems FOKUS and for Communication, Information Processing and Ergonomics FKIE. The objective is for this tool to combine different testing methods so that it can identify vulnerabilities right from the software development stage with greater precision than current tests. And it must still be so easy to use that even companies with no proven security experts can make an initial assessment of the security of their product, whether it is their own software or open-source software packages from other developers.

But to empower companies to build up their expertise in the long term and drive appropriate developments themselves, Fraunhofer IEM offers security champion training in its role as partner in the Cybersecurity Training Lab at the Fraunhofer Academy. "We want to pass on the expertise required for secure software development, but we also want to help develop the appropriate soft skills so that the security champions can act as multipliers and take charge of security matters in the company — including when dealing with managers," emphasizes Meyer. "In addition, we offer software security training that is specially designed for managers. In view of the upcoming EU regulations, a lack of security is not a trivial matter anymore. In fact, companies could be hit hard by being forced to pay hefty fines or even take a product off the market. That's why it is now definitely a task for the management level." ■



An open ear: Technical procedure for automatic language and speech analysis helps patients to communicate.

Let's talk

The new possibilities offered by language and speech analysis are helping people whose communication is limited due to illness. One day, these possibilities may even facilitate the early detection of certain illnesses.

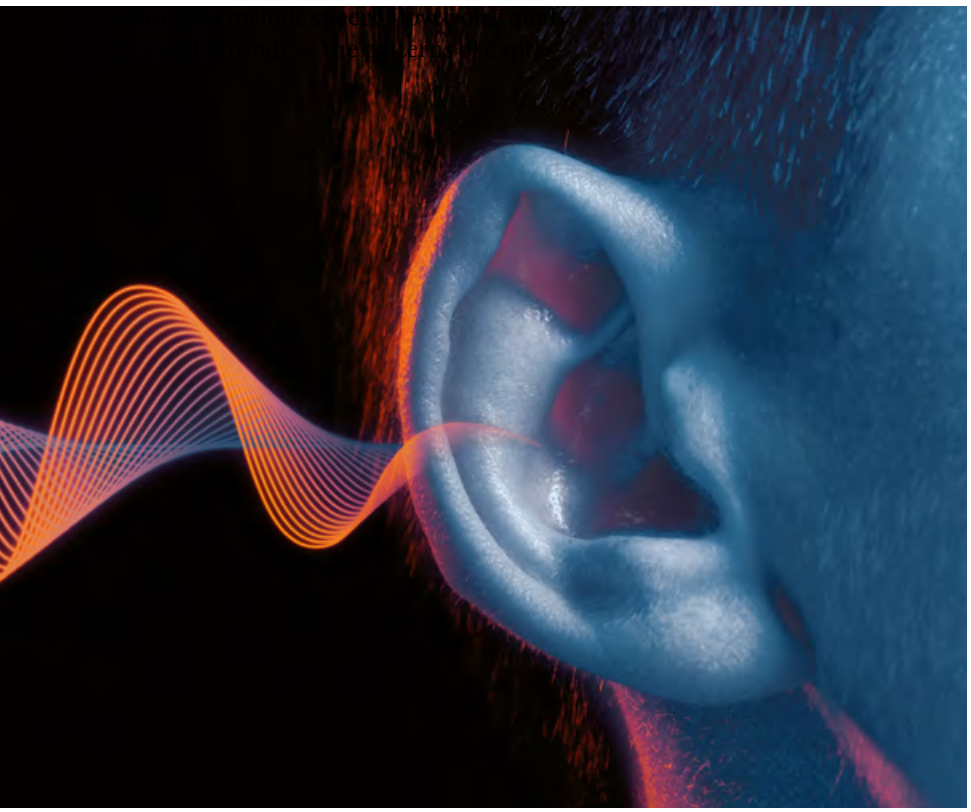
By Yvonne Weiß

It switches on the light for us, opens the blinds and turns the music down. In the car, it warns us of the next traffic jam, shows us the best route, reads out the news and takes the next phone call. Speech recognition can already do a lot — and soon it could do a whole lot more.

At the Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg, researchers are developing technical procedures for automatic language and speech analysis to help people who can only communicate in a limited way, such as those who have suffered a stroke or hearing loss.

"Our primary objective is to support people's communication skills," explains Laura Tuschen, head of the Assistive Speech and Language Analysis research group at Fraunhofer IDMT. "Language processing and digital procedures now offer great potential, but speech-language pathology and speech therapy are still very technologically underdeveloped. We want to change that and combine technical knowledge from both disciplines."

Unlike existing systems, the technology from the Oldenburg Branch for Hearing, Speech and Audio Technology HSA can analyze specific characteristics of disorders and make it possible to evaluate them in the context of illnesses. The aspects



sion used when speaking. This includes the volume of the voice, the tempo and the speech melody.

In the Theresiah project, the researchers have worked with partners to develop a digital therapy system that uses pronunciation and auditory training to help the hearing-impaired. Sufferers often lack audio feedback, meaning they cannot judge their own voice and way of speaking. This is where the integrated language analysis technology from Fraunhofer IDMT can help: It detects patterns of pronunciation and gives patients feedback, enabling efficient and individual training.

The OSST project (Oldenburg Speech and Voice Test) runs until the end of 2023 and takes this topic further: Together with research partners, the Fraunhofer researchers are developing a screening process that analyzes voice and speech disorders with the aim of supporting speech and language training. "What sounds can a patient with hearing loss no longer articulate correctly? Are sibilant sounds affected? Does the voice sound monotone, or in other words, is intonation impaired? In this project, we want to develop a prototype that gives us answers to these questions," explains Tuschen.

> "Our primary objective is to support people's communication skills."
>
> Laura Tuschen, Fraunhofer IDMT

Laura Tuschen is supporting patients with a digital training system.

Stroke patients, who often have impaired communication skills, can also have high hopes for the technology: In the HiSSS project (hybrid and interactive speech and language therapy after stroke), researchers are developing a therapy system designed to give these patients some of their communication skills back. It is intended to protect people from possible social isolation and improve their quality of life.

Digital training to supplement conventional therapy

Patients use an app to practice forming specific words and sentences, as well as train their ability to recall words and pronounce certain sounds. They then receive personalized feedback from the app.

"Because of the digital transformation and the shortage of skilled workers, new technologies are needed that can be used in therapeutic processes," believes Tuschen. She thinks digital training for use at home is an important step in this direction, as it is a flexible way to supplement conventional therapy in a clinical setting: "People who have had a stroke have been shown to need intensive speech therapy, but the provision of speech and language training is often inadequate. We want to close these gaps."

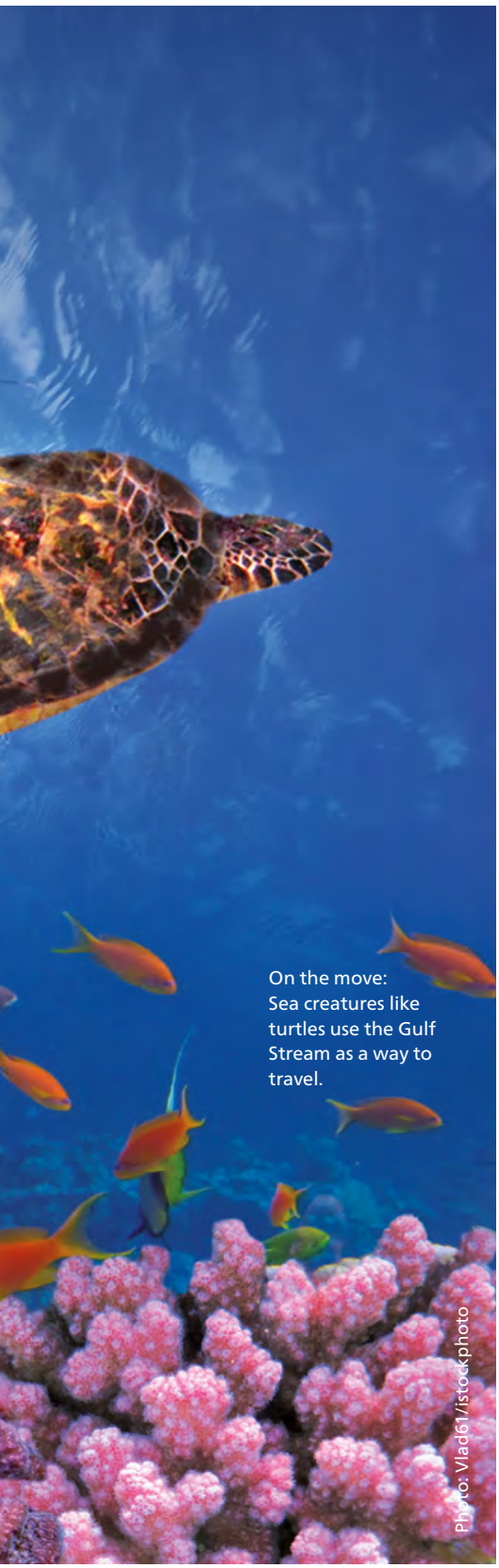
As well as improving provision, in the long term this technology for automatic and assistive speech and language analysis could even help in the early detection of conditions such as dementia: At an early stage, sufferers often have difficulty finding and using the right words. Aspects of communication skills, such as decreasing involvement and interaction in conversations, may also be impaired and could be indicators of the condition. The technology may be able to identify these signs in the future too. ■

Photos: Fraunhofer IDMT/Anika Bödecker, SvetaZi/istockphoto

More salt in the sea?

Rising temperatures are causing fluctuations in the ocean's salinity. This not only affects the Gulf Stream, but also endangers key organisms like plankton and algae. Fraunhofer researchers are investigating what to do now.

By Yvonne Weiß



On the move: Sea creatures like turtles use the Gulf Stream as a way to travel.

Photo: Vlad61/istockphoto

We know the consequences if it ever becomes weaker. The North Sea could freeze over for months at a time. Germany's green meadows could be transformed into barren landscapes. Sea creatures like turtles and eels might not be able to travel north anymore. The Gulf Stream is predicted to slow down as a result of climate change, and this is primarily due to the salinity of the sea. Higher temperatures in the polar regions cause more and more ice to melt; the saltwater is diluted by this additional fresh water. It is no longer cold and salty, so it is not heavy enough to sink. It loses the power it had to drive the currents.

"The salinity of the ocean is a crucial factor in climate research," emphasizes Dr. Till Röthig, deputy head of the Biodiversity Research department at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME.

According to Röthig, salinity has not received enough attention in climate research, given these possible impacts. He now wants to change that by working with research partners. As part of a study, Röthig and his team are investigating the possible consequences. In particular, the researchers are concentrating on the consequences of human interventions in nature. These exacerbate the fluctuations — particularly anthropogenic global warming.

Röthig and his team aim to use computer simulations to answer the following key question: How will different ecosystems cope with a change in the level of salt in the ocean by the end of the century? The model is based on two types of data: Salt tolerance values for different organisms, as well climate predictions in the latest report from the Intergovernmental Panel on Climate Change.

20 percent of the world's plankton could disappear by 2100

According to the calculations, organisms such as plankton, coral reefs and algae are particularly affected — these are key organisms that not only ensure the survival of many other creatures, but also are crucial in the fight against climate change.

"Plankton produce almost half of the world's oxygen. They also remove about as much carbon dioxide from the atmosphere as all the world's forests put together."

Dr. Till Röthig, Fraunhofer IME

"Plankton produce almost half of the world's oxygen," explains Röthig. He adds that they also remove about as much carbon dioxide from the atmosphere as all the world's forests put together. "Our study reveals that a change in salinity alone will threaten around 20 percent of the world's plankton communities by the end of the century — and that's quite apart from rising temperatures, which are of a similar significance."

He admits that this is not a reliable prediction as it is based on data projected into the future. Nevertheless, Röthig is convinced that there is an urgent need for climate researchers to include salinity as a central parameter in future studies: "We can only protect ourselves if we can make accurate predictions of what will happen." ■

Scan here to see the study:

No more turning a blind eye

The degree to which chemical substances irritate human eyes is generally tested on rabbits. The Fraunhofer Institute for Silicate Research ISC wants to end this with its new and extremely promising testing system.

By Yvonne Weiß

The eye is a highly complex organ. The human eye can see an angle of more than 200 degrees, while the wild rabbit has an almost 360-degree view. The eye can also be very simple. It is floating in a test tube as a piece of tissue, reduced to a model that replicates the cornea — the front section of the human eye. It is made from human cells and nourished by amino acids, vitamins and proteins. But as simple as this eye in a test tube may be, its focus is on animal welfare.

Every day, we come into contact with a wide range of chemicals. But these substances can cause irritation: A drop of shampoo is often enough to cause painful irritation of the eyes, if only for a short time. In order to rule out any long-term harm or even blindness, researchers test the irritation potential of chemical substances before products go on the market and end up in bathroom cabinets. The Draize test has been used for this purpose since 1944 — this is a procedure which involves dropping chemical substances into the eyes of rabbits.

Dr. Christian Lotz, head of the in-vitro test systems group at the Fraunhofer Translational Center for Regenerative Therapies TLC-RT at the Fraunhofer ISC, is looking into a promising alternative. Together with his team and external partners from industry and research, he is developing a process as part of the ImAi project that determines the potential dangers of chemical substances in vitro, without involving rabbits.

"We hope to develop an animal-friendly alternative to the Draize test that delivers reliable results," says Lotz, explaining the goal of the project. In a follow-up project, the new test system is then to be developed into the OECD test guideline and thus the new standard test procedure. This project is important to manufacturers in the EU because, since 2013, animal experiments have only been permitted to a limited extent in the EU and are already entirely banned when it comes to testing ingredients for cosmetics. As a result, there is an increasing demand for alternatives that do not involve testing on animals.

The cells in the tissue that Lotz and his colleagues are growing in a test tube — and that replicates the cornea — are surrounded by a membrane. Due to its chemical composition, this functions in the same way as an electrical insulator. Whenever the cells form one or more closed layers, a measurable electrical resistance is created.

In order to evaluate the irritation potential and classify chemical substances accordingly, the project team adds the critical chemical in the test. An impedance spectrometer then measures the electrical resistance in the model: "If the test substance is hazardous to the cornea, cells die and holes appear in the cell membrane. The resistance drops as a result and the electricity is able to flow freely once more," says Lotz, explaining the principle. If resistance is low, this means the substance has severely damaged the tissue. But if the value is high, the tissue has not been harmed.

This therefore turns the resistance into an indicator of how hazardous the substance can be for the human eye, without destroying the cornea in vitro. "It comes with the great advantage that we can examine the tissue again after a few days. This allows us to demonstrate whether the damage can be reversed — a crucial feature of classification that has not been achieved so far using previous animal-free testing," says the scientist happily. An additional bonus is that by testing human cells, more reliable results can be achieved since an animal's eyes are different to a human's at a cellular level. This makes the risk assessment in the new test much more robust.

> "We hope to develop an animal-friendly alternative to the Draize test that delivers reliable results."

Dr. Christian Lotz, Fraunhofer ISC

The project, funded by the German Federal Ministry of Education and Research (BMBF), is coming to the end of the initial funding period. Lotz and his team are currently conducting a study involving several laboratories: For the method to become part of the OECD guideline in around two to five years, it must be proven to work in laboratories worldwide. In the follow-up project, the researchers pass their technology on to the Expert Council at the OECD, which will then decide whether the process will indeed be adopted as a guideline or whether improvements still need to be made.

Lotz is hoping to enjoy success across Europe: "I think it would be amazing if we make the leap and actually apply technology that we once worked on in the laboratory in the form of an OECD guideline." ■

Keeping an eye on your health: A new testing method could protect the eye against dangerous irritation.

Photos: Science Photo Library/mauritius images (2), Katrin Selsam/Fraunhofer ISC

High tech to combat mines

In Ukraine alone, a third of the country's area is said to be littered with weapons. Fraunhofer researchers are working on technologies to reduce the risk involved in disarming booby traps — sometimes a burst of water helps.

By Mehmet Toprak

Long-term danger: Land mines can continue to kill decades after being deployed.

Photo: Smolyenko Dmytro/Ukrinform/ABACA/dpa

When it comes to explosions, researchers from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI know what they're doing. For many years, they have been studying what happens within just a few milliseconds: from the ignition that sets off the chemical reaction in the explosive and the spread of the reaction that releases large amounts of energy, right the way up to the sudden expansion of the hot reaction products that lead to shock waves in the air. It all happens so fast that the human eye is unable to take it in.

At Fraunhofer EMI, hydrocodes such as the APOLLO blast simulator for gas-dynamic processes and SOPHIA for the behavior of solids are being developed to simulate explosions. They are used to conduct research into and analyze the high-speed processes taking place inside the explosive and during the spread and impact of the blast waves. In the case of mines, the APOLLO blast simulator enables, for example, the risk of harm from a detonation to be estimated for a specific area and the harm to be quantified.

Danger of civilian deaths

The war in Ukraine reveals just how great the threat posed by mines can be. Back in the spring, President Volodymyr Zelensky spoke of the fact that around a third of the country's land is mined. According to press reports, the Russian Armed Forces have mined a stretch of land 1,000 kilometers long and 16 kilometers deep in order to halt the Ukrainian counteroffensive. They have deployed at least seven types of anti-personnel mine. Civilians in Ukraine are also affected. According to information in the land mine report, 277 civilians were killed in the first nine months of 2022 alone.

Fraunhofer's experts use their knowledge not only to conduct research into and simulate explosions, but also to disarm mines. Dr. Martin Lück, group manager for laser technology in the Impact Physics department, and his team focus on laser technology and have further developed the SOPHIA hydrocode for this purpose. A continuous-wave laser is directed at the mine or another explosive object such as an IED (improvised explosive device). Dr. Lück describes what happens next: "The heat penetrates through the shell ▶

and heats the explosive. This causes part of the explosive to react and the reaction gases increase the pressure in the shell. When the laser bores a hole into the shell or rips it open due to the pressure, the remaining explosive can be burned off in a controlled manner." As a result, the destructive detonation does not materialize. This does not mean that the mine has become completely harmless, however, as the toxic explosive does not generally burn off in full. The residues are still distributed in the environment as particles, aerosols or fragments.

In an ideal scenario, the technique works up to a distance of 100 meters, reducing the risk for deminers. However, researchers at Fraunhofer EMI are using a different method to prevent the mines or booby traps from detonating: They are destroying the weapons with a burst of water. "The jet of water is powered by pyrotechnics and is therefore extremely strong. When it hits the mine, the mine is broken down into its individual pieces by the kinetic impulse," explains Axel Sättler, head of the Experimental Ballistics department. The remaining fragments can usually be collected and then disposed of in an environmentally responsible manner. Projects on simulation and risk analysis, neutralization of weapons by means of lasers and destruction of weapons by means of effectors such as water have been developed on behalf of the German Armed Forces and are part of the European Commission's "Encounter" project.

Radar technique finds mines in the ground

Before mines are disarmed, they first need to be found. This is the focus of researchers led by Dr. Christian Bräu, group manager for ultrabroadband radar at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg, near Bonn.

The task of both finding and identifying mines poses a huge challenge. The reason for this is that many objects in the ground are not mines at all, but empty oil cans, broken shopping carts or merely old cola cans. What's more, with IEDs, scrap is also laid as a trap to make it more difficult for the adversary to detect the device. The Fraunhofer FHR team is therefore going all out with its technology and focusing on ultrabroadband radar. Radar is also able to detect non-metal objects — after all, land mines or booby traps such as canisters filled with manure are almost always made from plastic. The ultrabroadband radar works in a frequency range between 400 megahertz and 6 gigahertz. Due to the low frequencies, the electromagnetic waves penetrate deep into the ground. The high bandwidth improves the resolution and degree of detail of the objects being surveyed.

"We are constantly furthering our research to enable the German Armed Forces to improve the jamming ability of their systems and better protect their soldiers."

Dennis Gläsel, Fraunhofer FKIE

Bräu and his team are achieving further progress thanks to a novel combination comprising polarimetric and multistatic antennas. With the multistatic antenna arrays, an antenna emits the signal and up to six antennas receive the reflected signals from the ground. The different angles at which the reflected waves arrive enable an exact picture of the objects hidden in the ground to be produced. Polarimetric antenna technology provides even more accuracy. Bräu explains the approach: "We use the fact that objects that reflect radar waves also change their polarization, i.e., the plane in which the electromagnetic wave oscillates. The changes to the polarization data provide us with additional information about the geometry and the dimensions of the object in question."

Mounted on a vehicle, the radar systems also detect mines that are buried 10 to 20 meters in front of the vehicle. In dry environments, the radar waves could penetrate up to one meter into the ground. Wet ground, on the other hand, absorbs the electromagnetic waves and makes detection more difficult.

Jamming systems prevent booby traps from being triggered

Sometimes, a mine is not a mine at all, but an RCIED (radio-controlled improvised explosive device) that is triggered as soon as a vehicle or people are in its vicinity. Jamming systems provide protection here. They issue signals that act like a noise floor across the environment so that the radio receiver in the RCIED no longer "understands" the triggering signal for the explosion. As a result, the jamming systems also serve to protect deminers.

Dennis Gläsel is the project manager for jamming in the Communication Systems department at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE in Wachtberg. He is working on further developing and optimizing the jamming systems used by the German Armed Forces. They need to stop signals

with a wide range of different frequencies and strengths. The radio specialists from Wachtberg use the sweep technique here, for example. This involves the emitted jamming signal being guided over a predefined frequency range in zigzag lines. The change in frequency takes place within microseconds. Mine clearance teams constantly find themselves in situations where multiple enemy systems are present or suspected. That is why the Fraunhofer FKIE researchers are working on algorithms that automatically analyze the local signal situation to enable the jamming power to concentrate on the relevant frequencies. The algorithms determine in next to no time whether frequencies need to be changed and how long they need to be retained.

"New technologies from the civilian world such as 5G and 6G mobile communications are increasingly also being used for RCIEDs, mines or to control drones," explains Gläsel. "In this race, we are constantly furthering our research to enable the German Armed Forces to improve the jamming ability of their systems and better protect their soldiers."

International cooperation is a crucial factor in this work. The FKIE team works together with experts from a large number of NATO countries. In addition to regular meetings as part of a team of experts, the Fraunhofer FKIE researchers meet with partners to test out the jamming systems in annual laboratory measurements and biennial open area measurements and to trial new technologies.

Yet the risk remains — including for deminers. Physicist Armin Keßler, project group manager for technical safety in the Energy Systems department at the Fraunhofer Institute for Chemical Technology ICT, emphasizes the following, however: "Professional mine clearance is not a thrilling adventure, but rather the result of a complex process chain." Fraunhofer ICT works on planning that process chain. "We classify explosives, ensure they are handled safely and formulate safety concepts for every step," says Keßler. In short, research is attempting to make the risk calculable. ■

During the NEMO 2022 NATO exercise, a bomb disposal engineer demonstrates their work on an RCIED.

Photos: Fraunhofer FKIE / Dennis Gläsel

Getting the ingredients and the processing method right are crucial to the taste.

Full-flavored chocolate pleasure

Dark chocolate isn't for everyone. Many vegans or people who are lactose intolerant love the smoothness and sweetness of milk chocolate. Fraunhofer IVV is here to help them.

By Dr. Sonja Endres

Christmas time is a time for chocolate. Whether in the shape of Santa Claus, an angel or a golden bell, around half of all Germans prefer milk chocolate. Yet more and more people are looking to move away from cow's milk either completely or to some extent — for animal welfare reasons, due to food intolerances or because they are following a vegan diet. According to the results of a Statista survey from 2021, one third of people search for treats that do not contain cow's milk.

To ensure that they can find these with chocolate, Dr. Isabell Rothkopf at the Fraunhofer Institute for Process Engineering and Packaging IVV is conducting research into the perfect vegan substitute. It needs to melt in the mouth, have a delicate sweetness and full-flavored aroma. "Products that are currently available on the market don't achieve this for me," explains chocolate expert Rothkopf. Often, the smoothness is missing, something rough remains on the tongue and the plant flavor dominates, she adds. So what's going wrong? Manufacturers replace cow's milk with common alternatives such as oat, almond or soy milk. "But that doesn't work," finds Rothkopf, "as cow's milk in chocolate is more than a filler, it affects the product in many ways." When the cow's milk is processed, the aroma changes and the chocolate tastes more like fresh milk or caramel, for example. "I don't get that with plant-based products because the milk sugar is missing," says Rothkopf. She also adds that the milk has an effect on the flow properties, how the product looks and its shelf life. "So, first of all, we are analyzing precisely what it is that cow's milk does in chocolate. What effects do milk sugar, fat and protein have?"

Hazelnut oil instead of milk fat

First, Rothkopf and her team started with the milk fat and discovered that it can be replaced to great effect by regional plant-based oils. "When you use hazelnut oil, you also get the nutty character of the chocolate right," she explains. The milk sugar, lactose, is more problematic. Granulated sugar is too sweet, so the Fraunhofer IVV team is experimenting with grape and fruit sugars as well as with a new sugar, tagatose, and an innovative sweetener, allulose.

The milk protein is also not so easy to replace with plant-based proteins. It seems to have a lightly emulsifying effect, meaning that the cocoa butter and sugar bond more effectively. Rothkopf is currently investigating different plant-based alternatives that she wants to test in her chocolate. To do this, she can draw on an extensive in-house database at the institute.

To get as close as possible to the characteristic flavor of milk chocolate, not only does the Fraunhofer IVV team vary the ingredients, it also constantly adapts how they are processed. Rothkopf: "Plant-based products often have fibers, for example. I have to break these down differently so that I don't end up with any unpleasant particles on my tongue." During conching, a special kneading and mixing process that is crucial to the flow properties of chocolate and enhances the aroma, the scientists experiment with different temperatures and adjust the kneading time and power. "It is important that the aroma is distributed evenly in the mass. Unwanted substances such as acetic acids, which are present in large quantities in raw cocoa, should evaporate, but the sought-after aromas should be retained."

Appealing appearance, longer shelf life

Another shortcoming in conventional vegan chocolate is its appearance. It often lacks a flawless, shiny surface, with the bar quickly developing a gray finish, known as fat bloom. Rothkopf: "This is something you also see on normal milk chocolate. If it hasn't been stored properly or is older, the fat travels up and crystallizes. According to the latest studies, the classic milk protein casein is likely to have an effect that delays the occurrence of fat bloom. The product can therefore be kept for longer." Even if the chocolate has fat bloom, it is still fine to eat but it will have a little less flavor. The plant-based oils that the Fraunhofer IVV team is using in the chocolate are also advantageous in this respect as they inhibit the formation of fat bloom. "It is crucial that the oils are worked well into the mixture relatively early on. The fat is then less mobile." As appearance plays an important role when enjoying a treat in particular, what is the Christmas message from chocolate expert Rothkopf: "It needs to look appetizing. After all, you want to treat yourself." ■

Chocolate keeps for longest when it is stored in a **cool and dark** place at around

18

degrees Celsius. Then the chances are good that you'll still be able to enjoy it next Christmas.

Photo: Jill Chen/Stocksy/F1 Online

Goodbye to fogged-up surfaces: Fraunhofer IOF offers a clear view.

A clear view — coating after coating

If the car windshield fogs up, it's annoying. But if the camera on an autonomous vehicle fogs up, things can quickly become dangerous. A new optical coating system aims to prevent this.

By Stefanie Smuda

Is it possible to stop glass from fogging up? As well as bothering glasses wearers, this question is also the focus of Anne Gärtner, a doctoral student at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. She is working on anti-reflective coatings (AR coatings for short) and, together with her team, has developed a system that solves two problems at once: It prevents surfaces from fogging up and reflections from developing.

"Glasses wearers are familiar with their glasses fogging up when they come into a warm room from the cold outside, restricting their vision hugely," says Gärtner. "The same can happen to sensors such as the

LiDAR systems used in autonomous cars. It is important that surfaces remain highly transparent, even if fogging occurs, so that functionality is maintained."

To counteract loss of reflection, ghost images and residual images in optical systems, anti-reflective coatings are needed. Reflections occur even on one individual lens without an anti-reflective coating — and these mount up on systems with multiple lenses: Depending on the refractive index of the substrate material, reflection loss of around four percent may occur for each interface. To prevent this, nanostructures are generated on optical surfaces using AR-plas® technology.

The principle of AR-plas® technology draws on nature: The eyes of nocturnal moths contain anti-reflective structures, known as moth-eye structures. "Moths have black eyes that reveal a microstructure and a nanostructure under the microscope. We are recreating these nanostructures in the lab," explains Dr. Astrid Bingel, group manager at Fraunhofer IOF. The surface is manipulated in such a way that disruptive reflections are significantly reduced.

> "Moths have black eyes that reveal a microstructure and a nanostructure under the microscope."

Dr. Astrid Bingel, Fraunhofer IOF

Leica Geosystems AG from Heerbrugg in Switzerland came to Fraunhofer IOF to work together on an AR coating system for LiDAR systems. The company develops airborne LiDAR measurement systems for mapping and surveying applications. The abbreviation LiDAR stands for "light detection and ranging" and refers to laser systems used to carry out optical distance and speed measurements.

AR-plas2 technology: Reduce reflections, prevent fogging

The measurement systems are deployed, for example, on survey aircraft that capture images from altitudes of several thousand meters. In doing so, the aircraft sometimes cross different layers of air, which can result in extreme temperature differences between the LiDAR system and the environment. Subsequently, the optical surfaces fog up, affecting functionality. A solution was therefore sought that would not only reduce reflections for a special wavelength and incidence angle range, but that would also prevent the optical surfaces from fogging.

Anne Gärtner and her team developed a novel coating system using AR-plas2 technology, a development of the original AR-plas® method. This allows multiple nanostructures to be generated on top of each other. In this specific case, a polymer coating was combined with nanostructures. "We used a special coating that prevents fogging on an optical surface by acting as a water reservoir," explains Gärtner. This antifog coating acts like a water reservoir and swells as soon as the surface gets wet. As a result, the optical surfaces in the LiDAR system do not fog up.

"Using AR-plas2 technology, we then etched a nanostructure into the coating and applied a second nanostructure on top," says Dr. Astrid Bingel. The special process allows the polymer to become more hydrophilic: Instead of droplets, a uniform film forms on the surface and does not affect the vision. "However, differences in the refractive indices of the polymer film and the surrounding air lead to unwanted reflections and ghost light in the optical system," adds Gärtner. Here, the double nanostructure allows reflections to be minimized over a wide spectral range. Despite this, the function of the antifog coating underneath is not affected.

The AR-plas2 technology provides the researchers with maximum flexibility: "We can either stack multiple nanostructures on top of each other or combine one nanostructure with a classic coating system. We therefore have a broad modular concept for developing optical designs," says Gärtner. The technology can be used on almost all types of material — from polymers and glass to fluoride crystals — as well as in many areas. Combined nanostructures are already being used in particular in the automotive industry for autonomous driving systems and in the consumer goods sector for smartphone cameras, for instance. Research is also currently being carried out into a quantum computing application.

However, the technology does have one limitation in particular: Nanostructures are sensitive to touch. The coating system is therefore primarily suited to internal surfaces. So glasses wearers will have to continue to reach for their cleaning cloths. ■

Photos: Karl Hedin/Unsplash, Fraunhofer IOF

EUROPE

Clean aviation

Researchers in the HERWINGT joint research project, in which 25 European partners are involved, are working on environmentally friendly aviation. Together, they are developing novel high-performance wings for hybrid-electric regional aircraft with a range of up to 1,000 kilometers which will help to reduce fuel consumption by 50 percent. The innovative wing concept includes a larger aspect ratio with improved aerodynamics, new structure concepts and materials to reduce weight as well as aviation fuel systems that are compatible with biofuel. The integration of electrical systems is also being sustainably improved. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS is bringing its expertise in application-specific data collection to the project and supporting the development of an ultrasound-based sensor measuring system to be integrated in the wings. Using structural health monitoring (SHM), the structural condition and thus the functional safety of the wings is monitored continuously. The environmentally friendly regional aircraft are set to be launched on the market from 2035.

Short-haul flights without the guilty conscience thanks to hybrid-electric regional aircraft.

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

Diamonds help to improve driving efficiency and charging speed.

USA

A gem to drive

As well as being beautiful, diamonds are also superb heat conductors and are five times more conductive than copper. Researchers from Fraunhofer USA are taking advantage of these exceptional thermal properties when cooling the electrical components in electric vehicles. The scientists have succeeded in developing nanomembranes from synthetic diamonds that are thinner than a human hair. The flexible membranes can be integrated directly into existing electronic components and reduce the local heat load by up to ten times. The energy efficiency, service life and road performance of electric cars is improved significantly as a result. Another advantage is the fact that the diamond membranes used in the charging infrastructure contribute to charging speeds that are five times higher. What's more, mainframe computers in data centers could in future also be cooled more efficiently thanks to the new technology.

SOUTH AFRICA

Environmentally friendly power for South Africa

Scientists from the Fraunhofer Institute for Machine Tools and Forming Technology IWU together with South African and German companies as well as Stellenbosch University have developed a mobile, self-sufficient power supply system based on hydrogen. Electrolyzers that produce green hydrogen are combined with fuel cells to reconvert the hydrogen into electricity in microgrids half the size of a shipping container. The system is connected to external solar power sources; to create a fully self-sufficient solution, the roof of the container simply has to be equipped with photovoltaics. The aim of the HyTrA project is to establish hydrogen technology as an environmentally friendly and reliable way of producing electricity in South Africa and to increase the level of acceptance in the population through publicly accessible demonstrators. An initial industrial application is in operation at a manufacturer of vehicle-based rooftop tents in Cape Town.

Flexible microgrids produce hydrogen from solar energy.

DENMARK

Perfect coffee aroma thanks to AI

In future, artificial intelligence (AI) will be providing unadulterated coffee enjoyment: The Fraunhofer Institute for Manufacturing Engineering and Automation IPA is working alongside the Danish Technological Institute DTI to further develop an AI model that optimizes coffee blends using predefined flavor profiles. Until now, coffee experts who have trained their taste buds have been responsible for testing aromas.

Based on data on bean types, flavor components, blend ratios and degrees of roasting, AI has been trained to create the best recipes at the most affordable price. The aim was to find a more transparent model with a simpler structure to obtain replicable solutions. Using AI, coffee producers can adapt the procurement process for green coffee flexibly to seasonal conditions and price fluctuations without the quality being affected.

The smell is an important assessment criterion for coffee sommeliers.

Until now, petroleum-based plastic film has ensured that individual parts do not slip when they are transported on pallets.

AUSTRIA

Sustainable film packaging

A research consortium led by Fraunhofer Austria has developed a biobased stretch film that can be fully composted within just a few weeks without leaving any residue behind. The film meets all requirements for use in logistics. Its material composition, which is based on various lactic acid-based bioplastic granulates known as polylactides (PLA), demonstrates better mechanical properties such as ductility, elasticity and tensile strength than conventional stretch films. The innovative biofilm can also be recycled up to six times without any loss of quality.

Stretch film is ubiquitous in the transport logistics sector as a way of securing pallets — in the form of petroleum-based disposable packaging, only a fraction of which can be recycled. If the plastic enters the environment, it takes up to 400 years to decompose, often producing environmentally harmful microplastics. Another aim of the project is therefore to use biofilms as efficiently as possible: A newly developed control technology for machines that automatically wrap pallets with stretch film has so far facilitated material savings of 30 percent. It is currently being tested for industrial application together with the innovative film in the pilot factory at TU Wien.

Photos: istockphoto (5)

Life is sweet

All hail sugar: Glycobiotechnology opens up a wealth of possibilities — especially for the diagnosis and treatment of diseases.

By Beate Strobel

Sugar has an image problem. If you consume too much of it, you increase your risk of developing caries, becoming overweight or suffering from high blood pressure, cardiovascular diseases, diabetes mellitus, a fatty liver or gout. Yet there is more to this sweet substance than that. According to Prof. Ruben R. Rosencrantz: "Life would not exist without sugar."

The chemist and biologist at the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam is conducting research into the good sides of glycans, the name given to the biomolecule class of complex sugars. Glycobiotechnology is regarded as a genuine science of the future. The research community hopes that the capabilities of these sugars will enable exciting innovative approaches to be found for the pharmaceutical, food, cosmetic or medical technology sectors.

Living things need sugar — and not just to supply them with energy. Virtually every human cell has a highly specific sugar coat on its surface. The glycans within are attached to fats and proteins and protrude from the surface of the cell like small antennas. The glycoproteins and glycolipids have the job of a radio operator: They pass external information to the inside of the cell or transmit internal signals to other cells and passing proteins. And they serve as a docking site for bacterial and viral visitors. The job of the immune system, on the other hand, is to scan the sugar structure of cells and find out whether these belong to the body's own system or whether they are hazardous intruders that need to be destroyed. In the case of inflammation, special proteins (called selectins) snap up the white blood cells at their sugar antennas and move them through the wall of the blood vessel and into the inflamed tissue. "Without correct glycosylation, i.e., modification with special sugars, the function of proteins is restricted," explains Dr. Sophia Rosencrantz who, alongside her husband Ruben, conducts research at Fraunhofer IAP, focusing on glycobiotechnology.

> "Life would not exist without sugar."
>
> Ruben R. Rosencrantz, Fraunhofer IAP

The reason that nature relies on the help offered by glycans is also related to their variability: While proteins are comprised solely of amino acid chains, glycans are made up of ring-shaped single sugars which can vary in terms of module sequence, type of link, chain length and

Sugar is a pure taste sensation — and can do so much more than simply taste sweet.

Photo: PLubitz + Dorner/plainpicture

degree of branching. In a combination of just three single sugars, more than 27,000 different molecular structures are possible. So if you then imagine that several different sugars can be attached to one protein molecule, and these all help to determine the properties and functions of the protein, it becomes clear just how much fine adjustment is possible through glycans.

Medical research is opening up more and more new methods for diagnosis and treatment. Sophia Rosencrantz is working within the Fraunhofer Cluster of Excellence Immune-Mediated Diseases CIMD on a method for the early diagnosis of rheumatoid arthritis, one of the most common forms of chronic joint inflammation. "It is known that this auto-immune disease is associated with an abnormal glycosylation of certain immunoglobulins," explains the biotechnologist. "We now want to develop a tool that allows the sugar structure of the immunoglobulins to be scanned early on — ideally, to treat the disease before its onset and, if possible, even to cure it." With respect to cancer research too, there are hopes that glycans could be used as biomarkers, as tumor cells often have a different sugar pattern on their surface compared to healthy cells.

Sophia Rosencrantz is also working on altering the glycosylation of antibodies in terms of their enzymes so that the antibodies demonstrate an improved or enhanced effect. "By modifying its sugar antennas, the antibody is implanted in cells in a targeted manner and brings along its harmful protein cargo to force it to be broken down there," she explains. This method is set to contribute to the development of tailored and therefore highly effective drugs in future.

Ruben R. Rosencrantz, on the other hand, is working on producing glycopolymers, i.e., polymers that are able to capture sugar-binding proteins or even toxins by means of presented glycans. "In contrast to antibiotics, which act on the metabolism of a bacterium, these pathoblockers deliberately offer themselves as binding partners to certain pathogens and prevent them adhering to the actual target tissue. We hope that this form of treatment will demonstrate less resistance than antibiotics."

For a German-Israeli project, Prof. Rosencrantz has also developed glycopolymers which not only make wearing contact lenses more comfortable for the eyes, but which also allow the targeted release of drugs. The focal point here are mucins, special glycoproteins that are responsible for everything in the body that is gel-like or slick. "The idea was to coat contact lenses with such synthetically produced mucins that are similar to the naturally occurring sugar gels in the eye," the researcher explains. "Drugs contained in the lens can then be released slowly and have a much longer-lasting effect in the eye than eye drops, for instance."

The extreme variety offered by the world of sugar reveals many research options, yet is also a challenge when developing drugs, functional food or cosmetics: "Sugar synthesis is highly complex and therefore also very expensive," explains Sophia Rosencrantz. As soon as even individual atoms in the ring structure protrude upward or downward at the wrong place, the body identifies them as foreign. "Sugars are the masters of creating maximum effect with minimum change," explains Ruben R. Rosencrantz. "For this reason, a chemical synthesis has to be extremely controlled to ultimately achieve the exact sugar structure that is required."

Central databases and artificial intelligence are set to organize the extraordinarily large world of complex sugars more effectively and make the variety of interactions between glycans, proteins and lipids manageable for research and industry. Even insiders such as the Rosencrantz couple find it difficult to estimate the potential that is still lying dormant in glycobiotechnology for different industries. One thing that is certain, however, is that the potential is enormous — and is still largely undiscovered. ■

Innovative methods such as GreenLight laser vaporization allow gentle treatment of benign prostate enlargements. AI is set to optimize diagnosis in future.

Artificial intelligence to improve medicine

In the long term, AI could provide a valuable service in detecting cancer faster and treating it more efficiently.

By Dr. Janine van Ackeren

For many people, the technology of artificial intelligence (AI) primarily elicits feelings of anxiety at present: According to a representative survey from opinion research institute Civey, a good 80 percent of Germans expect AI to have between a somewhat negative and strongly negative effect on the world in the next ten years. Among other things, they fear its influence on public discourse (57%), job losses (34%) and growing economic inequality (27%). However, the risks associated with artificial intelligence could be eclipsed by the positive effects that this pioneering technology has on medicine, for instance.

One example of this is the use of AI in diagnosing and treating prostate cancer. In western Europe and North America, carcinoma of the prostate is the most commonly diagnosed cancer among men and the second most common cancer-related cause of death in this group.

High reliance on the expertise of the diagnostician

Diagnosis involves the PSA value (short for prostate-specific antigen) and a biopsy in which a piece of the prostate tissue is taken and examined as a tissue section under a microscope. Are the cells still growing or are the cell structures already breaking down? Although there are predefined morphological patterns that physicians can use to analyze the tissue sections, the result depends on the expertise of the diagnostician. This became clear in the PANDA challenge (Prostate cANcer graDe Assessment), the largest histopathology competition for AI systems to date, in which pathologists examined the same samples and came to drastically different results.

Artificial intelligence aims to make diagnosis faster and, above all, more accurate — and also to enable the survival time of the patient to be predicted more precisely. The Fraunhofer Institute for Digital Medicine MEVIS, Charité — Universitätsmedizin Berlin and Goethe University Frankfurt are working together on the PROSurvival project, which is led by the computer science institute OFFIS. "Our aim is to make a statement about the likely length of recurrence-free survival directly from the image, without having to take the indirect route involving subjective classification into morphological samples,"

explains Dr. Johannes Lotz, a scientist at Fraunhofer MEVIS. At the heart of the project, there is a question of great significance: After the prostate has been removed, how long is it likely to take for a recurrence to occur, i.e., for further tissue to be affected by cancer?

Instead of resorting to the microscopy images that have been used until now as the basis for this prediction, the researchers are using the tissue concepts generated from the images. "Artificial intelligence converts each image into a low-dimensional representation that only contains the relevant information," says Lotz. The reduced version, the research team hopes, should continue to reveal certain tissue features that are associated with a long life expectancy. The researchers trained the AI with numerous datasets containing more than simply data and images of prostate carcinomas. The reason for this is that the AI is intended to become a kind of all-rounder, be transferred to different medical centers and clinics and provide the foundation for numerous other projects. In the long term, it is set to investigate the severity of breast cancer, find lymphocytes, segment biopsies and even analyze prostate cancer, as in the PROSurvival project. To ensure this works, the images have to be reduced to such an extent that all relevant questions can still be answered using the reduced data volume. To guarantee this, the researchers feed the system with the raw data and have it made smaller via the AI. So do the acquired tissue concepts enable an assessment to be carried out that is similarly precise to the original microscopy images? This question is set to be answered as part of subsequent projects. "This pretraining contains a large amount of the variability that one would expect in the real world," confirms Lotz.

The variety of the datasets is also rooted in the fact that they come from different health centers. If artificial intelligence is only trained with data from a single center, it will only work accurately there later on and may have difficulties working with data from a different center. This is presumably due to differences when staining the tissue sections. "There is now a consensus that multicentric data is required, i.e., data from different centers and clinics," explains Lotz. However, this is an approach that proves difficult in practice; after all, the data is of a sensitive nature and — for good reason — the clinics are unwilling to hand it over. Faced with this challenge, the tissue concepts approach offers a solution here too: Every center trains its own deep learning algorithm on site using its entire dataset, which also contains the sensitive in-house data. The interim results are shared with the other centers via a coordinating node. This makes sure that all algorithms have learned the same thing at the end. "With federated learning like this, you usually have to always share the entire model. As we are using the reduced data, the data volume being shared is much smaller, so the data exchange should be faster," says Lotz. What's more, the shared low-dimensional representations contain no sensitive data; this all remains in the clinics. Only the algorithms and the prediction models are shared.

> The AI is intended to become a kind of all-rounder and provide the foundation for numerous other projects.

Alongside this initial, cross-project AI application, the researchers are developing a second deep learning system that focuses specifically on prostate cancer. This aims to make a range of predictions using the reduced data: How is the grading of the tumor? How long is the recurrence-free survival period likely to be? Where in the image are the tumor areas and which tissue patterns are particularly predictive? The researchers hope that, in a few years, these questions will be able to be answered much faster and more accurately with the aid of artificial intelligence — with all the advantages this will bring when it comes to treating affected patients.

AI for the cancer registries

Artificial intelligence in cancer treatment is also useful with regard to large text volumes, such as those that converge in the cancer registries of the various German federal states. In these registries, all data on cancers and oncological treatments is systematically recorded, evaluated and made available — with the aim of detecting tumor diseases as early as possible and improving cancer treatment. The cancer registries therefore collect data on courses of treatment using a large database. Which treatments are successful for which types of tumor? Which preventative and early detection programs are worthwhile? Is there room for improvement in certain hospitals? To answer these questions, the clinics submit the data of their tumor patients: from diagnosis and individual treatment stages to aftercare and recurrence and potentially death. Based on this data, scientists are able to assess the success of treatments and bring new findings into general medical care.

The crux of the matter, however, is that the reports the clinical cancer registries receive mainly consist of unstructured free text, i.e., free formulations from the attending physicians. The documentalists of the cancer registries therefore first have to read each report, check its plausibility and transfer the data into the registry manually. What's more, the data needs to be in a structured form to allow it be evaluated effectively. Given that there are hundreds of thousands of reports every year, this is a Herculean task.

Artificial intelligence is set to make this work easier for the documentalists. The relevant AI is being developed in the TeMeK project (text mining of report texts for standardized classifications) in which the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, Averbis GmbH, the Medical Center — University of Freiburg, and ▶

Photo: Amelie-Benoist/Image Point Fr/BSIP/mauritius images

the Baden-Württemberg Cancer Registry are involved. The cancer registries of Berlin/Brandenburg, Hesse and Rhineland-Palatinate are also contributing expertise and data. "The AI application is particularly interesting in view of the fact that the reports in recent years no longer simply contain macroscopic and microscopic information — i.e., the position and size of the tumor as well as the histological examination of the cells in the laboratory. Instead, and this is a groundbreaking shift in cancer research, the reports now also include the results of DNA analyses of the tumor cells," says Dr. Hanna Geppert, research group manager at Fraunhofer FKIE. In the pathology lab, investigations are carried out regarding whether certain genes reveal defects, known as mutations, in the tumor cells. As a result, various gene mutations can be identified for some lung tumors. For some of these gene mutations, there are specific treatment approaches that attack the mutation precisely. In some cases, DNA analyses are opening up new therapeutic options and improving the treatment of cancer in the long term.

"As genetic tumor diagnostics is still a completely new field, there are no standardized methods for reporting on it or for communicating this information in a structured way," says Geppert. "Yet, the scientific community is reliant on the results of the genetic studies to generate new findings on a large scale." The researchers at Fraunhofer FKIE are therefore dedicating their efforts in the project to the new sections of the reports. "A report text is often a sequence of several findings with results from a wide range of examination methods in an unpredictable order and structure," explains Geppert. As a first step, the artificial intelligence has to trawl through the text and find out whether it contains results from genetic studies and, if so, where they are.

A traditional approach versus AI

The basis for this task is formed by 20,000 report texts containing corresponding passages that the researchers have received from the cancer registries, plus additional texts as control tests which do not include any results from genetic analyses. Using this data, the team investigated whether the machine learning approaches are better suited to this task than traditional text mining approaches. The difference is that while the computer unlocks its knowledge independently during the machine learning process, in the traditional approach, the researchers create the rules and patterns that the computer then runs independently. "During the first step, the traditional approach is faster and better than AI. Using machine learning approaches would in this case be like using a sledgehammer to crack a nut," explains Geppert.

> "The scientific community is reliant on the results of the genetic studies to generate new findings on a large scale."
>
> Dr. Hanna Geppert, Fraunhofer FKIE

Even during the second step — which involves finding the summary assessment of the pathologist in the genetic results section — the traditional approach appears to be the better choice. "In a three- to five-page report, we are looking for a needle in a haystack, i.e., a few sentences in which the pathologist writes: 'No evidence of MET exon 14 skipping fusion' or 'Clear evidence of activating KRAS mutation: p.Gly12Val.' We have to find such sentences and understand them correctly," explains Geppert. At present, it seems that the researchers will probably also prefer to find these "needles" using traditional text mining rather than machine learning approaches. The researchers extract the range of writing styles and expressions for gene descriptions and mutations from the reports, consolidate them and send the results back to the cancer registries so that these can define standards for future forms of notation.

Once the correct reports and elementary sentences have been found in the document, the entire tool kit of artificial intelligence is then expected to be in demand. "We are experimenting with the entire spectrum of methods — traditional text mining processes for the initial steps as well as the latest deep machine learning-based language models," says Geppert in summary. The job of AI is to combine and correctly interpret the required overarching statements that are hidden in the flowing text and were found using traditional methods. Which gene mutations are described and which statements are made in conclusion? Currently, the researchers are still working on the pre-processing stages; the process of teaching the AI is planned for later on in the project. Even though the project covers artificial intelligence, a lot of work is involved in this stage: After all, the training data has to be built up by hand. Geppert explains: "We have to tell the AI, for example, in which sentences it should have found out whether there is a positive or negative statement regarding a specific gene mutation or whether no statement is made at all."

The result is expected in August 2025 and aims to be a software component that can be embedded in the in-house IT infrastructure of the cancer registries. It should automatically identify which reports contain molecular pathological results, then compress the statements about the genes and their mutations, highlight the corresponding sections for the documentalists in the cancer registries and summarize the result of the report. All of this should run automatically — and save the documentalists a huge amount of time. Ultimately, however, the final assessment of the AI results and the job of creating a sound basis for developing new therapeutic approaches still rest where they belong: in the hands of humans. ■

Photo: Fraunhofer FKIE

A date with research

A new portal to the world of knowledge: Via the Fraunhofer Match platform, companies and organizations can now easily find their perfect project partner.

By Beate Strobel

More than 20,000 researchers at 76 Fraunhofer institutes offering different scientific disciplines and portfolios: For companies, there is now a new option to easily make contact with the research organization and reach large numbers of Fraunhofer employees via just one channel. The free Fraunhofer Match portal searches for suitable experts at Fraunhofer on behalf of customers.

The idea behind Fraunhofer Match is that companies will enter their problem or research inquiry via the www.match.fraunhofer.de portal. The inquiry will then reach researchers at different institutes who will draft initial solution options. These will be sent back to the company and if the customer is persuaded by the merits of one of the approaches, they can then embark on a joint project.

Fraunhofer Match was planned and developed over a period of two years, led by Dr. Marie-Luise Fuchs in the Digital Technology Transfer department at Fraunhofer. However, the project only became possible through the involvement of many institutes, emphasizes project manager Dr. Carl Heinze — and through intensive collaboration with pilot customers. Designing the processes so that the matches work quickly and in a straightforward manner was one of the biggest challenges. "The variety of the institutes and the broad research portfolio is a major strength of Fraunhofer," explains Heinze. "The platform also allows cross-institute collaborations to be formed and synergies to be utilized in the interests of the client."

The four-strong development team for Fraunhofer Match had opted for the lean start-up principle in which a highly simplified platform prototype in live mode is modified and honed based on feedback from customers and researchers so that customer needs can be accommodated in the best way possible. In 2023, 70 customer inquiries have been processed to date and the first projects have even been completed. Many of the inquiries submitted relate to topics such as autonomous driving, energy and sustainable production. With Fraunhofer Match, you get to enter the "machine room of the R&D departments of the companies," emphasizes Carl Heinze; in future, this could enable Fraunhofer to tailor its research fields even more efficiently to their needs.

The protection of sensitive company data is ensured: All customer inquiries and the proposals for solutions developed by Fraunhofer are automatically marked as confidential; the terms of use for Fraunhofer Match correspond to the degree of protection of a non-disclosure agreement (NDA). The data does not leave the Fraunhofer cloud, which is regularly tested in terms of cybersecurity by the Fraunhofer Institute for Applied and Integrated Security AISEC.

In future, artificial intelligence (AI) is set to increase the efficiency of the platform further by helping it to classify customer inquiries so that the experts at Fraunhofer can be identified more and more effectively. And one day, a company may find lasting love with a research team every few minutes. ■

More info about Fraunhofer Match

Photo: Sebastian Kahnert/dpa

Guardian of the microbe treasure

In one of the world's largest collections of bacteria and fungi, Fraunhofer researchers are hunting for natural products to fight infectious diseases in humans, animals and plants.

By Beate Strobel

Not all treasures in this world are found in museum display cases, bank safes or shipwrecks at the bottom of the ocean. One treasure is stored at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Gießen. Cooled in liquid nitrogen, 120,000 microorganisms are waiting there in tanks to be awoken — and to realize their potential. This could become especially important with respect to climate change in particular.

Waiting to be used: Microorganisms can be stored for decades when cooled in liquid nitrogen.

Photo: luchschenF/AdobeStock

120,000 microorganisms — and yet the strain collection of the Center for Natural Product Research at Fraunhofer IME fits into a cellar covering 100 square meters. "The strains are secured in more than 650,000 cryo vials — tubes that are as big as your little finger — and although keeping them cooled to minus 196 degrees Celsius is a complex process, it ensures they are kept very safe," reports biologist Prof. Till Schäberle. As the head of the Natural Products department at Fraunhofer IME, he is essentially the guardian of the strain collection, which he genuinely considers to be a treasure trove.

This has been being amassed for many decades already and at a different location. The foundation was laid in the 1940s when researchers gathered cultures of microorganisms and scientifically cataloged them — this was just 12 years after British physician and bacteriologist identified the antibacterial effect of the fungus Penicillium notatum in a compound that had gone moldy during the summer vacation. The discovery of the antibiotic penicillin, which is still important to this day, triggered a gold rush mentality in the field of natural product research: Who will be the one to find the next antibiotic and who will defeat the next major infectious disease?

In medicine's fight against a whole host of diseases, microorganisms and their naturally developed survival strategies are absolutely essential players. It doesn't matter whether they are in the earth, on the seabed or in plants, animals or humans, microorganisms live together everywhere in what are known as microbiomes. The natural products produced by the tiny organisms structure the way of life in the microbiome and serve as a means of communication, as a warning against intruders and as a defense mechanism against other microorganisms. Medicine takes advantage of these substances and already deploys a large number of them in therapies: A good 35 percent of all approved drugs and 80 percent of antibiotic classes can be traced back to natural products.

However, the relationship between pathogens and pharmaceutical research resembles a long-standing arms race between hostile states, as their defensive capabilities constantly have to be improved. Confronted with more and more new antibiotics and antifungals, fungi and bacteria are reliably developing resistance to existing drugs. To counteract this, the research community has to continually find different ways to enable at least the most common infectious diseases to continue to be treated effectively. Diseases triggered by viruses, bacteria, parasites or fungi are among the most common causes of death worldwide; the increasing proliferation of multidrug-resistant germs is regarded as one of the biggest global health threats.

80 %

of antibiotic classes

can be traced back to natural products

Microbes can make you ill and even kill — yet at the same time, they can also provide new options for fighting others like them. The chances of getting to the bottom of this problem are currently improving: Thanks to new techniques such as genome sequencing, there are fresh approaches for identifying providers of valuable natural products or developing new active agents. Fraunhofer expert Prof. Till Schäberle is already talking of a "renaissance for natural products."

In 2014, pharmaceutical company Sanofi, the owner of the strain collection at that time, started a partnership with Fraunhofer IME. In the IME's newly built Natural Product Center of Excellence, the partners initially carried out joint research using the collection. In 2020, the Sanofi collection — one of the world's largest industrial bacteria and fungi collections — was permanently transferred to the Fraunhofer institute. Till Schäberle and his team have been digitalizing and working through this ever since. Among other ▶

"The natural product darobactin offers hope that multidrug-resistant hospital-acquired infections will be able to be treated more effectively in future."

Prof. Till Schäberle, Fraunhofer IME

areas, the researchers were involved in the development and optimization of darobactin. This new natural product is capable of specifically attacking gram-negative bacteria — highly defensive microorganisms with an extremely impermeable barrier. Schäberle: "What makes darobactin special is its mechanism of action which differs from all other antibiotics currently in clinical use. This offers hope that multidrug-resistant hospital-acquired infections will be able to be treated more effectively in future."

In taking over the collection, the non-profit Fraunhofer-Gesellschaft has accepted the task of making use of the collection on the general public's behalf. Since acquiring the collection, the organization has concluded research collaborations with various private sector, non-profit and public stakeholders with this objective in mind. Schäberle is continually expanding the research field beyond the search for antibiotics and other active agents for use in human medicine. In cooperation with Boehringer Ingelheim Animal Health, for example, the researchers at Fraunhofer IME are searching for novel natural products to fight animal parasites such as fleas, ticks and worms.

What's more, the bioeconomy is also set to benefit from this treasure trove. In the MbioShrimp project, which is funded by the German Federal Ministry of Education and Research (BMBF), the team is searching the databases for natural products that could be used to prevent post-mortem melanosis in shrimps. This is the formation of black spots on crustaceans which is caused by enzymatic processes after death and is a notorious problem for shrimp farmers. Even though this discoloration is harmless to consumers, the affected shrimps cannot generally be sold, which is why the producers are currently seeking to prevent melanosis with chemical food additives. "We are looking for a natural inhibitor against one of the enzymes that cause the black spots," explains Schäberle.

Who will be the one to find the next antibiotic and who will defeat the next major infectious disease?

At Fraunhofer, an environment has also been created in which searches can now also be performed for active agents that could be used to treat so-called neglected diseases, i.e., diseases for which the financial incentive for companies is too low. Together with colleagues from Justus Liebig University Giessen, research is being conducted into resistance-breaking substances to treat parasites such as blood fluke and liver fluke, for example.

The natural product detectives at Fraunhofer IME are also seeing opportunities in the agricultural sector too. Take, for example, the search for a microbially produced repellent or control agent against the scourge of farmers — leaf blotch. The plant disease caused by the fungus Septoria tritici affects cereal crops and can reduce harvests by up to 30 percent. One of Till Schäberle's current "favorite opponents" is, however, the bacterium Xylella fastidiosa. This pathogen is transmitted by sucking insects and can afflict more than 600 plant species, including vines, olive trees, cherry trees, peach trees and almond trees, but also forest trees such as maples, oaks and elms. The bacterium blocks the transport routes for water and nutrients, causing the infected plants to die due to dehydration. "Unlike in Latin America and southern Europe, for example, the bacterium has yet to become a significant problem in Germany. However, climate change could soon foster spread of the disease to regions that, until now, have been too cold," fears Schäberle. Currently, there are no ways and means to fight the bacterium. Nevertheless, the natural product researchers at Fraunhofer IME have already detected strains in the collection which may produce an agent that could fight Xylella fastidiosa. Schäberle and his team are therefore convinced that even more microbial treasures in liquid nitrogen are waiting to be used in the cellar of Fraunhofer IME — for the benefit of humans, animals and plants. ■

Photo: JLU Press Office/Rolf K. Wegst

From socks to safety

More and more people in Germany are approaching retirement age. Research can help ensure that life is livable for the 12.9 million people who will be in retirement in 2036.

By Manuel Montefalcone

Sometimes, very personal weaknesses can become a genuine strength. "The idea for OMNICONNECT," reveals project manager Dr. Christian Tschoban, "came to the project coordinator because he constantly kept misplacing his socks." In the future, these lost socks are set to help senior citizens to move around independently for as long and as safely as possible.

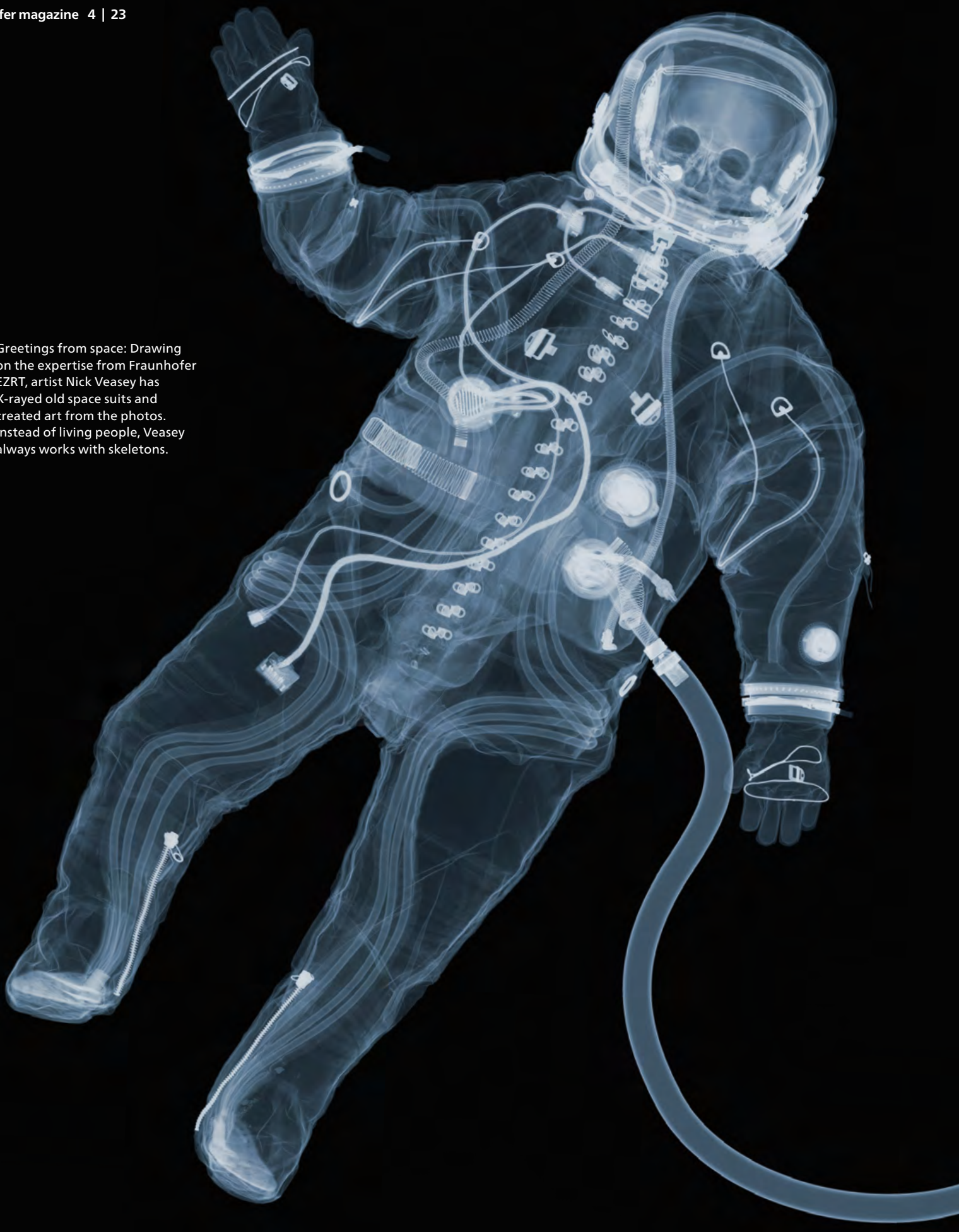
By 2036, 12.9 million people in Germany will have passed retirement age and increasingly require assistance. At the same time, 132,000 additional carers will need to be found by then, according to calculations of the German "Initiative for Sustainable and Generation-Appropriate Care". The gap between those needing care and those giving care is becoming even greater because the baby boomers working in the care sector are now also entering retirement. Across Germany, more than 250,000 positions will need to be refilled by 2035 due to age reasons. Technology can help to fill the gaps — as demonstrated, for example, by the OMNICONNECT project. Researchers from the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin have developed this assistance system. Four modules that are discreetly housed in an LED ceiling light achieve seamless 360° detection in a room. Artificial intelligence and algorithms learn the movement profiles of the residents and identify up to 30 people and objects over an area of up to 150 square meters. Passive receivers have to be integrated into people's clothing just once — either by sewing or ironing them on, for example. The advantage of these receivers is that "they function entirely without batteries, saving everyone the tedious job of replacing them." The small, flexible tags measuring just five by one centimeters can be attached to all kinds of objects. The radar system is then able to detect hazardous situations as well as provide assistance in helping to find objects such as socks that appear to have been lost. This makes it easier to care for people who are prone to falls, suffering from dementia or in need of other kinds of care. The demonstrator was fully manufactured at Fraunhofer IZM and was reliably able to detect position data to an accuracy of five centimeters in its final tests.

> "Social participation decreases as you get older. We are increasing it again and reducing loneliness."
>
> Simon Scherr, Fraunhofer IESE

The Fraunhofer OMNICONNECT invention helps senior citizens find lost socks — and raises the alarm if they have suffered a fall.

Photo: Halfpoint/AdobeStock

The wellbeing of the oldest members of society is also close to the hearts of the researchers at the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern. In the "Digital Neighbors" project, the team around project manager Simon Scherr are making an important contribution to combating loneliness. Digital voice assistants featuring screens, microphones and speakers were installed in the project participants' homes. The devices are easy to operate and provide news, reminders, weather forecasts and bus schedules. Over the course of the two-year project, the researchers constantly adapted the content to the senior citizens' needs. "Social participation decreases as you get older," explains Simon Scherr, "we are increasing it again and reducing loneliness." The idea works thanks to simple interaction using the spoken word. "At the beginning, many of the participants in the project didn't even have an internet connection. By the end, even the technophobes didn't want to give up their devices," says Scherr with a smile. In the end, digital neighbors who shared daily video calls became real neighbors — and, in some cases, real friends. ■



Greetings from space: Drawing on the expertise from Fraunhofer EZRT, artist Nick Veasey has X-rayed old space suits and created art from the photos. Instead of living people, Veasey always works with skeletons.

Photo & Fraunhofer

On the outside looking in

Researchers from the Development Center X-ray Technology EZRT at the Fraunhofer Institute for Integrated Circuits IIS in Fürth have revealed the high-tech nature of work clothing by making visible what is concealed inside an astronaut's suit. In cooperation with British artist Nick Veasey and the Hermann Oberth Space Museum in Feucht, they scanned a US Mark IV pressure suit from the 1950s as well as two Soviet Berkut and Sokol-K space suits. Wearing the Berkut, cosmonaut Alexei Leonov was the first person to complete a space walk in 1965, while the Mark IV inspired the space suits that were used on the Mercury program flights between 1958 and 1963.

The images from the RoboCT — developed by Fraunhofer for computed tomographic examinations of car and aircraft parts — reveal the complex inner workings of the suits with their various cable and tube connections, sensors and wires. When the astronauts are completing missions outside the spacecraft, these technologies protect them against UV radiation, micrometeorite impact and extreme temperatures as well as supply them with oxygen.

Nick Veasey has reworked the scans produced by Fraunhofer EZRT and refined them to create works of art that in future will provide visitors to the space museum with an insight into astronaut fashion. This is not the first time that the talented photographer has worked with Fraunhofer EZRT: The scientists previously scanned a Ferrari for him in the world's largest computed tomograph. In that case too, it was proved that it's the inside rather than the outside that counts.

Scan here for the podcast:
Prof. Tomas Sauer from Fraunhofer EZRT discusses X-rayed cultural assets in the current exhibition "Der Blick ins Innere" (A look inside) at Fraunhofer IIS in Erlangen.

Photo: Nick Veasey

The Polly project

No entry for other animals: At Fraunhofer IDMT, a team comprising two two-legged researchers and one four-legged friend is developing a smart cat flap.

For the cat: Mareike Helbig (with Polly) came up with the idea of flap 2.0.

By Beate Strobel

Lion or wild boar? When, in July 2023, the whole of Germany was puzzling over whether a big cat was actually roaming around Kleinmachnow, the Fraunhofer Institute for Digital Media Technology IDMT published a tongue-in-cheek LinkedIn post that presented a new technology as the solution for the next animal-based story to appear during silly season: The facial recognition software for cat flaps that the institute had developed could at least prevent a lion or wild boar from appearing in your living room.

AI detects who is bringing in animal "gifts"

The idea behind the playful post and the smart cat flap itself came from Mareike Helbig, cat owner and part of the communication team at Fraunhofer IDMT. While she wanted her cat Polly to be able to get out in the fresh air, she didn't want to constantly have to be opening the door for her and wasn't keen on other cats getting in or on seeing the animal "gifts" that expert hunter Polly kept bringing home. The commercially available cat flaps were not a solution for Mareike, as she didn't want to have Polly microchipped or saddle her with a collar and detection magnet — especially as these options would still enable her four-legged friend to bring mice or birds into the home.

In the SAISBECO and FaceEdutain projects, Dr. Alexander Loos, research scientist at Fraunhofer IDMT, had already been involved in developing a piece of software that can recognize species and individuals. Thanks to this technology, visitors to Leipzig Zoo were able to call up specific information on individual chimpanzees, as the technology is able to clearly distinguish the individual animals from each other.

"If something like this works for apes and bears, then why not for cats?"

Mareike Helbig, Fraunhofer IDMT

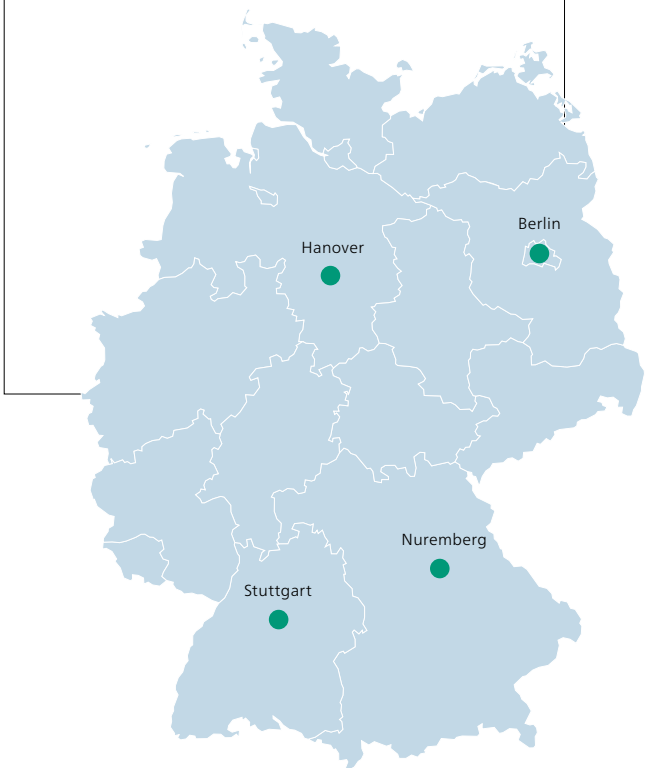
There has also already been an algorithm variant for grizzly bears. "If something like this works for apes and bears, then why not for cats?" wondered Mareike Helbig. And that's how the Polly project — officially: SIMSALA CAT — was brought to life.

For Helbig's idea of a smart cat flap, Loos trained the artificial intelligence with around 43,000 photos of approximately 8,000 cats until the algorithm had learned what to look out for in a cat's face. This can be quite a difficult task, as cats' faces — apart from the color of their coat — all look very similar at first glance. Yet, in the end, the AI was even able to distinguish the four-legged member of the project team — Polly — from neighbors' cats with similar colored coats without any issues. However, if Polly had an item of prey in her mouth, the smart doorkeeper refused her entry: "This is exactly what I'm looking for in a smart cat flap," says Mareike Helbig, delightedly.

As the humorous LinkedIn post on cat AI — which was started as an internal project — had garnered much media attention, a collaboration with a company from Switzerland has now been launched. A smart cat flap that can recognize prey will be available commercially from the start of 2024 and a follow-up version will also be able to identify an owner's own cat. As for mice, wild boars and lions, etc.? Unfortunately, they'll have to stay outside. ■

Photos: Katrin Pursche, Mareike Helbig

Fraunhofer on the road



Berlin
March 6–7, 2024
TRANSFORM
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Platform for the digital transformation of companies

Nuremberg
April 9–11, 2024
Embedded World
International exhibition for embedded systems — from hardware and software to services and tools

Berlin
April 9–11, 2024
DMEA
Trade show and congress for digital healthcare

Hanover
April 22–26, 2024
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Taking the plunge and staying dry
For the PFAS photography, Jan von Holleben dropped our Fraunhofer researchers deep into the ocean — without them getting wet. For 20 years, the photographer has been arranging the scenes for his photos on the ground, lending his subjects an incredible weightlessness. He took his first floor photo from the roof of a VW bus. Since then, his success has been steadily on the rise. He prefers to work from a height of 3.50 meters.

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