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Energy from car roofs

Paging Dr. Data

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Editorial

Pioneering research for the mobility transition

Prof. Reimund Neugebauer

The mobility transition is a basic requirement for achieving our national climate protection targets. By 2030, the German federal government aims to reduce transportation emissions by 40 to 42 percent and, according to the information released during the government summit on mobility held in January, it is also planning to increase the number of registered fully electric vehicles to 15 million. Battery cell manufacturing has a key role to play in this regard. To make industry-scale production cheaper and more efficient, 14 Fraunhofer institutes are teaming up and combining their expertise as part of the Fraunhofer Research Fab Battery Cells FFB in Münster. The aim of the FFB is to accelerate the innovation and commercialization process for cell production technologies. Fraunhofer FFB is making a particularly important contribution to developing energy storage technologies with which the German and European industry sectors can manufacture battery cells in an economically viable and environmentally friendly way.

Meanwhile, when it comes to decarbonizing the heavy-goods transportation sector, fuel cells that convert carbon-neutral hydrogen into electricity could represent a suitable alternative propulsion system. Devising an economically viable means of manufacturing these cells at industry scale is the goal of the 19 Fraunhofer institutes working on H2GO, a project with 80 million euros in funding from the German federal government. Digital simulations of the production solutions developed as part of this project are made available to the participants, so that they can be synergistically combined to form a virtual reference architecture for fuel cell production.

Reducing the environmental impact of rising transportation figures and passenger volumes in the long-term is not just a matter for our roads — we must look to the skies as well. Sustainable fuels that emit up to 80 percent less CO2 than conventional fuels represent the most important medium-term solution for decarbonizing the aviation sector. The Fraunhofer-Gesellschaft is considering all possible technologies as it researches approaches for rapidly expanding production capacity in the field of sustainable fuels. One such research initiative is the To-Syn-Fuel project, which was successfully completed in October 2022. It was the first time that researchers had managed to manufacture fuel from biomass waste in an industry-scale demonstration. In the process, they converted more than 500 tons of sewage sludge into 50,000 liters of oil, from which they then went on to extract 40,000 liters of gasoline, diesel and kerosene.

The challenges that Germany and Europe are facing in terms of the energy and mobility transitions call for inquiring minds and a pioneering spirit, along with the drive to quickly bring innovations into practical application. In this context, society's acceptance of innovations is as important as establishing close collaborations between science, industry and the political sphere. Let us work together to drive this transition, so that in the future, Germany will retain its status as an attractive industry location with a high quality of life.

Sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

Learn more about the main research topics of the Fraunhofer-Gesellschaft:
Prof. Reimund Neugebauer on LinkedIn

Photo: Fraunhofer/Stefan Obermeier

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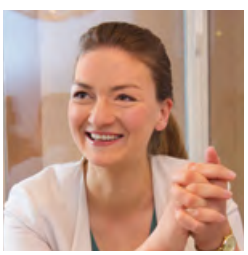

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Airborne danger incoming?

Detecting and tracking drones in 3D.

The way we travel is changing dramatically. According to figures from the German Federal Motor Transport Authority, 2.65 million new cars were registered last year, making 2022 **a historic low point**. However, exactly 470,559 new **electric, battery-powered** cars hit the streets — a 32.2 percent increase.

32 %

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Brief report

More years of service than Angela Merkel: the robots of the Roberta initiative. Nao the robot was programmed by Berlin schoolchildren under the guidance of Beate Jost, project manager at Fraunhofer IAIS (right).

"Roberta — Learning with Robots" celebrates its 20th birthday

Some 20 years ago, the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS launched the educational initiative Roberta to raise interest in technology, computer science, and science subjects among young girls — and it's become a true success story. "Robots offer children and teenagers an appealing way to access computer science," says Beate Jost, technical manager of the Roberta initiative and project manager at Fraunhofer IAIS. To date, Roberta coaches from Fraunhofer IAIS have trained more than 3,500 teachers in robotics and programming, thereby reaching over 650,000 schoolchildren. With the support of Google.org, Fraunhofer IAIS has developed the open graphic programming platform Open Roberta to bring the robots to life. Participants can have fun using the drag-and-drop function to create programs for various microcontrollers and robots. Since 2014, this free service has succeeded in reaching children and teenagers in more than 120 countries. Roberta has just welcomed its ten millionth user — coinciding with its 20th birthday. ■

Join in here: https://lab.open-roberta.org

Rheumatoid arthritis, a common condition: Even severely bent fingers can get optimal treatment using this joint implant.

More mobility with AI

The FingerKIt consortium, which represents the combined forces of five Fraunhofer institutes, is using artificial intelligence (AI) to produce 3D-printed finger joint implants. To this end, the scientists developed AI-based software that can use 2D X-ray images to generate 3D models of the finger bones and correct any malpositioning. Following this, the researchers derived the individual implant design from the finger model and sent it for 3D printing. Because the design is modeled on the original joint, it has the advantage of achieving far higher levels of mobility than conventional implants. The 3D printing process also allows the surface of the shaft to be structured in such a precise way that it can achieve more effective growth into the bone. ■

The sleep lab you can take home

A comfortable sensor system now makes sleep monitoring possible even outside of the sleep laboratory — but with the same high standard of data quality. Researchers from the Fraunhofer Institute for Digital Media Technology IDMT have developed this system as part of the REMUS project. Using radar technology, the sensors monitor breathing, heart rate and other vital signs. They can detect sounds such as snoring or coughing, even from beneath the covers. "This procedure makes it possible to take measurements over long periods of time — without restricting freedom of movement in bed and with lower disinfection and maintenance requirements," explains Dr. Insa Wolf, Mobile Neurotechnologies group manager at the Oldenburg institute branch.

In the sleep laboratory, any thorough investigation will involve the EEG as a central component — this measures brain activity using electrodes, enabling scientists to draw all-important conclusions regarding the phases and specific characteristics of a person's sleep. The procedure involves positioning some easily applied, discreet and flexible electrode patches around the facial area and behind the ear. To ensure that the data collected is as conclusive as possible, the EEG can be carried out in conjunction with an electrooculogram (EOG), which measures eye movements, and an electromyogram (EMG), which measures facial muscle activity. ■

Breathing interruptions during sleep can now be monitored from the comfort of your own bed.

Lower risk after heart surgery

External pacemakers and pacemaker probes stitched onto the heart's surface are often used to restore heart rhythm after cardiac procedures.

At the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden, a team is developing self-dissolving pacemaker probes. These are mainly composed of the metal molybdenum, which has several advantages: Not only does it degrade in the body at a uniform rate, but it is also biocompatible, electrically conductive and has a high rate of mechanical stability. To isolate the probe from surrounding tissue, the researchers coat the metal with biopolymers, which will likewise degrade over time. The team is examining and optimizing the materials used according to their mechanical, electrical and degradation properties. The medical faculty at TU Dresden, a partner in this project, is conducting preclinical studies to test the initial prototypes.

These innovative pacemaker probes could replace the traditional probes currently used to treat cardiac arrhythmia following heart surgery. These probes are temporarily stitched onto the heart's external surface, which carries several risks: Sometimes they grow into the surrounding tissue, which makes them difficult to extract manually at a later stage and can lead to complications. If the probes are capped and left inside the body, this can increase the risk of infection or result in the remnants moving around the body, often necessitating further surgery. ■

Forklifts travel at 6 to 7 kilometers per hour and may have an unladen weight of over 500 kilograms.

Greater safety in warehouse logistics

In the future, custom-developed optical sensors for vehicles like pallet trucks and forklifts could provide warehouse staff with better protection in their day-to-day work. "Our system is designed to protect users from crush injuries, especially in the area around the feet," explains Prof. Peter Hartmann, director of the Fraunhofer Application Center for Optical Metrology and Surface Technologies AZOM. An innovative proximity sensor detects whether the operator has come too close to the hazardous area in front of the vehicle and automatically applies the brakes. "This technology can be used in just about any transportation vehicle. It's a particularly intriguing prospect for autonomous vehicles," says Dr. Christopher Taudt, Surface Metrology group manager at Fraunhofer AZOM. He and his team aim to further optimize the technology behind the safety mechanisms. "Currently, we're working on the idea of integrating the sensors into a kind of retrofittable sensor strip rather than making them a fixed part of the vehicle. That would allow them to be added to vehicles of any type from a whole range of manufacturers," he explains.

According to statistics from the German Social Accident Insurance (DGUV) association, the most common injuries caused by pallet trucks and forklifts, known collectively as floor handling equipment, are bruising, crushing and fractures. As it stands, these vehicles do not feature any safety technology for preventing accidents in the area around the feet. ■

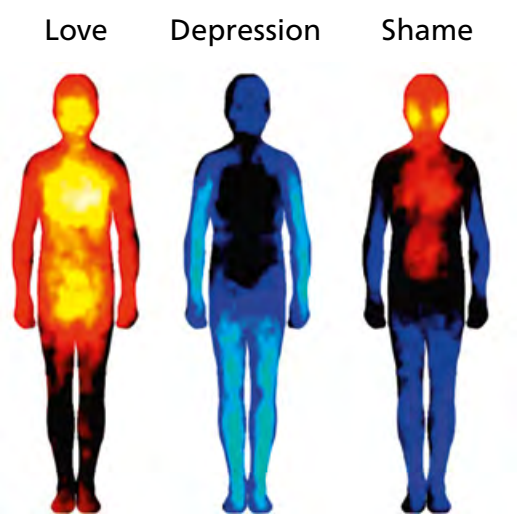
Getting a feel for individuals with autism

In research projects, the participation of the target group is crucial. As part of the UFO project, which uses VR-based neurofeedback training to support the inclusion of individuals with autism in the workplace, employees from Fraunhofer IAO took part in an autism awareness session run by its consortium partner auticon, which allowed participants to experience the confusion that can arise from a lack of understanding.

Individuals with autism are often accused of lacking emotion, and some imply that autism is a disease you can contract. Such preconceptions can crush an autistic person's career plans.

Some 5 to 15 percent of people have difficulty regulating their emotions or identifying with others — and this occurs 40 to 65 percent more frequently among individuals with autism. That is not to say that this is always the case with autistic people, nor is it exclusive to them. The double empathy problem, as it is known, has become a matter of much research: Where knowledge about differences is lacking, the deficit of empathy for individuals with autism actually lies with neurotypical people. They confuse a factual communicative style with a lack of feeling. Here, UFO aims to create further added value by involving the target group, represented by auticon, in the development process. ■

To find out more about the UFO project see the Fraunhofer IAO blog: https://s.fhg.de/ufo



Researchers in Finland have investigated the areas of the body where different emotions are felt. They believe that physical changes are the root of conscious perceptions of emotion.

Editorial notes

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Even herbs can grow in the new elements used for greening facades.

The green, green grass of home

Storms, torrential rain, drought — how can cities combat climate change? Flexible greening systems, which are currently under development at Fraunhofer UMSICHT, represent one possibility.

For some eight years now, scientists have been researching these innovative systems, which can also filter CO_2 from the air and reduce noise. They are now being introduced to the market and will be distributed by a partner company, Biolit Green Systems GmbH. "We have developed special construction elements for building green walls that are not attached to the ground," explains Holger Wack, deputy head of the Product Development department at Fraunhofer UMSICHT. "We use a mineral material that allows private individuals, cities, horticulturists, landscapers and sports ground contractors to design their own flexible, climate-friendly facades and garages, to name just two examples."

These systems not only enhance the cityscape, but also improve the quality of life. The green facades enhance quality of life by reducing noise and binding dust. They also serve as a means of both psychological and physical preventive healthcare. Since this greening process insulates and cools buildings and offers shade, it also saves on energy.

In order to optimize the construction elements, scientists at Fraunhofer UMSICHT are conducting research on their own wall. The plant stones they use are made up of a planting trough and an integrated irrigation channel. Biolit Green Systems GmbH uses this system to construct freely scalable solutions for facades, facing walls, partition walls, soundproofing walls and vertical farming walls, as well as for new architectural projects. "The response so far has been very positive," says Berthold Adler, founder of Biolit Green Systems. "To achieve rapid greening in a cost-effective way, we sow the walls with grasses and flowers. But it's perfectly possible to plant herbs, strawberries, tomatoes and chilies instead." Meanwhile, Fraunhofer UMSICHT is conducting further research in parallel. "We are currently looking at the positive influence of vertical greening on the microclimate and how it interacts with its surroundings," explains Holger Wack. ■

Mobility of the future

Mobility that's fit for the future: Dr. Martin Heinrich of Fraunhofer ISE is hoping to give the mobility transition a jump-start by using the car body to capture solar energy.

What drives the car of tomorrow?

From 2035 on, the combustion engine is a non-runner for new vehicles: something has got to be done on Germany's roads. Where does the path lead?

By Dr. Janine van Ackeren, photos: Philipp Gülland

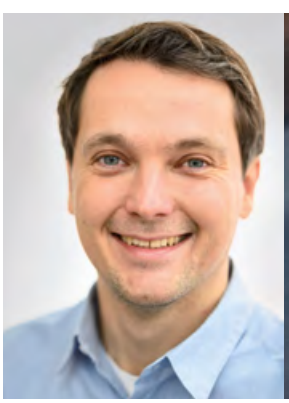
Mobility of the future equals electromobility: a simple equation, and to see the proof, you need only cast your eye out to the street. In fact, global sales figures for electric vehicles — i.e., battery-powered and hybrid vehicles, plug-in hybrids and vehicles with fuel cells — increased more than tenfold between 2010 and 2021, from just about 838,000 to more than 9,345,000 vehicles. Germany was well at the head of this trend: although less than 6,000 electric vehicles were sold nationwide in 2010, the figure had jumped to 750,000 by 2021. The pioneering field of e-mobility faces a big challenge in the form of batteries; every stage brings up issues to resolve, from manufacturing to disposal. Researchers at institutes and developers at automotive manufacturers are working hard to increase the energy density of the batteries — which would, in turn, increase the vehicles' range — through novel material combinations and new cell designs, improving the batteries' safety and lifespan and reducing production costs.

Photovoltaics in the mobility sector?

E-cars are only genuinely environmentally friendly when they are powered by electricity from renewable sources. As such, the ideal solution would be to generate energy at the point where it is needed, while the car is on the move. And capturing solar energy on car rooftops has already become more than just a nice idea. "We are working with a number of vehicle manufacturers to integrate solar cells into the car body," confirms Dr. Martin Heinrich. A group manager at the largest solar research institution in Europe, the 1,400-employee-strong Fraunhofer Institute for Solar Energy Systems ISE, he has made it his mission to "produce as much of the required energy as possible on the vehicle itself, independently of any other source." As part of the "3D" project, the researchers set out to manufacture curved solar modules — this shape would make it possible to integrate them inconspicuously into car rooftops. The greatest challenge here was the lamination process required to make the photovoltaic modules wind and weather proof. The question was, how can manufacturers work with the bent modules while still guaranteeing the required uniform temperature and homogeneous pressure across the entire surface?

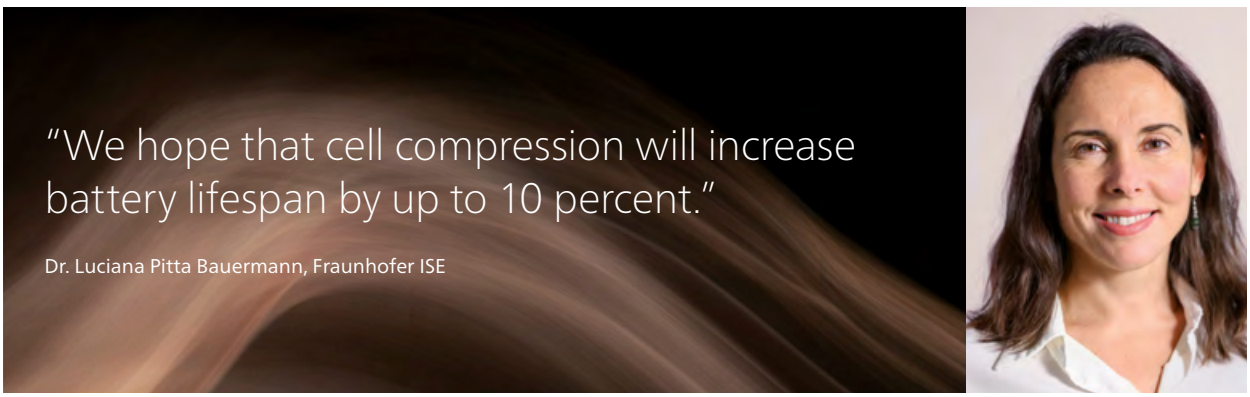
This problem has been solved, at least for some specific vehicles. For example, the automotive manufacturer Mercedes has already integrated the project's solar roof into its EQXX show car — invisibly, of course. The car's 117 solar cells supply a 12 volt battery, which then powers the full-dashboard display, among other things. This appreciably reduces the load on the high-voltage battery — the solar energy from the roof contributes a total of 25 kilometers to the car's 1,000 kilometer range. But car rooftops have space for even more cells: "If you were to integrate 366 invisible solar cells onto a car roof, they would generate 2,000 kilometers of range in the course of a year, according to initial rough estimates — on a good summer's day, you could get as much as 10 kilometers," Dr. Heinrich suggests. The overall potential is enormous: if you were to take the rooftop space of all the vehicles in Germany, you would have a surface area for generating solar power that's double the size of Liechtenstein.

The exact amount of energy generated depends on how much sunlight hits the modules during journeys and parking time, so Dr. Heinrich's colleagues are researching how much sunshine falls on Germany's roads. As part of the project PV2Go, researchers have developed sensors used by more than 60 volunteers across Germany on their roofs of their cars — they have been driving around the country since the start of 2022. If the car starts moving, the sensor collects data that is accurate to the nearest second, sending it to the server via a wireless connection. "We are using this data to develop and validate a model that predicts solar irradiation on a particular driving route,



"Our goal is to produce as much of the required energy as possible on the vehicle itself, independently of any other source."

Dr. Martin Heinrich, Fraunhofer ISE

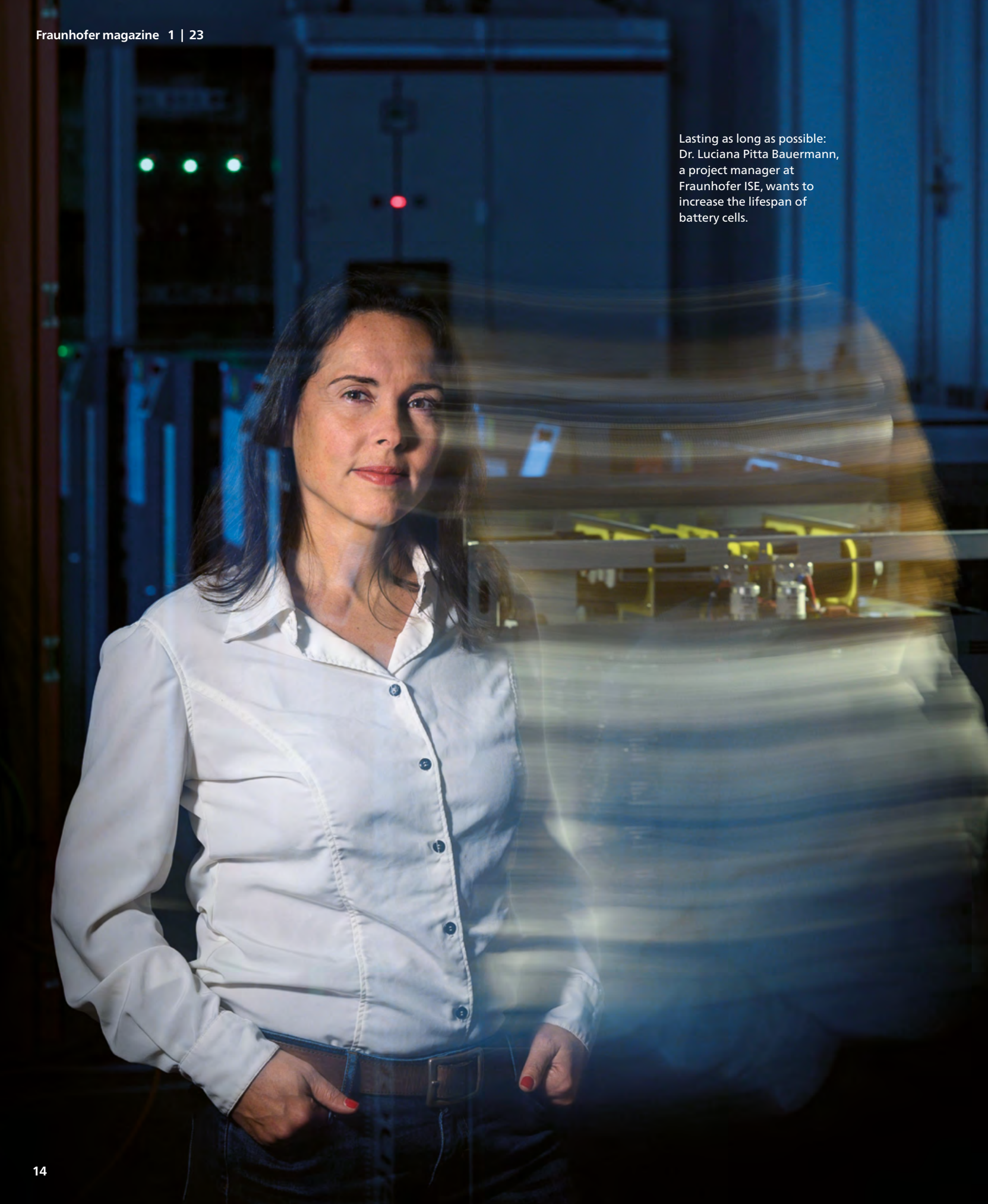


depending on the time of day and the season," explains Fritz Haider, a scientist at Fraunhofer ISE. In the long-term, solar car drivers could then select the route that would produce the most solar power from their vehicles' roofs.

Fraunhofer ISE is also involved in another initiative aimed at generating energy close to the point where it will be consumed. ASFINAG, the Austrian public corporation that manages the country's highways, has teamed up with Fraunhofer ISE and other partners in project PV-Süd to investigate the possibility of covering particular stretches of the highway with photovoltaic module roofs. The best place for these systems would be in close proximity to the consumers, for example, at service stations with charging facilities for e-cars. The design phase is already complete, and construction of a demonstrator near the "Im Hegau" service station on the A 81 is set to start in spring 2023. "To keep costs down and facilitate the building of other structures, we have deliberately opted to use commercially available photovoltaic modules," relates Dr. Heinrich. However, there are some very specific challenges to overcome. To avoid endangering road users, the modules cannot splinter upon breaking. The Fraunhofer researchers will next explore the level of energy the system generates and whether the photovoltaic construction can withstand wind and weather, including snow. Photovoltaic modules can also be mounted on the sides of highways, on noise protection barriers. The Fraunhofer ISE team is already investigating what conditions would be needed for this arrangement to work, how the modules could be installed on existing walls and how the sound-absorbing materials and photovoltaic modules can be combined when building new walls.

Longer lifespan for pouch batteries

Safe, reliable and highly efficient batteries are the core of electromobility, its make-or-break point. However, as anyone who owns a smartphone will tell you, lithium-ion batteries have a limited lifespan. The battery works reliably, but then its capacity suddenly plummets. Pouch cells are a common form of lithium-ion battery that are often used in electric cars; however, they are prone to cell aging, which arises due to factors such as the uneven loads that affect the batteries during charging. The parts of the cells that are close to the electrical contact point tend to expand more than the parts that are further away. Temperatures in these cell areas are also significantly higher, which results in quicker aging. This means that maintaining an equal load during charging could extend the battery's lifespan — that's the Fraunhofer ISE researcher's theory at least. They and their partners in project OrtOptZelle are working to find out whether the theory holds true. "First, we want to gain a better understanding of the local volume fluctuations and pressure distribution in the battery cells. To do that, we clamp the cell between two metal plates with built-in pressure sensors and investigate the effects that occur during charging," explains Dr. Luciana Pitta Bauermann, a project manager at Fraunhofer ISE. "Based on the data from the pressure sensors, we compress the cell mechanically, so that the entire battery has to expand to an equal extent. To do this, we use metal plates that have been milled at incremental depths to create tiers, meaning that batteries are under more pressure at the back than the front. This reduces the ionic resistance on a localized basis, which in turn compensates for the unequal expansion during charging." To find out whether the tiered plates produce the desired effect, the research team charged and ran down the cells until they broke down, measuring the charging capacity all the while so that they could determine how the cells were aging. Then they completed a kind of post-mortem analysis, whereby the cells were dismantled and underwent chemical testing to show what had happened in the different cell parts. ▶



Lasting as long as possible: Dr. Luciana Pitta Bauermann, a project manager at Fraunhofer ISE, wants to increase the lifespan of battery cells.

"At the moment, we cannot precisely quantify to what extent the tiered plates affect the batteries' lifespan. However, we hope to increase the lifespan by up to 10 percent. The advantage of the compression should become apparent after a loss of just 5 percent of the cell capacity," explains Dr. Bauermann. The project's findings so far already indicate that in general, the lifespan of compressed cells is much higher than that of uncompressed cells. In a subsequent project, the researchers plan to collaborate with an industry partner to replace the heavy, rigid metal plates with plastic sheeting, which would be lighter and thus more suitable for every day use.

Higher energy density, improved safety

The limited range continues to be one of the main points of criticism leveled at e-cars. How exactly is a car like that going to take its passengers on a long road trip for a well-earned vacation? The Fraunhofer ISE research team is also tackling the question of range, teaming up with industry partners in project FliBatt — the German name is short for "solid lithium batteries with non-woven materials" — and using this as an opportunity to improve safety. In this initiative, the team is replacing the standard lithium-ion batteries, which are based on a liquid electrolyte, with solid-state batteries. This makes it easier to use metallic lithium as the anode material instead of graphite, which is the most common choice at present. These changes increase the overall cell's volumetric energy density by around 85 percent. What's more, batteries with a liquid electrolyte can short-circuit; if this effect spreads, the heat it generates can vaporize and ignite the liquid electrolyte. This thermal runaway process may well be unlikely, but the risk does remain. However, with solid-state batteries, this kind of maximum credible accident (MCA) is impossible.

That said, there are still many unresolved issues in the manufacturing process for solid-state batteries. For example, the aluminum and copper sheets that the electrodes are deposited on and the separator between the cathode and anode are structural necessities, but their extra weight is costly in terms of energy storage. As it stands, the layer thickness is also limited by the technical restrictions of the production process, as very thin sheets tear quickly. "We are solving this problem by reversing the usual manufacturing process," reveals Dr. Andreas Georg, a project manager at Fraunhofer ISE. "Instead of depositing the electrodes on the metal sheets and then connecting them to the cell via a separator, we begin by manufacturing the separator and applying the electrodes as a coating." Finally, the metal arrester sheets are evaporated. In principle, for a process like this, thicknesses of around the single micrometer scale would suffice. Until now, however, sheets with a thickness of 10 to 20 micrometers have been required. This method could not only save material and costs, but also reduce the weight.

Stress tests for batteries

Solid-state batteries may well result in just a smidgen more safety in the future, but this does not mean the lithium-ion batteries that are currently used so much present any kind of safety risk — after all, they are equipped with built-in protection mechanisms during manufacturing. However, the problem is that they not only have to ensure safety during normal operations, but also in the event of accidents. The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institute, EMI, provides the facilities for the required crash testing. "We conduct crash tests for e-mobility batteries at all three levels: the cell level, i.e. the smallest components of the battery; the module level; and in the future, for entire battery packs as well," says Dr. Sebastian Schopferer, group manager for Measurement Technology at Fraunhofer EMI. At the cell level, the researchers are primarily testing dynamic material behavior. One discovery that the Fraunhofer team have made here is that the behavior of a cell that undergoes rapid deformation during an accident is fundamentally different from that of a cell that undergoes a slower form of stress. "If a crash occurs, even a slight deformation could be enough to bring about critical conditions," explains the expert. To perform the tests, the researchers drive a variety of differently shaped punches into the cells at varying speeds, precisely measuring the cells' resistance and deformation. This allowed them to determine the conditions that can trigger a thermal runaway, whereby cells break down with a chemical chain reaction that emits high levels of heat and ▶

> "If a crash occurs, even a slight deformation can be enough to bring about critical conditions."
>
> Dr. Sebastian Schopferer, Fraunhofer EMI

gas and can cause fires or even explosions. In addition to mechanical characterization, the team is also testing the thermal runaway process itself, along with the related internal cell safety mechanisms. To test the reliability of these safety mechanisms in the event of a breakdown, the researchers have developed a high-speed X-ray device — a novel piece of equipment that is unrivaled on the market. There were more challenges to overcome than just the high frame rate, although at 1,000 to 10,000 frames per second, the rate required for capturing high-speed processes is by no means negligible. To protect the X-ray device from explosions and damage, the team developed a robust protection chamber that the X-rays could penetrate, which was then used to house the battery cells during testing. At the module level, the researchers are concentrating on questions such as whether thermal insulation can prevent cell-to-cell propagation of thermal runaway. They have also recently expanded their portfolio to include crash testing for entire battery packs with capacities of up to 50 kilowatt hours. The new building where the researchers can conduct these tests by smashing impactors and batteries together was only opened in December 2022. "In the neighboring department, the Crash Center, we have learned what stresses affect the batteries during accidents. However, the center cannot be used to carry out tests with charged batteries, as the facility is not set up for that," Dr. Schopferer points out. "This means we have to extract the stresses that affect the batteries from the overall vehicle crash tests, and then reproduce these stresses with our own equipment."

European battery cell manufacturing? It's time to make the idea a reality!

At present, most battery cells are manufactured in China — and as we have seen in recent years, these kinds of dependencies can be quite problematic. That means that increasing industry resilience needs to be a top priority. But how is the European battery cell manufacturing scene doing? Researchers at the Fraunhofer Institute for Systems and Innovation Research ISI are collecting the data needed to answer this question in BEMA2020 II, a project initiated by the German Federal Ministry of Education and Research (BMBF). "The European market for battery cells is experiencing a lot of momentum," reveals Dr. Lukas Weymann. "Many battery cell manufacturers have reported significant growth, while start-ups and established automotive manufacturers are also getting involved in mass production of battery cells." In 2022, European manufacturers could produce a maximum battery cell capacity of a little over 100 gigawatt hours; however, by 2030, this figure is set to reach 1,700 gigawatt hours. "The challenge does not lie in getting more stakeholders involved in constructing battery cell factories in Europe in the coming years. In fact, the critical question is, how can we make the existing plans for mass production in Europe a reality in the near future and with sufficient quality levels?" asks Dr. Weymann of Fraunhofer ISI.

Research on the road to gigafactories

"When it comes to battery cell design and new materials for the batteries, Germany and Europe are very well-positioned; however, we are lagging behind in the area of large-scale production," confirms Dr. Thomas Paulsen, a group manager at the Fraunhofer Research Institution for Battery Cell Production FFB. Fraunhofer FFB has set out to tackle precisely this challenge, by acting as an open research platform for scaling product and process innovations. Asia is leading the pack in terms of battery cell production and it has no interest in sharing its knowledge with Europeans. "We want to build up experience in the mass production of battery cells and — most importantly — act as an open research platform for exchanging these learnings," explains Dr. Paulsen. Fraunhofer FFB was launched in 2019 as part of the FoFeBat project on researching battery cell production, which is funded by the BMBF. If all goes to plan, then the Münster-based Fraunhofer facility will become an institute in 2024. The first two battery production steps (out of a total of 19) are already underway. These involve preparing the anode slurry, a battery mixture that may consist of graphite, binding agents, conductive additives and aqueous solvents, and coating and drying the electrodes.

Construction is also nearly complete for the FFB PreFab, a building with 3,000 square meters of research space that could theoretically achieve production capacities of up to 200 megawatt hours per year. Why "theoretically"? Because, to reach these figures, all the equipment would have to work faultlessly around the clock. And that is not the goal of the FFB. Instead, the aim is to research production processes and environments with a view to making production cheaper, quicker and more environmentally friendly. The process of drying the electrodes is a good example here. At the moment, the process functions much like a pizza oven, meaning that it is incredibly energy intensive. This is why the researchers are working on an alternative drying process based on infrared beams, which are a far more energy-efficient option. Lasers could also be used for the drying procedure. "We know that this method works at a small scale, but not whether it could be scale up for a gigafactory. In FoFeBat, we are filling the gap that currently exists in Germany between the prototype stage and the gigafactory. We are also breaking new ground, in that we are consciously entering very high technology readiness levels," enthuses Dr. Paulsen. ▶

"We want to build up experience in the mass production of battery cells and — most importantly — act as an open research platform for exchanging these learnings."

Dr. Thomas Paulsen, Fraunhofer FFB

Reconquering the world of mobility: Moving mass production of battery cells to Germany is essential, according to Dr. Thomas Paulsen of Fraunhofer FFB.

Increasing road safety with artificial intelligence

In the context of the mobility of the future, the words "autonomous vehicles" come up over and over. However, if an AI system takes the wheel instead of a human being, then that system must have adequate safety levels — in fact, it should ideally be even safer than a human driver. Until now, the data required to set up new driving functions and, where necessary, to train artificial intelligence programs has mostly been generated from test drivers. However, the driving functions are becoming ever more comprehensive. Estimates suggest that it would take 2.5 billion kilometers of test driving just to make autonomous vehicles safe for highway use. However, realistic simulations of road traffic could be a promising solution for achieving AI safety in a more efficient way. Such simulations would have to provide valid models not only for typical traffic conditions, but also for very rare accidents and the scenarios in which they occur. To achieve this, the simulations must undergo data-driven optimization. However, very little data actually exists regarding the occurrence of accidents and critical scenarios that do not actually result in accidents — in fact, there is no valid way of identifying critical scenarios at present.

Researchers at Fraunhofer EMI are tackling both of these issues in project KIsSME. The team is developing a filter that can specifically identify critical scenarios and record the related data. The factors contributing to whether the data can be considered critical are drawn from various aspects of road traffic. The researchers intend to combine individual metrics with differing complexity levels, properties and scales to form sets of metrics for specific scenarios. These sets would be represented by a single criticality value. Some of the most important metrics here include time, e.g. the time to collision, and the physical dimension, e.g. the distance between road users. In project AVEAS, the Fraunhofer EMI team is developing processes such as data-driven optimization of traffic flow simulations.

Biomass beats gas!

Drivers have bewailed the record highs in gas and diesel prices over the past year. However, the EU project To-Syn-Fuel could pave the way forward here, as researchers from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT are developing a new method of producing fuel, which they have already implemented at a pilot scale. "We manufacture fuels from waste biomass such as sewage sludge, which results in sustainable fuels without any conflict with food production or use of plants that should serve as foodstuffs or animal fodder. This fuel delivers a carbon footprint reduction of over 85 percent per kilometer driven when compared to fossil fuels," says Dr. Robert Daschner, head of department at Fraunhofer UMSICHT.

The development is based on the well-established pyrolysis process, whereby biomass is heated to temperatures of up 600 degrees Celsius in the absence of oxygen until it is converted into oil. Dr. Daschner goes on to explain what makes the TCR® process developed by Fraunhofer UMSICHT so special: "We significantly improved the quality of the resulting oil, to the point that it's comparable with crude oil. This oil can then be processed via conventional refinery methods to convert it into fuels that meet the most important standard requirements for gas and diesel — meaning that they can be used without any need for engine alterations or impact on performance." The researchers achieved this quality hike by adding a second step to the procedure, so that the usual pyrolysis process is followed by a thermocatalytic reforming step. The team uses the carbon material produced in the pyrolysis as a catalyst in order to purify the synthesis steam even more and extract high-quality oil from it.

The process is already running at a demonstration plant that has so far extracted more than 50,000 liters of biogenic crude oil from 500 tons of sewage sludge. In other words, the facility can convert 10 tons of biomass into 1 ton of crude oil every day. The demonstrator plant was also used to refine some of the crude oil to produce fuel, which then powered a test vehicle through a 2,000 kilometer round trip across Europe. A German refineryis already planning to utilize sewage sludge on a large scale, with a bigger plant set to commence operations in 2023 and commercial operations set to start between 2024 and 2025. The mobility transition is in full swing.

Driving without gas or diesel? Dr. Robert Daschner of Fraunhofer UMSICHT is getting there — with sewage sludge.

"We manufacture fuels from waste biomass, which results in sustainable fuels without any conflict with food production or use of plants that should serve as foodstuffs or animal fodder."

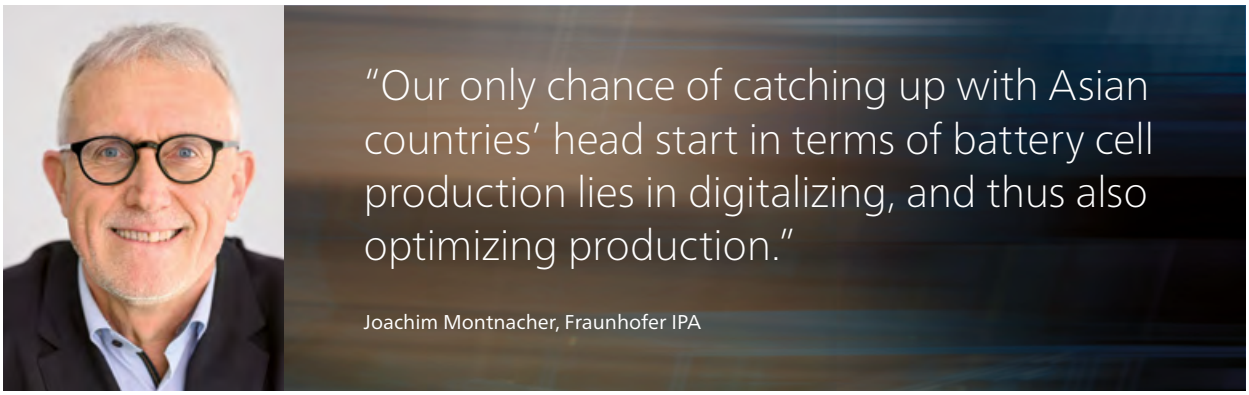
Dr. Robert Daschner, Fraunhofer UMSICHT

The FFB Fab, which is set to be completed by 2026, will have 20,000 square meters of floor space and a theoretical production capacity of 6.8 gigawatt hours.

Just one more step to go before gigafactory-scale production

The FoFeBat project is focusing on battery cells with high technology readiness levels, thus choosing battery technologies that are already very advanced. By contrast, the Fraunhofer Project Center for Energy Storage and Management Systems ZESS, which is operated by the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, for Surface Engineering and Thin Films IST and Manufacturing Technology and Advanced Materials IFAM, is concentrating on newer battery technologies. "We want to bring solid-state batteries from the laboratory scale to the pilot plant scale, which means going from a three to a six in terms of technology readiness levels," says Dr. Julian Schwenzel, director of Fraunhofer ZESS. "As such, we just have one more step to go before gigafactory-scale production: we have to actually develop the process technology." Because the manufacturing processes for solid-state and liquid batteries are very different. With solid-state cells, for example, the electrolyte has to be incorporated into the manufacturing process right from the beginning, whereas for liquid batteries, it is added at the end of the process. "At Fraunhofer ZESS, we generally work on three different solid-state battery technologies: polymer batteries, thiophosphate-based batteries and oxide batteries," relates Dr. Schwenzel. The primary advantage of the polymers is that they are easy to work with. The researchers primarily use novel polymers that remain stable when undergoing temperature changes and can conduct electricity. They have even submitted a patent application for a new polymer. "However, we have yet to discover a polymer that works as an all-rounder — instead, we have to work out precisely which polymer suits each application," says Dr. Schwenzel.

He sees much cause for excitement in the thiophosphate-based batteries. "They are the champions when it comes to conductivity." However, there are still some issues to be resolved even here: Thiophosphates are very sensitive to damp and have to be processed in a dry room — which would present a challenge for any plans for large-scale production. That's why the researchers are working to reduce these production steps and increase sustainability. The third runner in the race, the oxide batteries, is still very much on the starting blocks. The necessary high-temperature processes are difficult to control, so the ZESS researchers have quite a lot of work left to do before solid-state batteries can knock the established liquid batteries down from their top slot in the market. ▶



Battery cell production meets the digital transformation

Asian countries have gained a head start in battery cell production — so how can Germany and Europe catch up? "Solid mechanical engineering is not going to be enough there," asserts Joachim Montnacher, head of the Energy business unit at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. "The digital transformation is our only chance of regaining the ground we have lost," he adds. "In specific terms, by digitalizing, and thus also optimizing production." The key issues are the economic viability of the manufacturing process and the quality of the resulting cells. This is because the more cells roll off a factory's production line, the higher the reject pile grows. "If a gigafactory were to produce a billion cells per year and 10 percent of those goods were defective, you would be rejecting 100 million cells — that would be an enormous waste of materials," explains Prof. Kai Peter Birke, head of the Center for Digitalized Battery Cell Manufacturing ZDB at Fraunhofer IPA. The researchers hope to improve these figures by digitalizing the entire value chain, in projects such as a DigiBattPro 4.0. "We can validate our approaches on a large production line with mass-scale capabilities in a live operational setting with the help of our industry partner VARTA," reports Florian Maier of Fraunhofer IPA. "We can even rent out the entire production line in order to conduct our own experiments over the course of a full production shift. This means we can use a real-world setting to prove that our digitalization approach is suitable for the industry sector."

The aim here is to use the data to predict the quality of the finished battery during earlier production steps, in what is known as a predictive quality process. This will facilitate immediate removal of low-quality cells. "That is the top of the pyramid that we are trying to climb," explains Mr. Maier. "However, we must first lay the foundations, that is, automatic data collection. After all, no human being could manually enter the data for the tens of thousands of cells that would be manufactured every hour." The researchers hope to optimize the repeatability of the production process using cloud systems, real-time data processing and, in the long term, even digital twins — and to make German and European battery cell production competitive in the process. "The train hasn't left the station," affirms Prof. Birke. "We still have a chance to regain technology leadership in the next generations of battery cells. However, the next decade will be focused on production, not new cell technologies."

The alternative option: fuel cells

Fuel-cell-powered vehicles constitute another contender amid the ranks of electric vehicles — and thus also a beacon of hope for the mobility of tomorrow. These cars combine hydrogen fuel with air to form water and electrical energy, which then powers the electric engine. However, they must overcome much the same challenges as battery-powered vehicles. The sector is facing enormous pressure in terms of costs, which means that fuel cells have to become cheaper. The installation space is also limited, in trucks as much as regular cars — so the modules have to be as small as possible. And if they are to be deployed in trucks, then their lifespan must be increased even further.

In project SinterGDL, researchers at Fraunhofer IFAM in Dresden are working to reduce the costs of fuel cells for trucks, while also delivering a more compact cell design. The goal of the project is to develop a novel PEM stack unit that is both cheap and compact. The core element of the unit is the gas diffusion layer (GDL), which facilitates the supply of equal amounts of hydrogen and air over the entire surface area — which can be as big as a letter-size sheet of paper — and the removal of heat, water and elec-

tricity. “Crucially, instead of manufacturing the GDL out of carbon, we make it entirely out of metal,” reveals Dr. Olaf Andersen, head of department at Fraunhofer IFAM. “By doing this, we are making it easier to scale manufacturing processes up to high volumes, as well as reducing the production costs for the components. Metal components are also easier to install and recycle.” This is because the researchers are using processes from the paper industry, which are suitable for mass production; however, they are not only working with cellulose fibers, fillers and additives, but also metal powder. The end product looks like a sheet of paper, but the metal powder it contains gives it a gray color. It is also up to 200 micrometers thicker than paper, which generally only gets up to 80 micrometers. Next, the team burns out the cellulose at temperatures of up to 600 degrees Celsius, in a special inert gas atmosphere that prevents the metal from oxidizing. The purpose of this step is to cleanly remove all organic components, so that only the metallic parts remain. These are then sintered at 1,250 degrees Celsius, which causes the metallic elements to fuse tightly together. Because the researchers can adjust the metallic GDL’s properties to a great extent, for example, by using different kinds of fibers or altering the size distribution of the pores in the GDL as it forms, they hope that, on top of enabling cost-effective, mass-scale production, they will also improve the GDL’s performance parameters and thus reduce the installation space needed for the fuel cells. Fraunhofer is sowing fresh seeds of hope for fuel cells as an alternative power source in electric vehicles. ■

The digital transformation is vital to mobility according to Florian Maier, Prof. Kai Peter Birke and Joachim Montnacher of Fraunhofer IPA (from left to right).

A voice from the business world

A former car designer for the Volkswagen Group, Thomas Ingenlath has been CEO of Polestar, a Swedish e-car specialist, since 2017.

Turning a corner

Electrification is just the beginning: Even if the automotive industry transitioned to selling entirely electric cars tomorrow, its emissions would still be far above its total CO_2 "budget." At this crucial juncture in history, all the stakeholders in the sector must realize that it's time to work together.

So says Thomas Ingenlath, CEO of the Swedish electric car manufacturer Polestar.

Today, emissions from passenger cars make up 15 percent of all global greenhouse gas emissions. The good news is that, in contrast to other industries, the automotive industry already has an existing, scalable solution to the climate crisis: the electric car. So far, our industry has focused primarily on electrifying cars and speeding up distribution. If we are serious about tackling the climate crisis, however, we must concede that electrification is just the beginning rather than our end goal.

The Pathway Report — compiled by Polestar and Rivian, a US-based electric car manufacturer, in collaboration with the global consultancy firm Kearney — found that the automotive industry is set to exceed its global carbon budget by 2035. From this point on, it would massively overshoot the 1.5-degree limit on global warming, reaching an excess of 75 percent by 2050. Moreover, in simulations of a hypothetical "well-to-wheel" scenario based on an aggressive roll-out of battery-powered electric vehicles that — also hypothetically — run entirely on renewable energy, it has been shown that there will still be an excess of greenhouse gas emissions unless the issue of emissions from the manufacturing supply chain is also addressed at the same time.

The shocking results of the Pathway Report were shared by Polestar, Rivian and Kearney with some of the world's leading automotive manufacturers prior to the report's publication. We have also invited the industry to come together to review the data and begin work on certain aspects of collective climate action. The data reveals a possible path with three core elements. Element one is the speed at which fossil-fuel-powered cars will have to be replaced by electric cars. Element two concerns the expansion of renewable energies in power grids, while element three involves reducing greenhouse gas emissions in the manufacturing supply chain.

It is only if all automotive manufacturers take immediate, joint action that we still stand a chance: First, the industry needs to accelerate the transition to electric vehicles by investing in the required production capacity and establishing a firm end date for the global sale of fossil-fuel-powered cars. Second, it is necessary to expand the supply of renewable energy to global grids in order to ensure that electric vehicles can realize their full potential through a green charging system. Third, the industry must decarbonize its manufacturing supply chains for the production of these vehicles by switching to low-carbon materials and investing in supply chain solutions based on renewable energy.

"Our goal is to build a genuinely carbon-neutral car by 2030."

Thomas Ingenlath

- He has been overseeing the activities of the electric car manufacturer Polestar as its CEO since 2017. Polestar has been listed on Nasdaq since June 2022.
- He was awarded the Design Hero prize in 2017. The award recognized his achievements in creating a Scandinavian design for Volvo, where he had been Senior Vice President Design since 2012.
- He has had more than 20 years of experience in designing for the German automotive industry: at Audi from 1991 to 1994, at Volkswagen from 1995 to 2000 and at Skoda from 2000 to 2006. Since then, Mr. Ingenlath has served as director of the Volkswagen Design Center in Potsdam, which oversees projects for all Volkswagen Group brands.
- He was born in Krefeld in 1964. After graduating high school, he studied at Fachhochschule für Gestaltung (college of design) in Pforzheim and the Royal College of Art in London.

Tackling the huge challenges associated with this third element and decarbonizing supply chains will only succeed through collaboration. Together, we can send a clear signal to suppliers, by using our collective purchasing power to form demand coalitions and working together toward ambitious goals. In April 2021, we launched the Polestar 0 project. Our goal is to build a genuinely carbon-neutral car by 2030 — to do this, we will change the way cars are made instead of relying on misleading carbon offset schemes. In other words, we want to eliminate all CO_2e sources from the entire supply chain, from raw material extraction processes and material and vehicle production to delivery and end-of-life procedures.

So far, we have signed research agreements with more than 20 of the world's leading automotive suppliers from across the supply chain, including German market leaders such as the global technology company ZF, Vitesco, which provides powertrain and power transmission technologies for the automotive industry, and Schlötter, a specialist in electroplating technology.

We are delighted that so many others now share our vision and wish to participate in this project — however, our search goes on. We still need partners from the worlds of academia and industry, and we are focusing on finding partners for raw materials, bio-based chemicals, polymers, electrical components, noble gases and the production of other basic materials.

Car manufacturers and the industry sector must look past competition — the climate crisis is a shared responsibility. Consider this a call to collaboration. ■

Photo: Polestar

Focusing on safety: Nowadays, VR headsets can change young people's perspectives in important ways.

Out of the danger zone

Rethinking traffic education: Persuading teenagers to think ahead on the road and prioritize their own safety, using smart data and virtual reality.

By Beate Strobel

Focusing on correct behavior: In the 1960s, children practiced crossing the road at driving schools.

Between 7:00 and 8:00 a.m. every day, German children enter the danger zone. According to statistics, this hour-long period is the most dangerous time of day — especially when it's as damp and misty as it is today on this winter morning in the town of Hartha in Saxony. Most of the students making their way to Martin-Luther-Gymnasium, a local high school, are wearing dark parkas. Peeping out of fur-rimmed hoods, they fix their eyes on their feet or their phone screens. Others cycle down the road side by side, blithely riding without handlebars. Cars are double-parked; the doors are thrown open and then slammed shut again. A quick wave, and mom or dad speeds away. But did they look over their shoulder and in the side-view mirror first?

In 2021, around 22,000 children between the ages of six and 15 were injured in road traffic accidents. The vast majority took place in the morning as the children made their way to school. The statistics also showed other peaks around lunchtime and between 3:00 and 5:00 p.m. The largest share of the young victims (38 percent) were on a bike, while 21 percent were walking. These statistics validate the unease parents feel as they see their children off to school with a reminder to "Be careful!"

The forgotten demographic

At the Fraunhofer Institute for Transportation and Infrastructure Systems IVI in Dresden, around 90 kilometers from Hartha, three Fraunhofer researchers are working to change these accident statistics for the better. According to accident researcher Maria Pohle, 10- to 15-year-olds are "the forgotten demographic." "Boys in this age group who ride bikes are the most at risk of road traffic accidents," adds Dr. Christian Erbsmehl, group manager for Vehicle and Road Safety. Despite this, traffic education is put to one side for teenagers, although there are numerous programs for preschoolers, elementary school students and children starting middle school. This gap in education comes exactly at the point when young people start going out more on their own. Traffic psychologist Nora Strauzenberg jokes that another factor involved is that at this stage of life, "the brain is closed for renovation." During adolescence, bicycle helmets become an object of disdain, while red traffic lights become a challenge.

As part of a project funded by the German Federal Ministry for Digital and Transport, these three scientists have developed the Fraunhofer IVI Accident Prevention School (FAPS). This prevention course is aimed specifically at young people and is designed to provoke effective, long-lasting "aha" moments, using real accident data from the children's school environment in conjunction with new technology. As Dr. Erbsmehl explains: "FAPS doesn't aim to lecture students — it aims to persuade them." In 2017, FAPS received the German Mobility Award from the German Federal Ministry for Digital and Transport. Collaboration partners such as ADAC Sachsen are currently implementing the program in pre-high school classes across Saxony.

> "Our methods do not aim to lecture — they aim to persuade."
>
> Dr. Christian Erbsmehl,
> Accident researcher at Fraunhofer IVI

"In your opinion, how safe is your daily school commute?" This is the question posed by Michael Preller, a traffic educator at ADAC Sachsen, to seventh-grade students at the Martin-Luther-Gymnasium in Hartha. The unanimous response: it's fine, no worries. Mr. Preller then asks the students to draw their school commute on a street map of Hartha. There are red and green dots at certain intersections. These represent accidents involving cyclists and pedestrians — the bigger the dot, the higher the number of tragedies. The children are then tasked with counting the total number of accident-prone spots on their school commute. Most end up with a number between seven and ten. So is everything "fine"?

Law of the jungle

The next module also sees the students working on paper: In small groups, the students are asked to decipher graphs pertaining to bicycle and pedestrian accidents. Who was involved in the accident, and who was at fault? Who was hurt, and how? As one group after another presents their analyses, they each come to realize something that FAPS co-founder Dr. Erbsmehl describes as a core message of the program: In over half of all accidents, cyclists and pedestrians are not at fault. But in almost 100 percent of accidents, they are the ones that are injured or killed. Ms. Strauzenberg, the traffic psychologist, says that, up until now, traffic education has "focused too much on what to do right, and not on what could cause them harm." FAPS, on the other hand, aims to make students more aware that even if they follow the traffic laws, they cannot consider themselves completely safe. The roads follow the rule of the jungle — whoever is stronger, or at least bigger, will come out on top. This applies when a truck collides with a bicycle, a car with a pedestrian or an adult with a child.

FAPS is based on accident data collected from EUSka (Elektronische Unfallsteckkarte, electronic accident record card), a software developed for the police, which in this case is used to analyze ▶

22,000 children

between the ages of six and 15 were injured in road traffic accidents in 2021. Of these, most were on their morning commute to school.

Photos: Fraunhofer IVI (Wildstyle Network), Rolf Unterberg/German Federal Ar

Important analysis: What caused the accident — and what can we learn from it?

anonymous accident reports together with their geographical references. As they pore over the reports, the seventh-grade students realize the roads that feature time and again — Nordstraße, Karl-Marx-Straße, Straße des Friedens — are the ones they use every day. Reports such as that of a child who was fatally struck by a truck turning right onto a road as they were crossing — a road that the students pass each day — cause a chilled silence in the classroom.

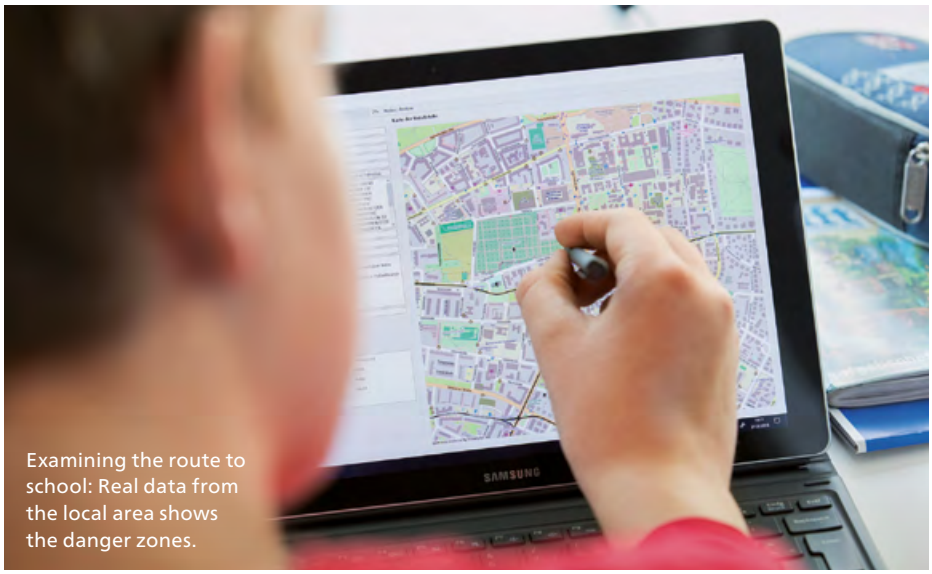
Mr. Preller asks the class: "How can you avoid this happening to you?" "Be more careful?" comes one uncertain reply. "Think ahead and stay on the defensive," says Mr. Preller more precisely. He repeats this key point once more, to drill it in: "Think ahead! And stay on the defensive!" However, the young people are only able to see things from a cyclist's or pedestrian's point of view; they have difficulty anticipating the reactions of other road users. What does a driver see when they pull out of a parking space? And when a truck driver wants to turn right, are they even able to see the person on the cycle path, who also has a green light but wants to move straight ahead?

Mr. Preller hands out tablets to the students — the display shows a stylized representation of an intersection. Using their fingers, the teenagers can place various types of road users on the road, from truck drivers and motorists to cyclists and pedestrians. A second window displays what the motorist, truck driver or cyclist is actually seeing. When a cyclist is placed to the right of a truck, the teenagers try pushing him further and further forward — finally, he appears as a tiny figure in the truck driver's field of vision. "That far forward?" says one girl, surprised. "But that's basically at the intersection!"

> "VR gives us the chance to experience all the emotions of an accident, without risking life and limb."
>
> Nora Strauzenberg, traffic psychologist at Fraunhofer IVI

The young people are far more captivated by their task on the tablets than by evaluating graphs on paper. The researchers at Fraunhofer IVI want to go a step further and allow students to virtually experience typical accident scenarios using VR headsets. As with FAPS, the follow-up project PAPS-XR (Public Accident Prevention School with eXtended Reality) also involves Wildstyle Network GmbH and other partners from the digital economy. Rather than using the acronym PAPS-XR, however, co-CEO Steve Nitzschner prefers to call it Collision Zero, meaning that there should never be another child involved in a road traffic accident. His vision is a little unrealistic, but that doesn't bother Mr. Nitzschner: "I'd rather aim too high than too low," he says. When it comes to the safety of our children and young people, it's alright to be "a bit big for your boots," he says.

A prototype has already been produced for the VR headsets. Put them on, and you'll find yourself looking at the very same intersection displayed on the tablet. Using a joystick, you can choose whether you want to travel by car, truck or bicycle. Do you want to squeeze your bike past the right side of a truck, and then make a turn? Not a good idea. Suddenly, you see the truck appear on your left. The resulting crash will only take place in the virtual realm, but you'll feel as if you are falling to the ground with your bike. As the truck driver, on the other hand, when you look to your right and behind you — just as you are meant to do — you won't see a thing. But once you turn right, the vehicle will



Examining the route to school: Real data from the local area shows the danger zones.

jerk and then stop abruptly. At this horrifying moment, you can easily imagine the driver's fear: Did I just run someone over?

Balancing fun and learning

"We want to create a learning experience that can actually change people's behavior," emphasizes Mr. Nitzschner. This means it must be as realistic as possible. "Virtual reality gives us the chance to experience all the emotions of an accident, without risking life and limb," adds Ms. Strauzenberg. However, Dr. Erbsmehl warns that the concept of gamification should not be overdone, especially when it comes to young people. "We want them to take it seriously — not cause virtual crashes like they would in a video game." Judging by the seventh-grade class at Martin-Luther-Gymnasium, his fears are well-founded: Some of the boys are skidding the virtual truck across the intersection with their fingers, looking for the best time to catch the cyclist.

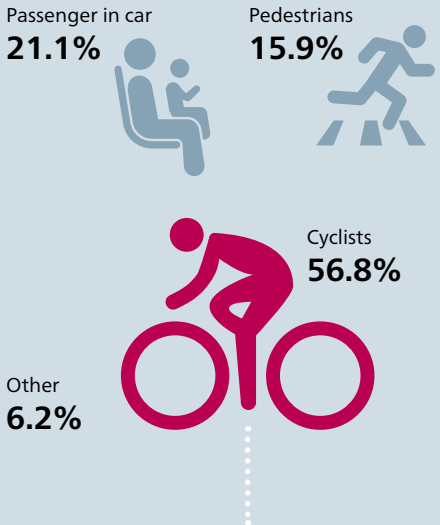
However, the scientists' ultimate aim is not only to bring the concept of interactive and immersive traffic education to high schools across Germany, but to also make it available to the public online and as an app — all while still enabling a learning experience that is tailored to the individual. Achieving this, however, "would require creating a digital map of typical accidents in all of Germany," explains Dr. Erbsmehl. For example, this is the only way parents could virtually walk their children through their real-life route to school and practice critical situations. To achieve this, Fraunhofer IVI would require access to accident data from all the federal states of Germany. As it stands, they only have data for Saxony, Brandenburg, Hesse, Saxony-Anhalt, Hamburg, Bremen and Bremerhaven. The fact is, even if the data in question is completely anonymized, it still concerns the suffering of individuals, and therefore requires a particularly responsible approach. "This means that for each state, there must be someone who supports the data being used to improve traffic safety and therefore takes responsibility for sharing the data," explains Dr. Erbsmehl. "That's where the process sometimes falls apart."

However, this is not stopping the researchers at Fraunhofer IVI from relentlessly pursuing their vision of Collision Zero. They envision a world where, come 7:00 a.m., a child's only worry is forgetting their homework — and they're not giving up until they get there. ■

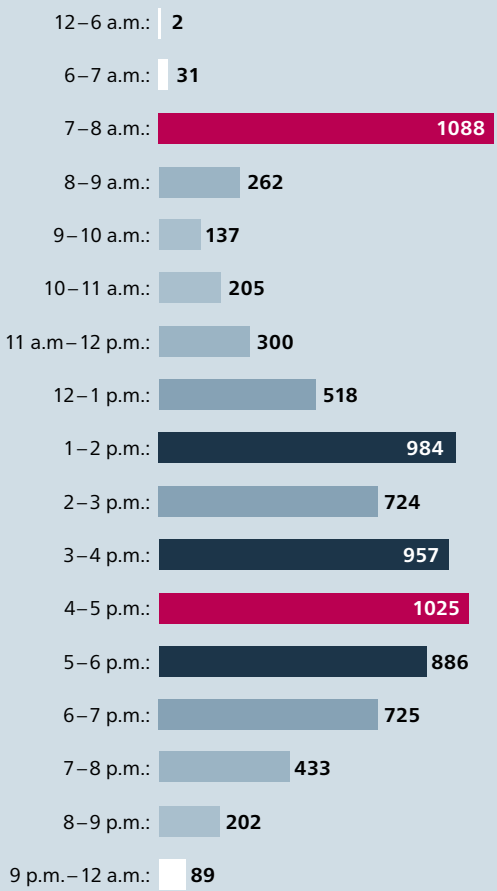
Scan here for the podcast:

Photos: Fraunhofer IVI (2), istockphoto (3)

Almost 12,000 young people between the ages of 10 and 15 were involved in road traffic accidents in Germany in 2020 (percentage breakdown by type of vehicle involved).



In 2020, cyclists between the ages of 6 and 15 were involved in road traffic accidents at the following times (number of accident victims).



Source: German Federal Statistical Office

Fly larvae pig out for mother nature

The fruit of the oil palm tree is an ingredient in many products, but it does not enjoy a particularly good reputation. Black soldier fly larvae could serve as an alternative source of fat. Researchers at the Fraunhofer campus in Stuttgart-Vaihingen are whether the possibility might fly.

By Kerstin Beckert

Palm oil evokes visions of sun, sand and tropical ambiance. However, this plant-based raw material has more to do with big business than vacation vibes — and business is booming. According to the German Federal Statistical Office, Germany imported and processed almost 667,000 tons of vegetable fat in 2021, along with an additional 124,000 tons of palm oil. Both types of fat are found in products like animal feed and chocolate, detergents and instant soups, shampoos and cookies. The problems caused by consuming high volumes of these substances are well-known: the destruction of rain forests, monoculture farming and species extinction.

So how can we reduce our dependence on palm oil products going forward? The larvae of the black soldier fly, or hermetia illucens, could be the answer. The larvae contain not only water and protein, but also saturated fatty acids with similar characteristics to palm oil and its relative, coconut fat.

With the aim of finding a way to harvest hermetia larvae as effectively as possible, researchers at the Fraunhofer campus in Stuttgart-Vaihingen are building a pilot version of an insect biorefinery (InBiRa). Measuring some 200 square meters, the plant has been under construction since October 2021. Susanne Zibek is the coordinator of the nationwide research team. In addition to holding a doctorate in engineering, she is a project manager at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB.

Biorefinery for insect larvae

The fly larvae are voracious eaters, constantly hungry and not too fussy about their food choices. It just has to be of organic origin. That's what makes them so interesting to Ms. Zibek and her team. In Germany, quite a lot of organic and food waste accumulates in places like the premises of food retailers or canteens. This can even include coffee grounds and fruit skins from the organic waste collection bin.

The research team is planning to enlist the fly larvae's help to "upgrade" this organic waste, transforming it into higher-value materials — organic upcycling, if you will. Some 30 to 50 percent of food waste could be a suitable raw material for this process. To begin with, the scientists are concentrating on expired fruit, vegetables, baked goods and dairy products that can no longer be distributed through organizations like food banks. They get this excess stock from discount supermarkets. Thanks to a special exemption, they are also permitted to use food waste from college restaurants and other canteens, since it is for research purposes. Canteen waste

The goal is to produce "higher-quality follow-on products from food waste."

Not beautiful, but useful: the black soldier fly

Photo: Arne Dedert/picture alliance/dpa

contains meat, which is legally prohibited from being used in livestock feed.

Organic waste becomes fly food

The organic waste material is shredded and further processed to form a suitable source of nourishment for the fly larvae. "We are looking for a food mixture that will make our flies achieve optimal growth," explains Christian Schmidle, doctoral student at the University of Stuttgart's Institute of Interfacial Process Engineering and Plasma Technology IGVP. As a chemist and budding process engineer, he has been involved in the design of the plant since April 2022.

It's important to get the right composition for the fly food. This is because the larvae, initially only a few millimeters in size, have to multiply their weight within 14 days to become little barrels measuring about 2 centimeters. With that in mind, the researchers ensure that they start life in a true paradise for hermetia illucens — blue tubs filled to the brim with food. The larvae feed until they are sated and plump, with no thought of staging a breakout. "That certainly is a possibility," says Mr. Schmidle. "The insects could make an escape if they weren't thriving, i.e. if the composition of the food was suboptimal." But they don't seem inclined to do so. They prefer to bury themselves in the warm substrate — and grow.

After two weeks, 1 gram of freshly hatched larvae yields around 8 kilograms of larval mass. The creatures are removed from the tub shortly before they are due to pupate, as this is the perfect time to collect them. They are then quickly inactivated at an elevated temperature, in a process similar to the way shrimp are treated on board a fishing boat before they are shelled.

The fat contained in the larvae should be separated from the protein in the most environmentally sustainable way possible. The larvae are first dried and put into an oil press, just like the ones used for making sunflower or rapeseed oil. They are fed into a pipe containing a screw conveyor, which crushes and compacts the larval mass. This increases the pressure inside the pipe, as Mr. Schmidle explains. The fat contained in the larvae is squeezed out and collected separately. This leaves behind the press cake, which contains proteins and chitin from the skin of the larvae along with some residual fats; these are extracted using a solvent.

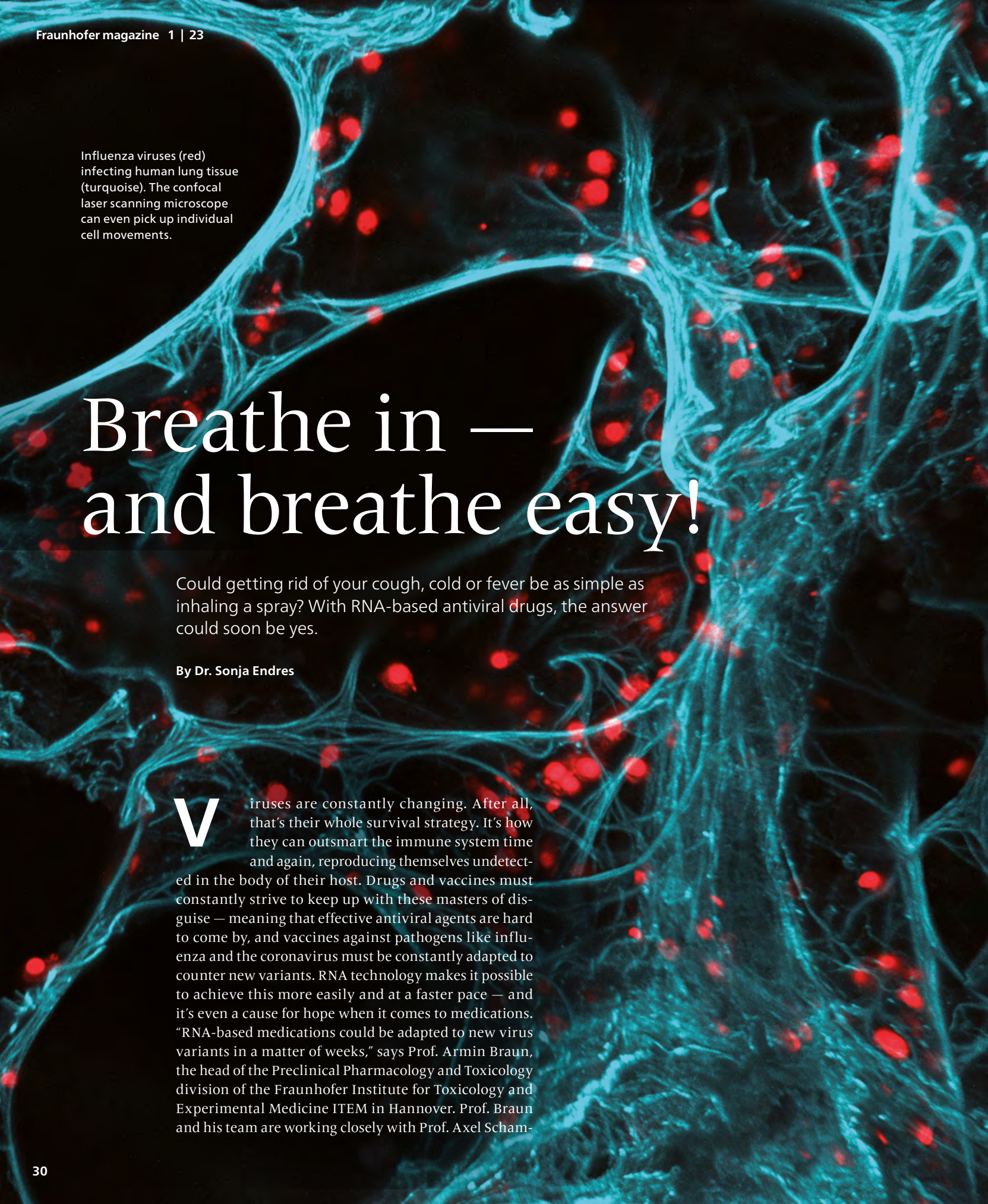
Much like plant oils, the fat extracted from the larvae can be further processed to form biodiesel, glycerin and lubricants. It can also be used to manufacture soap, although, as Mr. Schmidle notes, it would obviously no longer count as a vegan product in that case. The preferred use for larva fat is in biosurfactants — for example, detergents, which often use coconut fat and palm oil because of their medium-chain fatty acids. These are also found in larva fat. This would certainly offer a sustainable alternative to fats imported from the tropics.

The protein that can be extracted from the larvae also has a wide range of possible applications. It can be used to manufacture hair masks, thickening agents, biodegradable packaging film and adhesives (e.g., for wood).

A more or less circular process

The waste material from the tubs is handled separately. This includes the larval skins. These are composed of about 40 percent chitin, which can be chemically processed to produce waterproof textile coatings, for example. Previously, some initial approaches based on chitin or chitosan have used material sourced from crab shells.

Even the leftovers from the food mixture and the larval excrement will be used later on: nothing will go to waste. This residual material could be suitable for manufacturing fertilizer or biogas. According to Mr. Schmidle, the insect biorefinery just represents an interim step for garbage on its path from trash can to biogas. The goal is to produce "higher-quality follow-on products from food waste." Upcycling, in other words. ■



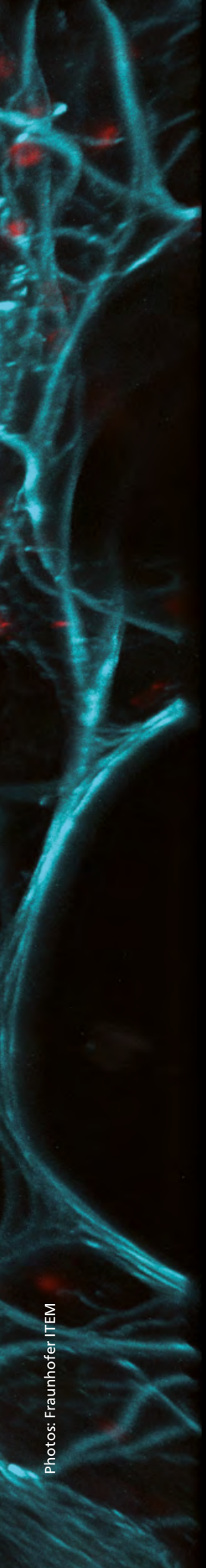
Influenza viruses (red) infecting human lung tissue (turquoise). The confocal laser scanning microscope can even pick up individual cell movements.

Breathe in — and breathe easy!

Could getting rid of your cough, cold or fever be as simple as inhaling a spray? With RNA-based antiviral drugs, the answer could soon be yes.

By Dr. Sonja Endres

Viruses are constantly changing. After all, that's their whole survival strategy. It's how they can outsmart the immune system time and again, reproducing themselves undetected in the body of their host. Drugs and vaccines must constantly strive to keep up with these masters of disguise — meaning that effective antiviral agents are hard to come by, and vaccines against pathogens like influenza and the coronavirus must be constantly adapted to counter new variants. RNA technology makes it possible to achieve this more easily and at a faster pace — and it's even a cause for hope when it comes to medications. "RNA-based medications could be adapted to new virus variants in a matter of weeks," says Prof. Armin Braun, the head of the Preclinical Pharmacology and Toxicology division of the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM in Hannover. Prof. Braun and his team are working closely with Prof. Axel Scham-



Photos: Fraunhofer ITEM

bach from Hannover Medical School (MHH) to research how RNA-based drugs can combat viral diseases.

The researchers' first target is the parainfluenza virus, which primarily circulates among young children, who often go on to infect their parents and other contacts. Those affected suffer from flu-like symptoms such as fever, cold or cough. In children and older people with weakened immune systems, the virus often causes inflammation of the deeper respiratory tract as well. This leads to bronchitis, which, in children, can sometimes develop into croup — an infection which causes swelling in the mucous membranes of the larynx and upper windpipe, making it difficult to breathe. In rare cases, the shortness of breath is so extreme that there is a risk of suffocation. The parainfluenza virus is particularly dangerous for organ or bone marrow transplant patients, whose immune systems have been intentionally weakened so that they do not reject foreign tissue. They are at the mercy of the virus, as there is no medicine or vaccine for it so far. Fourty percent of infected patients die. The virus is also a serious threat to people with chronic respiratory diseases such as asthma or COPD. An infection will exacerbate the disease severely, triggering a need for costly inpatient treatment.

> "RNA-based medications could be adapted to new virus variants in a matter of weeks."
>
> Prof. Armin Braun, Fraunhofer ITEM

Prof. Braun and his team have succeeded in developing an RNA therapeutic agent that blocks viral reproduction processes in the host body. "Viruses don't multiply on their own. They use the machinery of the cells that they infiltrate for that," he explains. At this point, the ribosomes — essentially, the protein factories of the cells — will no longer produce proteins for the body, which are normally used to form muscles, organs, blood, enzymes and hormones, among other things. Instead, they produce protein building blocks that the virus uses to create a new version of itself. "What we do is throw the virus off course by ensuring that the blueprint for some of its proteins becomes unreadable," says Prof. Braun. To achieve this, he and his team introduce RNA into the cell — and this RNA has been specifically adapted to the virus. Inside the cell, it activates an endogenous defense mechanism called the RISC complex. In simple terms, it causes a complementary RNA to bind to the viral RNA, making the protein blueprints unreadable. "Basically, it's like removing two or three pieces from a jigsaw puzzle. The virus can no longer put itself together. This disrupts the entire chain of infection." Higher amounts of missing viral proteins mean a lower risk of the ever adaptable virus learning to live without them.

But the researchers are going one step further. They can target particularly important viral proteins to switch them off, further reducing the risk that the virus will successfully mutate. "Certain viral proteins are very difficult to change or replace — one example is the protein that allows the virus to attach itself to the cell and penetrate it," explains Prof. Braun. With the help of artificial intelligence, the collaboration partners under Prof. Schambach at MHH successfully identified these important viral proteins in genetic databases, as well as their corresponding RNA sequences. "What's special is that we can tailor our RNA on this basis, targeting the Achilles' heel of the virus," says Prof. Braun — and they have already had great success here, having reduced virus replication in cell and tissue cultures by over 90 percent.

The RNA therapeutic agent will be administered by inhaling an aerosol, making it easy to reach all respiratory viruses on the respiratory epithelium. To achieve this, the therapeutic RNA is packaged in liposomal formulations, i.e., fat droplets. They ensure that the unstable RNA does not decay in the body, and allow it to penetrate the cells. The researchers are still working on the perfect formulation here. Next, they want to test the efficacy of the RNA therapeutic agent in animal models. It could be administered to patients for the first time as part of a clinical trial in 2025. "If we are successful, the procedure could be applied to new pandemic viruses in the future," reveals Prof. Braun. Even the German Federal Agency for Disruptive Innovation SPRIND was impressed by the technology, to the extent that it is now funding the second round of the project. Bad news for viruses. Good news for us hosts. ■

Sustainably snug

Heating with fossil fuels? In the long term, Germany will need to say goodbye to natural gas, oil and wood as raw materials for heating. The government is pushing heat pumps as the sustainable alternative — even in historic buildings and apartment blocks.

By Monika Offenberger

Photo: Erik Žunec/AdobeStock

Can we turn up the heating with a clear conscience as regards the environment? It's easier with a heat pump.

The German federal government aims to drive the energy transition by means of a massive expansion in climate-friendly heating systems. At a virtual summit on heat pumps held in June 2022, Robert Habeck, the German minister for climate action, revealed his plans to install six million heat pumps by 2030. The Green party politician has set a no less ambitious target for the operation of heating systems in general: By 2024, all such systems must run on a minimum of 65 percent renewable energy. "That alone singles heat pumps out as the systems of the future — because there is hardly any other option that can meet this requirement," says Dr. Marek Miara, who has been driving progress in this technology at the Freiburg-based Fraunhofer Institute for Solar Energy Systems ISE for 20 years.

Heat pumps use natural heat from the surrounding environment — i.e., the thermal energy from the air, water and earth — to keep buildings warm. Unlike wood, oil and gas heating, there is no energy carrier combustion and so no waste gas emissions to damage the climate. Instead, heat pumps operate based on a cyclical process that uses suitable cooling agents and alternating pressure, taking warmth from the surrounding environment and raising its temperature level before emitting the resulting heat directly into the building's heating and water systems. "Just 15 years ago, you constantly had to explain to people that yes, using cold air to heat a house actually works. Later on, people questioned whether heat pumps are efficient enough. And now, there are more than 5,000 different devices available on the market in Germany alone," says Dr. Miara.

Dr. Habeck's campaign is following the exact strategy for achieving climate targets that many scientific studies have been advocating for years. For the heating industry, the six million pump plan was a shock at first. Now, after many workshops and another heat pump summit, the stakeholders are rising to the challenge. Leading manufacturers are planning to join forces to invest several billion euros in new production capacity. "In the past, investments of this volume would not have been thought possible," emphasizes Dr. Miara, stressing how dramatic the recent developments have been. At present, around 1.6 million of these systems are operating in Germany. A good 200,000 new systems were installed in 2022, and another 350,000 are set to be produced, sold and installed this year. If this pace is maintained, then the annual minimum target of 500,000 units that has been set for 2024 onward would actually start to sound realistic. All the same, it's an extremely ambitious goal, and reaching it will not be a question of increasing heat pump efficiency. Instead, the focus is on how to quickly install these systems in as many houses as possible.

To solve this riddle, it is helpful to look back on what has already been achieved. Fraunhofer ISE is known for its extensive monitoring projects, which now cover more than 350 buildings that use heat pumps. In a study completed in 2020, Dr. Miara and his team conducted a metrological analysis of 56 models from different manufacturers, including models that use external air, indoor air and downhole heat exchangers as their energy sources. These systems were used to heat single- and multi-family homes (for up to four families) that were all at least 15 years old, and in most cases, more than 40 years old. The results disproved some widely held misconceptions, points out Dr. Miara, who headed up the study. "First of all, we showed that all the systems work well and provide sufficient heat, even in the existing building stock. This is something that is constantly being called into question. Second, we demonstrated that they also work efficiently in houses that have undergone little or no restoration work, and consequently have a high energy demand for heating. Our third finding is that heat pumps can function well with ordinary radiators. Naturally, underfloor heating and other forms of panel heating are better as a rule, because they can get by with a lower supply temperature. But radiators do not automatically disqualify a building from using a heat pump." The bottom line is that even for existing buildings, a correctly scaled pump can guarantee sufficient heating.

Heat pumps are also proving themselves in other contexts, even — and especially — in multi-family houses. This has been demonstrated in analyses from eight European countries, which were commissioned by the International Energy Agency. "But we are also seeing that there are too many different solutions," reveals Dr. Miara, who also led the IEA project. "To put it in slightly exaggerated terms, if in every one of the many thousands of models available on the market, the pipe connection openings in the device's housing are in a different place, then the technicians have to learn the new method from scratch every time they install a system. We urgently need more standardization here," insists the Fraunhofer researcher. "And that doesn't just apply to the products, but also to the models and system schematics." This is because connecting the heat pump to the house's existing ▶

or planned infrastructure for heat distribution, heat transfer and hot water is far more complicated than the pump itself. Installing the pumps in existing buildings is a particularly difficult challenge. As Dr. Miara has been a member of the relevant Association of German Engineers (VDI) standardization committee for many years, he has a say in the specifications that become part of the standards. "Based on the results of our studies, we are trying to propose suitable standards and guidelines for making heat pump installation simpler and more uniform for all countries, including Germany," the engineer explains. These guidelines formed the basis for developing calculation methods, installation instructions and training programs — although these are not yet compulsory.

The Fraunhofer team is also making an important contribution toward decreasing the ecological footprint of heat pumps — by using climate-friendly refrigerants. Conventional models primarily rely on synthetic F-gas refrigerants, the use of which is set to be heavily restricted by an EU regulation in the future. This is why researchers at Fraunhofer ISE have been looking into alternatives. In 2017, they began work on a model that uses propane, a gas with a global warming potential around 500 times lower than that of conventional refrigerants. Crucially, the refrigerant cycle can function on only 150 grams of propane. This extremely low quantity minimizes the safety risk and means that even though the gas is highly flammable, the heat pumps can be used indoors. "We built our prototype to show that this works. Since then, we have engaged in open dialog with nine European heat pump manufacturers to continue developing the system," explains Dr. Lena Schnabel, head of the Heating and Cooling Technologies department at Fraunhofer ISE. "Now we have three good refrigerant cycles that can achieve an output of 8 to 12 kilowatts with 150 grams of propane, depending on the different cycle variants and component configurations used. That's enough to heat an apartment or a single-family house — and its efficiency rating meets the requirements for the German Federal Funding for Efficient Buildings subsidy," says the engineer.

As part of a follow-up project, her team is once again collaborating with leading European heat pump manufacturers as well as stakeholders in the housing sector. The goal of the project, which is funded by the German Federal Ministry for Economic Affairs and Climate Action, is to make the new propane refrigeration cycles fit for installation in existing buildings. The team is focusing on three problems: How can gas boilers be replaced in apartments? How can oil and gas burners be replaced in the boiler rooms of single- and multi-family homes? And given the significantly reduced amount of refrigerant used, to what extent is it possible to make powerful air source heat pumps even more compact so that they can be installed outdoors in greater quantities, even in densely built-up cities? Ms. Schnabel stresses that their primary concern is to find quick solutions that will continue to be viable in the long term. "This is an area where we can use our expertise to support the industry sector and society as a whole."

Although the demand for air source heat pumps is increasing exponentially geothermal heat pump installations have been lagging behind. There are currently around 400,000 geothermal heat pumps installed in Germany, and over 20,000 new systems are put in every year. "The barriers blocking market success aren't so much on the technical side — instead, it comes down to grant guidelines, approval processes, a lack of willingness to invest and a shortage of skilled workers," explains Prof. Rolf Bracke, director of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG. With the support from the German Geothermal Association, Bundesverband Wärmepumpe e. V. and Erdwärme Gemeinschaft Bayern e. V., Prof. Bracke analyzed the regulatory and financial barriers that are preventing widespread use of geothermal heat pumps in Germany.

The end result of this analysis was a road map with recommendations for action for the various stakeholders. The purpose of the map is to help leverage the unexploited potential of geothermal heat pumps to a greater extent and speed up the energy transition. The recommendations range from collecting geological data across Germany, to tax incentives and simplified approval processes, through to providing training for workers in the plumbing, heating and air-conditioning trades. The road map also calls for targeted information campaigns to help increase society's acceptance of heat pumps. Because the higher initial investment costs continue to deter property owners and prevent them from seeing that the long-term operating costs are low, much to Prof. Bracke's distress — but he is also optimistic: "In the medium term, we can achieve the long-overdue transformation of the heating market through targeted adjustment of subsidization conditions and options. Because the advantages of heat pumps, particularly when powered by shallow geothermal energy, are clear." ■

"In the medium term, we can achieve the long-overdue transformation of the heating market through targeted adjustment of subsidization conditions and options."

Prof. Rolf Bracke, Fraunhofer IEG

Knowledge relay

New field of scientific research?

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Knowledge relay

Prof. Wilhelm Bauer, how will the concept of ***New Work*** look in the ***field of scientific research?***

Knowledge relay, episode 7

Prof. Wilhelm Bauer, how will the concept of New Work look in the field of scientific research?

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. Wilhelm Bauer,** director of the Fraunhofer Institute for Industrial Engineering IAO, answers a question posed by **Prof. Michael Waidner,** director of the Fraunhofer Institute for Secure Information Technology SIT.

As a country with little to draw on in terms of natural resources, Germany's ability to innovate is a vital factor for its future industrial success in an environment worth living in. Scientific work plays a key role here. The success of this relies on the expertise, motivation, dedication and working conditions of those involved. As such, we must do everything we can to optimize the peripheral conditions in which this work is performed, i.e., the buildings, laboratories and technical infrastructures. We must also strive to make the general working conditions for scientific research as modern and advantageous as possible, for example, by giving employees independence regarding their working hours and locations, providing opportunities for participation and development, for networking and creative dialogue, as well as safe, healthy working conditions. This is a challenge that affects the Fraunhofer-Gesellschaft as much as all other companies and organizations.

However, its status as a top-performing research organization also opens up some unique opportunities for the Fraunhofer-Gesellschaft in terms of shaping work in research organizations and, therefore, in competing for talent. Hybrid working models could be key to recruiting the most highly talented staff

Prof. Wilhelm Bauer is the director of the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart.

and combining their expertise in distributed, connected teams to form "power houses" that are dedicated to specific research topics. In the future, I expect that we will see traditional, more location-based research institutes being replaced by distributed research networks and virtual research ecosystems, with collaboration taking place through European and international hubs. These will stand out due to excellent leadership and project management, as well as meaningful research topics focused on the needs of society and industry which will, thus, attract and retain talent. This kind of model is also necessary in order to reach a sufficient "critical mass" of trained research staff that can even survive the competition with the — sometimes enormous — research departments at large digital companies in Asia and America. We also need to establish attractive "hardware hubs" to operate in close proximity to and within economic clusters. These hubs and their organizational structure must also offer easy-access options for mobility, collaboration and housing. In particular, I am thinking of co-living spaces that could facilitate temporary in-person collaboration on projects. At Fraunhofer IAO, we are researching all of these questions.

The need for self-determined working hours and locations

Scientific research is as much a product of close collaboration as it is of intensive reasoning and ideation. This takes place across project cycles and tightly timed workload peaks, as well as in long phases of design and experimentation work. This means employees must be able to independently determine their working hours and locations, while also complying with laws on working time and occupational health and safety requirements. Furthermore, scientists also have specific expectations in terms of leadership; they look for a good mix of technical supervision, personal support and high-quality team management. At the same time, scientific workers are often so well-versed in their field of expertise that they can and want to exercise significant authority in technical areas in their capacity as distinguished experts as well as contribute their own ideas and expectations. The resulting requirements can be quite well-encapsulated within the overall concept of New Work. The Fraunhofer-Gesellschaft has already been implementing the New Work principle for years, with great success. However, we are reaching the limits of what can be done under labor laws and collective bargaining agreements, which we are therefore eager to expand. This is why Fraunhofer and a number of other major research organizations are currently developing an experimental space for scientific research. Our vision here is to establish a highly flexible, productive and creative working environment that harnesses all of the latest possibilities that information technology presents, allows for intensive networking between employees and facilitates the most focused, customer-oriented and self-determined form of work possible. ■

Our vision is to establish a highly flexible, productive and creative working environment that harnesses all *the latest possibilities* that information technology presents.

In the next issue:

When will ***self-driving vehicles*** become an ***everyday sight*** on German roads?

Photo: Fraunhofer IAO

Title

The penicillin of our day

Only 9 percent of all German hospitals currently use artificial intelligence, although it has the potential to revolutionize medicine and significantly reduce the burden on medical staff.

By Dr. Sonja Endres and Beate Strobel, photography: Valéry Kloubert

"The healthcare industry is so endlessly complex, like mathematics. That's why it fascinated me instantly," enthuses Dario Antweiler. The mathematician and computer scientist is head of the Healthcare Analytics business unit at Fraunhofer IAIS.

Every minute counts when caring for severely injured persons. They are treated in the trauma room, which is located right at the heart of the emergency department and equipped with cutting-edge technology, respirators and powerful full-body CT scanners. The trauma room team need to determine any possible fractures or injuries to the brain or spinal cord as quickly as possible. Did the patient fall from a height of more than 3 meters? Were they in a bicycle crash? Are they diabetic? Every single detail affects crucial decisions, from the specialists should be brought in to help to the treatment steps taken — the also determine the order in which these actions are taken. This information sometimes makes the difference between life and death, but as it stands, it is only passed on orally by emergency service personnel. It is almost never recorded in any structured manner, creating a huge risk of information going missing.

Smart assistance for decision-making

Researchers at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS are working to change this alongside their partners in the TraumAInterfaces project. They want to build an AI-driven speech recognition system that will automatically record, analyze and structure the information exchanged during the handover of severely injured patients. "Our AI does not make any decisions," emphasizes Dario Antweiler, head of the Healthcare Analytics business unit at Fraunhofer IAIS. Its sole purpose is to support the trauma room team's decision-making processes as effectively as possible. A structured record of all the necessary information and the course of treatment is also valuable for documenting the case at later stages. "Producing this documentation wastes a lot of valuable time that doctors could be spending on patients instead," Mr. Antweiler points out.

He and his team spent days and days visiting various different hospital departments, observing work and administrative procedures, interviewing doctors and talking to hospital experts. "What we focused on above all was, what IT systems are they using? How do they communicate? Where is data generated and how is it used?" Next, the data scientists developed more than 40 use cases for deploying AI in such as way as to reduce the workload on medical staff at hospitals and improve the quality of treatment. "Patients are getting older and older, and more and more numerous, and the personnel shortage is becoming more serious. In the future, hospitals simply won't be able to get by without AI," Mr. Antweiler asserts.

54 percent
of doctors do not use AI in their hospitals, but would be in favor of it.

Saving precious time with AI

Artificial intelligence holds enormous potential for hospitals. AI-driven systems could establish statistical correlations based on hundreds of thousands of previous cases, allowing them to predict possible complications and risks at an early stage, for example. When combined with doctors' experiences, this information could be used to adjust treatment strategies accordingly, and improve the patients' chances of survival. AI can also help estimate the risks of a surgery in a more accurate way. Doctors could use "literature mining" to quickly find up-to-date information about the best treatment options — which would be a particular advantage in the complex, interdisciplinary, time-sensitive process of treating the severely injured. In literature mining, the AI analyzes large quantities of specialist medical literature, which is automatically updated on a regular basis. Not only is this process far quicker than searching online databases in the conventional way, but it's also much more accurate. AI can run semantic searches, meaning that rather than just searching for specific terms, it also searches for related content — and it can filter and classify the results, ensuring that a critical care unit is shown different articles from a regular unit, for example. "These days, AI is very good at extracting information from texts, which is something the healthcare sector desperately needs. Almost all information is in text form, from diagnostic findings and doctors' letters to documentation. Producing, reading and analyzing these texts takes up incredible amounts of time," explains Mr. Antweiler. However, clinicians simply do not have the time to study documents like a thick patient file con-

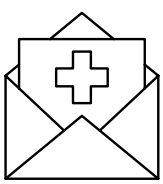
taining 20 years of medical history, so any important information it may contain can easily go unnoticed.

Producing doctors' letters quickly — at last!

Now, Mr. Antweiler and his team are working in the SmartHospital.NRW project to automatically extract important details on diagnoses, prior treatments and allergies via AI and present it in a clear, structured form for medical personnel to use. Starting in 2024, AI-driven text mining well be deployed at University Hospital Essen, one of the project partners and a trailblazer in the field of digital transformation in Germany. The hospital is also set to put the AI-based speech recognition system to the test in the near future, along with another Fraunhofer IAIS innovation, the doctors' letter generator. These documents, which are issued to every patient upon leaving the hospital, serve as the primary means of communication between hospitals and doctors' offices. However, they currently take doctors an average of three hours to produce. The letters contain details such as the patient's case history and suspected diagnosis assigned upon their admission to inpatient care, as well as any drugs that have been administered and any treatment steps that were taken in the hospital. Until now, medical personnel have had to go through the laborious process of collecting all this information from different IT systems. In the future, however, an AI program will automatically extract this information and insert it into the doctor's letter. Only the epicrisis, that is, the summary of the overall hospital stay, the conclusions to be drawn and the recommended treatment will still have to be drafted by the doctor for the final full text.

Prof. Jochen Werner, medical director and head of the executive board at University Hospital Essen, wants to make his clinic the first "smart hospital" in Germany — a mission that is already well underway, with the support of Fraunhofer IAIS. "Data is the penicillin of our day," Prof. Werner announces. He uses his YouTube channel to promote digitalization in medicine, with a view to allaying the fears of medical personnel and patients alike.

71 percent
of doctors firmly believe that strict data protection laws hamper medical progress.



University Hospital Essen started the process of converting its hospital information system — which had previously been used primarily as a billing system for medical services — into a data management system more than ten years ago. Now, all the available details on a patient and all the data that is generated during their hospital stay, from blood values and body temperatures to medications, is stored in the Smart Hospital Information System (SHIP). All hospital equipment is connected to this platform, so if a patient's blood pressure is measured, for example, the device will automatically record this value in the system. An open standard is a prerequisite for this setup, i.e. the software must allow interfacing with SHIP. "An open standard called FHIR is currently being developed in the international healthcare scene. Instead of text fields, this standard works with set codes that can be read anywhere in the world, with meanings like 'blood pressure decreased'," explains Mr. Antweiler.

Optimizing the search for ideal test persons for clinical trials

The problem is that so far, most patient data in Germany has not been recorded in a structured form nor stored in interoperable IT systems that can be connected to each other — this leads to issues in, for example, clinical trials that concern a number of different diseases. Even the process of searching for suitable trial participants is immensely time-consuming, as hospitals and doctors' offices must review their patient bases manually and compare them against the trial's catalog of requirements. "At the start of the trial, researchers simply estimate how many patients should be involved. It's not uncommon for these estimates to miss the mark. If the trial fails to reach the necessary size, then in the worst case scenario, it could fail, which can cost millions of euros," explains Sabine Kugler, a data scientist at Fraunhofer IAIS.

She is currently working on project PARIS, where she extracts the information needed for clinical trials from running texts and compares it with the requirement profiles. In an initial use case, she took the files of patients with psoriatic arthritis as a data basis. Approximate- ▶

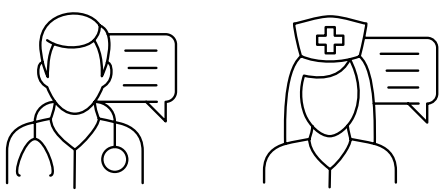
"It uses the sample data we feed it to learn and even formulate rules independently. The more data we give it, the better the results."

Sabine Kugler,
data scientist at Fraunhofer IAIS

Making clinical trials more efficient with AI: It's a mission for Sabine Kugler, a data scientist at Fraunhofer IAIS.

ly one third of the people that suffer from psoriasis go on to develop this particular form of the condition, which is associated with inflammation of musculoskeletal structures. Researchers at the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP worked with rheumatologists from Frankfurt university hospital to tag items of information that count as important selection criteria for clinical trials, such as the date of the patient's diagnosis, the intensity and duration of their pain, and the stiffness they experience in the mornings. "We use this as a basis for training our AI model. It uses the sample data we feed it to learn and even formulate rules independently. The more data we give it, the better the results," explains Ms. Kugler. The information it extracts will automatically be given a structure later on and saved in an easily searchable database. Patients can be filtered based on certain criteria via a search query. "Our AI model can easily be adjusted to other rheumatic conditions. We need less data for that, because the model has already learned many important characteristics of rheumatism. However, it would have to be completely retrained from the ground up for other diseases, such as cancer or diabetes," Ms. Kugler relates. ▶

Why hasn't the digital transformation made more progress in the healthcare sector? According to **91 percent** of the doctors surveyed, it's because of the complexity of the health system.



Unravelling the complex interaction of possible disease factors

But the Fraunhofer researchers are going even further. They also want to use large quantities of data to improve the processes of diagnosing and treating psoriatic arthritis (PsA). Since July 2021, they and 26 partners from Europe, the USA and Canada have been working on project

67 percent
of doctors think the health sector needs to pick up the pace when it comes to the digital transformation.

HIPPOCRATES, an initiative aimed at using data analysis to gain a deeper understanding of the complex interplay of a range of different factors involved in the emergence of PsA. After all, the inconsistent symptoms and the highly varied progression associated with PsA are precisely what make it so difficult to recognize and treat at an early stage. The condition often involves inflammation of the synovial membrane on the patient's hands and feet, but their tendons, eyes or intestines may also be affected. "This huge variation in the clinical symptoms means that the illness is diagnosed too late in most cases, which then significantly reduces the chance of the patient receiving effective treatment. This is why we need diagnostic tools that will allow us to make reliable diagnoses in practice," explains Dr. Michaela Köhm, a rheumatologist and leader of a research group at the Frankfurt-based Fraunhofer ITMP's Clinical Research division that collaborates closely with the university hospital. ▶

"We need diagnostic tools that enable reliable early diagnosis in practice."

Dr. Michaela Köhm, Fraunhofer ITMP

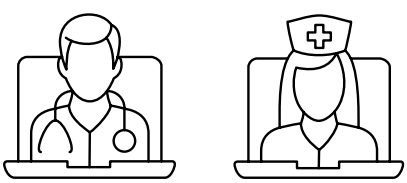
Delivering more effective help to individuals thanks to large datasets: Rheumatologist Dr. Michaela Köhm from the Clinical Research department at Fraunhofer ITMP in Frankfurt hopes to make this idea a reality.

"We are looking for machine learning methods that deal well with missing values."

Sina Mackay, data scientist at Fraunhofer IAIS

Working IT magic to improve medicine: Data scientist Sina Mackay of Fraunhofer IAIS is searching through thousands of datasets to find suitable algorithms for diagnosing PsA at an early stage.

74 percent
of doctors believe that healthcare data should be harnessed more effectively to provide more clarity and facilitate innovative treatments.
61 percent
of them even see this as an ethical obligation.



Pictograms: AlonzoDesign/istockphoto

Source: All the statistics on the use of AI in medicine that are listed in this article stem from a study on the digital transformation in doctors' offices and hospitals conducted by Bitkom (Germany's digital association) and the Hartmannbund doctors' association (October 2022). In the study, 535 doctors from all disciplines and both hospitals and individual practices were surveyed.

Envying the Scandinavians

HIPPOCRATES is combining the datasets and cohorts from the largest European PsA studies, so that an AI program can search for patterns that consistently occur across patient characteristics recorded in clinical settings, imaging procedures and molecular testing. Through this, the researchers hope to develop an accurate criteria catalog for more effectively predicting the disease and making prognoses. "In the clinical field, you would count yourself lucky if you had a dataset of just 1,000 patients," relates Sina Mackay, a data scientist at Fraunhofer IAIS. "But in HIPPOCRATES, we have many times that. Converting all this data into a compatible format is quite a feat, but it will soon pay off." That is not to say that the only issue with the data sets will be their uniformity: they will also likely leave much to be desired in terms of completeness. "As a result, we are looking for a machine learning method that deals well with missing values," explains Ms. Mackay.

In fact, Ms. Mackay, Dr. Köhm, Ms. Kugler and Mr. Antweiler feel some envy toward Scandinavia, where researchers can access much larger volumes of patient data for projects like HIPPOCRATES. For example, Finland has digitized all of the health data that it has collected since 1960, making the anonymized medical information available to researchers. Estonia is another target for the green-eyed monster: it also uses a central repository to collect and store its health data in a central repository in anonymized form, providing this to scientists upon request. "Here in Germany, we urgently need to find ways of facilitating medical research based on large volumes of health data while complying with legal requirements," insists Dr. Köhm. "Otherwise, we are missing opportunities to spot patterns that could help us draw conclusions about individual risks for illnesses, comorbidity or medication side effects; not to mention, we are losing the chance to keep pace with international research." We can only understand individual cases by studying the multitudes. ■

In the Fraunhofer podcast, Prof. Frank Behrens, deputy institute director of Fraunhofer ITMP, discusses a new way forward for patients, medicine and research: **the 4D hospital.**

A brave new world for hospitals

How can digitalizing medicine transform patients' experiences? A (tentative) glimpse into the future.

By Beate Strobel and Dr. Sonja Endres

Dario Antweiler, head of the Healthcare Analytics business unit at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, dreams of a digitally optimized hospital — and he has some pretty solid ideas about what patients could expect in the future. For example, patients may not be required to register on site, using paper and a pen. Instead, they would use digital patient portals where they can upload all the required documents and data from their electronic patient file. During their stay in the hospital, all the examination results and findings pertaining to them, as well as transcripts of their conversations with doctors, would be automatically added to this file.

A decisive step toward keeping patients informed: "Using the patient portal, they would have insight into everything that's happening at all times," explains Mr. Antweiler. "There would be apps or even chatbots available to explain the doctors' findings to them in detail, as well as possible treatment steps. After all, a lot of what goes on in hospitals is incomprehensible to the people affected." In the patient's room, he continues, "patients wouldn't have to call a nurse just to order a chamomile tea — they could conveniently do it themselves with an app." At the end of their stay, hospital guests would not only be immediately provided with a digital discharge letter via the portal, but would also be offered recommendations for aftercare, options for rehabilitation, prescriptions for treatments and remedies and tips on nutrition and exercise.

Mr. Antweiler's vision is still far removed from the reality of hospitals today. As he explains it, he and his team have "only just tipped the Lego bricks out onto the floor. Now, we have to assemble them." And, as anyone with experience in assembling Lego kits could tell you, that can be quite a Herculean task.

The future of hospital rooms

However, they've made a start: Since 2016, as part of the KARMIN collaboration project, TU Braunschweig's institute for structural design, industry and healthcare construction (Institut für Konstruktives Entwerfen, Industrie und Gesundheitsbau, IKE) has been working with the Fraunhofer Institute for Surface Engineering and Thin Films IST to research the hospital room of the future. What role do architectural details, equipment, materials and surfaces play in working and hygiene process — and thus also in healing?

Since 2022, a demonstrator of this futuristic hospital room has been available for research purposes at the Braunschweig municipal hospital (Städtisches Klinikum Braunschweig). A bedside terminal not only allows patients to access their usual entertainment program, but also to view information on their stay and their treatment plan. To avoid cross-contamination and infections transmitted by contact, the beds are not placed next to each other, but rather across from each other; each patient has a private bathroom on their own side of the room. Six disinfectant dispensers are distributed along the nurses' usual routes — and anyone that uses them is rewarded with a smiley face. The light in the room can be individually adjusted, ranging in intensity from soft, ambient lighting to bright examination lights. After all, even in a digitally optimized clinic, the actual well-being of patients and their path to recovery must naturally remain the main focus. ■

Photo: De Zwarte Hond/Michel Kievits

Is this what the hospital of the future will look like? The Zuyderland Medisch Centrum is the first paperless hospital in the Netherlands, and it exclusively uses single-bed rooms.

Interview

“An artificial intelligence ecosystem”

Judith Gerlach is Bavaria’s youngest minister — and Germany’s first dedicated minister for digital affairs. At the start of the year, the 37-year-old took over as chair of the D16 board, which brings together those German state government ministers, senators and state secretaries with responsibility for digitalization. Her goal: “Germany must achieve a leadership position in the digital world.”

Interview: Josef Oskar Seitz

The journey begins: Judith Gerlach, 37, at the Bavarian state parliament

Amazon, Google, Meta, Microsoft: All of these companies are cutting back on staff. "Come to Bavaria" is your resounding call in your current campaign to recruit digital experts. Ms. Gerlach, along with laptops, will you also be providing lederhosen and dirndl skirts to these would-be Bavarians?
We want to bring the smartest IT specialists to Bavaria, and this state can offer them top-class conditions. Its highly innovative research environment and wide range of interesting industry partners — ranging from start-ups and SMEs right up to DAX-listed companies — means job opportunities are plentiful and attractive. And to top it all off, we have an idyllic environment where they can make the most of their free time. Anyone that is seeking an exciting, high-impact role and places importance on security is a perfect fit for the public sector. In its role as an employer, the state offers protection against unlawful dismissal, compensation for overtime and the highly attractive mission of shaping the digital future of a state that is home to 13 million people..

Now that we're on the subject of the world of work: You once said that you had "the best job in the world." Unfortunately, that was way back in 2013, when you became the youngest member of the Bavarian state parliament. Ten years later, you have become Germany's first specialized digital minister. Does this represent a step down, to the second-best job?
My background is in social policy, and during my first legislative period, I served on the social committee. That made its mark on me, as it involves such direct human contact. As a politician, I want to work with and for the people. I still passionately pursue this line today in my role as digital minister. I want to create digital policies that directly improve the status quo for the people of this state. And yes, it's still the best job in the world, even if it involves different issues.

The curse of the superlative is coming into play here. Let's risk it one more time: Digitally speaking — where does Bavaria come out on top?
We in Bavaria have the most modern public authorities in Germany. The German Federal Ministry of Interior's digital ranking officially proves this. Nowhere but Bavaria offers people access to so many public services in digital form. And nowhere else invests so much in the technologies of the future. We are allocating a total of 3.5 billion euros in support to the research field alone here, as part of our High-Tech Agenda. And we are establishing 100 new professorships solely in the area of AI. In the process, we are generating important momentum for establishing an artificial intelligence ecosystem in Bavaria that is unparalleled in Europe.

> "Germany needs a clear strategy and more investment in the digital transformation."
> Judith Gerlach

Bavaria has created its own quantum computing initiative in the form of Munich Quantum Valley. What are your expectations of this?
In Quantum Valley, Bavaria has created a network that links politics, industry and prestigious scientific partners like the Technical University of Munich, the Fraunhofer-Gesellschaft and the Max Planck Society; it's the only platform of its kind in Europe. We must remain right at the forefront of this key technology. It's where the technical conditions are being created for many areas, from the financial sector through to security and defense solutions and energy management. That is why it's so vital that we play our own part in shaping the progress of quantum technology.

That's all in the future. The present looks quite different. In 2021, the EU ranked Germany in second-last position in terms of digitalization. What can you do better than Volker Wissing, the German federal minister for digital and transport?
I can't identify anyone in Berlin whose role it is to look after digital affairs. Mr. Wissing is responsible for mobile communications and broadband expansion, Ms. Faeser takes care of digital administration, and Mr. Habeck is in charge of innovation and start-ups. The areas of jurisdiction are all jumbled up and the responsibilities is completely scattered. No wonder progress has stalled. Here at the Bavarian digital ministry, it's different. Our cross-departmental drive to digitalize state government means the threads of digital policy can intertwine. This is why I wish there were an independent digital ministry at the federal level too. We really need to speed up the pace of the digital transformation! We are facing stiff international competition from China and the USA. Germany needs a clear strategy and more investment in the digital transformation.

You have just taken over as chair of the D16 board of digital ministers until the summer. How will you spur your colleagues into action? ▶

Photo: Christian Rudnik/BILD-Zeitung

1987: "Girl, don't drive yourself crazy!"
It runs in the family: Ms. Gerlach's grandfather Paul was a CSU Bundestag member. He gave his granddaughter Judith a little political advice: "Girl, don't drive yourself crazy, and fight with your heart and mind!"

2018: Germany's first digital minister
Bavaria's minister-president Markus Söder hands Judith Gerlach her letter of appointment.

2019: Soundbites in Bayreuth
Judith Gerlach and her husband Tobias Nitsch before a Wagner performance at the Bayreuth Festival.

2019: An (almost) unpolitical ascent
On the climbing wall Judith Gerlach proves her sporting talent. Her Instagram comment: "We're aiming high in the digital world!"

At D16, we are all striving energetically to achieve a common goal. Germany must achieve a leadership position in the digital world. A modern state is a service-oriented state. We want to ensure that the services available to citizens, companies and organizations are fit for the future, and that they can be used in a secure way.

A year ago in summer, Bavaria passed Germany's first digital law. Has it paid off?
The Bavarian Digital Law (Bayerisches Digitalgesetz, BayDiG) laid down the first legal foundation of its kind in Germany, and by European standards, it's quite progressive. It sets out the first legal framework conditions that ensure that everyone can benefit from the digital transformation. It is the foundation of the modern digital state.

While we're on the subject of laws: the results across Germany are pretty poor. The German Online Access Act (Onlinezugangsgesetz, OZG) stipulated that all administrative services were to be available to citizens in digital form by the end of 2022. The National Regulatory Control Council, the German federal government's independent advisory body, now calculates that of 575 government services, only 33 have been digitalized. Even the figure for the German Federal Ministry of the Interior has barely made it over 100. Why is it proving so difficult to digitalize public services?
In Bavaria, we have done our homework as thoroughly as possible and completed digitalization of over 98 percent of state services. As previously mentioned, we rank highest among Germany's federal states. But we still have a long way to go overall. Many services for citizens are not provided by individual states nor the federal government, but rather are largely the responsibility of the municipalities. We have offered incentives in this area, with some success. More and more districts are participating in our financial support initiative, the "Digitales Rathaus Bayern" (digital town hall Bavaria) program. Our state makes centralized online services available through what we call the BayernStore. The municipalities can simply subscribe to these online services for free and make them available to their citizens. We also motivate our municipalities by awarding them the "Digitales Amt" (digital office) label.

You are also approaching this from the other angle. Digital information centers are due to be set up in 30 Bavarian cities and municipalities. The application deadline falls in mid-March. Is there much interest?
We've had a huge number of responses! To me, this shows that advice desks are catching on and creating real added value, especially for those who aren't quite so digitally literate yet. My goal as digital minister is for everybody to benefit from digital progress — regardless of age, gender, income level or background.

We often see you visiting schools to read aloud to children. Isn't that a somewhat outdated activity for a digital minister?
No, absolutely not! Reading and text comprehension are basic prerequisites for confidently negotiating the digital world. The AI software ChatGPT is currently providing a particularly compelling example of why we should be examining digitally sourced content much more critically. We have to start that process right from childhood. Reading aloud is the best form of training for the little ones.

"The Little King" was one of your reading choices. I'm not quite familiar with it: Is it about Markus Söder?
That must have been a while back. The most recent one I read was "The Little Witch." And no, that one wasn't about me.

To return to the chalkface: We've just spent the pandemic period calling for increased digitalization in schools. Now we're debating whether ChatGPT is yet another indicator of the decline of the Western world. What form of education is right for the future?
I don't agree with using prohibitions and horror scenarios when it comes to innovation. The service won't disappear just because we ban it from classrooms. We have to learn to deal with it in a reasonable manner. But our education system must never cease to develop further. It's conceivable that in the future, traditional homework will take a back seat to oral exams, where AI can't be used as an aid to cheating.

In my circle of colleagues, without naming names, some say schoolchildren have long been using artificial intelligence to do their homework for them. You are, of course, not just digital minister, but also the mother of two children: How dangerous is this trend in reality?
In the future, we will need to use alternative assessment criteria in schools. If AI can pass

"That's why it was right to invest 3.5 billion euros in research and universities and to actively ensure the transfer of AI into industry as part of the Bavarian Hightech Agenda."

Judith Gerlach

an exam, then maybe we need to change the exam guidelines. In my view, the schools of the future should focus more on making incisive factual connections and critically scrutinizing information, instead of just reproducing content or presenting on a topic. It's paramount that we prepare our children to handle such technologies in the future. Someday, learning in school about how to interact appropriately with ChatGPT and similar tools could become as normal as learning your ABCs.

You are working on your own AI strategy. Where does Bavaria want to take this?
We need to do more than just understand the technologies of the future: we also have to shape them. That's why it was right to invest 3.5 billion euros in research and universities, to establish 100 new AI professorships and to actively ensure the transfer of AI into industry as part of the Bavarian High-Tech Agenda. Because we can't duck away from this. If we do, the rest of the world will pass us by, while we in Germany only hesitate. Bavaria is on the right road to becoming the most modern digital state in Germany. Our AI strategy also places us in a leadership position in the field of artificial intelligence.

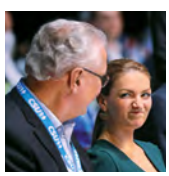
You recently appeared on a TV talk show alongside Pepper the robot. When asked whether artificial intelligence would spark a revolution, your digital colleague simply answered: "Yes!" Where do the greatest opportunities lie?
AI has a multitude of potential applications, such as Bavaria's SME sector, for example. We provide companies in this state with practical assistance to help make their business processes more effective and economical. Under our AI Transfer Plus program, for example, we work with companies like an agricultural machinery manufacturer whose machines will be able to use AI to recognize precisely whether they are dealing with a cultivated plant or a weed out in the field. This means pesticides can be used more sparingly and targeted more accurately.

AI triggers fears: Some are ill-defined, but some are very specific, like the worries that jobs could become obsolete. Which jobs do you see as being at risk?
In discourse around this subject, horror scenarios that have nothing to do with reality rapidly come into play. The question of how we use the great opportunities presented by new technologies lies in our own hands. It makes sense, for example, to use robots in nursing care. However, that doesn't mean that from now on, only robots will be used in retirement homes. Nobody wants that! But if robots can support us in some tasks, then care workers, who are in desperately short supply, will have more time for the actual human side.

To finish with a different kind of question, can a digital minister afford to go offline every now and again?
Of course! The best things in life are analog. There's no app that can replace spending time with family or talking to friends in person. ■

2021: Busy bees at the ministry
A webcam monitors flights into the high-tech beehive on the roof of the digital ministry. And the minister watches as data is collected for environmental protection purposes.

2021: Dressed in her best for carnival
The digital minister is all set, top hat and all, to celebrate the carnival session with the Fastnacht-Verband Franken (Franconian carnival association). "Straighten your bow tie and go!"



2022: Two generations at the party conference
A skeptical glance passes from digital minister Gerlach to Bavarian interior minister Joachim Herrmann.

2022: AI that makes you weak at the knees
At the Würzburg Center for Artificial Intelligence and Robotics, Judith Gerlach inspects an AI robot together with ministerpresident Söder.

Photos: Christian Rudnik/BILD-Zeitung, private (3), Tobias Hase, Eventpress Golejewski, Peter Kneffel, Julien Becker, Sammy Minkoff/all dpa

Harvesting ambient energy

Can we generate electricity from slight differences in temperature or barely perceptible vibrations and use it for energy-self-sufficient operation of sensors or small devices in the internet of things? It's time to consider energy harvesting.

By Mandy Bartel

By 2030, the internet of things (IoT for short) could potentially bring up to 13 trillion US dollars in added value to the global economy. According to analysts from McKinsey, by far the greatest potential lies in using smart networks of devices and machines in production environments. Here, large-scale networks could deliver greater productivity, fewer breakdowns and a higher level of transparency. The 5G mobile communications standard introduced in 2020, which enabled data transmission rates of up to 10 gigabits per second, will enable countless wireless sensors — the most important part of the IoT — to communicate, exchange and process data in near real time. Applications of this technology include condition monitoring and predictive maintenance for machinery, buildings and bridges, as well as smart meters.

However, these new opportunities also require new methods of supplying energy. After all, increasing numbers of sensors and devices mean an increased amount of effort for replacing batteries and installing or performing maintenance on a wired supply. Ana-

A green solution: Thanks to energy harvesting, it is possible to supply IoT sensors with power via a thermo-generator or vibration converter, all without cables or batteries.

lysts predict that by 2030, more than 25 billion such sensors and devices around the world will be connected in the IoT. On top of that, the electricity pumping out of our sockets is becoming ever more expensive. So why not harvest energy from the immediate environment, making use of slight vibrations, air currents and differences in temperature? The idea of "energy harvesting," as the experts call it, is nothing new. Hardly anyone knows this better than Dr. Peter Spies — he has been researching the topic for years at the Fraunhofer Institute for Integrated Circuits IIS in Nuremberg. "Earlier mobile communication modules consumed so much energy that it was difficult to meet the demand through energy harvesting alone. We would have needed huge converters to do it. However, new, wireless technologies and microelectronic devices are consuming smaller and smaller amounts of energy, meaning that energy harvesting modules are now a genuine, energy-self-sufficient alternative to batteries and cables."

Good vibrations

The researcher is focusing on the vibrations that emanate from machines, devices and structures, as well as temperature differences in pipes, wires and equipment. "All of these things release an energy that we can hardly feel, but which can be used to power brief moments of activity, such as the transmission of status data for machines and infrastructure," explains Dr. Spies. For example, a temperature difference of just 3 degrees Kelvin generates 100 microwatts of electrical power. Sources of heat, such as machines, motors or supply lines, can be found in almost all industrial plants. Even the human body is a potential energy source. Generating electricity from vibrations is also a promising prospect: A frequency of 50 hertz and an acceleration of 0.1 grams will allow a piezoelectric generator to produce about 3 milliwatts of electrical energy.

These small harvesting machines consist of a generator, which acts as an energy converter, a storage unit and a power management circuit; they can be attached to equipment in a variety of ways. Dr. Spies and his team's latest development is an energy-optimized narrowband IoT module that collects and transmits supply data in the 5G network. This opens up new possibilities for creating a self-sufficient energy supply for low-power, wide-area networks (LPWAN), as well as wireless systems that have higher data rates and consequently, higher rates of energy consumption. "For example, bidirectional communications could also be powered by a self-sufficient energy supply in the future, meaning that, going forward, the module could also be used to network objects in public spaces," explains the electrical engineer.

However, there are still a few challenges to address before this can happen: Fraunhofer IIS is currently working to develop more efficient power management circuits and intermediate energy storage solutions, as well as further miniaturizing the generators. "While there are already thermal harvester products that are fit for large-scale use, piezoelectric generators still have to be tailored to the specific application and the available energy sources in each case. For example, a vibration-based energy supply must always be adapted to the location's particular vibration amplitudes and frequencies." In the long term, researchers hope to simplify this process. The potential this holds for industry, logistics, building technology, smart homes and beyond is huge. What's more, as energy prices rise, so too does the significance of the energy harvesting option — and the number of queries from the industry sector. ■

"New, wireless technologies and microelectronic devices are consuming ever smaller and smaller amounts of energy, meaning that energy harvesting modules are now a real, energy self-sufficient alternative to batteries and cables."

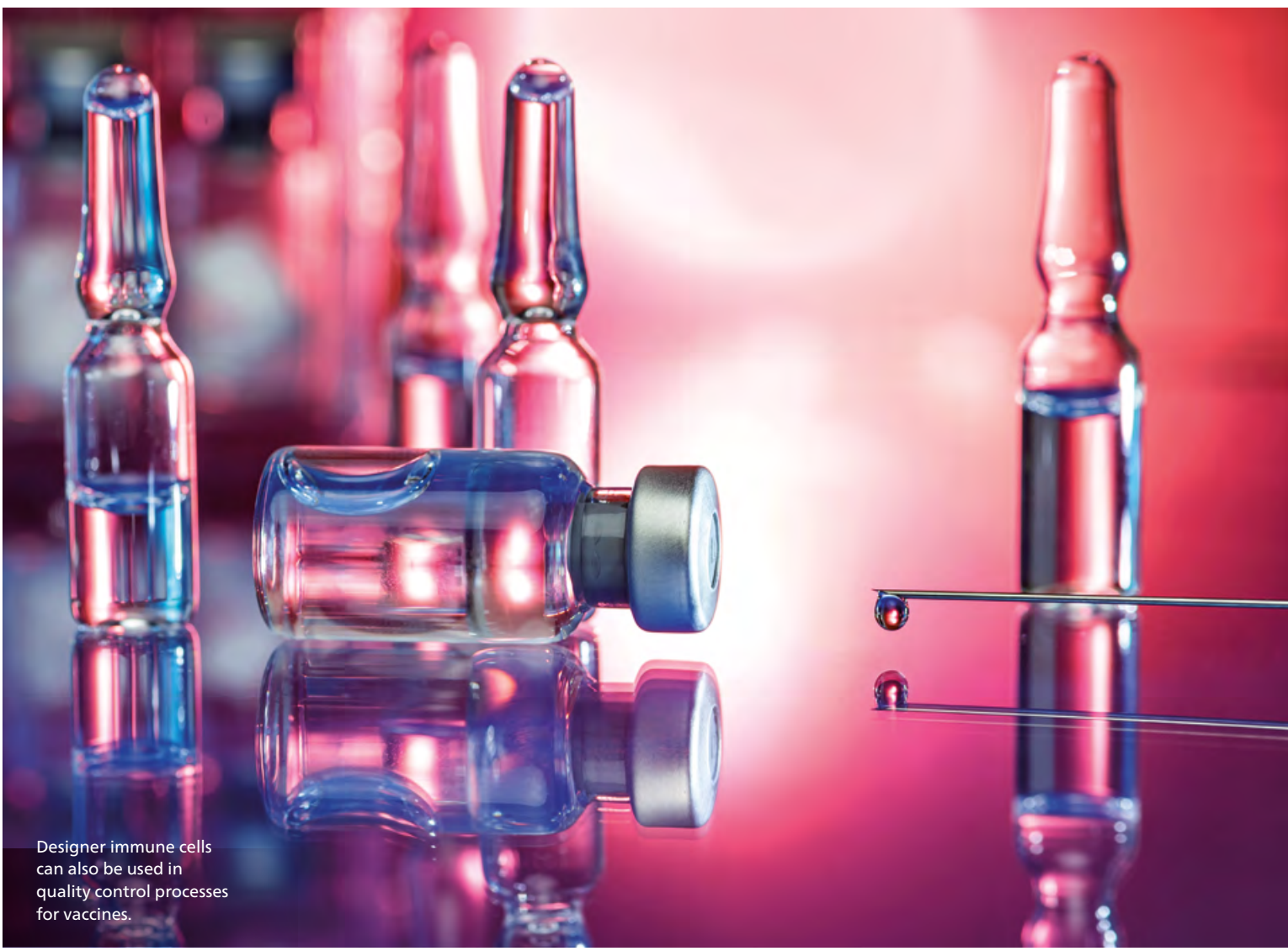
Dr. Peter Spies, Fraunhofer IIS

Photo: Peach/AdobeStock

Scavenger cells from the reactor

They can detect viruses, bacteria, harmful substances and drugs at lightning speed — and fight them, too. Without immune cells, humans would barely survive a week. They're also in high demand for medical and pharmaceutical research, where scientists hope to use the precious cells to develop new therapeutic agents and more efficient methods of animal-free testing. Now, for the first time, they can be scalably manufactured on a custom-made basis.

By Mandy Bartel



Designer immune cells can also be used in quality control processes for vaccines.

Prof. Nico Lachmann proudly holds up a glass cylinder containing a sort of snowstorm. The "snowflakes" are known as induced pluripotent stem cells (iPSCs). Their superpower? They can divide infinitely and develop into completely different cell types. This feature of the cells is exactly what Prof. Lachmann and his team at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM in Hannover are exploiting. "We stimulate the stem cells in the reactor in such a way that they form a certain type of immune cell called macrophages," explains the researcher. Macrophages are also known as scavenger cells, so called for the actions they take against invaders: They surround germs and viruses, using an enzyme to digest them and render them harmless.

There is massive demand for these designer immune cells in the medical and pharmaceutical industries — and their potential matches demand. Using these cells, it could be possible to test the efficacy and safety of drug candidates directly on human target structures. In the future, this could eradicate the need for animal testing, which only serves as an approximate indication of how a human body would respond in any case. The same applies to producing cosmetics. Introducing immune cells to artificial skin tissue, for example, would enable scientists to create even more precise representations of how human organisms react to an active substance, all without animal testing.

These versatile cells could also simplify quality control processes for medicines, as they can be genetically modified to light up upon detecting contaminants in medicines or vaccine serums.

Prof. Lachmann, who heads up the working group on Applied Stem Cells and Translational Macrophage Research at Hannover Medical School (MHH), as well as the project group at Fraunhofer ITEM (under the Fraunhofer Attract funding program), is looking even further into the future: "It could even be possible to test the indoor air quality using immune cells — after all, macrophages and other immune cells are the first to react to pollutants in the air once they are inhaled." However, their power to treat diseases is probably where their greatest potential lies. Artificially produced immune cells tailored to individual patients could soon be used to cure diseases such as cancer. In order to further explore this possibility and bring it to the application stage, designer cells are desperately needed.

Continuous, scalable production of immune cells: a world first

But as it stands, tailor-made immune cells are only available to a very limited extent. The reason is that for a long time, macrophages could only be grown in 2D, for example at the bottom of a Petri dish. However, Prof. Lachmann and his team have designed a 3D process based on the principle of a snow globe, which is currently the only one of its kind. "This means that, for the first time, we are able to continuously produce larger quantities of specific, mature immune cells," says the physician, who spent three years working to optimize and standardize the process. "The stem cells are placed in a solution inside a reactor vessel, where they are kept in constant motion — the speed and angle of the mechanism that achieves this is an all-important part of the process. Then, through special bioprocesses, the stem cells begin to continuously produce the desired immune cells. We renew the iPSCs after about three months, in order to ensure consistent quality."

This method is so successful on both a small scale and a large, industrial scale that the researchers are already working on other immune cell products and cell-based immunotherapies, with the aim of opening up new applications. They are currently investigating how this technology could be commercialized in a practical, economically viable way — after all, pharmaceutical companies, cosmetics manufacturers and research institutes are highly interested in the development. According to Prof. Lachmann, this is because "an idea becomes an innovation when it is put into application. It's important to me for my research to find its way to patients in hospitals." ■

Using his snow globe reactor, he can produce immune cells from induced pluripotent stem cells at any scale: Prof. Nico Lachmann.

Pioneers of stem cell research

In 2006, stem cell researchers Shinya Yamanaka and Sir John Bertrand Gurdon successfully converted mature skin cells into original, embryonic induced pluripotent stem cells (iPSCs). These have the ability to subsequently evolve into different types of cells, such as immune cells. In recognition of this, the Japanese Yamanaka and British Sir Gurdon were awarded the 2012 Nobel Prize in Physiology or Medicine — one of the shortest times between discovery and the conferral of the award in medical history.

Photos: Toshe O/istockphoto, Fraunhofer ITEM

Jump start for passion projects

For the first time in its history, the Fraunhofer Future Foundation put the spotlight on researchers' personal passion projects and gave the general public a say in which of the projects should receive funding. As part of the ScienceForGood crowdfunding competition, six Fraunhofer institutes received the familiar call: "On your marks, research, go!"

By Beate Strobel

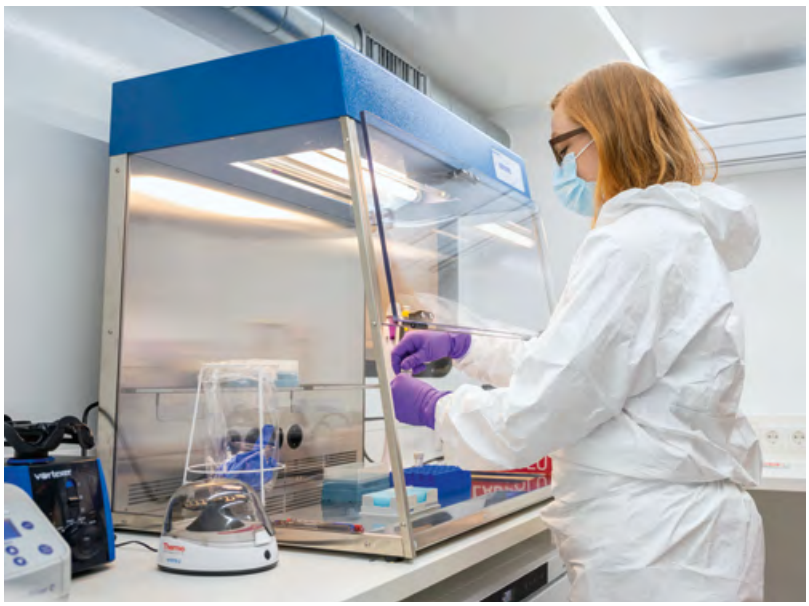
Which research project will win the public's heart? That was the decision facing the Fraunhofer Future Foundation — and they tackled it by putting out a call in this magazine, among other things. The 2022 ScienceForGood crowdfunding competition saw six projects go up for selection. As part of the project "Müllberge ade!" (No more mountains of trash!), researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU went on the hunt for an environmentally friendly method of dealing with hospital waste. Meanwhile, an interdisciplinary team from the Fraunhofer Institute for Machine Tools and Forming Technology IWU examined how information on the sustainability of goods transportation can be communicated to consumers. The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is considering methods of filtering phosphate out of polluted water to help make it usable again, and the Fraunhofer Institute for Transportation and Infrastructure Systems IVI has set out to develop an innovative safety system for bicyclists as part of their YES! project. Another contender, project 2detect, has seen a research team from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME demonstrate a cost-effective testing method for influenza and COVID-19. Finally, in project Learn AIfES, scientists from the Fraunhofer Institute for Microelectronic Circuits and Systems IMS are focusing on webinars that can serve as a channel for sharing knowledge on using the open-source AI software framework AIfES. Using the website www.startnext.de as a platform, the researchers had 55 days to win as many people as possible over to their idea and gain their support as donors.

Ultimately, the three projects described on the right made it through. The Fraunhofer Future Foundation supplied financing many times as high as the public donations with their total co-funding budget of 120,000 euros. In addition, they awarded prize money to the three teams that attracted the largest crowd of supporters. Now, in 2023, the teams will put their project into practice with the help of the donations and funding. Supporters are kept up to date via project websites and blogs — after all, it's their project, too.

"Crowdfunding is not just a way of co-financing a project, it's an important communications tool as well — and an initial means of testing the market." So says Alexandra Goßner, the project manager of ScienceForGood. What is the best way for researchers to present their personal enthusiasm, and how can they make their idea reach people? Ms. Goßner adds that engaging in dialogue with public on the crowdfunding platform and answering their questions proved especially valuable. The researchers took part in a coaching program, which supported them in communicating about their projects. One of the valuable lessons they learned here was that you don't have to be a showman. "Even people with introverted personalities can use their passion to win people over to their project," says Ms. Goßner. ■

First place: 2detect

A fever, a cough, a runny nose — what's behind it all? When influenza and coronavirus waves combine in the autumn and winter, it's virtually impossible to tell these two viral diseases apart based on the symptoms alone. However, quick diagnoses are necessary if patients are to receive optimal treatment. As part of the 2detect project, a team of five from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME is looking to expand the highly reliable LAMP test procedure, which is currently used to detect coronavirus. Specifically, they want to use the nasal swab method to test for coronavirus and influenza at the same time, in effect performing two tests at once. This will save on materials, costs and time and allow doctors to begin the proper course of treatment at an early stage.



On the way to 2-in-1 testing: Lena Freund from the 2detect project.

Making water clean again: Steffen Roth, a researcher and amateur diver, has discovered a solution.

Second place: Phosphatfänger
(phosphate trap)

One of the nutrients that severe pollutes our waters is phosphate — in extreme cases, it can even cause a body of water to become a dead zone. At the same time, this salt is urgently needed in the agricultural sector, where it acts as an important fertilizer. That is why Steffen Roth, a scientist at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Straubing, aims to use biobased proteins to extract phosphate from polluted waters, making them a viable source of raw materials for agriculture. This approach is intended to close the phosphate cycle while simultaneously protecting bodies of water.

Third place: Müllberge ade!
(No more mountains of trash!)

3.5 million tons of plastic waste a year: Hospitals are the fifth-largest producers of waste in Germany — and not just since the pandemic. Because most of the products used in hospitals are disposable — from syringes and tests to packaging and cups. For hygiene reasons, this waste generally has to be incinerated rather than recycled. Susanne Kroll and Marc Luginsland from the Fraunhofer Institute for Machine Tools and Forming Technology IWU plan to first decontaminate plastic waste from hospitals, before processing it in such a way that the recycled material can be used in the manufacturing of new products.

A second life for disposable products: Eliminating the need to incinerate hospital waste.

Photos: gettyimages, Fraunhofer IME, IGB, IWU

From residual to raw material

Industrial wastewater can contain nitrogen, phosphorus, valuable metals and more — so why throw it out? Fraunhofer researchers are working on recovering these valuable substances.

By Mehmet Toprak

Is wastewater really just wastewater? As happened previously with other forms of waste, opinions are changing here — after all, there can be a lot of value in wastewater. More than 9,000 public wastewater treatment plants in Germany treat, filter and purify 10 billion cubic meters of wastewater each year. In the past, the sole objective was to purify the water; now, the focus has turned to extracting useful raw materials from industrial process water. Researchers from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS are working on the technologies and systems required to do this.

Process water refers to wastewater that has been contaminated with chemicals or residues from industrial production processes. Many different types of chemicals are needed for manufacturing and pretreating products, cleaning materials and carrying out chemical reactions and synthesis processes. Much like product residues, these chemicals often remain in rinsing and cleaning baths. The water in these baths is then considered process water, and is treated as such so as not to harm the environment.

Recovering sufficiently pure process chemicals such as sodium hydroxide (NaOH) and hydrochloric acid (HCl) from this wastewater would benefit both the environment and the economy. After all, the compounds extracted from the process water can then be reused for production. Nitrogen and phosphorus are also of interest here — these can be extracted from some process waters and used as fertilizers in agriculture. Even metals such as silver and copper could be recovered in metal-processing plants and returned to the material cycle.

"This allows industrial companies to save a considerable amount of raw materials and resources," explains Dr. Burkhardt Faßauer, head of the Circular Technologies and Water department at Fraunhofer IKTS. He adds: "At a time when the price of raw materials is rising around the world, this is big help when it comes to lowering costs, and marks a huge step toward a circular economy."

The Fraunhofer experts have chosen a very special location to carry out their research work on: the Bitterfeld-Wolfen community sewage treatment plant. One of the largest and most modern sewage treatment plants in central Germany, this facility treats the wastewater from nearly 300 establishments located in a nearby chemical park. The researchers have not established a laboratory in the usual sense of the word, instead setting up several containers that can be fitted with various types of equipment for experiments. "This means we have a flexible technology platform that allows us to develop innovative cleaning processes for industrial clients' specialized needs, and test them right on site," says Dr. Faßauer. This is crucial, since wastewater treatment is not a matter of using two or three standardized methodologies. "Often, the process of efficiently purifying water means combining very disparate processes that are individually adapted for the wastewater in question," Dr. Faßauer explains. In addition to Fraunhofer IKTS, the Fraunhofer Institutes for Solar Energy Systems ISE, for Molecular Biology and Applied Ecology IME and for Microstructure of Materials and Systems IMWS were involved in setting up the research platform.

The researchers at Fraunhofer IKTS are drawing on their many years of expertise in membrane technology. By combining advanced ceramic membranes with electrochemical, sonochemical, photocatalytic and even biological processes, complex industrial process water can be filtered and treated as required. It then no longer poses any threat to bodies of water and groundwater. Moreover, it is often possible to recover some energy and recyclable materials.

The cooperation between sewage treatment plants, Fraunhofer and the world of industry also helps to implement a concept that the experts on site refer to as a "materials network." This involves an exchange of raw and residual materials between manufacturers. In a nutshell, Dr. Faßauer says: "One person's waste is another person's raw material." ■

Photo: tuastockphoto/AdobeStock

More than

9,000

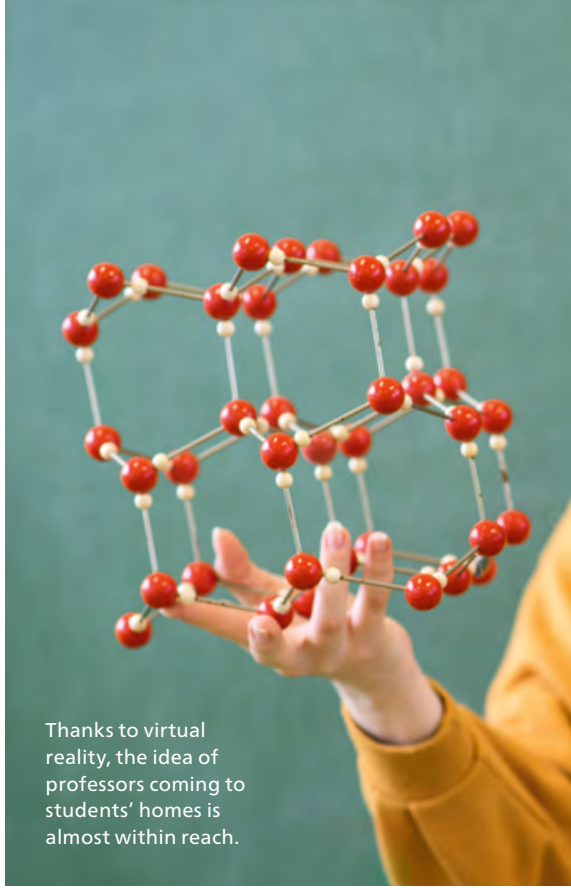
public wastewater treatment plants in Germany treat, filter and purify ten billion cubic meters of wastewater each year.

A somewhat unusual source of raw materials: Opinions regarding industrial wastewater have changed.

The VR lecture hall

An interactive mixed reality application has the power to revolutionize the future of online education.

By Yvonne Weiß



Thanks to virtual reality, the idea of professors coming to students' homes is almost within reach.

Once you put your headset on, it's as if your professor has beamed directly from the lecture hall into your dorm. She stands in front of your couch, furrows her brows and shakes her head vehemently. Then, she responds in detail to all the questions that came up during her lecture. It's a private office hour, so to speak, but no one — neither the student nor the professor — needs to leave the house.

The VoluProf project, which is funded by the German Federal Ministry of Education and Research, is currently investigating how to make this scene a reality for our universities. Led by the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, the research team has been working since 2021 to develop a mixed-reality application that can be accessed using a VR headset. It enables students to meet with their professor around the clock in the form of an avatar and talk directly to them. "The basic idea is that you can bring your professor home with you," explains Dr. Cornelius Hellge, head of the Multimedia Communications group at Fraunhofer HHI, who initiated the project.

Crucially, the avatar is not an imaginary character — it is entirely photorealistic. "We consciously chose to pursue a 1:1 representation of the professor," explains Dr. Anna Hilsmann, head of the Vision & Imaging Technologies department and manager of the Computer Vision & Graphics group at Fraunhofer HHI. This way, students will feel as though they are talking to their actual professor in an interactive space, creating an entirely different atmosphere to current online teaching methods.

To develop the photorealistic avatar, Fraunhofer HHI and project partner Volucap GmbH are recording volumetric video footage of a real professor at the University of Rostock. This video format — from which the project takes its name, and which is already being used for oral history interviews — shows the professor in 3D. Later, to make her appearance in the application seem even more realistic, the team equips the avatar with the professor's own repertoire of gestures and actual movement patterns, and enables her to speak with her own voice.

> "We consciously chose to pursue a 1:1 representation of the professor."
>
> Dr. Anna Hilsmann, Fraunhofer HHI

A module developed by Aristech GmbH, a software manufacturer based in Heidelberg, first converts the listeners' questions into text; this is forwarded via a chatbot to an AI module created by the German Research Center for Artificial Intelligence (DFKI). Finally, the AI generates the professor's answer. This is then sent back to the Aristech module in text form, where it is converted into speech, allowing the avatar in the virtual space to answer questions in the professor's voice.

"The sense of communicating in real time is particularly important here, as the user will find any delays to be disruptive," says Dr. Hellge. Being able to stream to mobile devices, i.e., cell phones, tablets and VR headsets, is also vital. That is why Fraunhofer HHI is currently working on

"The sense of communicating in real time is particularly important here, as the user will find any delays to be disruptive."

Dr. Cornelius Hellge, head of the Multimedia Communications group at Fraunhofer HHI

securing fast transmission via mobile 5G networks, together with project partner Deutsche Telekom AG.

According to Dr. Hilsmann, a major advantage of this software is its omnipresence. When it comes to education, this is particularly important. "Information is available to students 24/7 through the application. At the same time, it is possible to interact with the lecturer at any time, for example if questions come up when a student is reviewing a lecture." Cumbersome email correspondence and even office-hour visits could one day be a thing of the past.

As far as the technical aspects are concerned, the project is well on its way. "The basic functionality and individual components are already there. Now it's time to integrate them into the overall system," explains Dr. Hellge. After that, the team will work on optimizing the details, from ensuring the avatars are rendered in the best quality possible to improving the overall latency. The goal is to be able to demonstrate the use case with a prototype by the time the project ends in 2024. At this point, the application will not just run in labs, but over actual networks.

However, before professors' avatars can actually make their way to students' dorm rooms, there are still a few ethical questions that must be addressed. The University of Rostock is looking at these in their role as project partner. "For example, there's the matter of ensuring the professor retains control within the virtual space," explains Dr. Hellge. "Maybe they wouldn't want people walking behind them. We still have to clarify these issues." And there are other data-protection aspects to take into account. "We also need to safeguard what can be done with the image data," Dr. Hilsmann says. Data protection plays an important role, he says: they must balance their need to work with the data with the need to protect the privacy of everyone involved at all times.

Ongoing user tests at the University of Rostock will ensure that the application is easily usable. If the project is well received, it could revolutionize other areas of everyday life as well. "Virtual representations of humans represent an intuitive interface for communication. It is particularly promising in areas that where human interaction is required, but there is not enough human capacity," says Dr. Hilsmann. This applies to the field of therapy and to real-time communication, for example. Fraunhofer HHI is already in the process of implementing projects in these areas.

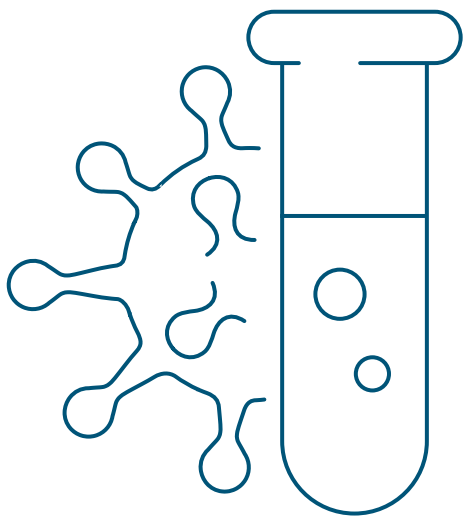
But should people be concerned that virtual spaces could replace personal contact in real life, or one day even supersede real professors entirely? Not at all, Dr. Hellge and Dr. Hilsmann insist. "Personal contact is something else entirely. Besides, as it stands, only a portion of human perception can be transported into virtual space, namely audio and visual perception," notes Dr. Hellge. All the other sensory perceptions have to stay out — for now.

Dr. Hilsmann emphasizes that the real goal is to offer additional alternatives. "Immersive media should create possibilities for dealing with situations where direct contact is necessary, but not possible." This applies to ensuring better preparation for future pandemics, sharing a coffee during your lunch break with a colleague that lives 200 kilometers away, or even giving professors a space on students' couches. ■

Photos: Andrea Obzerova/istockphoto, Fraunhofer HHI

3×3 questions on a three-year pandemic

The coronavirus came to Germany on January 27, 2020. On March 11, 2020, the disease was officially declared a pandemic. What role did Fraunhofer institutes play in the fight against the virus? And what can we learn from the three years of the pandemic? Three Fraunhofer experts weigh in.



1 Personally, what was the most important thing that you have learned during the three years of the pandemic?
Probably the fact that we can act quickly and flexibly when we need to, even in Germany, without getting too tangled up in red tape. This is something we need to build on. In the scientific community, we must take a critical look at ourselves and ask why we did not manage to coordinate and combine our efforts more in a more effective way, particularly at the start of the pandemic.

2 Let's try and look ahead a little. The SARS-CoV-2 virus has long been researchers' enemy number one: will they soon be able to defeat it, or at least drive it into a corner?
SARS-CoV-2 has led to many insights in the field of virological research. The virus will probably continue to exist as an endemic pathogen, but scientists' efforts in researching vaccines, diagnostics, preventative measures and treatment have led them to discover and test many new techniques and approaches. That will definitely stand us in good stead when it comes to other diseases. As new variants have dwindled, SARS-CoV-2 has lost the terror it once held.

3 Considering all the knowledge we have gained over the last three years, what insight could prove to be the decisive factor in avoiding or mitigating the severity of future pandemics?
We have seen for the first time how mRNA technology allows vaccines to be rapidly manufactured and deployed worldwide; this could prove very important in the event of future outbreaks. We have also seen that providing adequate protective equipment and disinfectants and ensuring social distancing can be effective ways to bridge the gap in the period before vaccines and therapeutic agents are available. The pandemic also underscored the need to maintain greater therapeutic and diagnostic reserves. ■

Fraunhofer ITMP in the fight against the pandemic

Various pathogen models have been processed in a modular system to enable the rapid development and supply of diagnostic and therapeutic tools in the event of an outbreak. The institute is also establishing a global network with the aim of supporting the international community in coordinating a rapid response in the event of a viral outbreak.

Prof. Michael Hölscher, head of the Penzberg/Munich branch of the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP

Photos: merovingian/istockphoto, DZIF, Fraunhofer/Piotr Banczerowski, SPD-OV Altbach

Project DEFEND-CoV2

In order to better prepare for future pandemics caused by viral pathogens, researchers at the Fraunhofer Institute for Cell Therapy and Immunology IZI have set up a vaccine and drug pipeline; they have also established an infrastructure specifically for use in smaller companies and academic institutions that can help test and evaluate vaccines and drugs against SARS-CoV-2.

1 Personally, what was the most important thing that you have learned during the three years of the pandemic?
Because our high-security lab is focused on researching vaccines and infection pathology, we have been involved in a wide range of projects and studies on the pandemic since the very beginning — and still are, in fact. The high volume of requests, particularly from the industry sector, meant that we had to learn how to work fast and be flexible. We built many different test systems in a very short time; for example, we recreated the air conditions of an airplane cabin in the lab and researched how SARS-CoV-2 behaved in that environment.

2 Let's try and look ahead a little. The SARS-CoV-2 virus has long been researchers' enemy number one: will they soon be able to defeat it, or at least drive it into a corner?
The only way to beat a virus is to exterminate it completely. However, with SARS-CoV-2, that's very unlikely. Still, you can make it less deadly with vaccines and treatments. And we have already achieved a lot in both areas. The existing vaccines offer protection against severe cases of COVID, and there are many drugs in development that can mitigate the course of the disease.

3 Considering all the knowledge we have gained over the last three years, what insight could prove to be the decisive factor in avoiding or mitigating the severity of future pandemics?
It was important to see that vaccines can be approved quickly during a pandemic. However, next time, nations must pull together more effectively. Vaccines must be produced more cheaply and distributed globally as quickly as possible. ■

Dr. Sebastian Ulbert,
head of the Vaccines and Infection Models department and deputy director at the Fraunhofer Institute for Cell Therapy and Immunology IZI

The pathogen analyzer

The mobile analysis device developed by Fraunhofer IGB and IPT in conjunction with the Fraunhofer USA Center for Manufacturing Innovation can quickly and reliably inform patients of their coronavirus infection status. Just as with a PCR test, the virus' genetic material is detected by swabbing of the nose and throat. However, this new test delivers results within a maximum of 40 minutes.

1 Personally, what was the most important thing that you have learned during the three years of the pandemic?
The escalating conflict between COVID deniers, anti-vaxxers, vaccine critics and COVID sceptics on one side and COVID and vaccine believers on the other was not good and represented a serious disruption to our social cohesion. For the future, I have learned that we must be respectful in our dealings with each other, even when there are major differences of opinion.

2 Let's try and look ahead a little. The SARS-CoV-2 virus has long been researchers' enemy number one: will they soon be able to defeat it, or at least drive it into a corner?
The virus is actually defeating itself right now. The COVID pandemic is now becoming endemic. Let's hope that it stays that way and that the virus doesn't find its way back through poorly protected population groups in early 2023. However, I am certain that we can get this problem under control through research. The fight against the pandemic is supported by rapid, precise tests that can be adapted quickly.

3 Considering all the knowledge we have gained over the last three years, what insight could prove to be the decisive factor in avoiding or mitigating the severity of future pandemics?
We have learned a lot on the matter. In my opinion, the first lockdown was (almost) the correct, logical course of action. But afterward? Hopefully, the mistakes or misjudgments have helped us learn from this experience and we'll handle the next pandemic more skillfully. I'm thinking of children and young people in particular, and of our dependency on medications from other countries. ■

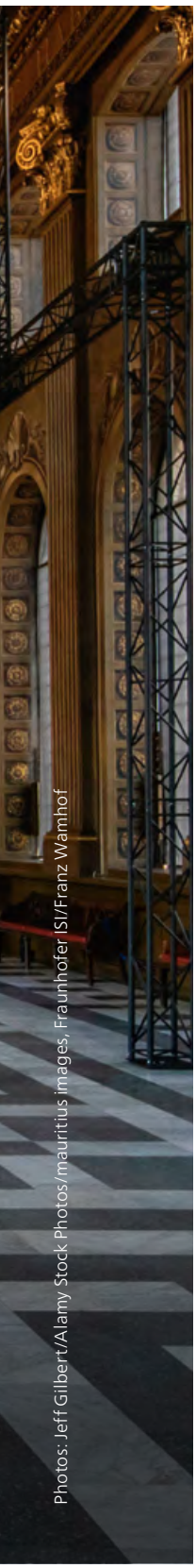
Dr. Achim Weber,
Functional Surfaces and Materials department, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

"Harnessing collective human intelligence is vital"

Uncertainty has become a constant feature of a world that once seemed well-planned and consistent. Dr. Philine Warnke from the Fraunhofer Institute for Systems and Innovation Research ISI shares her vision for the future and how we can come to a better understanding with each other in society.

Interview: Mandy Bartel

The world at a glance: the GAIA installation project, by British artist Luke Jerram, at the Old Royal Naval College in Greenwich.



Photos: Jeff Gilbert/Alamy Stock Photos/mauritius images, Fraunhofer ISI/Franz Wamhof

You head up the Futures Dialogs business unit at Fraunhofer ISI. What can we expect in 2023?
The level of uncertainty will continue to increase. In some areas, such as climate change, it's clear that we are already reaching a tipping point. And when complex systems reach these junctures, this creates more and more turbulence. Developments regarding the coronavirus in China will have a concrete impact on us this year, which we will also see in our value chains in Europe. But I must stress that there could of course also be some positive unexpected developments. Uncertainty is not always necessarily negative.

What issues do you deal with in your field exactly?
As part of Futures Dialogs, we support groups in taking a strategic approach to dealing with the future so that they can better handle uncertainties. The aim is to broaden their views, opening them up to other perspectives. After all, the way we think about the future has a very big impact on the possibilities we can see in the present.

What methods do you use to do this?
One approach involves applying machine learning methods to get a better outlook on what is happening in the present moment. For example, this can help us more quickly find out which subjects are gaining traction on social media. But this is just a tool. Interactive methods of engaging in dialogue, such as workshops and future workshops, are much more important. Using these platforms, we bring people together to exchange ideas on the significance of these changes and expand their minds to imagine new things. Harnessing collective human intelligence like this is vital.

Now that we have some degree of hindsight, can you tell us what lessons we as a society have learned for the future from the coronavirus pandemic?
Everyone has a much greater awareness of how we need to take uncertainty seriously and improve the resilience of our systems. In order to emerge from a crisis in a stronger position, however, it is important to maintain a social identity. That's the only way we can learn from it collectively. But we now see that a crisis can also lead to polarization, with each group drawing their own lessons from it.

Interview

Dr. Philine Warnke

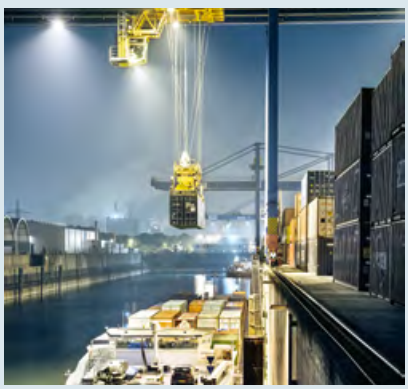
This is also what the 2022 Club of Rome identified as the greatest challenge of our time: not climate change, but our inability to come to an understanding with others in society and cooperate with each other. What would you advise politicians to do in order to overcome this?
I wholeheartedly agree with the Club of Rome's findings. Our work can also play a small part in this — for example, by establishing more forward-looking initiatives that can bring people together to collectively solve problems. In these situations, it can help if we move away from our current way of thinking and take a longer-term perspective. This can often help defuse situations that are causing conflict in the present moment. It often lets people see that they have more in common than they might have initially thought. These things need to be worked out. On top of this, other initiatives, such as citizens' councils, can help shape and strengthen democracy in a different way. ■

Listen to a podcast of the full discussion:

EUROPE

Green logistics for inland ports

With their connections to other transportation routes by water, rail and road, inland ports offer optimal conditions for flexible transportation solutions. As part of the EU-led MulitRE-LOAD project, the Fraunhofer Institute for Material Flow and Logistics IML is working with a group of 21 partners from the worlds of port operation, industry, services and research to investigate ways of making freight transportation more sustainable and efficient by integrating European inland ports. The aim of the three-year collaboration, which is led by the Port of Duisburg, is to allow the ports' capacities, from infrastructure to data, to be shared in the future. Fraunhofer IML is playing a significant role in the development of various prototypes for digitalizing and automating operational processes. One example is an automated system for unloading trains with the help of smart sensors. The researchers are also working on services in the field of logistics that enable computer-generated recommendations for action based on artificial intelligence. The solutions that the researchers develop will be evaluated and implemented at ports in Duisburg, Basel and Vienna.



Extending across 40 kilometers of shoreline, the Port of Duisburg is considered to be the largest inland port in the world.

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

Transporting packages by tram instead of by delivery van could reduce CO_2 emissions and cut down on urban traffic.

AUSTRIA

Packages to go

Ordering online is a convenient, easy and speedy process — but it is not environmentally friendly. In order to reduce delivery traffic, scientists at Fraunhofer Austria are developing a climate-friendly "last-mile concept" as part of the Öffi-Packerl (Public transportation packages) project: Passengers on local public transportation can carry small packages from one package box to the next — these are located along the route at busy stops. A feasibility study involving 6,000 respondents found that, in principle, two thirds were willing to transport packages on their route. One of the researchers' tasks at the moment is to analyze passenger flows in order to identify suitable routes and locations for the package stations, which are self-sufficient in terms of energy. A test phase will begin in 2024 on two tram lines in Vienna and two bus lines in Upper Austria. The aim of this holistic collaboration project is to develop an app that can align the passengers' transportation capacities with the volume of packages. Making packages available at the bus stops will likely improve the delivery service, too. Researchers are also evaluating the economic, ecological and social effects of this. What they don't have to worry about is demand: 113 million packages were delivered to residents of Vienna last year.

AFRICA

White hydrogen: an alternative energy source

As part of the LEAP-RE program, the international research project HyAfrica is aiming to exploit naturally occurring supplies of hydrogen as an innovative source of energy on the African continent. Geochemical reactions within certain geological formations ensure a continuous supply of this gas, known as white hydrogen. This could be used to reduce energy costs and provide small to medium-sized communities with a secure supply of electricity. The project is focused on four regions in Morocco, Mozambique, South Africa and Togo. The scientists in the project are identifying local hydrogen deposits and investigating if and how they could be used for self-sufficient energy plants. They take into account both the socioeconomic and techno-economic impacts that these plants would have, allowing them to create business and action models tailored to specific regions. Based on the data, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE is evaluating the advantages and disadvantages of hydrogen use in local energy systems and developing socially and economically compatible solutions for its implementation. These will enable regional authorities to integrate renewable hydrogen into autonomous or existing mini-grid systems.

Nature provides a free supply of hydrogen in some regions of Africa.

EUROPE

Bioelectronic treatment for brain tumors

There are many types of brain tumors. Methods of diagnosis and treatment vary widely.

In the future, implanted, externally controllable nanonetworks could help target brain tumors locally while also monitoring their growth. The Fraunhofer Institute for Biomedical Engineering IBMT is working on this technology together with academic centers and companies across Europe, as well as a university in Japan. The implant has been developed using both cell-based and electronic components and can be autonomously controlled and monitored. It is designed to stimulate the production of special therapeutic exosomes — these are small, extracellular particles encased in a fat droplet that can facilitate cell communication. Built-in sensors make it possible to continuously monitor the growth of a tumor. With the help of ultrasound-based solutions, the implant can be provided with a targeted, efficient supply of energy, even when deep within the tissue.

The PreCare team wants to significantly increase rates of vaccination.

SOUTH AFRICA

Providing medical care in the bush

Rural areas of Africa often have insufficient access to modern healthcare due to a lack of mobility. The PreCare project aims to change that: In collaboration with Stellenbosch University in South Africa, the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Fraunhofer Institute for Solar Energy Systems ISE are developing a low-cost medical platform that will enable preventive medical check-ups, tuberculosis tests and vaccinations in inaccessible regions. The platform can easily be mounted on a pickup truck for flexible off-road use. As part of a year-long pilot phase by a South Africa-based NGO, their prototype of a solar-powered cabin, which includes a water treatment system featuring an electrochemical on-board disinfection system, medical equipment, Bluetooth-enabled examination devices and a satellite-based laptop, is currently being tested and adapted to local needs. The mobile unit will support the development of healthcare programs and make a significant contribution to strengthening the resilience of the population. Collaborations are already in place with companies in the area in advance of a later mass-production stage, creating jobs and enabling local value creation.

Renovating the construction industry

The construction industry is facing worker shortages, at a time when hundreds of thousands of homes need to be built. Construction robots could provide a solution. But is the industry ready for them?

By Beate Strobel

Around the year 1900, illustrators in France drew a series of postcards literally depicting the world in one hundred years' time. They came up with moving sidewalks, flying firefighters, mobile houses — and a construction site with a robot worker slaving away around the clock. And nowadays? We've been taking escalators and fighting fires using aircraft for many years — and traveling in a motor home is huge trend. It's only on the construction site that very little seems to have happened. Houses are still primarily being built by humans.

Why has robotics yet become established in this industry the way it has in sectors such as automotive manufacturing? Thomas Kirmayr, general manager of the Fraunhofer Building Innovation Alliance, can cite quite a few reasons, like the fact that no construction site is exactly like another, and that they change every day. Construction work takes place out in the elements, rather than in a controlled environment. A multitude of different tradespeople can work at one construction site, and the workflows can be very complex. However, Mr. Kirmayr adds: "If we want to boost productivity and increase the rate of construction, we have no choice but to implement more mechanization and automation in the construction industry. But the industry needs to develop its own methods and solutions, and work on simplifying and systematizing its processes to begin with." Robots that just do what humans are doing today are not the solution — we need to rethink the whole construction industry to some extent. "Maybe," says Mr. Kirmayr, "that's one reason this vision hasn't become a reality yet." ▶

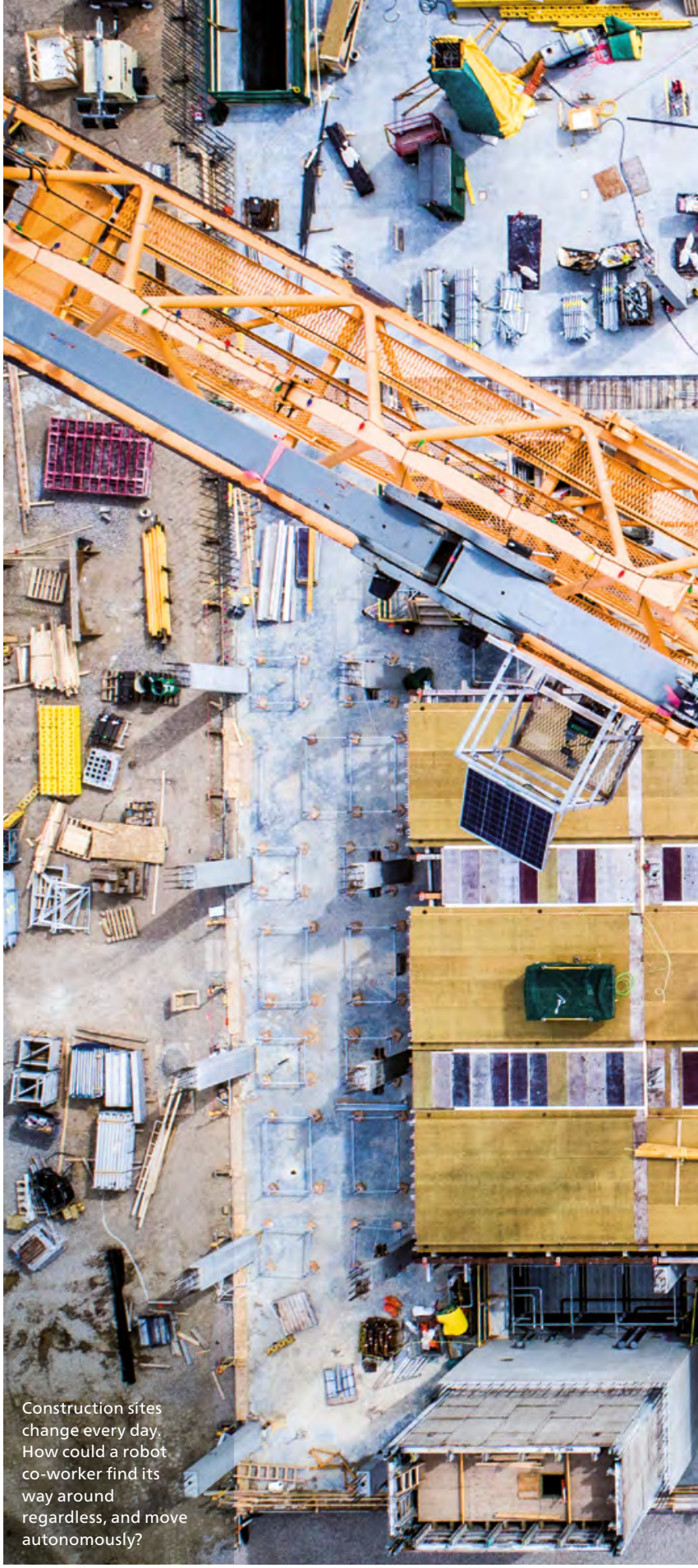


Photo: Arie/AdobeStock

Construction sites change every day. How could a robot co-worker find its way around regardless, and move autonomously?

The construction industry is facing enormous challenges. In order to relieve the strain on the real estate market and make housing affordable again, the coalition of the SPD, the FDP and Alliance 90/The Greens wants to have 400,000 new apartments built in Germany — every year. At the same time, if we are to achieve our climate targets, the rate of home renovations must be increased from the current figure of around 1 percent to at least 2 to 3 percent. However, manpower is in short supply. In a 2021 survey by the German Chamber of Commerce and Industry, 66 percent of companies in the construction sector complained that they can no longer fill vacant positions — a much higher figure than in industry (53 percent), retail (45 percent) and the service sector (50 percent). How can we increase construction and renovation rates in spite of the worker shortage? "If we want to achieve the targets set out by the government with our limited workforce resources, we need to put an intensive focus on increasing productivity as a matter of urgency," says Mr. Kirmayr.

"We have to stop thinking of construction robots as always just being a substitute for human labor."

Thomas Kirmayr, general manager of the Fraunhofer Building Innovation Alliance

So robots are going to replace people? No, according to the researchers of the Fraunhofer Building Innovation Alliance — a consortium of 14 Fraunhofer institutes. In their position paper on the future of the construction industry, the alliance discussed approaches for increasing productivity and efficiency in construction. The goal should be for robots and humans to work together to master the complexities of construction.

If this transformation process is to be successful, it must happen gradually. In the short term, technology can and must support operational processes, especially when it comes to heavy loads and difficult work inside buildings. In order to increase mechanization, it is essential that we develop construction systems to reduce complexity and allow for more prefabrication. Where possible, building components would be created in advance in production facilities and on assembly lines; these workspaces eliminate exposure to the elements for humans and machines, and so are far more suitable for robots.

Many architects and builders are concerned that modular construction would result in buildings that all look the same. However, Mr. Kirmayr rejects the obvious comparison with prefabricated buildings: "Systematic construction processes and architectural diversity are not mutually exclusive," he emphasizes. The Fraunhofer Building Innovation Alliance is calling for a transition toward systematic construction and renovation processes. However, this approach will only succeed if it allows for individuality, even if there is a large amount of prefabrication involved. This is precisely where architects need to use their creativity and come up with solutions for a new kind of construction, using smart design to take the predefined elements and transform them into exciting architectural structures. Transitioning to a sustainable circular economy also depends very much on being able to dismantle buildings — and that requires systematic, modular construction.

The past ten years have seen an increase in research into construction robotics. Prototypes have been developed for various fields of application. The first specialized robots are now stacking bricks on top of each other and taking on welding tasks. There are high-tech assistants that drill holes in walls, and robot dogs that can walk around and survey construction sites. However, it's already becoming clear that there is very little actual added value in just transferring humans' work processes over to robots.

How does a robot get vital data on a construction project? With the aim of creating an interface between the Robot Operating System (ROS) and Building Information Modeling (BIM), mechatronics engineer Michael Terzer helped develop a prototype called ROSBIM at Fraunhofer Italia Research. This prototype used the HUSKY, a mobile platform that autonomously moves around construction sites and can transport heavy loads. The interface technology is needed for construction robots to dynamically receive the environmental data they require.

Based on their experiences with HUSKY and a disinfection robot called BALTO, researchers at Fraunhofer Italia Research are now planning the first modular robots for construction sites. These robots will be part of the EU-funded consortium project H2020 Concert (CONfigurable CollaborativE Robot Technologies). By using different superstructures or gripper arms equipped with various attachments, the robots can be adapted to work on specific tasks on the construction site, even by non-engineers. According to Mr. Terzer, they are primarily suited to jobs that are "very repetitive, unergonomic or hazardous to people's health."

However, researchers at Fraunhofer Italia are also looking beyond BIM and toward creating digital twins for buildings. These can be used to map the entire life cycle of a building, from the planning stage through all the construction processes to maintenance, right through to demolition. "If a digital system is to support construction robotics, it must not only ensure the robots can safely, autonomously navigate the construction site, but also answer logistical questions," says Dr. Dietmar Siegele, head of Process Engineering in Construction. What material does the robot need right now? How much of that material is there, and

66%

of companies in the construction sector complain that they can no longer fill vacant positions.

Using HUSKY A200, Michael Terzer at Fraunhofer Italia Research is investigating how mobile platforms will be able to drive autonomously around construction sites and perform tasks such as transporting loads.

how can the robot get it? What needs to be delivered, and when? "If I have to manually take the robot through the room, program it with my smartphone and supply it with materials myself, then it's not really making things any easier and financially, it isn't worth it."

Robot co-workers: Mr. Terzer believes that cobots — robots that assist people — could act as a stepping stone to help the construction industry move toward fully automated construction sites. Cobots can help people overcome their apprehension about using high-tech devices, and really highlight the benefits. Exoskeletons could have similar results. For a long time, external support structures were seen as a gimmick within the industry, but as retirement ages grow later, many construction workers are glad to reduce stress on their back and joints during their work.

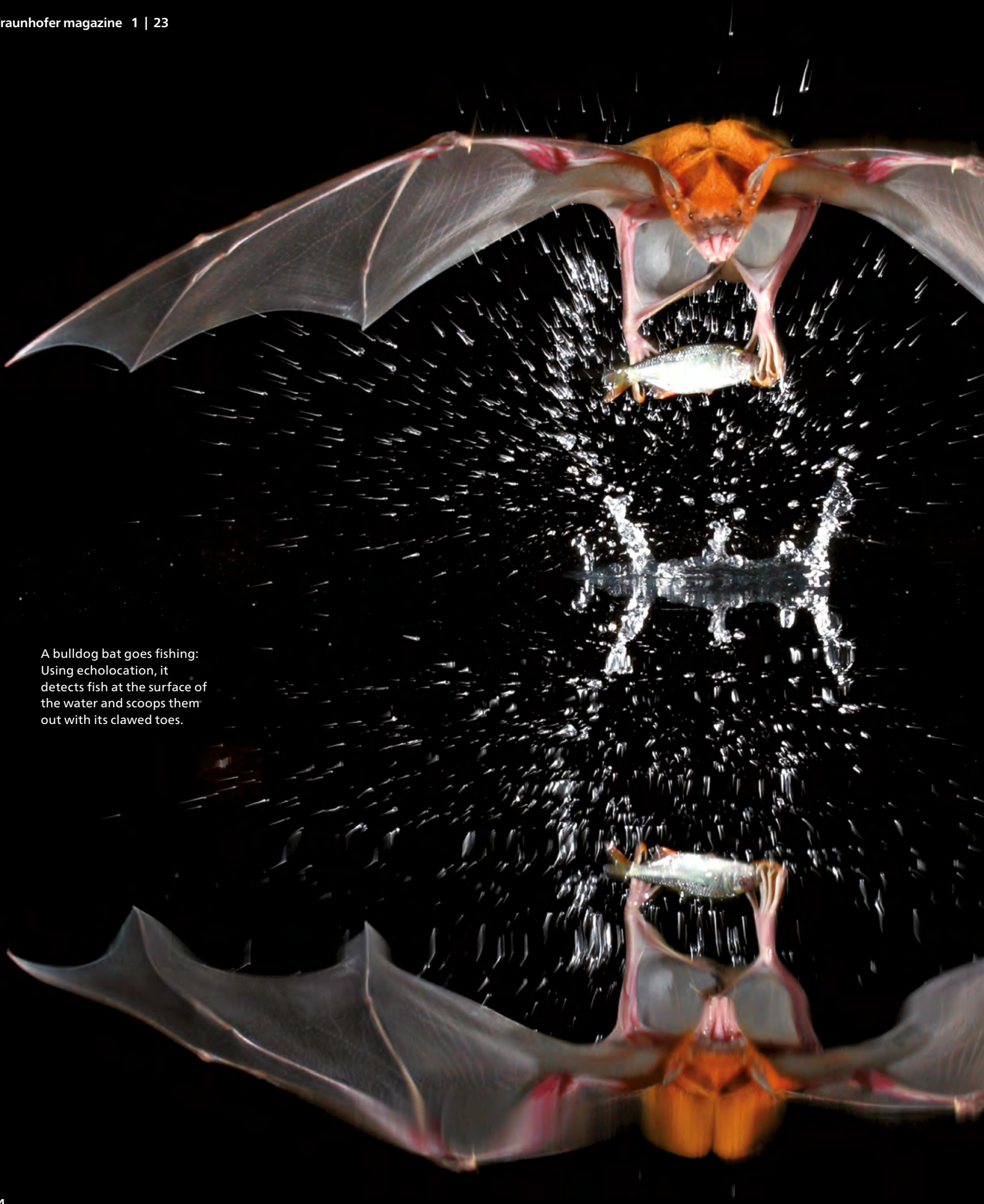
When it comes to renovating and converting existing buildings, however, Dr. Siegele of Fraunhofer Italia believes cobots are more than just a stepping stone — they're the solution. "In the next few years, constructing new buildings will quickly become less important because of sustainability," he predicts. However, processes like renovating, extending, and repurposing or adding floors to existing buildings are always very specific and offer little scope for automation.

"We have to stop thinking of construction robots as always just being a substitute for human labor," explains Mr. Kirmayr. "We need to rethink the entire process of designing and constructing a building if we really want to achieve noticeably increased productivity, become climate-neutral and produce buildings that can be dismantled." This is why the general manager of the Fraunhofer Building Innovation Alliance believes we need a revolution in the industry, rather than a transformation. He predicts that within the next decade, we will see the construction industry change in many areas — when it comes to the materials used and the circular economy, but also in terms of construction systems and the level of automation. "Contrary to many opinions, we believe that the very fragmented and medium-sized natur of the construction industry can result in agility and make it a model of pioneering transformation, rather than being a hindrance." Can we let another century go by without making any fundamental changes? "No — we simply can't afford that any more." ■

"In the next few years, constructing new buildings will quickly become less important because of sustainability."

Dr. Dietmar Siegele, Fraunhofer Italia

Photo: LIVE-STYLE Eppan



A bulldog bat goes fishing: Using echolocation, it detects fish at the surface of the water and scoops them out with its clawed toes.

Photo: plainpicture/Christian Ziegler

Photo & Fraunhofer

Do it like the bats

Nature is a source of inspiration for poets and researchers alike. For example, scientists borrowed details from the structures of the Indian lotus leaf to create self-cleaning surfaces, while hook-and-loop fasteners can be traced back to naturally occurring burs. This discipline, which concerns the transfer of knowledge from the animal or plant world to technical materials and applications, is known as bionics.

In project PaintVisco, researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA found their key source of inspiration in bats. In order to locate prey and avoid obstacles in completely dark environments, these flying mammals send out short, ultrasonic calls into the night. Each call consists of both low and high sound frequencies, which blend seamlessly into each other.

The aim of the PaintVisco project was to precisely simulate the complex flow behavior of paint films. Normally, a rotational rheometer delivers the required measurement data here. A disc attached the device rotates or oscillates a liquid paint sample so that the force required to produce deformations in the material can be measured. "However, previous devices have prevented solvents from evaporating, meaning that the results are only of limited use for the paint industry," says Dr. Fabian Seeler from Fraunhofer IPA. Moreover, the measurement is normally only carried out at a single oscillation frequency, which is not sufficient for virtual predictions of the process.

On the other hand, the new PaintVisco rheometer works much like a bat, using frequencies that blend into each other. This ensures that the changes to the viscoelastic paint properties during curing can be recorded far more precisely. In addition, the process of deforming the paint no longer takes place in a closed disc, but rather in several rings arranged inside each other. This allows the solvent to evaporate through the gap between the rings.

"Our measurements have shown that the multifrequency measuring technique can be used to determine the change in viscoelastic paint properties over the entire painting process," says Dr. Seeler in summary. From an industry point of view, this means achieving simulation results in the shortest possible time, which has the benefit of reducing the cost of developing new paints and painting processes.

Friend or foe? A new technology will identify flying objects within milliseconds.

Airborne danger incoming?

Fraunhofer researchers have developed a new method for detecting and tracking drones in real time and in 3D. With its array of antennas and innovative radar system, this technology is the first of its kind worldwide.

By Mehmet Toprak

Day after day, images from Ukraine are proving just how dangerous drones can be: they are damaging critical infrastructure, plunging civilians into darkness and freezing temperatures. The Fraunhofer Institute for Applied Solid State Physics IAF is using its 3D, real-time millimeter-wave sensor technology to develop new methods for quickly detecting drones. This could be used to protect the public from threats at major events, for example. The technology is based on a high-resolution millimeter-wave camera that generates 3D radar images at a frequency of around 94 gigahertz. The researchers chose to use the W band (75 to 110 gigahertz), as these frequencies can even penetrate rain, snow, dust, fog and sand devils. The scientists' work is being supported and funded by the German Federal Ministry of Defence.

Achieving more by saving resources

The basic principle for generating 3D radar images involves positioning multiple transmitting and receiving antennas in a two-dimensional array, which makes it possible to determine the solid angles (azimuth and elevation angles) as well as the object's proximity and velocity. When an object appears that must be detected, the antennas receive waves reflected off the object; the system uses the infinitesimal differences in how long the waves take to reach the antennas to calculate the object's spatial position. However, the innovative radar system, developed by the Freiburg-based Fraunhofer researchers does without the second antenna dimension. This enables a more compact design, and requires fewer resources. These savings are made possible thanks to the high bandwidth offered by the semiconductor technology at Fraunhofer IAF. The second spatial dimension is recorded by frequency-controlled antennas. "The direction the waves flow from the antennas changes with the frequency, so we get both angles from only one set of antennas and can use that to detect objects," explains Christian Zech, researcher at Fraunhofer IAF. "That way, we can map objects' trajectories in 3D."

A range of several hundred meters

Eight transmitting and receiving antennas are arranged next to each other in Fraunhofer IAF's new radar. The combination of this hybrid aperture with a digital modulation process in the backend is a worldwide first and the resulting system is compact, resilient and innovative. The system measures how the waves reflect off the flying object and examines its flight behavior — this allows the drone to be compared with a database to identify its type.

The entire process, from sending out the radar wave through to identifying one or more flying objects, is carried out within milliseconds — even from a distance of several hundred meters. Once equipped with this data, a defense system could react incredibly quickly and use interference radiation to throw the drone off course or render it harmless. The radar system developed at Fraunhofer IAF can not only help to protect large events (in sports stadiums, for example) from potential drone attacks, but also power plants, dams or strategically important points along gas and power grids. ■

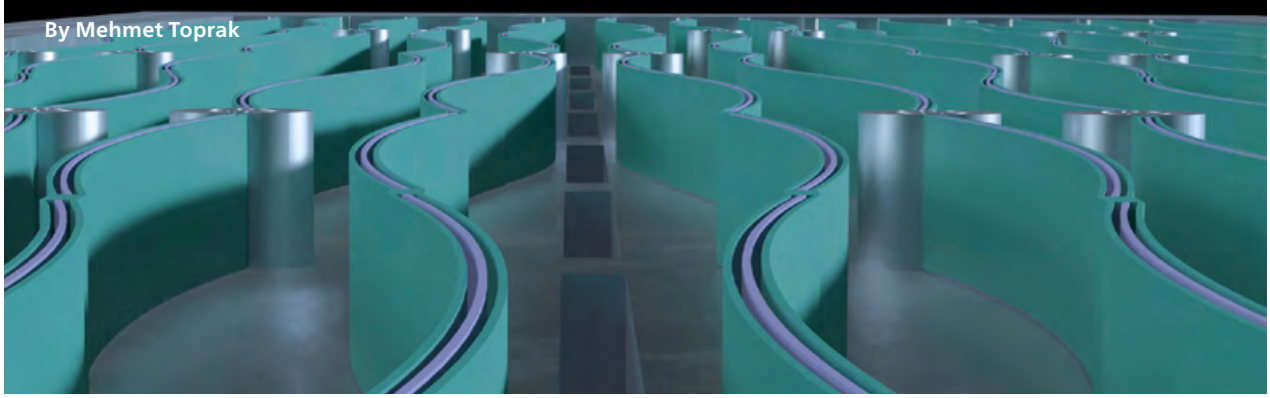
The high-resolution millimeter-wave camera uses a specific frequency range that allows it to penetrate even rain, snow, fog, dust and sand devils.

Photo: Aleksandr Gusev/Pacific Press/dpa

An in-ear interpreter

Less power consumption and completely new functions: The next generation of in-ear headphones can do much more than just play music, thanks to flexible lamellae and electrostatic actuators.

By Mehmet Toprak



This is where the music happens: **120** bending beams, each barely one millimeter long and 70 micrometers wide.

Just imagine: wireless in-ear headphones that function as a mini-PC — in addition to playing music, they can be used as heart rate monitors and temperature sensors. And in just two or three years, they could be on the market. This technology was developed by Dr. Bert Kaiser and his team at the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. Dr. Kaiser, who is head of the Monolithically Integrated Actuator and Sensor Systems business unit, does not rely on membranes commonly used in loudspeaker technology, instead using tiny bending beams and flexible lamellae.

"Electrostatic forces cause the bending beams to vibrate. The base material is a highly doped — i.e., particularly conductive — silicon. The higher the tone, the faster the beams vibrate," explains Dr. Kaiser. For example, at a frequency of 3,000 hertz — roughly the pitch of a human voice — the beams oscillate 3,000 times per second. At this frequency, the air also starts to move, which generates the sound. A MEMS (micro-electro-mechanical systems) loudspeaker contains 120 such bending beams, each barely one millimeter long and 70 micrometers wide, in an area of about ten square millimeters. Several years ago, Dr. Kaiser and his team developed the basic principle behind this little technical marvel. As a result, a successful Fraunhofer spin-off, Arioso Systems, was founded in 2019; it was taken over by Bosch Sensortec GmbH in 2022.

Their current project now sees the Fraunhofer-developed sound transducer technology take another leap forward. One new feature, for example, is the symmetrical design of the flexible lamellae. This has several advantages. For instance, it extends the range of frequencies that the mini-loudspeaker can produce, which is currently between 10 hertz and 10 kilohertz. This not only beneficial for reproducing music, but also for noise canceling: the MEMS speakers can cover a wider frequency range when generating counter sound waves, meaning that they can cancel out ambient noise that has particularly low or high frequencies.

Another important factor for music fans is distortion, i.e., the portion of electrical energy that lies outside the frequency range determined by the respective music signal. A lower distortion factor means a purer sound. The MEMS loudspeakers from Fraunhofer IPMS currently have a distortion factor of only 1.1 percent. This creates an especially balanced, neutral, clean sound, even at higher volumes.

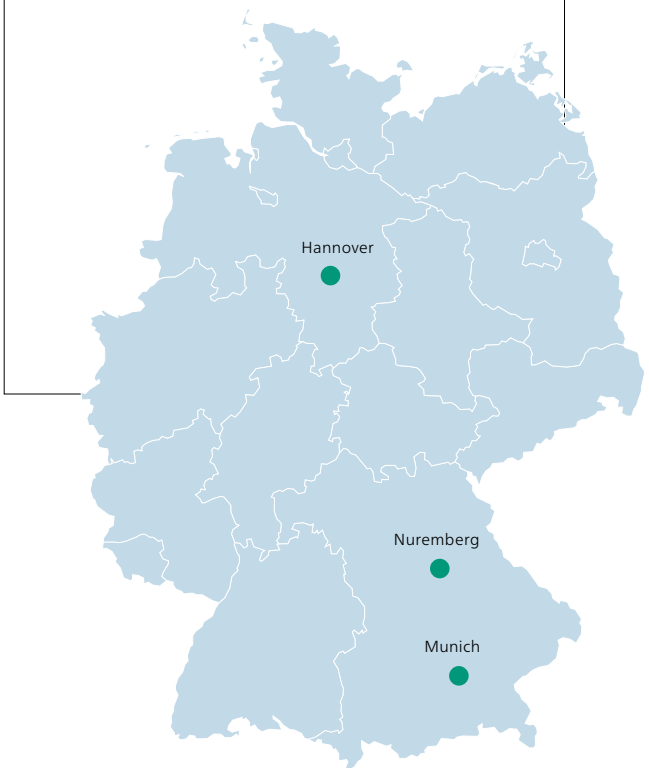
Another advantage is improved efficiency. The experts at the Dresden-based Fraunhofer institute were able to reduce the required voltage level from 45 to 15 volts. This, in turn, increases battery life by up to 30 percent at the same volume. The electricity saved while listening to music can be used for other functions — it would be easy to integrate a heart rate monitor, blood oxygen sensor and temperature sensor, which are often found in smartwatches these days. The data could be processed inside the in-ear headphones themselves. Experts refer to these headphones as "hearables."

"When combined with an integrated microphone and a smartphone connected via Bluetooth, it would also be possible to incorporate speech technologies from areas such as the Internet of Voice and speech recognition," predicts Dr. Kaiser. "This could even enable simultaneous interpretation services." ■

Scan here for the podcast:

Photo: Fraunhofer IPMS

Fraunhofer on the road



Nuremberg
March 14–16, 2022
Embedded World
International trade fair and conference for embedded systems

Munich
April 17–22, 2023
BAU
The world's leading trade fair for architecture, materials and systems

Hannover
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Hannover Messe
The world's leading industrial trade fair
High-tech, innovative solutions to meet global industrial challenges

Munich
May 9–22, 2023
transport logistic
The world's leading trade fair for logistics, mobility, IT and supply chain management

"Buried within vast data sets gained from clinical trials and healthcare provision is a store of valuable knowledge for diagnosing and treating a wide range of diseases. However, in order to detect these critical relationships, it is necessary to establish a close interdisciplinary collaboration between medicine and data science."

Sina Mackay, data scientist at Fraunhofer IAIS

Fraunhofer