Fraunhofer
3 | 22

Fraunhofer

The magazine for people shaping the future

Our diet is about to go green
Food for everybody — from the sea

Our energy

Where it comes from
How we can secure

Prof. Clemens Rohde, Fraunhofer ISI

Breast cancer: hunting down cells in the blood stream
New diagnostics — faster, more efficient, safer for patients

"We are well-positioned in terms of applied research!"
An interview with Bärbel Bas, president of the German Bundestag

Fraunhofer
ZUKUNFTSSTIFTUNG

Join forces to support research with crowdfunding!

Vote by November 30, 2022
each vote counts

Crowdfunding competition 2022 ScienceForGood, the initiative of the Fraunhofer Future Foundation

ScienceForGood is our way of asking society:
Which future-oriented research topics are important to you? Which research projects sound convincing? And which team will win the crowdfunding competition 2022 of the Fraunhofer Future Foundation? **#ScienceForGood22**

Scan me!

www.startnext.de/pages/fraunhofer-zukunftsstiftung

Editorial

Innovation: the key to solving the energy crisis

Prof. Reimund Neugebauer

Energy is the overriding concern in Europe these days. Renewable energy will not only play a vital role in making our industry and society carbon neutral, but it will also be important in ensuring the security of Germany's energy supply. To ensure our competitiveness and technological sovereignty in the long term, we must increase our domestic energy production. However, we will only succeed in this if we can accelerate the expansion of renewable energies such as wind and solar power, as well as ramping up the implementation of a hydrogen economy so that we can decarbonize our industry.

The Fraunhofer-Gesellschaft has been driving strategic research advancements in various fields of climate innovation for decades. For an example of our outstanding energy research, look no further than the Fraunhofer Institute for Solar Energy Systems ISE's high-efficiency solar cells, which have already set multiple world records. Most recently, in May, Fraunhofer ISE managed to increase the efficiency of their best solar cell to date to 47.6 percent, thanks to a new anti-reflective coating. What's more, the costs of photovoltaic technology have been reduced by more than 90 percent since 2010.

With a wide variety of possible applications in industry, transportation and the power and heat generation sectors, hydrogen also represents a crucial component for achieving climate neutrality in the medium term. According to a recent Fraunhofer study, the global share of hydrogen in end energy consumption will reach between 4 to 11 percent by 2050. However, if hydrogen is to achieve widespread use as an energy source, then it must be produced through climate-neutral processes, at economically viable prices and in sufficient volumes. Now, an initial milestone on the road to a hydrogen economy has been reached, with the recent launch of the National Action Plan for Fuel Cell Production H2GO. The project, which is receiving 80 million euros in funding from the German federal government, is a combined effort by 19 Fraunhofer institutes to develop a highly scalable industrial production process for fuel cells, primarily for use in heavy goods vehicles in road freight. Under these conditions, H2GO is sure to help scale up fuel cell production and smooth our transition to the "Hydrogen Republic of Germany."

In the long term, we may also be able to unlock nuclear fusion's great potential as carbon-free energy source. Just 1 gram of deuterium-tritium fusion reactor fuel can release as much energy as burning 11 tons of coal. The USA is already exploring a number of promising approaches here, which we in Germany are well-placed to support with our expertise and new technologies.

It's not in spite of this crisis, but because of it that Germany must focus more on research and innovation in order to compete at a global level. Because after all, sustainable innovations in the energy sector are the best way of increasing productivity and safeguarding sustainable value creation, prosperity and competitiveness in the long term.

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/Bernhard Huber

back to page 1

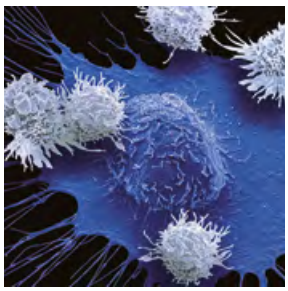
Contents

70 Feathered air force

Vultures will soon take to the skies with an early warning system for ecological cluster crises

58 Emotions: a passion project

A new technical assistant is set to help autistic people get a feel for feelings.



76 Detecting breast cancer cells in the bloodstream

A novel diagnostic method is putting an end to long, painful waiting periods — and it is much less physically demanding for patients.

Since war broke out in Ukraine, the European Union has produced 24 percent of its power from solar and wind plants — more than ever before. According to the calculations from a recent study by Ember and E3G, this allowed the member states to save around 99 billion euros on costly gas imports.

24%

Front and back cover photos: Jonas Ratermann, Xander Heinl/photothek/dpa, istockphoto;
Photo content: Jonas Ratermann, Thomas Trutschel/photothek/dpa, André Kirsch, Matjaž Krivic, Kniel Synnatzschke/plainpicture, Steve Gschmeissner/Science Photo Library

back to page 1

Brief report

At present, we incinerate more than half of the sewage sludge we produce — but Fraunhofer researchers have a better idea.

Extracting hydrogen from waste

How can we produce pure, climate-neutral hydrogen for operating fuel cells without relying on solar or wind energy? According to researchers from the Fraunhofer Institutes for Surface Engineering and Thin Films IST and for Environmental, Safety and Energy Technology UMSICHT, the answer is bio-waste.

These scientists are developing a two-step process for extracting high-purity hydrogen from biogenic residues such as sewage sludge. In the first step, the researchers use a thermo-chemical conversion process to generate a hydrogen-rich synthesis gas from the organic waste material. Then, in the second step, they plan to isolate the high-purity hydrogen using membranes with metallic coatings.

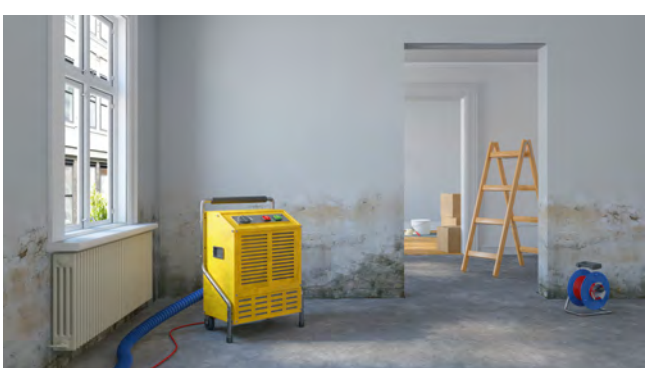
Decentralized production of high-purity hydrogen is a key component of Germany's National Hydrogen Strategy, which aims to reposition the country as a climate-friendly industry hot spot. This innovative process could trigger a significant increase in the amount of green hydrogen produced in Germany while simultaneously reducing the risk of dependencies and protecting security of supply. ■

Water damage: Mold doesn't stand a chance

A new, innovative technology can dry damp walls quickly and quietly, while using very little energy. In addition to being 85 percent more energy-efficient than conventional dehumidifiers, FastDry® also makes much less noise. Because the drying modules do not use a fan or compressor, they can easily be run in an office during the day or in a private home overnight.

FastDry® was developed by researchers at the Fraunhofer Institute for Building Physics IBP. The drying module, which consists of a large, rectangular insulation panel, is attached directly to the user's wall so that it can heat it via an integrated wire. The material allows diffusion, so the resulting steam is free to escape to the external environment, while the insulation keeps the thermal energy inside the wall. This means that very little power is needed to maintain the temperature and the room is not heated more than is necessary. The system has a working temperature of around 55 degrees Celsius, which even sensitive building materials can easily withstand. The technology is ready for market launch and mass production. ■

Conventional dehumidifiers need to run or at least four weeks and often more, resulting in enormous electricity costs.



Another chance for old tires

The process of retreading old tires saves over 60 percent of the CO_2 emissions when compared to the manufacturing of new tires with a similar quality level. This is primarily due to the reduced raw material and energy requirements. These figures come from a recent study conducted by the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT on behalf of the Allianz Zukunft Reifen AZuR (future alliance for tires) network and funded by the German Federal Environmental Foundation (DBU).

In Germany, around 570,000 tons of old tires end up as scrap every year, and most of them are incinerated or broken down into rubber granules and dust. Retreading them is a far more environmentally friendly option, but this alternative is rarely used. "The problem is that people generally do not trust retreaded tires," explains Christina Guth, who coordinators the AZuR network. However, as the study indicates, retreaded tires can last for just as many miles as new tires with a comparable quality level. And the research shows that there are many other benefits to the recycled tires. "If we used this process on a larger scale, we could save huge quantities of crude oil, rubber and steel," says Ms. Guth. What's more, the retreaded tires cost less than new ones. However, if consumers are to be won over, they will need to be better informed regarding the environmental and economic advantages of recycled tires. ■

Recycled tires are just as good as new ones and much more environmentally friendly.

Mobile food check

Don't have a dog to sniff test your ood for ripeness and quality? Then Fraunhofer researchers have the solution you need.

How can we tell if the flesh of an avocado is rotten underneath its thick skin? In the future, a small, mobile scanner system will provide quick answers to this question; the device is being developed at the Fraunhofer Institute for Photonic Microsystems IPMS. The system will also make it possible to check for quality, ripeness and freshness without any need to touch the produce. Being quite small, these devices can be integrated into tablets or — perhaps in the future — even smartphones.

The scanner's compact size is made possible by micro-electromechanical systems (MEMS), but it still delivers high-precision measurements. The data the device collects undergoes a chemometric analysis either on site or online, so that specific characteristics can be identified. This allows the system not only to declare whether the foodstuffs are ripe and fresh, but also to check that correct mixing ratios were applied in the food processing step. The devices will also facilitate rapid inspections for incoming and outgoing goods and targeted selection in recycling and reuse processes. Ultimately this means that decreasing product freshness can be detected at an early stage throughout the entire supply chain, which will in turn reduce food waste. ■

back to page 1

Every year, Germany produces around 3.3 million tons of road construction waste that is contaminated with tar.

Recycling tar

Germany has prohibited the use of tar in road construction since 1984, due to its carcinogenic properties. Up until that point, however, many millions of tons of the substance had been used. In the "InnoTeer" project, Fraunhofer researchers are developing a multi-stage process to remove the harmful tar contamination from road construction waste and extract the remaining mineral content in a high-quality form.

A team from the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB is working on a safe, automated process for separating uncontaminated road construction waste from the tar. The uncontaminated material can be reused immediately. Previously, the remaining contaminated waste was burned at high temperatures of 850 to 1,000 degrees Celsius, which resulted in high levels of CO_2 emissions. Now, however, they are pyrolyzed at lower temperatures in an oxygen-free environment. In this process, the heat breaks down the tar, which renders the dangerous substances it contains harmless, but does not damage the aggregate. At the end, only sand, limestone and carbon are left and these will be used to produce asphalt and other building products at the Fraunhofer Institute for Building Physics IBP. ■

On the whey to sustainable glue

Researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS and TU Dresden have developed an eco-friendly adhesive based on whey.

Whey — produced in large quantities when milk curdles to form cheese or quark — is sometimes sold as a beverage, often flavored with added fruit. Individual whey components like lactose and protein can also be used in the pharmaceutical and food industries, but until recently, there was no use for the remaining molasses, which left manufacturers with a very expensive disposal process on their hands.

Now, using fermentation and special membranes, researchers have succeeded in extracting ethyl acetate from these molasses. This colorless solvent is an important ingredient in various products, including adhesives, printing inks and paints. Until now, ethyl acetate has been produced from natural gas and petroleum derivatives. However, the sustainable alternative that the scientists have extracted from the waste molasses can easily be broken down by microbes, and it has a high purity grade of 97.5 percent. This means it can be used directly as a raw material without any need for further processing. ■

Whey was acclaimed for its healthy properties in the 19th century. Health fanatics in Switzerland even created dedicated whey spas — until it became clear that the mountain air was the determining factor for recovery, not the liquid byproduct of cheese production.

Editorial notes

Fraunhofer. The magazine, magazine for research, technology and innovation
ISSN 1868-3428 (print edition)
ISSN 1868-3436 (online edition)

Published by:
Fraunhofer-Gesellschaft
Hansastrasse 27c, 80686 München, Germany
Editorial address as above
Phone +49 89 1205-1301
magazin@zv.fraunhofer.de
www.fraunhofer.de/magazin

Free subscription:
Phone: +49 89 1205-1301
publikationen@fraunhofer.de

Editorial team:
Roman Möhlmann (responsible for content),
Josef Oskar Seitz (editor-in-chief),
Dr. Sonja Endres, Beate Strobel

Editorial assistants:
Dr. Janine van Ackeren, Mandy Bartel, Dr. Katja Engel, Meike Grewe, Robert Grill, Sirka Henning, Tim Schröder, Mehmet Toprak and Yvonne Weiß

Layout and lithography:
Vierthaler & Braun
Cover image and cover story photography:
Jonas Ratermann
Nutrition article photography:
André Kirsch
Printed by:
Zeitfracht GmbH, Nuremberg

Fraunhofer in Social Media:

@Fraunhofer
www.facebook.com/fraunhoferde
www.instagram.com/fraunhofergesellschaft
www.linkedin.com/company/fraunhofer-gesellschaft
www.youtube.com/fraunhofer

Carbon neutral
Print product
ClimatePartner.com/11586-2210-1007

MIX
Paper from responsible sources
FSC® C022647

Photos: Frank May/dpa, istockphoto (2)

Safer e-scooter mobility

There are almost as many accidents involving e-scooters as mopeds and motor scooters. Fraunhofer researchers used crash test dummies and computer simulations to investigate how to improve safety for e-scooter drivers.

In 2020, there were 2,155 e-scooter collisions in Germany.

Research teams at the Fraunhofer Institutes for High-Speed Dynamics, Ernst-Mach-Institut, EMI and for Mechanics of Materials IWM have joined forces in the HUMAD project to analyze the typical sequence of events in common accidents and identify the associated injury risks. They also tested the suitability of a variety of helmets and protective equipment.

The researchers found that even at a seemingly low speed of only 10 km/h, a collision at a 90° angle puts an enormous acceleration stress of 170 g on the human body. Conventional bike helmets and protective gear reduce the severity of the impact, but do not offer total protection in collisions with hard objects.

Dr. Jörg Lienhard, who oversees matters relating to lightweight construction in the Component Safety and Lightweight Construction business unit, explains: "Protective gear often uses plastics with a type of honeycomb structure. Our tests in the laboratory showed that materials with a TPMS (triply periodic minimal surface) structure could offer much better protection against kinetic effects." The TPMS is a remarkably "airy" and open structure that allows for particularly effective distribution of kinetic energy across the surface while reducing the pressure on individual impact areas. This concept originates from the field of biomimetics, meaning that is inspired by nature — insects' chitin exoskeletons and others like starfish ect. have a similar structure, for example.

TPMS helmets and protective gear could be manufactured via 3D printing, using many different kinds of materials. Thanks to the flexibility of 3D printing processes, safety-related components can be individually manufactured in line with the specific needs of each application and its typical risks — and with direct light processing (DLP), they can now be manufactured in large batches. ■

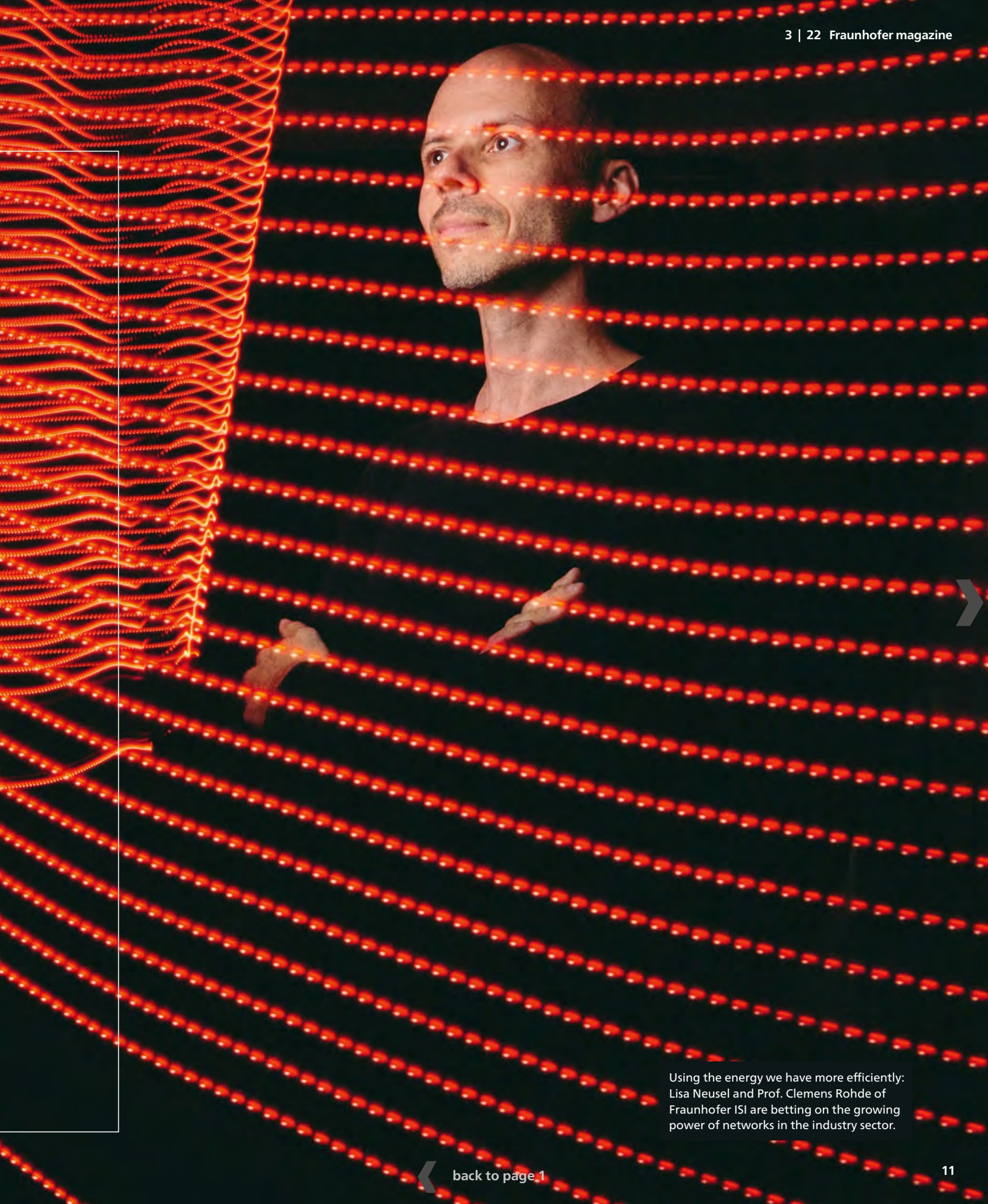
back to page 1

Title

Let there be… energy!

Power is expensive; more expensive than ever. Our efforts at accomplishing energy transition so far have been half-hearted at best — now we have to pick up the pace. But how?

By Dr. Janine van Ackeren;
photographer: Jonas Ratermann; photographic assistant: Carsten Bredhauer



Using the energy we have more efficiently: Lisa Neusel and Prof. Clemens Rohde of Fraunhofer ISI are betting on the growing power of networks in the industry sector.

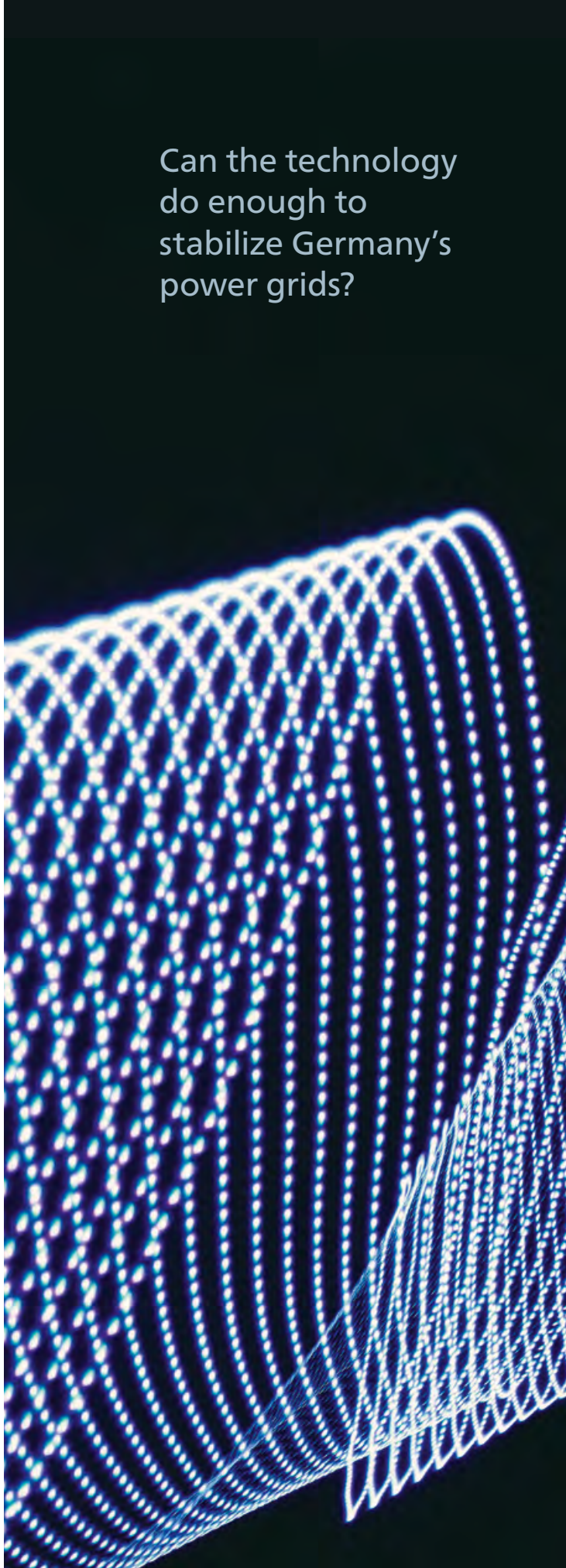
back to page 1

It was September 15th — in the last few days before the calendar turned to fall, Germans were basking in the mild temperatures of late summer, with 17 degrees in Berlin and 23 in Munich. Then suddenly, a chilling fear spread over Germany, as the Deutscher Städte- und Gemeindebund e. V. (German association of towns and municipalities) warned of widespread power outages. "There is a danger of blackouts," confirms Gerd Landsberg, the association's managing director. His concern stems primarily from the 650,000 fan heaters that consumers have purchased this year, fearing a cold winter and extremely high heating costs. Emergency tips are going around like wildfire: camping stoves for hot meals, battery-powered radios, candles and flashlights. Russia's war of aggression against Ukraine has brought about a host of new developments to Germany — but Germans are determined to develop themselves even further, and quickly.

How can we prevent major power supply faults? In the joint project "Netzregelung 2.0" (grid control), researchers at the Fraunhofer Institute for Energy Economics and Energy System Technology IEE have set out to answer this question, in collaboration with partners such as TU Braunschweig, the University of Kassel and Germany's four transmission system operators, as well as power converter manufacturers and the Network Technology/ Network Operation Forum at VDE. In addition to various other studies, the team created a worst-case scenario based on a real event: On November 4, 2006, a chain reaction caused by a switching operation in the transmission system split the combined central European grid split into three parts. The researchers simulated the events of the fault, but under even more challenging conditions. In their simulation, the grid had to transport far more power. Dr. Philipp Strauß, deputy director of Fraunhofer IEE, explains the problem the team had to work on: "Conventional power plants have large rotating generators which store mechanical inertia. If a fault occurs or a power plant is shut down unexpectedly, this rotating mass continues to move for some time afterward, as it cannot simply stop all at once. This is then reflected by electrical inertia in the grid, which compensates for faults." At present, renewable energy generators are mostly connected to the grid via power converters, which do not provide any inertia. The converters are supposed to adjust the energy that they feed into the grid to its existing voltage and frequency — for example, at a photovoltaic solar plant, the converter will change the direct current the plant generates into the alternating current that most grids use. Now, Fraunhofer researchers are working on a digital control system for converters that will ensure they operate in a similar way to rotating generators in the future.

This involves setting up the power converter in such a way that if the current fluctuates, the converter ▶

Can the technology do enough to stabilize Germany's power grids?



"The answer to that question is an unequivocal 'yes.' With the right control system, you could actually have grids that only use converters; even in the worst-case scenario, they would do enough."

Dr. Philipp Strauß, Fraunhofer IEE

back to page 1

"With this study, we hope to spark discussions within the political sphere about the importance of the digital transformation for the energy transition."

Dr. Marijke Welisch, Fraunhofer Cluster of Excellence Integrated Energy Systems CINES.

continues to function as normal for a period of time afterward, thus activating the instantaneous reserves, which then stabilize the grid.

"We wanted to find ways of controlling these power converters within an integrated grid system. Is there any way they could be used to absorb major grid faults?" asks Dr. Strauß, who is coordinating the entire project at Fraunhofer IEE. Can the technology fulfill the researchers' hopes and do enough to stabilize Germany's power grids? "The answer to that question is an unequivocal 'yes.' With the right control system, you could actually have grids that only use converters; even in the worst-case scenario, they would do enough," reports the researcher. The new control system can even coexist with the current systems — and this will be an important point if renewable energy is to replace fossil power plants on a step-by-step basis. The researchers have even designed the necessary control procedure for current stabilization. These grid-forming power converters with digital electrical inertia are already required in maximum-voltage applications and large-scale power converters in the transmission system. However, although plans are in place to integrate converters into the distributed grid as well, this will require further research. One tricky issue here is how the converters interact with existing protective technology — the last thing the researchers want is for the new power converters to create new problems.

> "In the future, the value of energy will be dependent on the data associated with it."
>
> Study: "The Digital Transformation of the Energy System — 14 Theses for Success," by the Fraunhofer Cluster CINES

The energy transition cannot happen without the digital transformation

Ensuring grid stability is no mean feat — but the digital transformation is capable of much more. In many quarters, it's seen as the key to achieving the energy transition, reducing our dependency on fossil fuels and alleviating the worst effects of the climate catastrophe. "The digital transformation has picked up speed significantly at the various grid levels, particularly in maximum- and high-voltage grids," reveals Dr. Marijke Welisch, managing director of the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES. "But with all the discussions around price increases and gas supply problems, the issue has been relegated to the background. And that's disastrous. After all, practically every aspect of the energy system transformation relies on digital technology — without extensive digitalization, the energy transition cannot be achieved in time." One of the reasons for this is that the energy system is becoming very compartmentalized, due to the proliferation of photovoltaic plants, heat pumps and electric vehicles, etc. However, the grids cannot simply be expanded at random. Likewise, as it now consists of millions of plants instead of a few very large power stations as in times gone by, it would be almost impossible to control the system without digital intelligence to monitor the external influencing factors and divide up the signals. The time needed for the energy transition is another sticking point. Many processes can only run quickly and efficiently if they are run by digital means. "There is a great deal of new equipment and network components in need of approval. However, if the approval applications end up on the relevant official's desk as a fax, that's not effective, and it's not appropriate for the times we live in. The digital transformation absolutely has to happen here too," comments Manuel Wickert, head of the cluster's research team for digital transformation.

In "Digital Transformation of the Energy System — 14 Theses for Success," a study published at the end of September 2022, the researchers in the cluster outlined a number of theses on the subject; each one is accompanied by a summary of the key facts for policymakers and specific recommendations for action for the energy sector. "We started by analyzing project scenarios: What might a completely digitalized energy system look like in five years time? What about a completely analog one? Or a system that maintains the status quo? Using these scenarios as a basis, we combined trends from the energy sector and the digital transformation, and looked for areas of overlap," explains Dr. Welisch. This process allowed the researchers to identify five key focus areas: data economy, energy systems integration, power plant communications, cybersecurity and grid operation and planning. When it comes to the data economy, it is essential for grid operators to have sufficient data for power trading and planning related system services, such as instantaneous reserves. Because after all, uncertainty increases the costs of compensation. This is why the first thesis states that in the future, energy's value will be dependent on the data associated with it. This is best explained using an example: There was a solar eclipse on March 20, 2015 and it was not clear how this natural phenomenon would affect the generation of solar power — as such, compensating current was provided at very high prices. The more meteoro- ▶

back to page 1

logical and photovoltaic data available, the more effectively and cheaply these kind of events can be managed. "This is why we should not just be relying on smart meters as an efficient data source; we should also take plant manufacturers' cloud systems into consideration," the researchers add. The scientists also advocate for cybersecurity reforms. In the study, they suggested that rather than trying to protect every energy system without exception, it would be better to change our attitudes at a fundamental level. Instead of attempting to achieve an all-encompassing defense, we must try and design systems that can handle possible faults, attacks and outages more effectively — and maintain operation of critical processes even in difficult situations. "With this study, we hope to spark discussions within the political sphere about the importance of the digital transformation for the energy transition," concludes Dr. Welisch. And this might just give Germany's energy transition the push it needs.

In fact, Germany's energy market is in ever more urgent need of fresh ideas to increase its resilience against the impact of international political developments — and to stem the tide of climate change too, of course. For some people, looking back on Germany's dependence on gas pipelines brings to mind the image of a patient hooked up to an IV. The Fraunhofer Institute for Solar Energy Systems ISE's Energy-Charts platform offers an overview of this "medical history." The platform, which is freely available online and updated hourly, offers important data and interactive graphics on topics like electricity production and stock exchange prices — meaning that it plays an important role in keeping discussions around the energy transition transparent and factual. "We use data from ten providers, including the EEX energy exchange in Leipzig, where all transmission system operators report their data and the equivalent association for European transmission system operators, ENTSO-E," explains Prof. Bruno Burger, who created the Energy-Charts at Fraunhofer ISE. The graphics reveal various patterns: For example, the charts tracking the annual expansion and contraction of Germany's net installed solar capacity show clear dips corresponding to the policies of particular energy minsters — the "Altmaier drop" and the "Gabriel trough," as the researcher calls them. While an additional 7.91 gigawatts of net capacity was installed in Germany in 2011, only 3.7 gigawatts were added in 2013. Then in 2014, that number fell to 1.19 gigawatts. In addition to illustrating the changes in power and gas prices, the charts also allow viewers to see the share of renewable energy in the energy mix, trends in power consumption, weekly and yearly power supply volumes and the typical daily development of power generation and consumption figures.

For the electricity prices, the researchers not only analyze data from the past and present, but also make projections for the future. Unfortunately, these pre- ▶

"Russian gas was cheap. Now it will take us until at least 2030 to really get back on course."

Prof. Bruno Burger, Fraunhofer ISE

back to page 1

dictions provide little in the way of hope. In December 2022, the price of power is expected to reach 51 cent per kilowatt hour; by the first quarter of 2023, it is set to jump to 68 cent. Even by the first quarter of 2024, the prices are likely to be at a level of 43 cent — so no relief in sight. "We warned previous German governments over and over that if nuclear energy and coal are phased out, we would need renewable energy to compensate. But Russian gas was cheap. Now it will take us until at least 2030 to really get back on course — the current government cannot put this situation right in one legislative period," says the researcher.

Smart coatings keep the heat in or out depending on the season

Energy savings don't have to come at an exorbitant price, especially given the new opportunities that new technologies are creating here — take smart windows, for example. They can reduce the need for air conditioning by blocking the sun's thermal radiation in summer and then reduce the need for heating in winter by letting the sun's warmth in. These thermo- or electrochromic coatings can reduce a building's cooling and heating energy requirement by anything between 10 to 60 percent, in extreme cases. Researchers at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP are working with partners to develop the basis for these coatings. "In the EU project Switch2Save, we and our partners at the University of West Bohemia in Plzeň succeeded in manufacturing thermochromic vanadium dioxide coatings on ultra-thin glass at pilot scale using the roll-to-roll process," reports Dr. Cindy Steiner, group manager at Fraunhofer FEP. "This achievement is an important step on the road to scaling this technology!"

The Fraunhofer Cluster of Excellence Programmable Materials CPM have made a similar breakthrough with programmable insulation for building facades, enabling the outer casing of a house to react to the external temperature. This insulation is based on a foam that changes its form depending on the temperature. At high temperatures, its pores open and expand; then at night, it becomes compressed, allowing fresh air to circulate through openings in the rear-ventilated facade. During the manufacturing process, the producers can determine how the foam will change its form and at what temperatures. What makes this foam so special is that the process is reversible, meaning the foam can keep re-opening and closing its pores. "This kind of insulation makes a massive difference for cooling especially, where it can save up to 40 percent of the energy," says Dr. Susanne Lehmann-Brauns, who heads up a group devoted to these programmable materials at Fraunhofer CPM.

However, energy saving measures by companies have a greater impact than those in private households. The latter accounts for only 26 percent of Germany's power consumption, while industry makes up 44 percent. For those looking for possible ways of saving energy in the industry sector, the Fraunhofer Institute for Systems and Innovation Research ISI is there to lend a helping hand. Since 2009, the ISI's researchers have been conducting

Make some room! Finding space for solar modules and wind turbines

Germany has set itself some ambitious energy transition targets, and solar and wind power are the cornerstones of its strategy. For solar energy, the country has stated that it aims to expand its capacity to a 400 gigawatt peak by 2040. That raises a number of questions: For one thing, will we have enough space for all the photovoltaic modules we need? If yes, where will we put them? And how can we find room for them with as little conflict and as much public support as possible? "We will have enough space," asserts Dr. Harry Wirth, head of the Photovoltaic Modules and Power Plants section at the Fraunhofer Institute for Solar Energy Systems ISE. "And it's all thanks to integrated photovoltaics. And that's not all they can do. Integrated photovoltaics have the potential to create useful synergies in a wide range of applications." For example, in agriculture, the modules can be mounted on stands over the fields, where they will give crops a certain amount of shade and protect them from extreme weather events. The researchers are using simulations to determine how much light would come through, how various types of plant would fare under the modules and how the photovoltaic systems would affect harvests. Scientists are also investigating the possibility of floating photovoltaics. In addition to protecting quarry ponds and artificial lakes from overheating and excessive evaporation, the modules could reduce wave action, which would reduce the erosion of the shorelines. Building facades also have plenty of room to spare, but as yet they have only rarely been used for generating solar power. However,

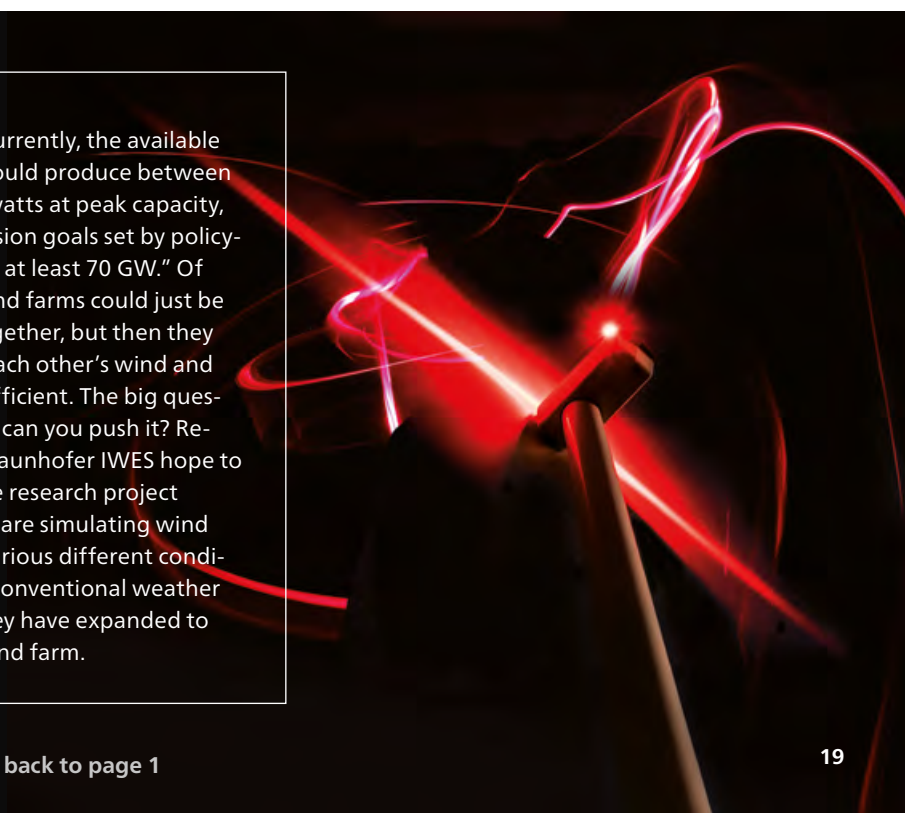
the preparatory work that allows for quick implementation of solutions today. "We already set up 30 pilot networks more than 13 years ago. They generally consist of 8 to 15 companies and a technical energy consultant that link up for a period of 2 to 3 years with the goal of implementing energy efficiency measures in areas like heating and cooling, lighting, air compression, process optimization and operational workflows, so as to reach a specific energy saving target," explains Lisa Neusel, a research fellow at Fraunhofer ISI. The foundation of this initiative is a network management model developed during the pilot phase of Fraunhofer ISI's "Lernende EnergieEffizienz-Netzwerke" (learning energy efficiency networks) project: This uniform standard makes it possible compare the networks' energy saving successes in a scientific manner. The tool the researchers developed for the model records various details, such as the amount of CO_2 saved by a particular measure, the category the measure belongs to and how much it cost. The companies also engage in a moderated discussions, which is a vital factor for the networks' success. "Regular peer-to-peer discussions help the businesses involved to quickly learn where they can save energy," Ms. Neusel points out.

The German federal government was quick to adopt this impressive network model: In 2014, it joined forces with 22 industry associations and organizations to create the "Initiative Energieeffizienz- und Klimaschutz-Netzwerke" (energy efficiency and climate protection networks initiative). The initiative now comprises 346 networks and over 3,000 companies. Since 2014, the process of implementing the steps proposed in the initiative has been supported by annual voluntary monitoring conducted by Fraunhofer ISI and the adelphi research and consultation institute.

> "We have been wondering how to get companies to consider the question of energy efficiency at board level for quite some time. Now, unfortunately, Putin has done it for us. Energy has gone from a typical secondary issue languishing in a corner to a strategic priority."
>
> Prof. Clemens Rohde, Fraunhofer ISI

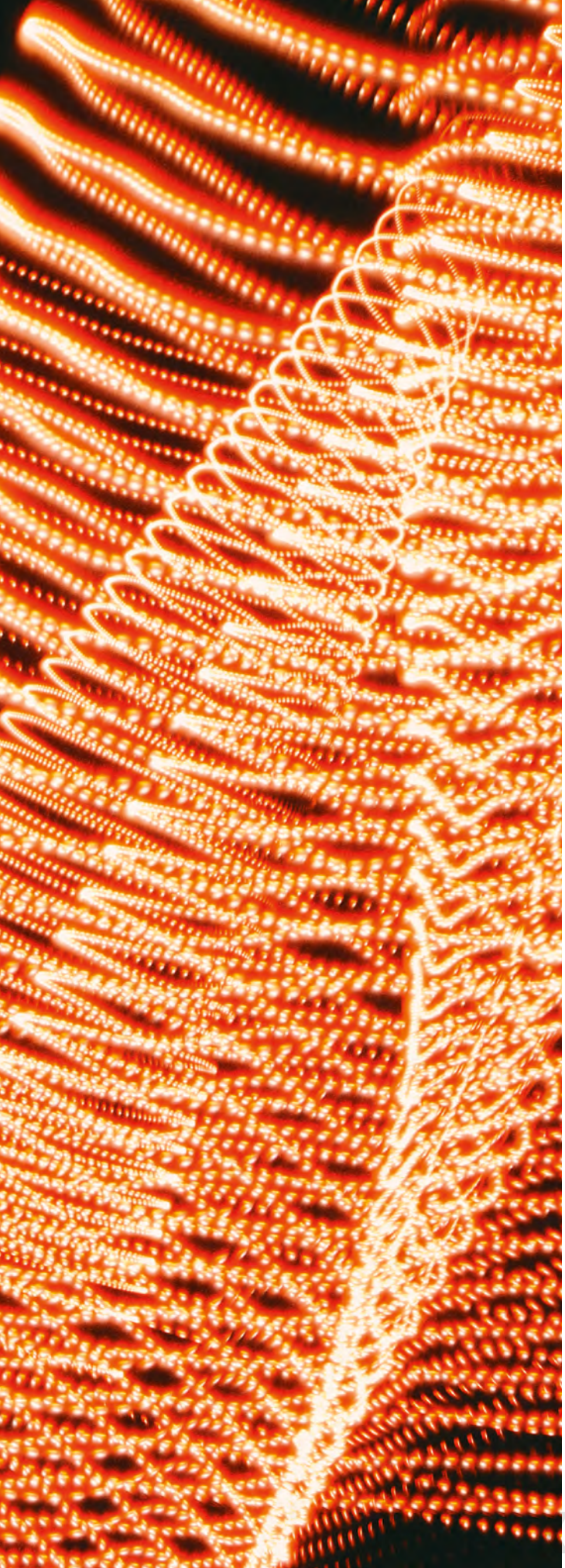
Now, finding ways to save energy quickly is a more topical subject than ever in the initiative. The networks help the companies to reduce their energy consumption and mitigate the effects of energy price increases within the space of four weeks, through practical, low-investment measures that can be implemented in the short term. "The best option here is a change in the way a company consumes energy, i.e., measures that can be adopted without any large investments," explains Prof. Clemens Rohde, a business unit head at Fraunhofer ISI. Prof. Rohde estimates that depending on the company, short-term measures can achieve savings of around 5 percent. "However, in the medium term," the professor continues, "companies must take a strategic approach to this issue. We have been ▶

with Fraunhofer ISE's MorphoColor® coating, solar modules will no longer be a threat to architectural aesthetics — instead, they will come in a blaze of brilliant colors. Space can also present an issue where you would least expect it: at offshore wind farms out to sea. However, there are obstacles like nature reserves and shipping routes to contend with. "There is no other country apart from Germany that has set such high targets in proportion to its size, while having so little space available for offshore wind energy," says Dr. Martin Dörenkämper, group manager at the Fraunhofer Institute for Wind Energy Systems IWES. "Currently, the available surface area could produce between 50 to 60 gigawatts at peak capacity, but the expansion goals set by policymakers call for at least 70 GW." Of course, the wind farms could just be built closer together, but then they would block each other's wind and become less efficient. The big question is how far can you push it? Researchers at Fraunhofer IWES hope to find out. In the research project X-Wakes, they are simulating wind flows under various different conditions, using a conventional weather model that they have expanded to represent a wind farm.



back to page 1

Can Kaymakci of Fraunhofer IPA has developed a platform for smart energy flexibility management in the project SynErgie.



wondering how to get companies to consider the question of energy efficiency at board level for quite some time. Now, unfortunately, Putin has done it for us. Energy has gone from a typical secondary issue languishing in a corner to a strategic priority." Saving energy is important. However, using the energy we generate in the most consistent way possible may be even more important, as consistent energy use brings a double advantage. Not only does it have a positive effect on companies' balance sheets, but it also improves grid stability. And that's a big plus, because although fluctuations don't do the power grid any favors, they are an inherent part of wind and solar energy. Making our energy requirements more flexible could be at least a partial solution here.

> "The companies can use the market platform to find various services that will help them commercialize their energy flexibility."
>
> Can Kaymakci, Fraunhofer IPA

However, this will require incentives, such as energy balancing markets, for example. These markets are attractive for large-scale energy consumers such as aluminum or paper manufacturers, because they can save a great deal of money if they bring their systems on- and offline in accordance the grid's needs — which will also stabilize the electricity grid. However, to do this, companies need to know what opportunities for energy flexibility their business offers, and grid operators and companies must communicate with each other. Luckily, researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and their partners in the project SynErgie have developed an energy synchronization platform that can make this happen. "The platform is divided into two subplatforms, one for production companies and the other for offering and procuring market services," explains Can Kaymakci, a Fraunhofer IPA scientist. The company version shows businesses the various measures they can adopt to make their energy requirements more flexible. It analyzes data from companies' machinery, identifies areas that offer dynamic energy flexibility in production processes and infrastructure, and shares this information in a standardized way. While these processes can be fully automated, most companies prefer to have a human as the final decision-making authority.

Options for creating energy flexibility include delaying production start times and adapting machinery ▶

back to page 1

layout plans and working hours. It is also possible to implement technical measures for improving energy flexibility, such as switching energy carriers or taking advantage of processes' inherent energy storage capacity. Other opportunities lie in the control systems for company infrastructure, for example, the air compression and air conditioning systems. "Cooling and heat generation are a particularly promising areas of potential. For example, depending on energy prices, a furnace can run on gas and/or hydrogen, or electricity; you can even switch from one source to another during operation," explains Mr. Kaymakci. To take another example, if there is an oversupply of electricity, the furnace can be set to full power and heated to a higher temperature for a short period, and then draw from this higher temperature when electricity prices increase later on. The platform already offers integrated services for optimizing this kind of load curve. "The services' central database and functionalities are standardized; however, there are different services for each process, which are also adapted to suit the specific company," Mr. Kaymakci points out.

The researchers also described the market side of the platform. "The companies can use the market platform to find various services that will help them commercialize their energy flexibility," Mr. Kaymakci continues. The platform cannot be used to conduct transactions or exchange data or energy — it is intended to function more like a kind of business directory. Because even large companies are not active on the energy market themselves; they leave this to marketers and aggregators that combine the energy flexibility of multiple businesses into a "virtual power plant" and make it available on the energy market. Essentially, the market platform makes it easy for companies and marketers to find each other.

> "We have a potential of 19.7 gigawatts. Our system can drastically reduce the load on the energy grid."
>
> Can Kaymakci, Fraunhofer IPA

Boosting industrial energy saving potential through targeted incentives

But how effective is this kind of solution? "With the industries and sectors in our consortium alone, we could reduce the energy grid load by 10.7 gigawatts for 15 minutes, or increase it by 9 gigawatts. That means we have a total potential of 19.7 gigawatts — which is equivalent to 5,620 onshore wind farms or 540 of the largest photovoltaic plants in Germany. So, our system can drastically increase grid stability", says Mr. Kaymakci. All the boxes have been checked from a technical perspective — now it's a question of unleashing this potential. And that calls for regulatory incentives. The Fraunhofer IPA researchers are playing their part here too. When Dr Robert Habeck, Germany's Federal Minister for Economic Affairs and Climate Action, brought the energy market back into the spotlight, the IPA team produced a paper to serve as a guide on the topic; now, with the third amendment to the Energy Security Act (Energiesicherungsgesetz, EnSiG), the researchers' efforts to drive regulatory change are bearing fruit.

This basic principle of flexibility and networking also works at a smaller scale, making it possible to achieve new levels of security even in difficult times. For example, there is great potential to be unleashed in the area of electric vehicles, as not only can they store energy for themselves, but they can also compensate for grid fluctuations by acting as storage batteries. That presents an advantage for both grid operators and the users of e-vehicles. In a one-year trial run in Denmark, users earned 1,300 euros on average from feeding power into the energy network on a counter-cyclical basis. However, many e-car owners would be unable to benefit from this type of system, because they would need a vehicle with bidirectional charging, and the first models are only coming on the market now. "In order for electric vehicles to be integrated into an intelligent power grid, the network operators would need to know how many cars they can charge up or draw from, at what times and to what extent," explains Oliver Warweg, a group manager at the Advanced System Technology (AST) branch of Fraunhofer IOSB. "If they have to control each vehicle separately, the costs will be enormous." And these costs do not yet reflect the current value. That's why Fraunhofer researchers are working in a variety of different projects that aim to make the process less costly by enabling grouped communications with the vehicles.

In one such project, Shared Area Charging, the scientists plan to equip a parking lot with 40 charging stations and treat it as a virtual storage facility. In the long term, many of these virtual storage facilities could be merged, allowing the energy suppliers to communicate with them as one group. The key ingredient here is an app where vehicle owners can specify the charging level their cars need. The researchers at Fraunhofer IOSB-AST are using the information from the app to operate the system and develop the algorithms needed to combine large numbers of vehicles into one entity. "For example, we need projection models for planning which cars would be available at what times and how much storage capacity they have. We are also working on integrating the flexibility this would create into our market offering, i.e., dividing up

the theoretical flexibility shown in our calculations and assigning it to individual vehicles that are actually available." An initial pilot project is running in a neighborhood of the city of Suhl in Thuringia and plans are in place to conduct a larger pilot in Erfurt. The team are also working to create a shared area charging model for an entire city district. Rather than taking place under controlled lab conditions, this project is being carried out in the real world — and now, the researchers' vision is gradually coming to life.

A 'self-aware' energy system?

That's not the only dream now becoming a reality, as climate activists' hopes of seeing a rise in the share of solar energy are also coming true. Many people are installing rooftop photovoltaic systems on their houses in preparation for winter — in fact, almost every module on the market has been bought up. However, with every new set of solar cells and every new electric car connected to the grid as a power storage unit, the energy system becomes more decentralized and complex. And that means it is also much harder to manage. "It's not as easy to match up generation and consumption as it used to be," confirms André Baier, a project manager at Fraunhofer IEE. "What we really need now is a high degree of automation, including artificial intelligence, so that in future, we will be able to coordinate complex processes with each other in real time." The Bundesverband für Energie und Wasserwirtschaft BDEW (German federal association for the energy and water sectors) is clearly thinking along the same lines, as it hopes to make the energy sector a leading market for artificial intelligence. And that is an important goal for Fraunhofer IEE as well.

That is why the institute is bringing its expertise to bear in various related research initiatives, such as IC4CES, alongside other stakeholders from research, industry, society and politics. Their mission is to give the energy system an "awareness" of the state of its systems, so that it can control them autonomously in the future. "We hope to use artificial intelligence to create cognitive energy systems that will make an energy supply based on renewable energy possible, secure and affordable," says Mr. Baier. The researchers are focusing on three key areas here: The first key area is cognitive energy grids, namely a grid that has the ability to guarantee energy security even in increasingly complex situations. The ideal outcome of this research is to achieve security of supply without increasing the cost of the entire energy system. The second key area is cognitive energy system technology, which covers everything that is connected to the grid, from inverters to the photovoltaic systems themselves and the energy consumers. The last factor is the cognitive energy sector, meaning the problem of how to bring this fluctuating, decentralized energy to the market. Here, the researchers are investigating what kind of new business models would be needed, for example, to account for the interactions between consumers or producers and public utility companies.

To demonstrate the potential of artificial intelligence, the researchers turned to the example of energy trading, specifically wind energy. "We were able to show that artificial intelligence can automatically make any energy that is generated available on the market, and achieve results that are just as good as human sellers, or even better in some cases," affirms Mr. Baier. The research team is using a variety of artificial intelligence approaches here, such as supervised learning, whereby the system makes decisions based on a controlled data set that is used to train it. This is a good fit for applications such as predicting wind and solar energy generation. By contrast, in reinforcement learning, the system runs in a strictly controlled environment, such as a group of power supply lines with a specific operating load. If one line breaks down, the system will detect this and attempt to find the best way of distributing the corresponding quantity of energy across the other lines. If this is not possible, the system must then disconnect individual lines or reduce the amount of power coming from them — which can also be accomplished using AI-driven approaches. Although artificial intelligence is already fit for use in prediction applications, more research is needed in the field of automated grid control. This is because the AI solutions that exist currently are still black box systems — meaning the researchers do not know how AI engines come to the decisions they make. However, Fraunhofer and the University of Kassel plan to change this over the coming years. Awareness is on the rise everywhere; our awareness of energy, and the energy system's awareness of itself. ■

> "We hope to create cognitive energy systems that will make an energy supply based on renewable energy possible, secure and affordable."
>
> André Baier, Fraunhofer IEE

Could artificial intelligence protect our energy grids from cyberattacks? Scan here for the podcast:

back to page 1

German Future Prize 2022

From fast charger to energy saver

Electric cars are viewed as one of the cornerstones of the energy transition. But long charging times and short ranges are making many car drivers hesitate about switching to electric. A new system that can charge a car in minutes is set to change this — and it also offers a solution for a completely different issue.

By Mandy Bartel

As of April 2022, there were precisely 687,200 electric cars registered in Germany. This number has doubled annually since 2020. However, particularly now, when uncertainty is the watchword for our energy supply, an increased number of electric vehicles also increases the risk of overloading local power grids. Together with the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, the medium-sized enterprise ADS-TEC Energy from Nürtingen has now come up with a solution for this problem — and with it, some good news for millions of electric car drivers. They have developed a fast charging system called ChargeBox, which cuts charging time to just a few minutes without overloading the energy infrastructure. And what's more, it even works reliably with a poor or fluctuating electricity supply.

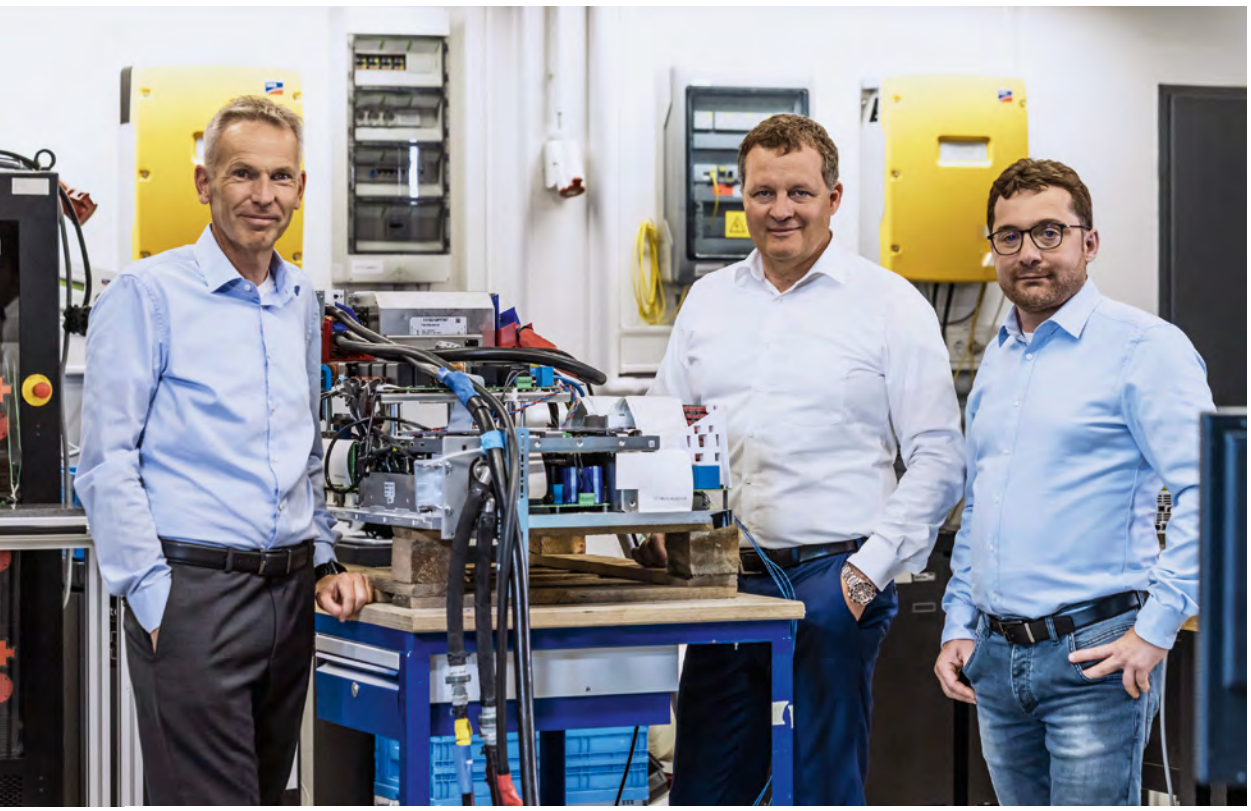
Battery storage trumps grid expansion

According to the German Federal Network Agency, as of mid-2022, Germany had approximately 54,000 standard, alternating current charging stations, which take 2 to 4 hours to charge a car, and 10,000 fast charging points that run on direct current, which reduces charging to 30 to 60 minutes. ChargeBox is based on a new, flexible approach. It consists of a compact and powerful electronic converter, a cooling unit adapted to the converter, and a storage battery — all contained in a space of about 1.5 square meters.

Stefan Reichert, project manager at Fraunhofer ISE, explains the principle behind the system: "The integrated battery storage creates a buffer for the load peaks that occur during fast charging, by storing the energy temporarily. It's only the slower process of recharging of internal batteries that burdens the power grid. This means that costly grid expansion is unnecessary." The battery can hold 140 kilowatt hours (kWh) of energy. By comparison, a two-person household uses around 166 kWh per month, when electric water heating is excluded. The energy conversion losses caused by the power electronics are also minimal. The system can reach 95 percent efficiency when charging the internal storage battery via the grid, and as much as 98.5 percent efficiency for the current flow between the storage and vehicle batteries.

Each ChargeBox can charge two electric cars at the same time. Even during this dual operation, the system can achieve a comparably high charging power of 160 kilowatt per car. When charging a single car, the system can deliver double the charging power. This means that a standard vehicle battery with 100 kWh capacity can be charged to 80 percent within approximately 15 minutes. "The exact time saving is dependent on several factors," says ADS-TEC CEO Thomas Speidel. He goes on to illustrate the advantages using an example: "For a vehicle from a higher performance category, such as a Tesla, it is possible to save around 45 minutes of charging time with the ChargeBox and a normal 50 kW connection, when compared to other systems with the same connection."

The idea for the intelligent fast charger was first sparked by Porsche. When introducing its new electric vehicle Taycan in 2017, the car manufacturer was concerned that existing charging infrastructure would not be capable of charging a car as powerful as it is energy-hungry in a reasonable time. Porsche approached ADS-TEC Energy with the idea of a battery-powered solution, which led to the development of the ChargeBox. However, the system required power electronics that would not only take up much less space, but also offer greater efficiency than solutions that were already available. To tackle this challenging task, ADS-TEC called on Fraunhofer ISE for support. The Freiburg-based Fraunhofer team put their many years of research expertise in the field to good use



The compact and powerful inner workings of the ChargeBox. Dr. Thorsten Ochs, Thomas Speidel and Stefan Reichert (from left to right) proudly present the technology they developed together.

Photo: German Future Prize/Ansgar Pudenz

The German Future Prize has been awarded by the German president since 1997 to honor technological innovations that have definite potential for practical application and represent a significant advancement on current levels of progress in research and technology. The prize is worth 250,000 euros and is awarded annually.

and developed a new kind of power electronics with multiple converters that adjust the voltage gradually and so enable faster and safer charging. To create this technology, they are using innovative semiconductors made of silicon carbide, which have been the subject of research at the institute for several years.

ADS-TEC took charge of the storage battery and the integration and industrialization processes and scaled the ChargeBox up to mass production in 2020. A new production location was set up specially in Saxony, creating several dozen jobs. Over 1,000 systems have been shipped to Europe and the USA so far, and the order books are filling up nicely. "Due to the rapid increase in the volume of electric cars on the road, there is huge growth potential in the fast charger market alone. We expect to produce around 5,000 fast charger stations per year, which is why we have further increased the capacity of our production facility in Dresden," Mr. Speidel tells us with pleasure.

A key component for a resilient energy supply

Besides offering faster charging for electric cars, the ChargeBox has a far bigger future ahead. As a key component in future power grids, it has significant potential to help make our energy supply more resilient. While in the past, energy generation has been based on projected capacity and consumption forecasts, the fluctuating availability of renewable energies is making it increasingly difficult to meet volatile energy demands in good time and cover peak loads. Consequently, local storage solutions are gaining importance as buffers that offer flexibility. ChargeBoxes could potentially also be used in industry or private households to temporarily store power from photovoltaic systems or heat pumps and supply it when needed. If connected to virtual power plants in an intelligent network, they could provide a promising solution to the energy supply problems that are currently causing such concern. This forward-thinking innovation won ADS-TEC Energy and Fraunhofer a place among the three nominees for the 2022 German Future Prize. ■

Scan here for the podcast:

back to page 1

Bärbel Bas, 54, president of the German Bundestag since October 26, 2021

Interview

"We will live more sustainable, digital lives, in our homes and in business!"

She likes soccer, rides a motorcycle — and is the woman with the highest-ranking position in Germany. As a child, Bärbel Bas learned to go without. As president of the Bundestag, she insists that "Upward social mobility shouldn't be the exception!"

Interview: Josef Oskar Seitz

Ms. Bas, we're coming to the end of a difficult year. What gives you hope for 2023?
There is a strong sense of solidarity in Germany. It's much stronger than we often believe. Our general public is very engaged. And our country is proving itself capable of action. Even when it comes to making difficult decisions and saying goodbye to old certainties, such as in security, defense or energy policy. Our skilled workforce is extremely well trained and we have an innovative industry sector — partly because we are so well positioned in terms of applied research. And yes, I am talking about the Fraunhofer-Gesellschaft specifically here.

How can research help us overcome challenges?
We obviously need new technologies for the energy transition. And when it comes to combating climate change, research plays a major role. We're all currently dealing with the war in Ukraine. The most important thing in this regard is determined, political leadership. When it comes to defending ourselves against cyberattacks or safeguarding critical infrastructure, research plays an important role. Before I was elected president of the Bundestag, as deputy chair of my SPD parliamentary group, I was responsible for the areas of health, petitions, education and research. So of course I know that even outside of the current crises, research is becoming ever more important. The Fraunhofer Institute for Microelectronic Circuits and Systems IMS in my constituency of Duisburg is doing outstanding work.

What is more dangerous for our society: the crises, or people's fear of the crises?
We know fear is a bad advisor. It paralyzes us and leads us to make mistakes. Optimism gives us the power to solves problems and overcome crises. That especially applies with regard to Ukraine. Putin's propaganda is deliberately trying to spread fear and divide Ukraine's supporters. We can't let ourselves be intimidated.

On German Unity Day, you said: "Our country has the skills to drive major transformations." What skills are these — and how will our country transform in the next ten years?
In ten years' time, we will be living more sustainable, digital lives, in our homes, in business and in travel. I am confident that we will handle this transformation well. In my speech on German Unity Day, I looked back on the upheaval in our recent past: both the decades of structural change in the area I come from, the Ruhr region, and the upheaval that the East Germans overcame after reunification. These two cases show that our country is capable of a lot — when we pull together and support those that are hit particularly badly by the upheaval. We have so many brilliant minds, and so much creativity, flexibility and imagination in Germany!

Which future-oriented field would you like to see Fraunhofer focus on?
As president of the Bundestag, I must refrain from making public recommendations on matters that fall under the responsibility of the education minister. But since you brought up my speech on German Unity Day, I will say this: Due to my work in eastern Germany, I know the Fraunhofer-Gesellschaft will soon be opening a new location in Lusatia. I think that's exactly the right approach, given the requirement for a structural transformation. As far as I'm aware, at that new location, they will be carrying out research into topics surrounding energy, among other things. Of course, there is also a lot of work being done in that field at the other Fraunhofer institutes. It's clear to see that's exactly the type of research we urgently need at the moment.

In his final speech as president of the Bundestag, your predecessor, Wolfgang Schäuble, said: "Politics is about more than just scientific knowledge — and after all, scientific knowledge is certainly not the same as a democratic majority." Will science be more important in the future? And how can research help you as the representative of the democratic majority to take action more quickly?
Yes, I believe research will become increasingly important for our society, and its significance has become more visible during the pandemic. Wolfgang Schäuble was correct — scientific evidence cannot replace the struggle for a political majority. It's all about weighing up each side, and about values and interests. Parliament and the government need to use scientific findings to help them make, and take responsibility for, political decisions. During the pandemic, we've been able to clearly see what that looks like in practice. As part of the political process, scientific findings on the coronavirus had to be weighed up against factors such as citizens' rights to freedom. That's where political responsibility comes into play.

You visited Ukraine in the spring, spending 12 hours on a night train, sometimes even wearing a helmet and protective vest; what was that like for you as a woman born in 1968, part of the post-war generation? ▶

Photo: Thomas Trutschel/photothek/dpa

back to page 1

Away from politics

Together with her husband, Bärbel Bas watches MSV Duisburg play in the Women's Champions League. Siegfried Ambrosius passed away in September 2020.

Close to her roots

Ms. Bas is a keen campaigner for cleaner air in the Ruhr Valley — and it's a goal she's willing to go above and beyond for.

Bouquet for the boss

On October 26, 2021, parliament member Rolf Mützenich congratulates the newly elected Bundestag president with a bouquet of flowers — while German chancellor Olaf Scholz (right) applauds.

Need for mobility

The Bundestag president drives a Harley Davidson Low Rider S — to this day, she loves to feel the 106 hp gasoline engine under her.

I was lucky enough to grow up in a time of peace. As I'm sure many people of my generation did, I took peace for granted. For me, war in Europe was unthinkable. Then in Kyiv, Bucha and Irpin, I understood what it actually means to reach a turning point in history. War has returned to Europe.

You were on the ground in Bucha and Irpin, two locations of possible war crimes carried out by Russian soldiers. Has this encounter with death changed your perspective?

Yes, this visit really moved me. I'll never forget what I saw in Bucha and Irpin. It reminded me once again that we must resolutely stand by Ukraine.

You describe yourself as a pacifist. Can continually sending more weapons bring peace?

The war in Ukraine has brought about a turning point in my own mind. When you're talking about a brutal attack that violates international law and human rights, weapons are indispensable for self-defense. Putin is not prepared to enter into any serious negotiations. We have to face up to this bitter reality. The most recent missile attacks on Ukrainian cities — on civilians and non-military targets! — have shown that we must support the Ukrainian people so they can fight back and protect themselves. That's why it was so important to quickly provide a modern air defense system.

You're only the third female president of the Bundestag, while there have been eleven men. Do we need gender quotas for women?

It is still mostly men who assign positions. Unfortunately, it's been shown in the past that they only look for women when they're obliged to meet a quota. That's why we need quotas. For many years now, the proportion of women in the Bundestag has remained around a third. We can't accept that any longer. Better representation of women is one subject being addressed by a commission that the Bundestag has set up to reform electoral law. As president of the Bundestag, I cannot preempt the work of the commission. But I haven't made any secret of what I want personally. It's high time for all parties to create candidate lists with an equal gender balance. I very much hope that they'll find ways of fulfilling this requirement that comply with the constitution. Incidentally, we don't only need equal representation in politics, but in other areas as well. I'm certain that the research sector can benefit from that too.

You've had a meteoric rise in your career. What were the greatest challenges for you? What obstacles were put in your way, and what does our education system need to make it easier for children to progress?

After my older brother failed high school and dropped out, it was considered inconceivable for me, a girl, to go to high school, let alone graduate — at least from my teachers' and parents' perspectives. So that meant my only option was to find a good vocational training course. Nobody showed me any alternatives, or helped me to pursue them. It's still that way today for a lot of teenagers whose parents didn't graduate high school.

Since my vocational training, I have met so many people who believed in me, encouraged me and offered me opportunities. Others are not so lucky. We need more targeted support to help overcome social prejudices and barriers — regardless of a person's social class, migrant background or gender. There are still few women in technology-related fields. That's detrimental to us all. We need to stop pigeonholing people. It shouldn't be unusual to see someone progress — that should be possible for anyone and everyone. Our education system can definitely do more to counter existing inequalities. That needs to change. Of course, money is a factor here. Education must be free and easily accessible to anyone and everyone.

You've been speaking up more and more often, especially to call for more protection for the more vulnerable members of German society. How have your own life experiences helped you better understand peoples' concerns?

During my childhood, I learned what it's like to go without a lot of things. For a long time now, this has been an everyday experience for too many people. Now they're scared they might not even be able to afford the basic necessities. Dramatic changes like these can leave a mark that lasts a lifetime. Not everyone has the strength or the means to get back on their feet all by themselves. In times of crisis, we must do everything possible to prevent anyone being left behind.

How has your view of the country changed now that you are no longer "one of us down here" but "one of them up there?"

> "We have an innovative industry sector — partly because we are so well positioned in terms of applied research. And yes, I am talking about the Fraunhofer-Gesellschaft specifically here."
>
> Bärbel Bas

We are all shaped by our own background. For this reason, I certainly don't see myself as "one of them up there." At the same time, of course I know that's how many people perceive me. I'm also very conscious that I have now joined the ranks of the privileged in our country. When I hear expressions like "you people up there" or "you Berlin types," it worries me. This distance is not good for our democracy. That's why I support the concept of citizens' assemblies. This is a new way for people to participate, whereby randomly selected citizens from all walks of life, and with the widest possible range of backgrounds, discuss a political problem and then present their recommendations to the Bundestag. I believe that this format can reduce the perceived distance between parliament and the people. For me, it's also very important that I spend as much time as possible at home with the people of Duisburg. On the soccer field, at street festivals, in the community gardens, in the local bar or on visits to local businesses. Those are places where I can talk to people on equal terms and without barriers. Having this closeness with our citizens is very important to me.

You used to play soccer for KBC Duisburg, where current national trainer Martina Voss-Tecklenburg was a teammate of yours. What was she like as a player?
I had the opportunity to play alongside her twice. I saw that as a great honor — especially since I wasn't in top form at the time, to be honest. I only have good memories of Martina Voss-Tecklenburg. I enjoy thinking back on those games, and these days I am delighted to see her successes and remember our encounters on the field.

You always played on the left wing on the field. What did you learn from soccer that you were able to bring to politics?
Perseverance, determination and, above all, team spirit and taking pleasure in what I do. Win together, lose together. Of course, in politics you sometimes have to assert your position against others, but there's got to be a sense of solidarity, whether on the field or in parliament.

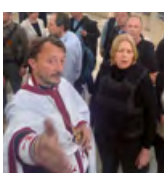
You drive a Harley Davidson Low Rider S. Why does this motorcycle appeal to you — and what would it take for an electric vehicle to pique your interest?
To be honest, I do like to feel the horsepower when riding my Harley. On the other hand, e-cars can now imitate a classic motor. You asked me earlier about where I would like the Fraunhofer-Gesellschaft to direct its focus. If you could develop something in that area, I might be convinced to try an e-motorcycle.

What do you hope people will say about Bundestag President Bas at the end of her period of office?
Ask me again in three years' time.

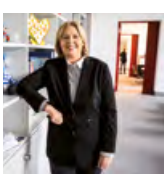
What will Bärbel's friends say about her?
She's still the same Bärbel we've always known. ■

Always on the ball
On her inaugural visit to Poland, the Bundestag president visits a social facility in Warsaw for Ukrainian refugee children — and demonstrates her talents as a left-wing soccer player.

Train journey into a war zone
"I can honestly say that for those 12 hours on the night train, fear was my traveling companion," reported Bärbel Bas after her journey to Ukraine.



Horrific images
Priest Andrij Halawin showed his Berlin visitor photos of the atrocities committed in Bucha.



60 square meters
That's the size of the president's office — "which is bigger than my Berlin apartment," jokes Bärbel Bas, "my home is just 42 square meters."

Photos: Xander Heinl/photothek, Bahmut Pavlo/Ukrinform/Abaca, Andreas Stein/all dpa, Hayrettin Özcan/FUNKE Foto Services, Henning Schacht, Stella von Saldern/both German Bundestag, private, Niels Starnick/BILD am Sonntag

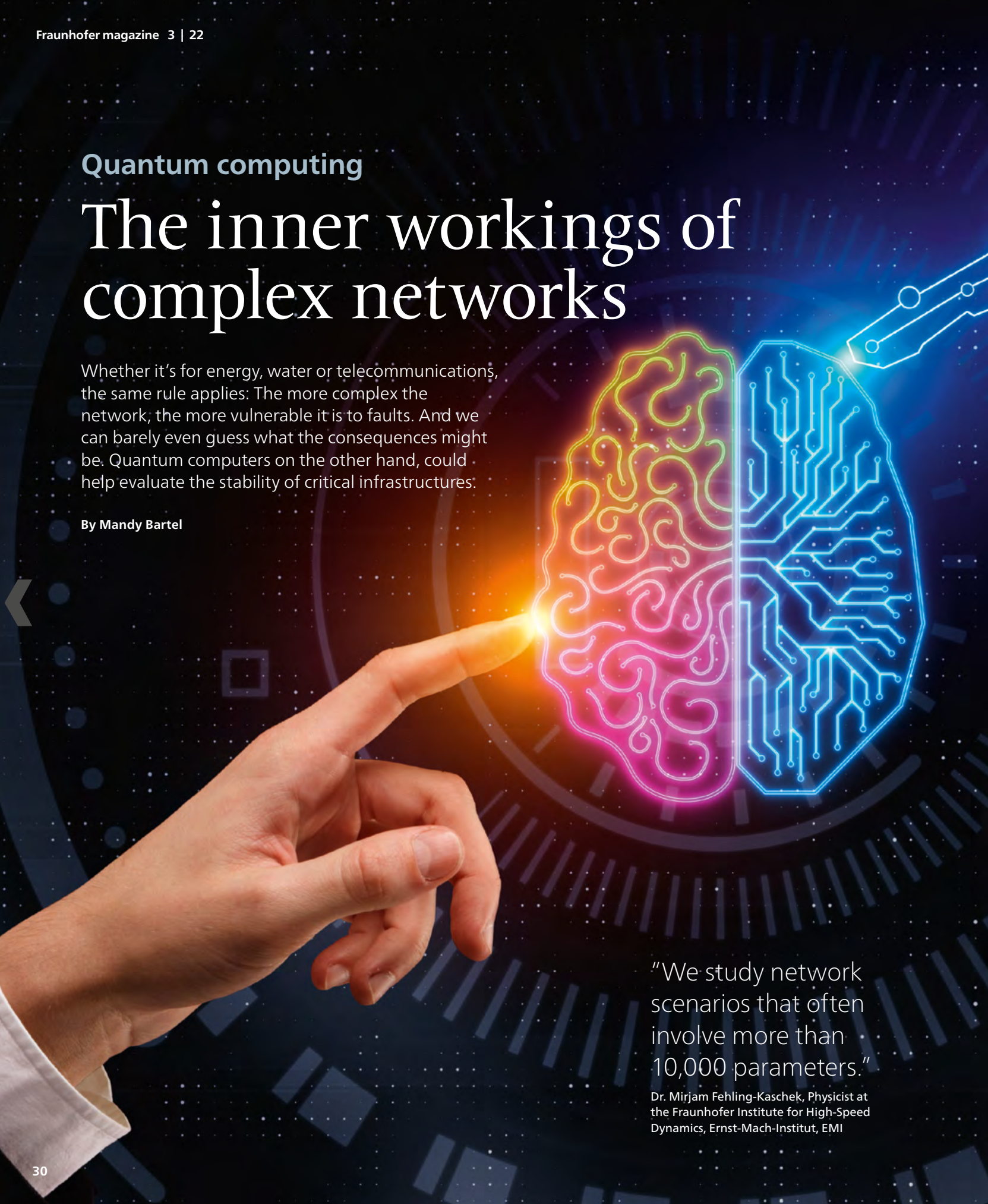
back to page 1

Quantum computing

The inner workings of complex networks

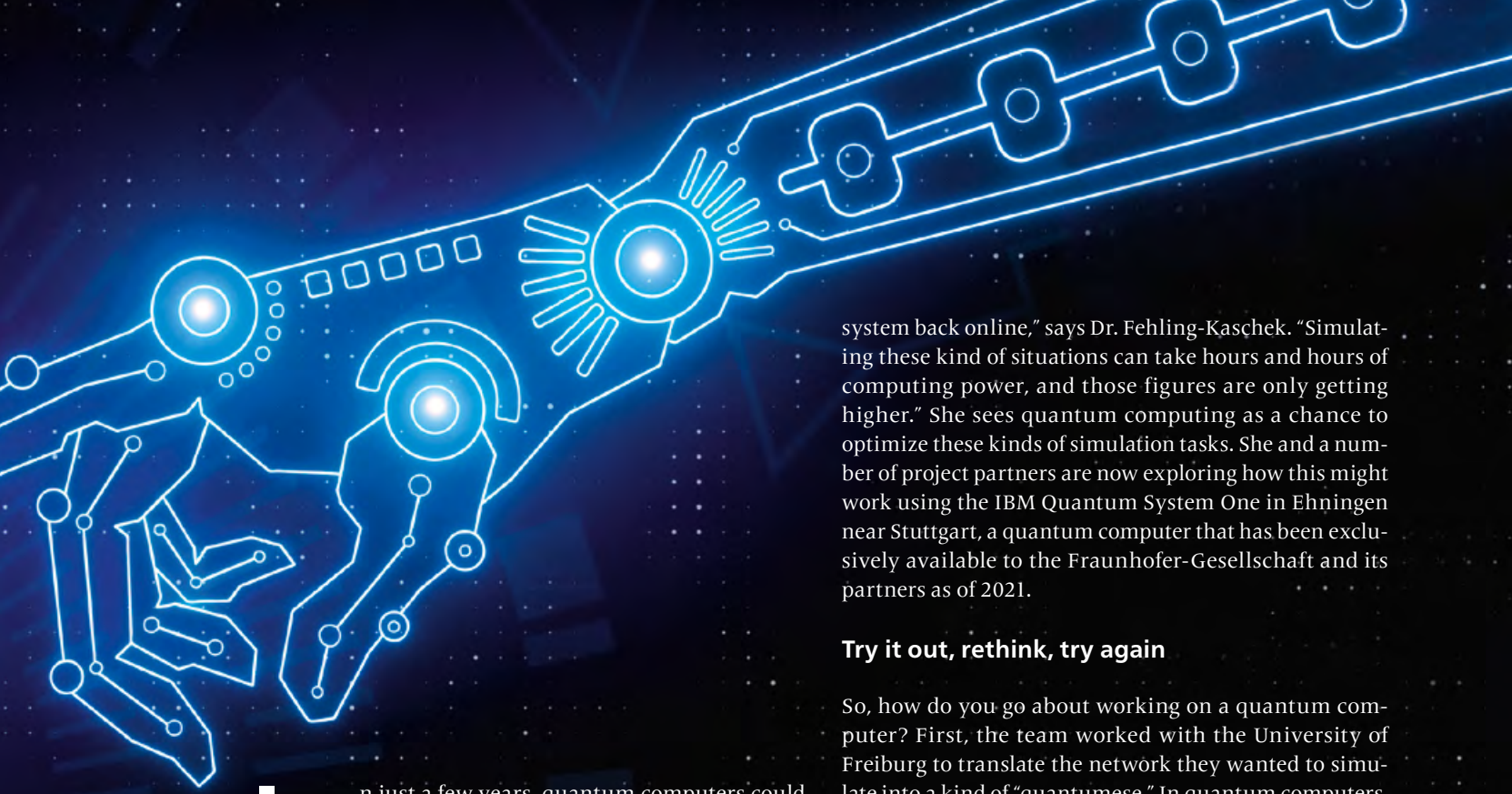
Whether it's for energy, water or telecommunications, the same rule applies: The more complex the network, the more vulnerable it is to faults. And we can barely even guess what the consequences might be. Quantum computers on the other hand, could help evaluate the stability of critical infrastructures.

By Mandy Bartel



"We study network scenarios that often involve more than 10,000 parameters."

Dr. Mirjam Fehling-Kaschek, Physicist at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI



In just a few years, quantum computers could change the world — to some extent at least. Certainly, the process of working on quantum computing and its possible fields of application will change the professional world. In fact, the transformation has begun already, or at least it has in Dr. Mirjam Fehling-Kaschek and Dr. Corinna Köpke's experience. "The project brought together a lot of people that had almost nothing in common before that. Now, we are working more closely together across not just departments, but also institutes, and everyone is benefiting from all these different perspectives and forms of expertise," reports Dr. Köpke.

Even though it may be some time yet before quantum computers can solve practical problems, the collaborative research process is an advancement in itself. Since 2020, Fraunhofer researchers have been looking for concrete problems that could be solved more quickly and efficiently with quantum computers.

The conventional computer is reaching its limits

Dr. Mirjam Fehling-Kaschek, physicist at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI was instantly sure: "I have to give this a try!" She and her team have been working to evaluate the resilience of critical infrastructures using simulations. But as energy, telecommunications and water supply networks reach ever more intricate levels of complexity, the computing power needed to map them grows higher and higher.

"We study network scenarios that often involve more than 10,000 parameters — from potential cascade effects and repair times to the optimal sequence for bringing a system back online," says Dr. Fehling-Kaschek. "Simulating these kind of situations can take hours and hours of computing power, and those figures are only getting higher." She sees quantum computing as a chance to optimize these kinds of simulation tasks. She and a number of project partners are now exploring how this might work using the IBM Quantum System One in Ehningen near Stuttgart, a quantum computer that has been exclusively available to the Fraunhofer-Gesellschaft and its partners as of 2021.

Try it out, rethink, try again

So, how do you go about working on a quantum computer? First, the team worked with the University of Freiburg to translate the network they wanted to simulate into a kind of "quantumese." In quantum computers, information is stored in the form of qubits. Quantum circuits between these qubits allow quantum computers to understand their tasks. Because today's quantum systems do not have enough qubits for the EMI team's large-scale problems, the scientists first had to reduce the network in question to a small number of parameters. They made this task easier using a workaround whereby they divided the problem up into smaller subsections, putting the transfer of information between the individual "nodes," i.e., the parameters, in one section and the fault and its effects into another.

"While quantum computers can already map the first section quite well, we have found that simulating the parameters relating to a fault still requires more research," reports Dr. Köpke, who shares joint responsibility for the project with Dr. Fehling-Kaschek. Now, they need to rethink and try again. For their next step, the researchers plan to test a different approach that will reduce the complexity even further.

However, testing and thinking flexibly will not get them off the starting blocks, so long as their research is hindered by the limits of the hardware. "To simulate a realistic number of nodes using our current approach, we would need many times the amount of entangled qubits," explains Dr. Köpke. "And that's still a long way away." Despite this, they have no intentions of waiting idly, as Dr. Fehling-Kaschek has made clear: "The only way to bring the application stage any closer is to try things out now and keep on doggedly pursuing our course." However, the two researchers fully agree that even today, just the opportunity to conduct research on a quantum computer has taught them an enormous amount. ■

Photo: peshkova/AdobeStock

back to page 1

Airmail 2.0

Drone delivery takes off in Malawi: A new mobile communications module enables the remote control of drones — even over long distances and difficult terrain. However, the technology may also be of interest to Germany.

By Tim Schröder

High-tech carrier pigeon: Thanks to the SUCOM system, drones can be operated remotely and securely via a mobile communication network.

The idea is simple, and pretty compelling. It was just the technology that had proved tricky — until now. In Malawi, one of the poorest countries in the world, many areas are cut off from access to medical care during the rainy season. Drones are therefore used to deliver drugs, blood reserves and other life-saving supplies. Flying distances of up to 40 kilometers across remote, hilly terrain, the drones are operated remotely by pilots via a mobile communication network. However, this is where conventional mobile communications technology falls short. Network losses occur frequently, just as they do when traveling by train or car in Germany. The drones are then forced to switch to expensive satellite communications technology. As part of the collaborative SUCOM project, experts from the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, HHI in Berlin as well as the Hessian drone manufacturer Wingcopter and two other companies have therefore come together to develop a highly reliable mobile communications module that comes integrated in the drone.

> "Just because your mobile phone connection drops when driving or when traveling by train does not necessarily mean that the same applies to a SUCOM drone."
>
> Tom Piechotta, Fraunhofer HHI

Drones now take off from four airfields in Malawi. At each airfield, a "remote pilot" enters the current route into the system and defines the waypoints that will guide the drone. One click is all it takes to send the flight details to the drone. The data needed to make this happen is sent by the remote pilot to a server in Cape Town, from where it is transmitted to the SUCOM module and then on to the flight controller on the drone. A second click launches the drone. While in transit, the drone is monitored continuously by the remote pilot in real time. If a critical situation arises, such as an approaching aircraft or helicopter, for example, the pilot can intervene manually via the system. The drone is also equipped with satellite technology, which can be used if the DSL connection fails. On the down side, radio communication between the drone and the ground-control station via satellite is slow and expensive. As part of the SUCOM project, Tom Piechotta's team at Fraunhofer HHI have succeeded in making communication via DSL sufficiently stable to all and to eliminate connection loss.

This success was based on intensive research into the reasons why connections drop. "Among experts, there are several hypotheses about why autonomous drones that communicate via a mobile communication network drop connection so often," explains Tom Piechotta, who is coordinating the SUCOM project. One possible explanation is insufficient network coverage. Another explanation is that when flying at high altitude, the drone has access to too many cell towers and keeps switching between radio cells, which can cause the connection to drop. However, in collaboration with his team, Tom Piechotta found that it is the communication protocols typically used by the drones that are causing issues. They are not robust enough to handle fluctuating data rates. As a result, some data packets take longer to transmit, while others are lost altogether.

For the SUCOM module, Tom Piechotta and his team developed a new set of communication protocols that are better able to withstand erratic data streams. The drone stays connected, even if the data rate fluctuates. "For comparison purposes, we equipped a drone with a commercial DSL system and our own SUCOM module," he explains. "With the conventional module, the connection kept dropping, whereas the SUCOM module maintained a steady connection." For Piechotta, this clearly demonstrated that when it comes to drones, connection loss is not solely down to insufficient network coverage.

There's more to SUCOM. To ensure the rapid transfer of data between the drone and the server in Cape Town, customizations were made to the server hardware and software. The connection is now so fast that the drones in Malawi are able to communicate with Fraunhofer HHI back in Germany in almost real time. 170 milliseconds is all it takes for a data packet to make its way from the drone to Berlin via the server in Cape ▶

Once airborne, the drones are continuously monitored by remote pilots in **real time.**

Photo: Falco Seliger

back to page 1

Safe flight Using mobile communication technology, SUCOM ensures that the ground-control stations remain continuously connected with both the drones themselves and their flight position on the air-traffic con ol visual display system.

Illustration: Fraunhofer HHI

170 milli-seconds is all it takes for a data packet to make its way from the drone to Berlin via the server in Cape Town using a mobile communication network.

Town using a mobile communication network. "The transmitted video images display clearly and in some cases we can even see the drones' precise location."

The remote pilots ensure the routine operation of the drones across Malawi's four airfields. Their main task is to launch the drone and to monitor it once airborne. The drones can also be operated via a smartphone and VPN connection if needed. "The local population are really excited about the project," explains Wingcopter engineer Carsten Ramk, who supported the tests on the ground. "We've even had positive feedback from local health centers. Orders and inquiries are increasing steadily." Malawi now has several SUCOM-enabled drones in operation across the country.

"The local population are really excited by the project. We've even got positive feedback from local health centers."

Carsten Ramke,
Wingcopter project partner

The SUCOM system will soon be put to use in Germany too. With the support of the German Federal Ministry for Digital and Transport (BMDV), Wingcopter is to start deploying delivery drones from spring 2023 to ensure greater coverage for remote areas. "However, here in Germany, there is still a certain amount of skepticism around the reliability of mobile communication systems for drones," Tom Piechotta explains. "Just because your mobile phone connection drops when driving or traveling by train does not necessarily mean that the same applies to a SUCOM drone in the field." To demonstrate, the project team recently arranged for drones to fly over one of Germany's largest mobile dead spots, covering a distance of some 14 kilometers of extensively forested terrain in northern Brandenburg. The flight was a success. Thanks to the SUCOM module, the drones did not lose connection at any point during the flight. ■

Knowledge relay

well prepared critical security

back to page 1

Safe flight: Using mobile communication technology, SUCOM ensures that the ground-control stations remain continuously connected with both the drones themselves and their flight position on the air-traffic control visual display system.

Illustration: Fraunhofer HHI

170 milliseconds is all it takes for a data packet to make its way from the drone to Berlin via the server in Cape Town using a mobile communication network.

Town using a mobile communication network. "The transmitted video images display clearly and in some cases we can even see the drones' precise location."

The remote pilots ensure the routine operation of the drones across Malawi's four airfields. Their main task is to launch the drone and to monitor it once airborne. The drones can also be operated via a smartphone and VPN connection if needed. "The local population are really excited about the project," explains Wingcopter engineer Carsten Ramk, who supported the tests on the ground. "We've even had positive feedback from local health centers. Orders and inquiries are increasing steadily." Malawi now has several SUCOM-enabled drones in operation across the country.

> "The local population are really excited by the project. We've even got positive feedback from local health centers."
>
> Carsten Ramke, Wingcopter project partner

The SUCOM system will soon be put to use in Germany too. With the support of the German Federal Ministry for Digital and Transport (BMDV), Wingcopter is to start deploying delivery drones from spring 2023 to ensure greater coverage for remote areas. "However, here in Germany, there is still a certain amount of skepticism around the reliability of mobile communication systems for drones," Tom Piechotta explains. "Just because your mobile phone connection drops when driving or traveling by train does not necessarily mean that the same applies to a SUCOM drone in the field." To demonstrate, the project team recently arranged for drones to fly over one of Germany's largest mobile dead spots, covering a distance of some 14 kilometers of extensively forested terrain in northern Brandenburg. The flight was a success. Thanks to the SUCOM module, the drones did not lose connection at any point during the flight. ■

Knowledge relay

Prof. Michael Waidner, how *well prepared* are Germany's *critical research* and industry infrastructures *in terms of cybersecurity?*

back to page 1

Knowledge relay, episode 6

Prof. Michael Waidner, how well prepared are Germany's critical research and industry infrastructures in terms of cybersecurity?

Series:
Knowledge relay

The times we live in are raising lots of questions — Fraunhofer researchers are working hard to find the answers. 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. Michael Waidner,** Director of the Fraunhofer Institute for Secure Information Technology SIT, responds to a question posed by **Prof. Tobias Melz,** Director of the Fraunhofer Institute for Structural Durability and System Reliability LBF.

The cybersecurity situation has seen some dramatic developments in the past few years, in Germany as much as everywhere else. According to a survey by Bitkom, an industry association for the digital sector, in 2021, at least 84 percent of all companies in Germany suffered damage as a result of cybersecurity attacks, resulting in a total loss of around 203 billion euros — an eye-watering sum that far exceeds the damages caused annually by natural disasters and road traffic accidents, to name just two examples. The attacks not only affected businesses, but also government administrative bodies such as the district of Anhalt-Bitterfeld and scientific institutions such as TU Berlin — not to mention, of course, private individuals.

The attackers' aims varied widely, ranging from espionage, blackmail and cryptocurrency theft to sabotage and the destruction of physical systems; attackers also stole people's identities in order to commit credit card fraud and spread disinformation for destabilization purposes. Often, they are "only" aiming to cripple a system. The perpetrators of cyberattacks also come in many different shapes and sizes; some are individual offenders, some are criminal groups that offer attacks as a service and others are groups that pursue

specific objectives on behalf of nation-state attackers.

There is no indication that the situation will improve in the near future. On the contrary, as war rages in Ukraine and economic conditions worsen for many people around the world, the rate of cyber-attacks is liable to increase.

High risk of cyber espionage

Outside of Germany, various nations have reported cyberattacks on critical infrastructures, some carrying serious consequences for the local population. In 2015, a Ukrainian power supplier was the victim of an attack by a Russian group — presumed to be directed by the state — which resulted in a power outage that affected more than 200,000 people and lasted several hours. In 2021 the American pipeline operator Colonial Pipeline was the victim of a ransomware attack. The attack targeted the company's administrative systems; however, Colonial Pipeline also shut down its pipelines as a precaution. This resulted in a shortage of gasoline, and a state of emergency was declared in 17 states.

To date, there is no record of a successful cyberattack against Germany's "critical infrastructures" as defined in the Critical Infrastructure Ordinance of the German Federal Office for Information Security BSI (BSI-Kritisverordnung) — according to this definition, if these infrastructures were to break down, there would be dramatic, lasting consequences for more than 500,000 people. German law prescribes strict regulations for these infrastructures' cybersecurity systems and, as a result, they are comparatively well protected against commonplace cyberattacks that target multiple victims at once. For this reason, it is unlikely that one of Germany's critical infrastructures will break down due to a random wave of ransomware attacks. However, there is a high likelihood that cybercriminals directed by a foreign state could successfully carry out an attack on critical infrastructures in Germany. As Wolfgang Wien, vice president of the Foreign Intelligence Service of Germany reported in June 2022, there are indications that Russian and Chinese groups have already infiltrated some of Germany's critical online infrastructures in order to steal data or plant malware. Similar traces have been found in the USA and Australia. This means that the likelihood of cyber espionage against critical infrastructures is very high. I consider cyber sabotage to be just as likely or unlikely as sabotage by conventional, kinetic means. The political considerations should always be paramount, as opposed to the tools used to commit the sabotage.

Prof. Michael Waidner heads up the Fraunhofer Institute for Secure Information Technology SIT and the National Research Center for Applied Cybersecurity ATHENE.

We must be more ambitious

The cybersecurity situation may appear bleak, but it is in no way hopeless. However, we need to become more active and ambitious overall.

The cybersecurity situation in many German companies, government administrative bodies and scientific institutions is still far behind the latest technological developments. There is not enough motivation or willingness to invest — not to mention a shortage of staff. The latter is particularly dangerous in Germany, because here, people still believe that the best way to protect ourselves is to do everything ourselves. Other countries have a much greater reliance on service providers and cloud providers. Implementing general recommendations for basic IT protection, such as the recommendations by the BSI, would block a large proportion of the attacks that succeed today, at least for the time being. Likewise, much could be achieved if the scope of the definition of critical infrastructures given in the BSI-Kritisverordnung were to be expanded significantly

It is also important that we in Germany take expeditious action to modernize our cybersecurity architectures. Implementing zero-trust architectures is obviously a vital step here. Until now, many organizations have based their cybersecurity systems on the idea that there is some kind of trust boundary between their own systems and those on the internet, meaning that everything within their system is trustworthy, while everything outside of it is suspicious. This boundary is protected by firewalls and VPNs. The reality, however, is completely different. Cyber-attackers are almost always able to infiltrate these internal systems, which makes this boundary pointless. This means that our defenses need much more extensive and granular structure. And we are lagging behind other countries here too. For example, the U.S. federal government has mandated that all federal agencies must implement a zero-trust architecture by the end of 2024. What is the most practical way for companies, government authorities and scientific institutions to implement zero-trust models? This exact question is currently one of the most important research topics at my institute and the National Research Center for Applied Cybersecurity ATHENE. ■

In the next issue:

What will the *IT research institution of the future* look like, and what form will *New Work* take in the scientific field?

Photo: Fraunhofer SIT

back to page 1

Our diet is about to go green

Algae have been producing oxygen for 3.5 billion years. Every second oxygen molecule that we inhale originates from them. These photosynthesizing miracle workers could help supply us with food in the future.

By Dr. Sonja Endres, photographer: André Kirsch

Feeding the world

Elke Böhme of Fraunhofer IMTE in Lübeck helps product developers in the food industry source the right algal ingredients for their culinary creations — which range from beer and bacon to ice cream.

back to page 1


Heute
Algen-Ravioli
der vegane Fisch

This fi e powder made from microalgae packs quite a punch. Dr. Ulrike Schmid-Staiger of Fraunhofer IGB has perfected the art of cultivating algae. More protein? Or more carbohydrates, perhaps? Not a problem.

"Compared to terrestrial plants, our algae contain around **ten times** the amount of valuable nutritious substances."

Dr. Ulrike Schmid-Staiger
Fraunhofer IGB

The United Nations has calculated that on November 15, the world's population reached the eight billion mark, meaning that it has doubled in only 50 years. Although the growth rate has significantly slowed in recent years, predictions show that the population will rise to 8.5 billion by 2030, and 9.7 billion by 2050. More people mean less arable land, less drinking water and less food per head of population. Now, with the climate crisis, these shortages are noticeably worsening. Desertification, a process whereby soil deteriorates to the point where the landscape becomes a desert, claims a worldwide acreage the size of Bavaria each year. Within the past 40 years alone, one-third of all fertile land has become unusable — the result of excessive crop cultivation and overgrazing. What's more, our food requirements are set to grow by around 70 percent between now and 2050, estimates the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German society for international collaboration). However, certain aquatic organisms — quite unjustly relegated to a niche existence in the agriculture and food industry, particularly in Europe — could be of help here: algae.

Algae have as much protein as the soybean, are rich in valuable nutrients like fiber and minerals, and contain vitamin B12, which can otherwise only be found in animal products. This superfood does not require fresh water or land. It grows sustainably in the sea, or can be cultivated as single-celled microalgae, normally in enclosed facilities.

Tiny but mighty

Dr. Ulrike Schmid-Staiger is group manager for Algae Biotechnology at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. For 25 years now, she has been perfecting the cultivation of microalgae in photobioreactors — transparent water tanks that supply the tiny organisms with light, CO_2 and nutrients until they grow to form a thick green soup. Dr. Schmid-Staiger currently devotes most of her time to the marine Phaeodactylum tricornutum, which can generate particularly large quantities of omega-3 fatty acids, and to Chlorella vulgaris, which feels most at home in ponds and brackish water and stands out thanks to its high protein content of around 50 percent. When suspended in water, neither alga is detectable to the naked eye. "Compared to terrestrial plants, our algae contain around ten times the amount of valuable nutritious substances," declares Dr. Schmid-Staiger with pride. Every single cell contains the same rich mix of nutrients. Terrestrial plants, on the other hand, also have roots, stalks and leaves. The substances contained in the cells vary in the different parts of a ▶

back to page 1

plant — the protein content of a corn kernel is different to that of its leaves or roots. "I can make use of every part of the algal biomass we grow here. There is hardly any waste material," emphasizes Dr. Schmid-Staiger. And these are not the only advantages microalgae have to offer. For one thing, they grow much more quickly than their botanical, land-based cousins. While 1 hectare of farmland can yield around 30 tons of corn biomass, a photobioreactor with artificial lighting can yield up to 150 tons of algae from the same surface area. Dr. Schmid-Staiger and her team have developed sophisticated systems that can achieve peak yields of some 900 tons per hectare per year.

To create these systems, the team from Fraunhofer IGB connects a set of closely packed flat-panel reactors in series; each layer is 3 to 5 centimeters thick. LED panels that shine on both sides are inserted between the reactors, ensuring a sufficient supply of light. "Light is the key ingredient for cultivating algae," emphasizes Dr. Schmid-Staiger. The light intensity and distribution, which needs to be as uniform as possible, will determine the growth rate. This means that the reactor's contents have to be mixed continually, so bubbles of air and CO_2 are allowed to rise through the container to agitate it. Small baffles on the reactor's interior walls create a special current that repeatedly swirls each cell past the reactor's outer surface, so that they always have a sufficient light supply. "If I give them too much light, it will not be used efficiently and then I'm wasting energy. If I give them too little, the algae won't thrive. We have to find the optimal level between these extremes," says Dr. Schmid-Staiger. The more the algae grow, the more light is needed — meaning the levels require constant readjustment. And different algae have different needs. "Our Phaeodactylum doesn't like too much light, for instance. Chlorella, on the other hand, is a sun-worshipper," says Dr. Schmid-Staiger, chuckling.

> "Light is the key ingredient for cultivating algae."
>
> Dr. Ulrike Schmid-Staiger
> Fraunhofer IGB

A nutrient mix made to order

For a long time, she and her team used to cultivate the algae outdoors. "We had to make do with whatever sunlight was available. We could only produce algae for six months out of the year; after that, the days got too short." While the artificial lighting costs more, it pays for itself, as productivity is up to ten times higher. Moreover, the closely packed photobioreactors can be installed anywhere, even underground, and stacked one on top of the other. So naturally, they do not take up much surface area. Up to 3.5 tons of algae per year can be grown on a plot of only 20 square meters. The same quantity of soybeans would require an entire hectare of fertile arable land, along with some 2,000 cubic meters of water. The algae can grow in a mere quarter of that space. What's more, most of the water supply can be recycled to cultivate the next crop.

Dr. Schmid-Staiger and her team can adjust the cultivation conditions to make the algae produce greater amounts of certain substances. "Of course, to do this, we need to know what function these substances fulfill in the algal cell. For example, if we increase the nutrient supply, this will cause a rise in protein production, while reducing the supply will result in more carbohydrates and fats," she explains. Algal proteins are especially in demand in the food industry these days, as they can be used to replace animal proteins. Researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV extract these proteins and add them to vegan foods. The particular challenge here is eradicating their fishy flavor and green coloring.

Fruity, not fishy

Dr. Stephanie Mittermaier, Head of the Food Process Development department, is experimenting with smoothies, pasta and pesto to begin with. Color does not present a problem in those dishes. She uses various flavorings and herbs to mask the taste of the algae. "I like to use strongly flavored fruits in the smoothies, because the acidity comes to the fore and overcomes the fishy flavor," reveals Dr. Mittermaier. Otherwise, she concentrates on savory products. "Algae can also have a savory or umami flavor." She is still feeling her way toward finding the right amounts. In the process, she has to bear in mind not only the food's flavor, but also its consistency. "For example, if I add too high a concentration to the pasta dough, it can start to crumble, which makes it harder to work with." Does she ever sample her own creations? "Yes, of course, it's important to do that when you're experimenting. Just so I know what I'm doing to ▶

Dr. Stephanie Mittermaier of Fraunhofer IVV is still feeling her way toward finding the right amounts. Before a food goes for tasting, she always samples it herself.

Algae have a high protein content of up to

50 %

and a rich mix of fiber, fats, vitamins and minerals.

back to page 1

"There is so much goodness in seaweed. There's no doubt that it's an important source of nutrition for humanity."

Dominic Wimmer, Fraunhofer IVV

Dominic Wimmer likes to cook with seaweed as often as possible. His hot tip: cod fillet w apped in a saccharina latissima leaf. "It has a marvelous caramel flavo ," he rhapsodizes.

my testers and our trained panel of institute colleagues," she says, laughing.

In the long term, she can envisage making a good vegan fish substitute by combining algal and plant proteins. The algae's fishy flavor could even be an advantage here. However, the color still presents a problem. Anyone for green salmon fillet or green cod? No, thanks. "We will probably lean more toward tuna fish. We could achieve a brownish color, but white is not a possibility." This is because the algal pigments are either proteins themselves, or are so closely bound to the proteins that they cannot be removed without causing damage.

Up to now, microalgae have been sold in tablet form as a food supplement for the most part, while consumers and food industry stakeholders are more familiar with multi-celled marine macroalgae, or seaweed. Most people will have seen this in sushi, where nori, a savory/sweet seaweed, is used to wrap up rice and fish. However, while seaweed has been a dietary staple in the Asiatic world for centuries, Europeans are still dubious about this superfood. It is rarely served in the form of a salad or soup. Yet even consumers that avoid sushi have probably already eaten algae without realizing it, as alginates and carrageen are common food additives. Alginates are often used as a gelatin substitute, while carrageen is added to products such as cream to prevent flocculation and ensure even fat distribution.

Just like their smaller algal counterparts, seaweeds have a high protein content of up to 50 percent and feature a rich mix of fiber, fats, vitamins and minerals like zinc, iron, selenium, potassium, calcium and especially iodine. They are usually grown on long ropes under the sea. Seaweed farming is extremely sustainable, as it only uses resources that are already naturally available. However, it does present one disadvantage: Seasonal and climatic fluctuations mean the quality and amount of nutrients the seaweed contains can vary. In addition, processing macroalgae into food products is more difficult than processing their one-celled cousins from the reactor.

Seaweed sausage? "Tasty" say the food testers

Dominic Wimmer, Project Manager for pilot plants at Fraunhofer IVV, explains: "In barley or wheat, carbohydrates and proteins are simply stored in the center of the kernel. If I put the kernels through a crushing mill, this exposes the endosperm, which I can use right away. However, in seaweed, the proteins and carbohydrates are deeply embedded in the cell wall, so extracting them requires a number of steps.

The dried seaweed leaves must first be ground to a fine powder in order to break the cells open as much as possible. Then, to release the valuable nutrients they contain, Mr. Wimmer mixes the seaweed powder with additives such as enzymes harvested from snails that consume and digest algae. He also enlists the aid of hydrochloric acid and a sodium hydroxide solution. The powder is first steeped in water multiple times; the mixture is then warmed and stirred. The nutrients gradually leach out into the surrounding water, which is then repeatedly centrifuged, that is, separated into solids and a rich aqueous solution by means of a centrifuge. This process allows Mr. Wimmer to achieve a yield of up to 90 percent when extracting proteins from seaweed. He has used these proteins to make products like vegan sausages — with great success. The seaweed sausage was an even bigger hit among food testers than its equivalent meat-based product.

However, the color still presents a problem. Anyone for green salmon fillet or green cod? No, thanks.

Living for seaweed

Mr. Winner "is crazy about seaweed," as he says himself. The qualified master brewer spent several years as a food industry consultant before moving on to a role as a process engineer at Fraunhofer IVV. Since then, he has been working on a range of projects based on the use of seaweed as a food. One of the products he developed from seaweed was a healthy alternative to salt, which he used to flavor snacks like chips and peanuts; he has also experimented with using algae in bread, meat products, soups and sauces. However, his attempts to eradicate seaweed's fishy flavor have been unsuccessful so far. "Either we will get used to it, or I will have to keep looking for a way to remove it ," he says, laughing. "There is so much goodness in seaweed. There's no doubt that it's an important source of nutrition for humanity. I think it offers amazing opportunities for the food industry," he says with conviction.

And the food industry is increasingly taking the same view. The market for vegan products is growing rapidly. According to the Federal Statistical Office of Germany, ▶

back to page 1

More than just fishy: Elke Böhme of Fraunhofer IMTE rates algae's diversity of flavors highly and wants to introduce them to the public.

the country saw a 62 percent increase in the production of foods like vegan sausage and schnitzel between 2019 and 2021. Giving up meat is a trend seen mainly among teenagers and young adults. Compared with the general population, twice as many 15–29 year olds are vegetarian (10.4 percent) or vegan (2.3 percent). A further 25 percent describe themselves as flexitarians, that is, they only eat meat occasionally, while 44 percent want to reduce their consumption in the future, mainly for climate protection and animal welfare reasons. A recent study by Boston Consulting Group has confirmed that alternative protein sources also have a central role to play in food security. The amount of capital invested in this area has increased from 1 billion dollars in 2019 to 5 billion in 2021 — an annual growth rate of 124 percent.

However, many food industry product developers still have no clear concept of how to use algae as a raw material. Elke Böhme and her team at the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Lübeck are giving them some guidance. The food specialist hosts regular algae workshops to show stakeholders from the agriculture and food industry the range of ways in which these marine plants can be used. She is also occasionally contacted by companies that want to do "something with algae." She then tells them about the different types of algae, and describes their features and possible applications. A tasting session is always part of the program. "If workshop participants can taste, smell and feel the products, it makes it much easier to develop their own ideas," says Mrs. Böhme.

Walnut-flavored seaweed

The range of possible applications is vast. Mrs. Böhme has already integrated algal extracts into muesli bars, barbecue sauce, spreadable pastes, beer, lemonade and gin. "Right now we're working on a vegan bacon, using red dulse seaweed for its savory umami flavor. We've developed a special procedure to bring out the flavor even more effectively," she says. She also mentions an algae that, when fried, tastes just like bacon. "Of course, its appearance and consistency are different. Up to now, consumers have only been willing to accept substitute products if they imitated the original as perfectly as possible." This is why Mrs. Böhme uses red dulse as a natural colourant in vegan burger patties, for example. Its color changes from red to brown in the hot pan — just like beef does.

Mrs. Böhme is convinced that eating habits can be changed. It's just a question of increasing people's contact with substitute products.

Workshop participants are regularly surprised to be faced with seaweed ice cream. "Most of them don't expect seaweed to be able to taste like walnut," she says. "To be honest, we were surprised too."

Mrs. Böhme and her colleagues also taste their algae in their unprocessed forms, so they can introduce industry product developers to the full diversity of their flavors. The mildly savory sea spaghetti, or Himanthalia elongata, has been going down particularly well. "We just boil it together with normal spaghetti. This requires less salt, and is a healthier meal containing more dietary fibres", says Mrs. Böhme. She is convinced that eating habits can be changed. It's just a question of increasing people's contact with substitute products. After all, it worked for her: The food specialist has now started using seaweed more often in her own home cooking. What's her favorite? "Nori, for its lovely dark purple color. And its wonderful umami flavor." ■

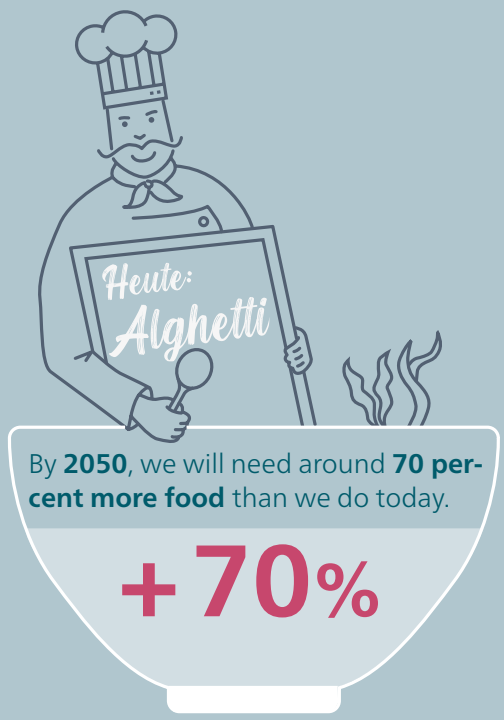
Dinner is served: sea spaghetti entwined with its more familiar wheat-based counterpart. It's a healthy, less-sodium meal.

Photos: istockphoto (4)

back to page 1

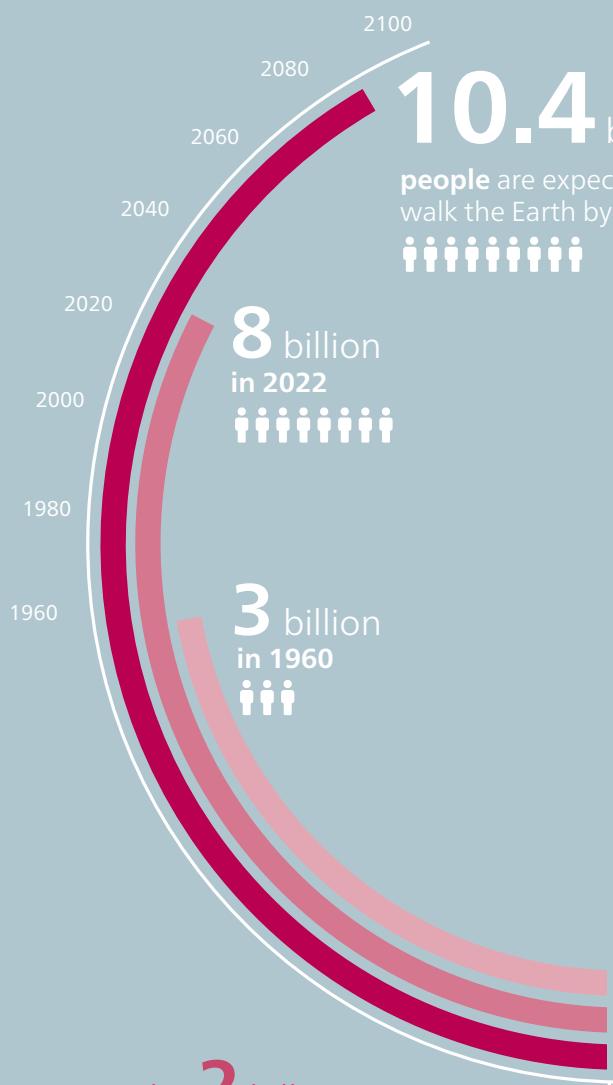
How will we all get enough to eat?

The world's population is growing and arable land is getting scarce — how can we ensure food security in the future? The unassuming alga is one option. Cultivating algae can be very resource-efficient and their nutritional value is high.



By **2050**, we will need around **70 percent more food** than we do today.

+70%



10.4 billion
people are expected to walk the Earth by **2086**.

8 billion
in 2022

3 billion
in 1960

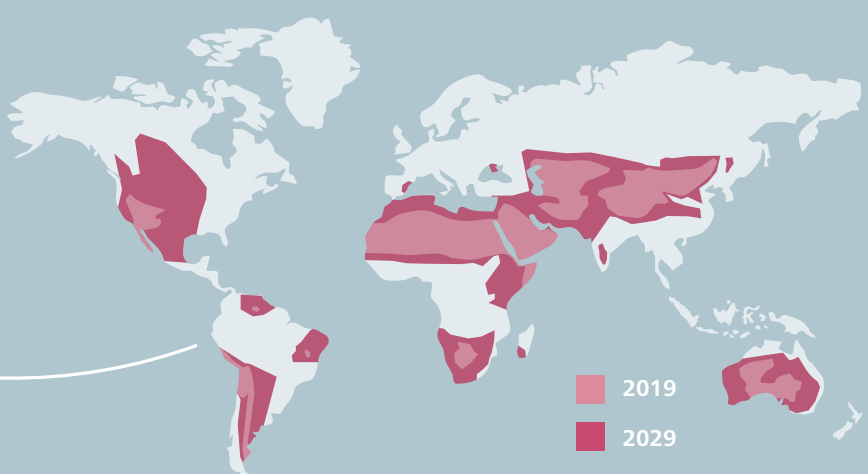
Climate change

Climate change and **soil degradation** are making **droughts** more frequent and more severe. Since the year **2000**, they have increased by **29 percent**. Every year, **55 million** people are affected.

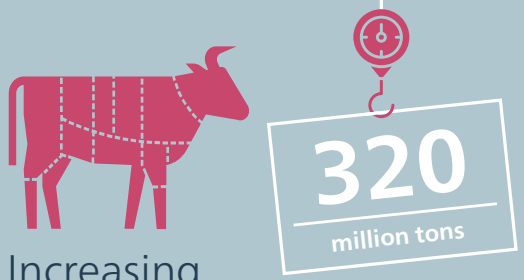
55 million people
worldwide are affected by drought every year

Desertification

Over the past **40 years**, about **one third of the world's arable land has become unusable** due to overgrazing, deforestation and soil leaching. **Global desertification** will **massively increase** in the years to come.



Just under **2** billion
people are suffering from **"hidden hunger"** because they lack essential **vitamins** and **minerals.**



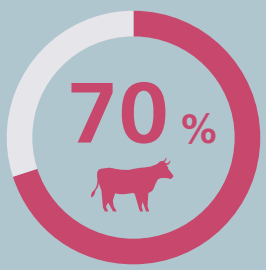
Increasing meat consumption

Global meat consumption has more than **doubled** over the past **20 years**, reaching **320 million tons** in 2018.

1 billion tons

of soy and corn are used as feed worldwide every year.

3 × The **area of arable land used to grow soybeans** is now **three times the size of Germany.**



About **70 percent** of all **agricultural land worldwide** is used for **livestock farming.**

One hectare of arable land can produce about **3.5 tons of soybeans** per year. However, the **same mass of microalgae** can be produced with just **20 square meters of surface space** and the **protein content** is much the same.

10,000 m² (1 ha)
3.5 tons soybeans

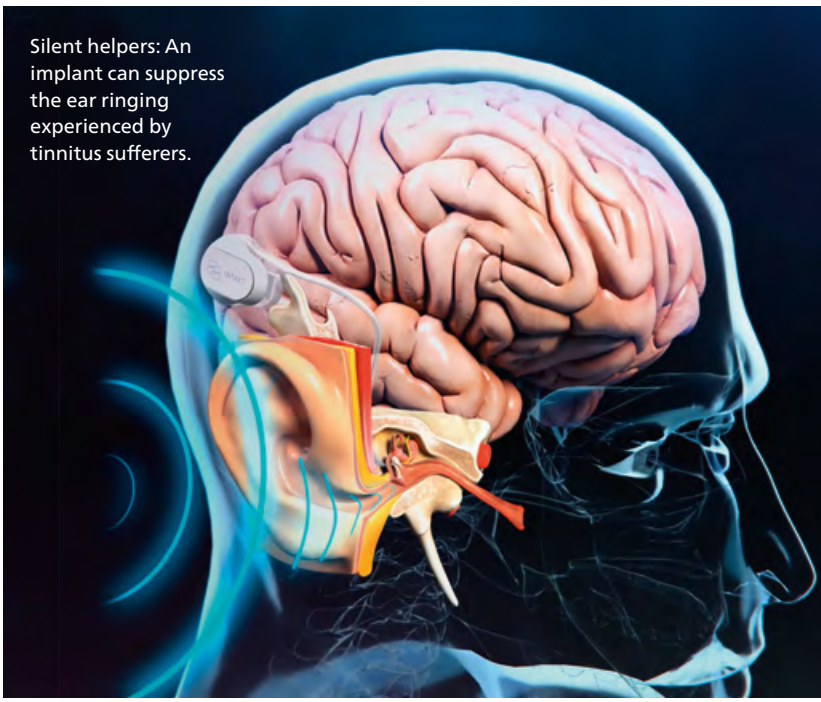
20 m²
3.5 tons of seaweed

The amazing algae

A glass of milk a day for healthy bones? That's ancient history. There are many **types of algae** with a much **higher calcium content.** They also contain an abundance of other **minerals**, as well as plenty of **vitamins, fiber, proteins, carbohydrates** and **fats.** (All concentrations given as **mg/100 g**)

Illustrations: NounProject, Robert Grill/Sources: Fleischatlas 2021, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Institut de Phytonutrition, France, McCance RA et al. McCance and Widdowson's Composition of Foods. 6th ed. Cambridge. Royal Society of Chemistry; 1993, UNO World Population Prospects 2022, United Nations Convention to Combat Desertification (UNCCD), Welthungerhilfe

back to page 1



Silent helpers: An implant can suppress the ear ringing experienced by tinnitus sufferers.

A network of miniature assistants

Under the coordination of Fraunhofer IBMT, the INTAKT innovation cluster has developed a new generation of micro-implants that can communicate with and respond to each other. The researchers have high hopes that this innovation will make life easier for many people someday.

By Beate Strobel

Whole, functional and healthy: The word "intact" means all of these things at once and much more, both in English and in German. Being physically intact makes it easier to work and take part in social activities. In the innovation cluster INTAKT, the word doubles as an acronym for "interactive microimplants" (or "INTer-AKTive Mikroimplantate" as the Germans have it). But it all comes back to the same idea: The whole point of the developing these tiny devices and implanting them in the body is to improve quality of life for people with functional limitations.

There are many types of active implants, or bioelectronics as they are also known, ranging from brain and heart pacemakers to cochlear implants and prosthetic limbs. The common element in all these technologies is their ability to use electrical impulses to stimulate the nervous system or modulate afferent nerve activity. These tiny, sophisticated devices differ from many drugs in that they have a direct, local impact but hardly side effects. This is because they mimic the body's own processes, i.e., they send electrical signals. But although microimplants are among the most technically advanced medical products in current use, they do still have some shortcomings. For example, the cable connections between the central implant and the electrodes can break down, and their batteries have to be replaced on a regular basis. In addition, once the implants have been put in place, it can be hard to adjust the way they function from the outside.

Funded by the German Federal Ministry of Education and Research, the INTAKT innovation cluster was established with the aim of developing a new generation of active, wirelessly connected microimplants that could ideally be implanted in the body for life. Led by the Fraunhofer Institute for Biomedical Engineering IBMT, the cluster's 18 partners from industry, science and the medical sector developed a secure network where up to twelve microimplants can communicate with each other wirelessly and in real time.

Collaboration on equal terms

Not only can these small electronic components interact with each other, but now patients and their doctors can finally communicate with the network of implants from the outside at any time. "The patient can configure their implants to suit their current needs at any time via their laptop or smartphone, and optimize their treatment or recovery process in consultation with their doctor," explains Prof. Klaus-Peter Hoffmann, head of Biomedical Engineering at Fraunhofer IBMT. Prof. Hoffmann sees the development as a key step toward participatory decision-making, whereby doctors and patients collaborate on equal terms.

When the INTAKT collaborative project was first launched in 2016, the cluster partners selected three application fields to start with: treating tinnitus (better known as "ringing in the ears") using microimplants in the middle ear; mitigating motility disorders, i.e., remedying musculomotor disorders in the gastrointestinal tract; and at least partly restoring the hand's gripping function in paraplegic patients. These three applications differ not only when it comes to the task the implant must complete but also the com-

> "The patient can configure their implants to suit their current needs at any time via their laptop or smartphone."
>
> Prof. Klaus-Peter Hoffmann
> Fraunhofer IBMT

Complex functionality in a tiny capsule: The microimplant consists of an eight-layer circuit board.

plexity involved: While it only takes two microimplants to alleviate tinnitus, restoring movement to a patient's arm and hand requires up to twelve.

Inductive and adaptive charging

In the treatment for tinnitus, the patient is given one implant for each ear. These stimulate the cochlea via the round window, modulating auditory nerve activity and "dampening" the phantom noise that makes everyday life so wretched for approximately ten million people in Germany — and prevents them from sleeping well at night. Gastrointestinal motility disorders can occur after abdominal surgery in diabetic or paraplegic patients. The treatment involves placing implants at strategic points in the gastrointestinal tract, where they each collect data on the activity of one section of the patient's system and then send this information to a central control unit. This unit analyzes the data and instructs the corresponding implants to stimulate the entire intestinal tract, ensuring that the digestive process runs as smoothly as possible.

Partial restoration of a patient's gripping function is a particularly complex challenge. However, scientists have succeeded in restoring as many as eight hand movements by means of a microimplant network that can stimulate up to twelve of forearm muscles in a coordinated way. The patient controls their hand movements via an eye-tracking system whereby certain set movements of the eyes, eyelids and head send commands to the central control unit, which then sends the corresponding instructions to the network of implants.

"Developing this network has given rise to several concurrent advantages," explains Roman Ruff, electrical engineer and group manager at Fraunhofer IBMT. One of the examples he gives is improved biostability. "We integrated the sensors and actuators directly into the device's housing to avoid the need for fragile cable connections." The implants interact with each other via wireless and infrared signals instead. Because they are linked to form a network, they can also be used to treat complex processes within the body and stimulate larger organs. The Fraunhofer Institute for Integrated Circuits IIS has developed a highly miniaturized application-specific integrated circuit (ASIC) for the implants. The ASIC can detect and pass on biosignals from areas such as the arm muscles or the stomach and intestines, and also trigger the electrical signals required to stimulate them.

However, the issue of energy supply is causing a hold-up in the bioelectronics development process. Batteries take up a lot of space and require regular replacement — and for an implant network where each individual device consumes different amounts of energy depending on the load applied to it, this is a particularly expensive process. The INTAKT cluster is opting for inductive charging instead. This means that the central control unit can reliably supply the network of implants with energy, 24 hours a day. In each of the three applications described above, the patient can wear this base station either as a cuff around the arm or abdomen, or as an ear wearable device. "This external energy supply ensures that the implant network will remain stable in the long term," stresses Prof. Hoffmann. "What's more, the energy supply is adaptive, i.e. each individual implant receives the exact amount of power it needs and no more." In case of emergency, the implants include a battery for buffer storage; this is also charged via the inductive system at regular intervals.

In its research, the innovation cluster also considered the social, legal and ethical implications involved in this kind of human-technology interaction. This included challenges such as designing the platforms and control systems in such a way that not only are they suited to the specific application area, but they can also be operated easily and securely by both doctors and patients. There is also the question of what ambient data the eye-tracking system should record, process and store. Prof. Hoffmann mentions the example of wearing the eye-tracking glasses when visiting a sauna. "While at the sauna, the patient has to be able to grip things in order to get dressed and undressed, or spread out a towel. But what about the privacy rights of the other visitors?" These are, of course, questions to which there are no straightforward answers.

Initial preclinical tests and trials with experimental users have already demonstrated that the applications developed thus far by the INTAKT cluster function as they should. Nevertheless, there is still a long way to go before these devices can actually be implanted in the human body.

The microimplants have already been reduced to just the size of a thumbnail, but the Fraunhofer IBMT coordinator still believes there is room for improvement when it comes to miniaturization. This is why it is vital to attract industry partners, so the INTAKT cluster's achievements can progress even further. ■

INTAKT collaboration partners:
Fraunhofer IBMT, University Medical Center of the Johannes Gutenberg University Mainz, University Hospital Heidelberg, Charité-Universitätsmedizin Berlin, Fraunhofer IIS, University of Mannheim, TU Ilmenau, GeSiM Gesellschaft für Silizium-Mikrosysteme mbH, inomed Medizintechnik GmbH, Soventec GmbH, Wilddesign GmbH & Co.KG, IL Metronic Sensortechnik GmbH, Glück Engineering GmbH, Würth Elektronik GmbH & Co.KG, VARTA Microbattery GmbH, Heraeus Medical Components, CeramTec-ETEC GmbH and CTC advanced GmbH

Photos: Wilddesign

back to page 1

A voice from the business world

Prof. Klaus Josef Lutz (64) has been at the helm of global agricultural trading group BayWa AG for the past 14 years.

Harnessing crises as a catalyst for growth

The pandemic, the war in Ukraine and this summer's heatwaves are all inspiring a rethink in the food production industry. Smart farming, agrivoltaics and alternative proteins could see major breakthroughs.

Opinion article by Prof. Klaus Josef Lutz, chief executive officer at BayWa AG

Harnessing crises as a catalyst for growth: Without the pandemic, digital transformation would never have achieved the major breakthrough it has. Remote work and virtual doctor appointments would still be a long way off. Now the war in Ukraine and the climate crisis, which this summer's scorching heatwaves finally brought to the fore again, are putting our way of life to the test. With no real experience of food scarcity, we in Germany have long dismissed food shortages experienced in other regions. Now, basic foodstuffs are even becoming more expensive in Germany, with some supermarket shelves remaining empty for periods. Demand for products such as fertilizer is high, and supply chains are fragile. Everything is interlinked: If energy supplies drop, containers such as glass bottles cannot be produced.

It's time to rethink agriculture, food production and food distribution. But the good news is the required technology is already available. We just need to start using it on a larger scale. And avoid getting bogged down in pointless angst. Standoff debates like "eco versus conventional" do not help. Instead, both from an ecological and geopolitical perspective, we can agree that the best solution is to grow local products with as much resource efficiency as possible, and to consume them directly within the same local region. This applies right across the board — whether in Upper Bavaria, Australia or Africa.

I believe that the following three trends will revolutionize our food supply:

Smart farming: Subarea management makes it easier for farmers to accurately determine and control what they sow, irrigate and fertilize, when and where, and in what quantities. Advanced GPS-controlled technology also helps in controlling weeds and pests, while self-propelled hoeing robots are being rolled out to compensate for labor shortages. What's more, pesticide usage can be significantly reduced. Satellite images document the progress of individual harvests — and can even be used to provide reliable economic analyses, such as the yield forecasts for Ukraine provided by BayWa subsidiary VISTA this summer.

For countries with difficult climate conditions, smart farming opens up the possibility of reducing dependence on imports.

"The best solution is to grow local products with as much resource efficiency as possible, and to consume them directly within the same local region."

Prof. Klaus Josef Lutz

- has been chief executive officer at BayWa AG since 2008. He drove the diversification and internationalization of the company, which was founded in 1923, while also preserving its historical roots.
- Prior to that, in his role as managing director, the 64-year-old restructured a number of companies, not least the media house Süddeutscher Verlag, which publishes the newspaper Süddeutsche Zeitung. Since 2021, Prof. Lutz has been president of the Chamber of Commerce and Industry for Munich and Upper Bavaria (CCI).
- The Munich native studied law at Ludwig-Maximilians-Universität München (LMU) and qualified as a lawyer in 1987.
- In 2013, Prof. Lutz was appointed honorary professor for cooperative management by the Technical University of Munich (TUM).

Regardless of climate, it is worth questioning whether today's cultivation methods and growing areas, crop rotation and storage techniques are viable for the future. One result of geoscientific analyses could be that we see more soybeans or sorghum growing in German fields in the future.

Agrivoltaics: Agrivoltaics allows us to kill two birds with one stone. Using arable land for electricity production reduces land consumption while simultaneously increasing productivity in crop cultivation. Here is one example from Gelsdorf in Rhineland-Palatinate, where BayWa r.e. and the Fraunhofer Institute for Solar Energy Systems ISE have initiated a research project. Photovoltaic modules installed high above the treetops provide targeted shade for apples, protecting them from heavy rain, hail and frost. The electricity they generate can be used directly for electric, self-propelled agri helpers or for irrigation technology.

Alternative proteins: Alternative plant-based or cell-based proteins are becoming increasingly attractive as a supplement to traditional meat, fish and dairy products. They can often be produced locally and all year round.

A good example is the Berlin-based start-up VEgg, which produces a vegan egg, complete with shell. A young man from Austria, who I met at the Future Food conference we organized in early 2022, has taken it a step further. His company, Kern Tec, produces baking ingredients and oils from apricot and cherry pits that would otherwise end up as garbage. We are literally talking about leftover food here, but in more investor-friendly terms, this is referred to as upcycling and zero waste.

What are the risks facing the revolution in food production and supply today? Two factors could weaken its momentum. Firstly, our complacency and lack of foresight. And secondly, I have deep concerns about the regulatory obsessions of German and European authorities. An entrepreneur can win over any number of supporters to their project — but all it takes is just one official to stand in their way, and bring innovation to a grinding halt. It's good to have an intermediary like the Fraunhofer-Gesellschaft in your corner, as is the case for VEgg co-founder Verónica García-Arteaga. ■

Photo: Thomas Einberger/argum/imago images

back to page 1

Front-row seats for all

Attending a concert as an avatar: The SocialSTAGE-VR project is aiming to digitalize cultural events — and transform them into social experiences.

By Beate Strobel

On August 20, 2022, German singer Helene Fischer held her only live concert of the year. Over 130,000 fans packed into the Neue Messe München exhibition center, and with the amount of people arriving and entering the venue, there was chaos. Fans in the cheap seats could barely see the star of the show, and struggled to hear the music. To top it all off, it poured with rain during one of the driest summers since records began. Even concertgoers who had treated themselves to a premium VIP package to see pop queen Fischer were soaked. For 599 euros a head.

What if all 130,000 fans had had VIP access? Right at the front, with the best view and best sound — and dry feet?

As part of the SocialSTAGE-VR project, which is funded by the Federal Ministry of Education and Research (BMBF) and coordinated by the Chemnitz University of Technology, stakeholders

Not alone, but together: The goal is to enable virtual proxies to interact at events.

"We're developing technology for the YouTube of the metaverse."

Dr. Frank Dittrich, Chemnitz University of Technology; initiator and project coordinator of SocialSTAGE-VR

Illustrations: SocialSTAGE-VR, Ready Player Me

from research and the arts are currently working to make this vision a reality. The goal of the project is to record cultural events — such as plays, operas and concerts — in 3D and project them onto a virtual stage. With the help of a VR headset, the public can experience the event live from their own homes. The project's main focus is on creating a visual and auditory experience that is as realistic as possible, and has a social component, too. By using avatars as digital proxies in virtual space, the aim is to enable guests to talk, laugh and enjoy the event together.

A large number of photos were used to create a virtual 3D copy of the auditorium at the Chemnitz opera house, forming a stage for the initial pilot studies. In order to show live events there in the future, the visuals and audio of the stage must be recorded and reproduced to give viewers the most realistic experience possible. This is where the Fraunhofer Institute for Integrated Circuits

back to page 1

Global revenue from virtual reality is forecast to increase to

22.37

billion US dollars in 2025. In 2020, this figure amounted to 4.48 billion US dollars. *(ARtillery Intelligence, 2021)*

Sales volumes for VR and AR headsets are set to rise worldwide from 5.84 billion units in 2020 to

50.46

billion units in 2026. *(IDC, 2022)*

IIS, a SocialSTAGE-VR project partner from the beginning, comes in.

Aiming for maximum immersion

The team from Fraunhofer IIS is bringing a lot to the table, including their recording technology based on light field cameras, which capture all the light rays within a space. "We process this content so that it can seamlessly reproduced via a VR headset and guarantees the most immersive experience possible," explains Dr. Joachim Keinert, head of the Computational Imaging and Algorithms group at Fraunhofer IIS. Specially designed algorithms allow for parallax, which means that the events on stage appear to shift correctly if the viewer changes their position by leaning slightly to the side.

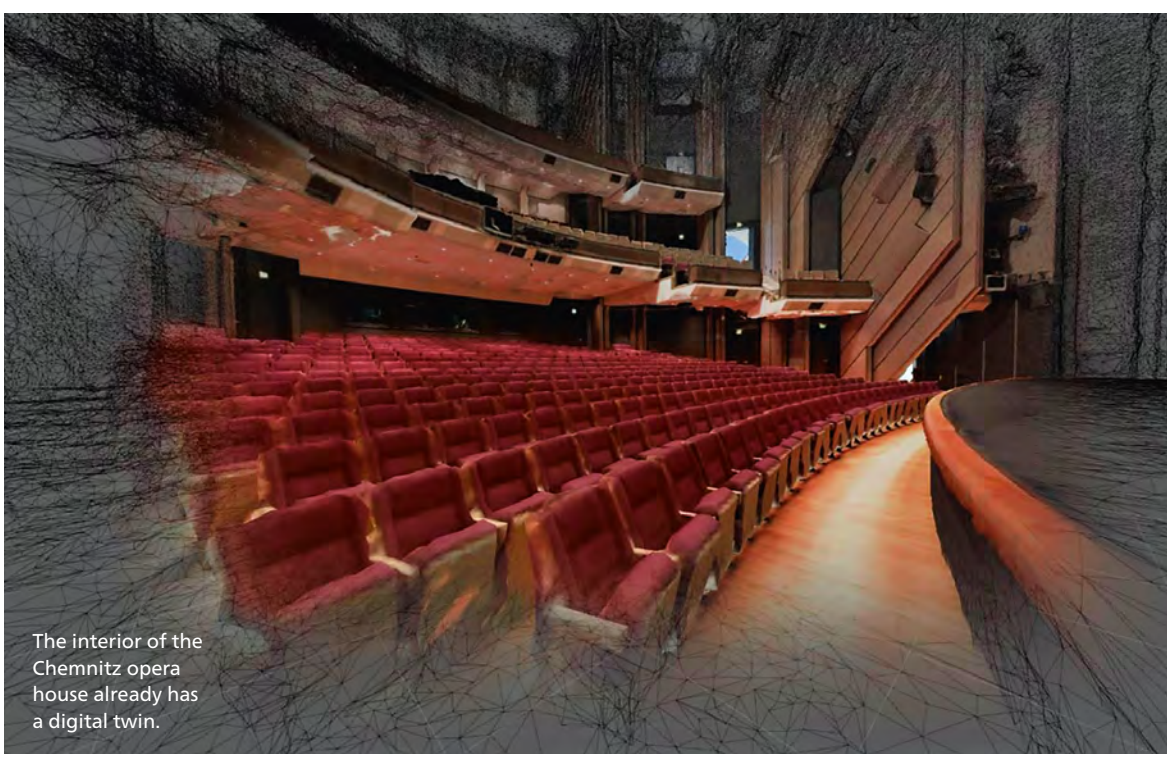
"Virtual reality offers artists and fans opportunities that live entertainment can't provide."

Robert "Bob" Schütze, bassist with Berlin band MIA., which is participating in the project.

Fraunhofer IIS is also responsible for the acoustics. The researchers are providing a software library for the spatial reproduction of sound. This allows acoustic signals to be processed so that all sound sources — actors, the orchestra, as well as applause and other audience noise — are localized according to the viewer's head position. "When headphones are used, the sound will always move with the user's head movements, as if the orchestra itself is moving with their head," explains Dr. Keinert. But since the orchestra actually stays in the same place, the VR headset must compensate acoustically for head movements to ensure the most immersive experience possible. In simplified terms, the sound scene is rotated in the opposite direction to the user's movements.

Cultural sector falling behind in terms of digital transformation

"Our project aims to make users feel like they're in the middle of the action, despite the actual distance," explains Dr. Dittrich. A professor of ergonomics and innovation management at Chemnitz University of Technology, where he also completed a doctorate in industrial engineering, he is the project's initiator and coordina-



The interior of the Chemnitz opera house already has a digital twin.

tor. The idea for SocialSTAGE-VR came to him during the first coronavirus wave in 2020, when holding live events became impossible and the industry was looking for alternatives. "Up to that point, many areas of the cultural sector had only dabbled with digitalization," says Dr. Dittrich. "This placed many at a real disadvantage during the pandemic."

Berlin-based electropop band MIA. released their album "Limbo" right at the beginning of the pandemic, and had no opportunity to perform it live due to the first lockdown. The band made do with a streaming event. Looking back, bassist Robert "Bob" Schütze feels that while this was "pretty successful", it only scraped the surface in terms of the technological possibilities. "Virtual reality offers artists and fans so many new opportunities. That doesn't mean it will replace live concerts, but it's an exciting addition to them."

"I see SocialSTAGE-VR more as an extra opportunity for the culture industry to distribute its content much further and in a much different way than before," explains Dr. Dittrich. Avatars also open up the world of concerts to people that cannot generally attend for a variety of reasons — for example, people with medical conditions, and people who are unwilling to travel, who find the music too loud or who don't feel like jostling their way to the stage through a crowd.

"We want to develop a solution for people, rather than making people adapt to the technological possibilities."

Dr. Joachim Keinert, electrical engineer and head of the Computational Imaging and Algorithms group at Fraunhofer IIS, Erlangen

Avatars that wave, clap and wink at each other

"Attending via an avatar allows people to be present not only spatially, but socially too," adds Dr. Dittrich. Plans are underway to enable these artificial likenesses to reflect real gestures and facial expressions using recognition technology built into the VR headsets. The idea that these devices will become a must-have technology in the near future "is what we're betting on with SocialSTAGE-VR," says Dr. Dittrich. He believes virtual reality will permeate the working world first, with office workers of the future using VR headsets to work on screens that do not exist in reality, or meeting colleagues that live and work far away up close and personal in the virtual world. In addition, Dr. Dittrich expects a further technological boost to be sparked off by the vision of a future metaverse, a virtual world where people will also meet in non-work contexts, for instance to go shopping or attend cultural events together.

Fraunhofer IIS is also working on other projects that focus on making cultural events accessible virtually. For Dr. Keinert, however, SocialSTAGE-VR has a special status due to its focus on the user experience: "The project is about developing an optimal solution for people, rather than making people adapt to the technological possibilities."

This means the goal is to make the technology so easily accessible that it can be used by any event organizer and any end user, for any kind of cultural event — from the New York Met to the Wacken heavy music festival. Project initiator Dr. Dittrich is thinking big: "We're developing technology for the YouTube of the metaverse."

Arriving on a virtual bus full of fans

Meanwhile, MIA. bassist Mr. Schütze is excited about the many untapped creative possibilities for artists that the SocialSTAGE-VR project presents. For example, fans could go on stage or into the backstage area as avatars. Or customize the event to their own preferences using various audio channels. The hours before the event — usually taken up with travel and waiting around — could also be transformed into a social event, such as with a virtual fan bus or a digital "meet and greet" with the artists. "It's not about fooling the audience into believing it's real, but rather pushing physical boundaries and discovering new dimensions," he emphasizes. "It's the only way to create a product that can take its place alongside live entertainment."

MIA. are finally touring again in November, with 26 performances on real-life stages in Germany, Austria and Switzerland, in front of real live audiences. But after that, Mr. Schütze definitely wants to continue his involvement with SocialSTAGE-VR. He abides by the credo that it's better to get in on the act early, rather than follow a trend later. "25 years ago, we were one of the pioneers of German pop. Now we're daring to do that again on a whole other level." ■

In 2018, only 17 percent of Germans surveyed could see themselves **using a VR headset**. By 2021, this number had risen to

41%.

(Bitkom, 2022)

According to forecasts, **revenue from VR content** in Germany will increase from 40 million euros (2019) to

280

million euros (2024). *(Deloitte)*

At **79%** the most common use for **VR technology** in Germany is playing computer and video games, followed by movies (67%), travel experiences (63%) and music concerts (41%). *(Bitkom, 2022)*

Illustrations: SocialSTAGE-VR, Ready Player Me

back to page 1

In Germany, roughly one person in 100 has trouble interpreting their own feelings and those of others.

Emotions: a passion project

Individuals with autism have a hard time understanding feelings — which can be problematic, not least in the world of work. A team from Fraunhofer IAO, headed up by cognitive neuroscientist and neuroergonomics expert Dr. Mathias Vukelic, is developing technologies to assist these individuals in deciphering the feelings around them.

By Yvonne Weiß

Is that person smiling at me — or showing me their teeth? Are they narrowing their eyes because they are laughing — or are they angry? In Germany, roughly one person in 100 has trouble interpreting and evaluating their own feelings and those of others. This is just one aspect of the challenges faced by autistic people on a daily basis. Depending on the individual, the inability to understand feelings can not only interfere with a person's private life, but also seriously hinder their ability to enter the working world. Dr. Mathias Vukelic, a cognitive neuroscientist and neuroergonomics expert from the Fraunhofer Institute for Industrial Engineering IAO, is hoping that the results of the UFO project will make it easier for autistic people to interact with others in everyday life, specifically in a professional context.

In order to minimize the obstacles impacting communication, the project team is developing a virtual, secure training environment, which is accessed through virtual reality (VR) glasses. Within this environment, the first step is to measure brain signals and other physiological responses from the users — such as changes in brain and heart rate activity, and the skin in response to sweat secretion — using various neurophysiological sensors.

The next step is then to "translate" the physiological responses into tactile feedback in the form of physical sensation, whereby the emotions are relayed to the user via a special wristband or glove emitting frequency patterns or vibrations.

"With the tactile feedback, the initial goal is to enable the user to classify their own feelings into positive and negative categories," says Dr. Vukelic. Even simply classifying feelings in this way tends to be an impossible task for autistic people, he tells us. But, he adds, because this forms the basis for also dealing with more complex feelings in social interactions further down the line, such as fear, anger or joy, it remains the primary focus at this stage.

But how much pressure will they apply in the next step, in order to signal either a positive or negative feeling? This remains a matter of research for Dr. Vukelic and his team. "Our aim is to develop a calibration procedure that feels pleasant for each individual person", says Dr. Vukelic.

Feeling emotions

According to Dr. Vukelic, the idea of using tactile interfaces for human-technology interaction is not a new one for the team. For example, blind people can already get from A to B more easily thanks to a vibrating navigation belt with a built-in compass. "What we are considering now is whether someone can also use the tactile sense to learn to perceive emotions and how to process them; in other words, to acquire a sense for emotions," continues Dr. Vukelic. The method of measuring brain signals and providing feedback to influence a person's own brain activity could even extend beyond autism and help with illnesses such as depression or anxiety disorders, for instance.

"We want to design technology in such a way that it can really support people, give them assistance when they need it, and, in doing so, address their individual needs and foster their individual abilities." It is this philosophy that has driven Dr. Vukelic's work at Fraunhofer IAO since 2015. After studying biomedical engineering with a focus on neural engineering and earning his doctorate in neurosciences and behavioral sciences focusing on brain-computer interfaces, Dr. Vukelic has headed up the Applied Neurocognitive Systems department since 2021. He and his departmental team are researching how humans and technology can work together efficiently. Dr. Vukelic's objective here is to establish "applied neurosciences as a new research discipline, so they can be utilized for the benefit of applied human factors and ergonomics."

The goal is better understanding — in both directions

Alongside Dr. Vukelic and his team from Fraunhofer IAO, the UFO project also has the support of the Department for Teaching and Learning with Intelligent Systems (LLiS) and the Department of Vocational Education focused on Teaching Technology (BPT) at the University of Stuttgart, as well as the University's Institute of Human Factors and Technology Management (IAT). On the development and industry side, Sensovo GmbH, a start-up supplier of wearable technologies equipped with tactile feedback, NIRx Medizintechnik GmbH, a manufacturer of neurosensors, and auticon GmbH, an IT consulting firm that employs autistic people as IT consultants, are also participating in the project.

In the long term, Dr. Vukelic hopes that his "passion project" will enable autistic people to use technology to interpret the feelings of others, as well as their own. But the development of a corresponding VR module could not only allow autistic people to tap into the feelings of other people, but also do the reverse. And so technology — the very thing we often describe as emotionless — would ultimately provide the key to greater understanding and greater sensitivity in interactions with others. ■

Dr. Mathias Vukelic, Fraunhofer IAO, preparing an EEG (electroencephalography) test.

"We want to design technology in such a way that it can really support people."

Dr. Mathias Vukelic

Photos: Kniel Synnatzschke/plainpicture, Ludmilla Parsyak/Fraunhofer IAO

back to page 1

Fungi foundations

Building materials supplied by nature: Fungus-based materials have enormous potential as an ecological alternative to bricks, cement and polystyrene that provides better resource security.

By Beate Strobel

If you're thinking about the future of housing, you might want to take a look at the Smurfs' houses. Created by Belgian artist Peyo, the Smurfs live in hollowed-out mushrooms. That means these blue cartoon characters are green pioneers. Their houses don't use fossil fuels — in fact, you could say that it's natural free home delivery. Smurfs never experience supply bottlenecks or a scarcity of building materials. And when their little houses have served their purpose, they can simply be composted.

These are all are good reasons for the construction industry to envy the Smurfs right now. As a result of the coronavirus pandemic and Russia's war of aggression in Ukraine, supply bottlenecks are creating delays and money problems for many construction projects. Building material shortages like this have not been seen since 1991, according to a June 2022 report by the ifo institute. ▶

Photo: udomsook/AdobeStock

A wide network of thread-like fungi: Mycelium can colonize organic material and break it down.

back to page 1

A paste developed by the FungiFacturing project can be made into a solid object using 3D printing and then colonized by fungi.

Around **120,000 types of fungi** are known to science. However, researchers assume that up to 4 million types exist.

The **biggest living organism** in the world is a fungus: If you include the mycelium, an Armillaria (honey fungus) in Oregon stretches across approximately 1,000 hectares.

Since they do not use photosynthesis, fungi are **more closely related to animals** than plants.

Fungal spores can even survive in **space**.

In forest floors, 1 square meter can contain approximately **one billion mycelia** or fungal spores.

Some types of fungi can metabolize plastic, dioxins and crude oil. Others can even be used as an energy source for **nuclear radiation**.

Structural steel is especially hard to come by, but there is also a shortage of bricks and insulation material on German construction sites. Within a year, the price of cement has increased by about 15 percent, polystyrene by 25 percent, wood by 39 percent and reinforcing steel by as much as 79 percent.

"Change is urgently needed in the construction industry," observes biodesigner Julia Krayer from Fraunhofer UMSICHT. "There's a lot of rapid construction happening in Germany at the moment, but buildings are being demolished again just as fast." Every year sees the construction of new buildings using billions of tons of lime, gravel, sand and steel. After demolition, cement and concrete may be used as low-grade filler material in road construction, at best. Meanwhile, other building materials are simply hazardous waste and there is no way of recycling them. The construction and real estate industry is responsible for 38 percent of global carbon dioxide emissions. It will therefore play a crucial role in achieving the Paris Agreement climate targets.

Glue from nature's workshop

Mushrooms, or more specifically what lies beneath them, could provide a solution. The actual fungal organism lives underground, where it forms a multi-branched network of fungal threads. This network, known as mycelium, is able to spread though the forest floor, wood and other organic material and bind it all together like putty into a solid structure. This means that fungi have great potential for use as a construction material in the future.

At Fraunhofer UMSICHT, biodesigner Julia Krayer and biologist Lina Vieres have been driving the development of fungus-based insulation material as part of the FungiFacturing project, in collaboration with Fraunhofer IBP and with funding from the German Federal Ministry of Food and Agriculture. The team was established in 2016 with the aim of creating environmentally friendly sound absorption material from mycelium and plant substrate. It turned out that the fungus-based material was indeed an efficient acoustic absorber, and could potentially be used in construction as environmentally friendly sound insulation. Polyester foam or mineral fiber-based composites are currently the materials most commonly used to soundproof rooms.

The FungiFacturing project has also produced a paste made from straw and other byproducts from agriculture and forestry. "This substance is suitable for 3D printers, which allows for a wide range of creative possibilities," explains Ms. Vieres. "Once printed, an object can be colonized by mushroom mycelium to form a solid structure." But even without this "mushroom glue" holding it together, the paste itself already has "interesting material characteristics," says Ms. Vieres. It could potentially be used in the production of building boards. However, the bioeconomic concepts of the circular economy and upcycling are paramount here. "A new material is being created from something previously considered a waste product." There is also an additional advantage: The carbon dioxide bound in the raw material remains inside it, rather than being released during waste incineration.

Insulation could also be another interesting area of application for the fungus-based material. Ms.

Mushrooms at work: The substrate is colonized by the mycelium and becomes firm. The mycelium is killed off at the end during a drying process.

The construction and real estate industry is responsible for **38 percent** of global carbon dioxide emissions.

Vieres has experimented with various substrate components and fungus types to identify the optimal combination in terms of thermal conductivity. Although the research project was small in scale, it is already evident that mycelium material can at least compete with fiberboard when it comes to thermal insulation. In comparison to polystyrene — to date, the most commonly used material in building insulation — the fungus-based material does not perform so well. However, Ms. Vieres is optimistic. "I think it's definitely possible that we could improve thermal conductivity further by using other base substances and processing methods."

Mycelium insulation would also offer other benefits. For instance, its ecological footprint is likely to be remarkably small. In contrast to standard composites, the fungus-based material can simply be recycled or composted when a building is demolished. Once automated and energy-efficient production is possible, it could also be manufactured relatively cheaply; after all, the raw materials are waste products. "We are testing many different kinds of waste materials, but prioritizing those produced in the locality, as this gives a certain level of resource security," says Ms. Krayer.

The two researchers have already presented the material to industry stakeholders in workshops; mostly to the construction industry, but car manufacturers and packaging companies have also expressed interest. "The participants were allowed to submerge the material in water or try to set it alight or break it," recounts Ms. Krayer. "You need to have the fungus-based material in your hand and experience it to understand its potential." However, it also became clear during workshops that in order to assess how useful the new building material will be, the industry urgently needs definite information on its characteristic values — such as its stability, fire behavior and hydrophobic properties. "We want to focus on this in follow-up projects," says Ms. Krayer. But although many questions remain unanswered, she can at least report that: "We've made a start."

Houses built from mushrooms on the Moon and Mars?

At the Karlsruhe Institute of Technology (KIT), mycelium has already been used to manufacture bricks. These are not only significantly lighter than classic bricks made from clay or lime and sand, but much more durable too. The NASA space agency is researching whether houses made from mushroom material could be used for future settlements on the Moon and Mars. This is because fungal spores take up hardly any room n space transportation, but could be revived with water at their final destination and grown around a scaffold, for instance. Back on Earth, the US start-up Ecovative has already built an entire tiny house using board insulation made from dried mushrooms. The "Tiny Mushroom House" is waterproof, fireproof, free of chemicals and fully compostable. They're Smurf houses for people, in a way.

Within Fraunhofer, multiple institutes are also researching innovative solutions in this area, from many different angles. These institutes have already joined forces to create an internal collaborative project within Fraunhofer. Their aim now is to drive research in this area together. Getting connected, and growing as a result: That's a strategy for success we can learn from mushrooms. ■

Fungi have been on the planet for over **800 million years.**

If all the fungal threads present in the top 10 centimeters of the soil on Earth were connected, their length would equate to **half the diameter of our galaxy.**

Penicillin and many other **antibiotics** are the metabolic products of fungi.

More fungi than ants: After plants and bacteria, fungi constitute the **third-largest biomass** on Earth.

Photos: Fraunhofer UMSICHT, Adobe Stock, digitalerblick/AdobeStock, geargodz/istockphoto, rotofrank/istockphoto

back to page 1

A case for Detective Quantum?

In the future, our energy system will be hugely interconnected, with millions of influencing variables. How we can guarantee security of supply? Fraunhofer researchers aim to crack this case with a little help from their friendly neighborhood quantum computer.

By Mandy Bartel

Super computers are set to optimize our energy flows

According to the German Federal Network Agency, the German grid has 219,536 power stations, ranging from large-scale coal, gas and nuclear plants to smaller wind and solar plants. They all need to be operated in different ways, as many of them cannot just be powered on or off at the press of a button, or have to run for a certain period of time. Now imagine a situation where there are many distinct, individual producers feeding power into the grid at different times; the sun is shining, but the wind is not blowing; and the gas supply has not been restored, which has to be compensated for — the system quickly becomes an incomprehensible tangle.

Meanwhile, demand can only be planned in a very approximate way and mapping its exact time frame is virtually impossible. Yet this demand must be covered at all times, and at a reasonable cost. And don't forget that power lines constantly have to maintain a certain minimum voltage. Essentially, the German energy market is as complicated as it gets. To balance supply and demand on an hourly basis with the lowest possible cost, you would have to take millions of individual parameters and variables into account. The interaction between these factors can be mapped through fundamental modeling. However, these simulations have become an enormous challenge, especially because of the increasing share of renewable energy, which is as unpredictable as it is volatile.

These days, not even the most powerful super computers are capable of creating a simulation of the entire energy network, which is why energy producers are clustered into individual units or regions. These clusters are treated as separate entities, although high-level correlations can be drawn between them when necessary. Like projection models for load curves and the weather forecast, power supply and demand can be predicted to a certain extent. However, as far as Pascal Halffmann of the Fraunhofer Institute for Industrial Mathematics ITWM is concerned, there is plenty of room for improvement. "Because of the system's constantly increasing complexity, even a slight improvement in the calculations for this fundamental model offers enormous potential for cost savings," he affirms. This is why his team and their partners in the EnerQuant project are researching how quantum computers could help optimize energy modeling.

Improving mapping of uncertainties in energy modeling

Why turn to quantum computers? "We have a classic optimization problem to solve here," explains the mathematician. "The quantum computer's units of information, known as qubits, can exist in a superposition of states, which we hope will allow us to calculate different fundamental modeling parameters simultaneously. This could help us search through this enormous solution space for the best option far more quickly. Quantum systems also offer a further advantage in that they are intrinsically stochastic, i.e., they are designed to operate in a probabilistic way. This may allow them to map uncertainties in the energy model more effectively than previous systems."

"In addition to modeling, benchmarking different quantum computers and comparing them to conventional computers is another important goal for our project."

Pascal Halffmann,
Fraunhofer Institute
for Industrial Mathematics
ITWM

Photo: Forrest9/AdobeStock

Fraunhofer IOSB-AST's researchers are shining a light on another use case in the EnerQuant project. They are developing a model that will show how a small airport's e-vehicle fleet could be powered by as much self-generated solar energy as possible, while taking various different factors into account.

Listen to the podcast to find out more:

To demonstrate this, Mr. Halffmann and his colleagues tested a simplified fundamental model on multiple systems at the same time. To conduct their calculations, they used the 27-qubit IBM Quantum System (which is located in Ehningen in Baden-Württemberg, and exclusively available to Fraunhofer and its partners), other IBM systems in the USA and a quantum annealer, which, while it may come out on top with its 5,000 qubits, is only suitable for very specific optimization tasks. Soon, they will also expand their arsenal to include a quantum simulator based on ultra-cold atoms. Developed at Heidelberg University, the simulator uses "qudits" for its calculations.

From the qubit to the qudit

In contrast to qubits, which can hold any state between 0 and 1, qudits can take on the values 0, 1, 2, 3, 4 and more, as well as all the superpositions in between. This means that they can be used to process more data with fewer units of information. "In addition to modeling, benchmarking different quantum computers and comparing them to conventional computers is another important goal for our project," emphasizes Mr. Halffmann.

However, the classic problem of working with quantum computers still remains: Today's systems are nowhere near offering the number of qubits and the high level of connectivity required to create complex models. That meant that the research team had to think flexibly and mathematically reformulate the model right from the start so that it required as few qubits and as low a connectivity level as possible. "It worked so well that we were able to make significant improvements to the process of transferring our virtual model to physical qubits," the mathematician reports. This achievement will also form the basis for subsequent stages of the research process — and there are many of those left to go before the team reaches the point of practical application. It is particularly important to have good partners when working in this field, as the EnerQuant participants know very well. Fraunhofer ITWM is teaming up with its sister institute Fraunhofer IOSB's institute branch, the Institute for Advanced Systems Technology (AST) to work on the modeling, while Heidelberg University is providing the quantum simulator prototypes. A start-up called JoS QUANTUM GmbH is working to make the algorithms more advanced, as well as supplying the software platform where the collective results are being pooled. This platform will be used to make the results available to the industry sector once the project is complete, where they will hopefully contribute to Germany's future security of supply. ■

According to the German Federal Network Agency, the German grid has

219,536

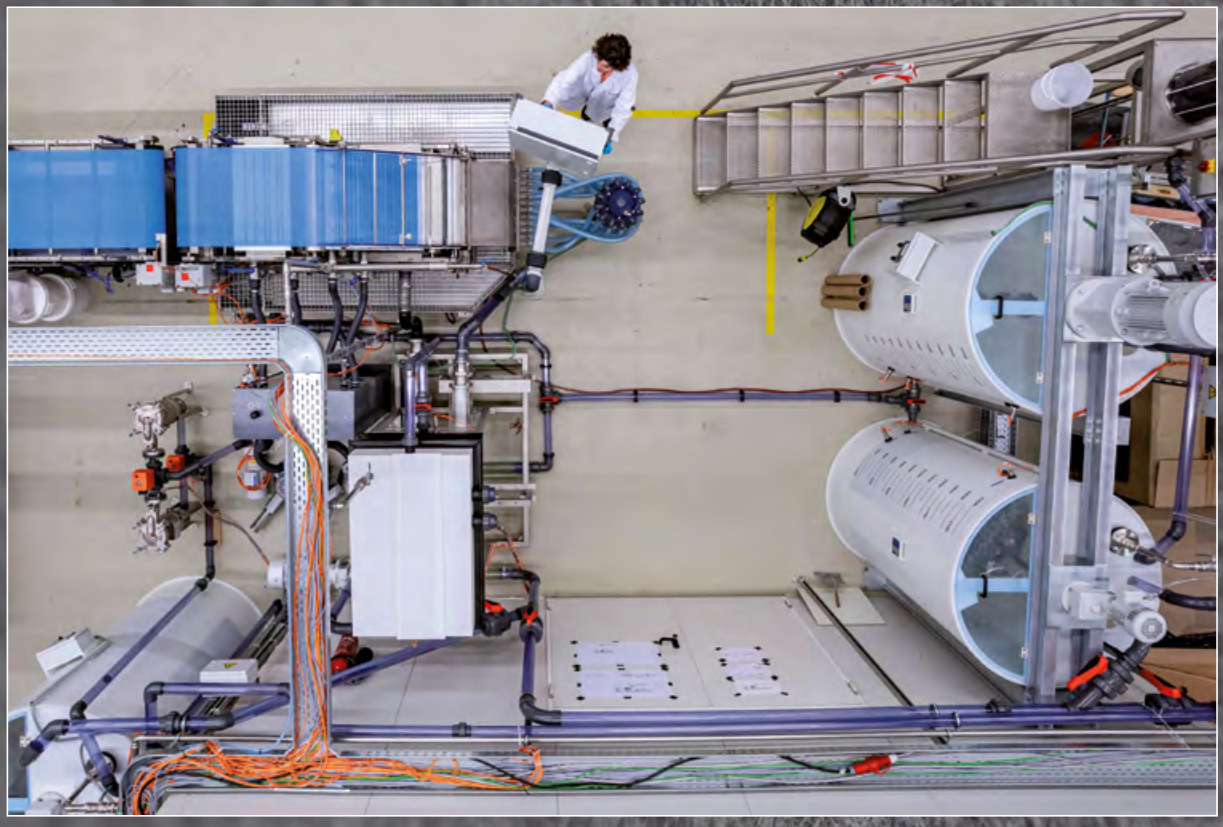
power stations.

back to page 1

Carbon-fiber recycling meets papermaking

Using technology from the world of paper manufacturing, Fraunhofer IGCV is giving a new lease of life to previously non-recyclable carbon fibers.

By Claire Stark



Not your average fleece: Carbon fibers are reborn as gray non-woven fabric on a papermaking machine.

Carbon fiber-reinforced components are commonly in use as a strong but lightweight material in all manner of applications — for example in the transport sector, wind turbines and sports equipment. But what happens to these components when they come to the end of their life cycle? Up to now, the answer has usually been: nothing. The Fraunhofer Institute for Casting, Composite and Processing Technology IGCV aims to change this — using wetlaid non-woven technology. As with cellulose fibers, the process allows carbon fibers to be separated in water, aligned and then drained. This produces rolls of non-woven fabric that can be reused, for instance, in the automotive sector.

The materials we know as carbon are composites consisting of carbon fibers embedded in a polymer matrix. Up to now there have been very few options for recycling these composites. "This year we have a global carbon fiber capacity of 170,000 tonnes. Only around a twentieth of that will be recycled," claims Michael Sauer of Fraunhofer IGCV. Indeed, thermal and chemical processes for recovering carbon fibers from the polymer matrix do exist. But the majority of these carbon fibers are too short to be used as part of established processing methods. However, with wetlaid non-woven technology, shorter fibers are easier to handle — as such, the previously unusable portions of recycled carbon fibers can now be harnessed as a raw material. This also helps to reduce the CO_2 footprint of the material. "Because so much effort has been put into the production of the fiber, it makes sense to reuse this valuable commodity," says Violetta Schumm, from Fraunhofer IGCV. The wetlaid non-woven machine works in a similar way to a papermaking machine, but with one crucial difference — it processes recycled carbon fibers, not paper fibers.

Mr. Sauer and Ms. Schumm, a materials scientist and a textile scientist respectively, now operate the one and only papermaking machine in the Fraunhofer-Gesellschaft. During construction of this machine the pair was able to draw on a wealth of existing expertise from the paper industry, but they did also have to solve certain specific problems relating to their use of recycled carbon fibers. Mr. Sauer describes the challenges: "It is basically a waste product, with differing fiber lengths, contamination, and fibers that are often tangled and hard to disperse." In order to produce a homogeneous non-woven fabric despite the difficult source material, the wetlaid non-woven machine at Fraunhofer IGCV was designed to be especially flexible and robust. This means it can handle a wide range of fiber lengths and also cope with large disparity in fiber lengths within one batch. To prevent the electrically conductive carbon fibers from short-circuiting the system, the machine is completely enclosed.

> "This year we have a global carbon fiber capacity of **170,000** tonnes. Only around a twentieth of that will be recycled."
>
> Michael Sauer, Fraunhofer IGCV

The non-woven fabric that is produced from the recycled carbon fibers on the wetlaid non-woven machine can be used in various applications. Even structural components such as engine hoods and undercarriages can be created from a composite made from recycled carbon fibers and a polymer matrix. "Our products outperform any new glass-reinforced component. Even though we are using such short carbon fibers, they are carbon fibers nonetheless," adds Mr. Sauer.

One advantage is that the fabric can be adjusted to meet precise requirements. Not only can the thickness and density of the material be specified; the electrical conductivity can too. The latter depends on the orientation of the fibers, as conductivity is much higher along the length of the fiber axis than it is across it. It is thus theoretically possible to achieve an infinitely variable level of conductivity in the finished material — from isotropic non-wovens formed by distinctly intersecting fibers, to virtually parallel fibers. The current challenge with this is actually orienting the fibers accurately.

In the long-term , it is hoped that plant technology can be used for more than just manufacturing non-woven fabric from waste products that would otherwise be useless. Another focus is developing products that contain minimal binding agent. This means that the constituent materials remain free-flowing and can be integrated more easily into normal production processes in place of existing materials.

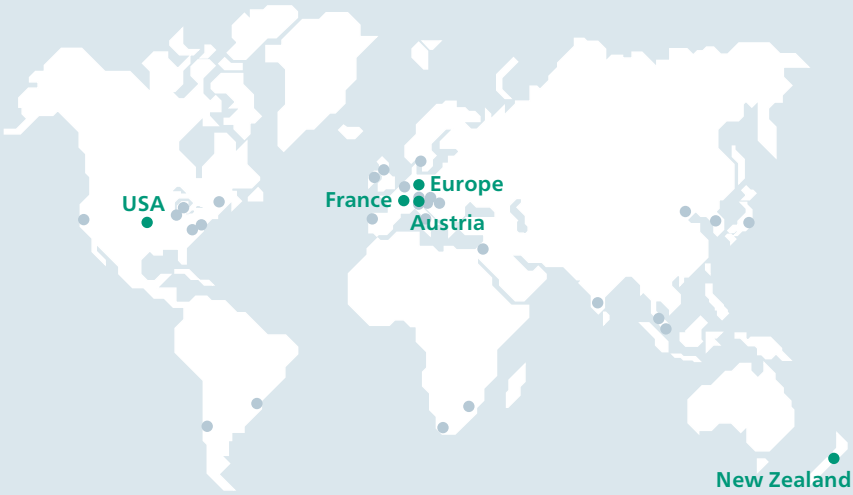
In comparison to a traditional papermaking machine, the Fraunhofer IGCV machine is relatively small, measuring 61 centimeters wide and having a maximum processing speed of 30 meters per minute. This allows the researchers to work even with small quantities of sample fibers. "The good thing about the machine is that an industry customer can come to us with their new fiber material, and we can test its processability within a day," says Ms. Schumm. Although the focus in plant technology is on the processing of carbon fibers, the machine can basically handle any fiber material. In addition to recycled carbon fibers, Ms. Schumm and Mr. Sauer have also processed cellulose and various polymer fibers. During the coronavirus pandemic, the papermaking machine at Fraunhofer IGCV was used to manufacture FFP2 face masks. ■

Scan here for the podcast:

Photos: Christian Strohmayr/Fraunhofer IGCV

back to page 1

Fraunhofer worldwide



Locations of the Fraunhofer-Gesellschaft

EUROPE

Making patients safer with AI

As part of the SafePolyMed project, 11 European partners are working to increase the safety of medical treatments. Alongside them, a team from the Fraunhofer Institute for Biomedical Engineering IBMT is developing a pharmaceuticals management platform aimed at reducing the individual risk of unwanted side effects — taking into account both interactions with other administered medications and drug-gene interactions. The researchers are using artificial intelligence (AI) to analyze genomic information, demographic data, current and chronic health conditions and drug-related details. This allows individual dosage recommendations to be made or alternative drugs to be administered.

In Europe alone, around 197,000 fatalities per year can be attributed to adverse drug reactions. Anybody who has two or more long-term health conditions will inevitably be ingesting a large number of drugs on a regular basis. In conjunction with a person's individual genetic disposition, this has a major influence on the effectiveness of drugs and increases the frequency and severity of side effects.

In Germany, approximately 42 percent of over-65s regularly take five or mo e prescription drugs.

Plug-in hybrids are driven on gas significantly more often than on electric power.

USA

Misleading packaging: gas-guzzling plug-in hybrids

The fuel consumption and CO_2 emissions of plug-in hybrid electric vehicles (PHEV) are many times higher than officially stated — and in newer models even more so. Such was the outcome of a study on the actual usage of PHEVs in Europe, carried out by the Fraunhofer Institute for Systems and Innovation Research ISI and the U.S. research organization, the International Council on Clean Transportation (ICCT).

According to official testing, PHEVs use, on average, around 1.7 liters of gas per 100 kilometers. In real terms, however, these values are three times higher in privately owned plug-in hybrids, and even five times higher in company cars. In the first six months of 2022, around 9 percent of all new cars registered in Europe were PHEVs — that is, roughly 400,000 cars. As they are equipped with both a combustion engine and an electric drive, the contribution they make to reducing carbon emissions is heavily dependent upon how they are actually used.

On average, privately owned PHEVs are driven in electric mode no more than 50 percent of the time, while for company cars this figure only reaches a maximum of 15 percent. Despite this, the purchase of PHEVs continues to be state-subsidized. The EU Commission has now responded by adopting proposals from the Fraunhofer ISI and ICCT study in its new draft regulation. As a result, from 2025 PHEVs will be evaluated on a much more realistic basis, and this could mean the end of the plug-in hybrid in the medium term.

AUSTRIA

Smart timber transport

Researchers at Fraunhofer Austria Research GmbH are working toward consolidating goods transport operations and implementing an intelligent network to move cargo efficiently and in a sustainable manner. To this end, they have developed transportation containers that can be used collaboratively across transport networks, as part of a pilot project called Smart Timber Logistics. These special containers are intermodal, and so are suitable for use on roads, railways and waterways. Various sensors and a GPS ensure that the container is "smart," while the built-in weighing technology prevents overloading and facilitates re-loading.

The containers can transport both tree trunks and other wood products, such as wood chips, which helps avoid empty runs. Container loading and transport are controlled via a marketplace and an open IT platform, which suggests the best transport route — from the forest to the processing plant — depending on ecological factors and costs. With smart timber logistics, it is possible, in an example region, to shift 30,000 of the current 100,000 tonnes of transport volume from the road onto the railways.

Truck journeys to re-loading points have been significantly reduced thanks to this innovative container.

NEW ZEALAND

Making green hydrogen industrially viable

New catalysts make water electrolysis more sustainable and more efficien

Scientists from the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM are collaborating with other scientists from the University of Bayreuth and three New Zealand universities on a project named HighHy, which aims to establish a resource-efficient and cost-effective method for water electrolysis. To do this, the project team are developing highly active catalysts specifically designed for AEM electrolysis, which guarantee a rapid and reliable oxygen evolution reaction. Crucially, these catalysts do not contain rare precious metals such as iridium, but instead are based on nickel and manganese — two readily available and inexpensive metals. The researchers hope to accelerate the market introduction of AEM electrolysis — a young technology that brings together the advantages of the processes commonly used up to now — and establish it as a viable industrial solution. Green hydrogen obtained through electrolysis from renewable energy is a key technology in the energy transition.

What is the most appropriate course of action? A digital platform helps with decision-making.

FRANCE

Fighting epidemics effectively

AIOLOS, a Franco-German collaborative project, represents a bid to learn from the coronavirus pandemic. The researchers are developing a digital platform that enables early detection of new epidemics triggered by respiratory pathogens, monitors their spread and simulates different intervention options to assist decision-makers in determining the appropriate international response.

The Fraunhofer Institutes for Translational Medicine and Pharmacology ITMP and for Algorithms and Scientific Computing SCAI are leading the project together with the French pharmaceutical company Sanofi, supported by a number of other industry partners. The multidimensional platform is designed to integrate real-time data from a wide range of sources — primarily from the healthcare sector, but also from text and media analyses, demographic and mobility data, and even wastewater analyses. Artificial intelligence models then use this data to develop plausible epidemic scenarios, which are displayed on a dashboard. The findings are intended to help private and public interest groups put in place scientific, economic and political provisions and introduce effective countermeasures.

back to page 1

A feathered air force to patrol the savanna

Artificial intelligence in a backpack: A new generation of miniature transmitters aims to better protect vultures and other wild animals — and this early warning system may also be of interest for industry.

By Dr. Katja Engel

King vulture Conchita from the Tierpark Berlin zoo is now flying on behalf of research.

Today is Conchita's first ever flight with a backpack. Taking a dive, she swoops close over a group of visitors to the Tierpark Berlin zoo. The female vulture has been fitted on the back and chest with an animal sensor that contains a camera for taking aerial photographs. And soon, the addition of built-in artificial intelligence (AI) will allow the photos to be evaluated and the result sent to a satellite in real time, in the form of a short text message. These messages could be combined with GPS data, so that vultures flying freely around the savanna could send a text such as: "Many dead zebras on the ground, please investigate immediately."

Vultures are often the first to discover dead animals. By eating carrion, they prevent the spread of wildlife diseases from dead to living animals. Within the ecosystem of the savanna, the vultures act as a kind of sanitary police force. But they also are indicators of change. For instance, they might show that water and animals are suddenly present again in an otherwise dry area. Or conversely, if vultures no longer fly over a certain area, it could be a sign that the wildlife population has collapsed. The outbreak of an animal epidemic may be evident from a large number of bodies within a small area.

"It is a genuine early warning system that can be used to rapidly identify hot spots such as disease outbreaks, poisonings or other changes to the ecosystem."

Nina Holzer, Fraunhofer IIS

Until now, researchers have had to manually analyze small amounts of data to get this information. Some animals have already been fitted with transmitters, also known as tags, but at present, these devices only store GPS and acceleration data. Not only that, but measurement data is only transmitted to the researchers when a bird happens to be flying over an area with a cellular network.

Now, a new generation of miniature transmitters is set to provide a significantly improved data basis for vulture research and the conservation of their ecosystem. As part of the joint project GAIA-Sat-IoT, researchers from the Fraunhofer Institute for Integrated Circuits IIS have been working together with the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW) since the beginning of 2022 to develop an innovative animal transmitter system that contains significantly more sensors and indicates environmental changes at an early stage. One component of this system is attached to the vulture's back and collects data on its position and acceleration, among other things. The other module contains the camera and sits on the bird's chest, facing forward . The two components work closely together.

Nina Holzer is heading up the GAIA-Sat-IoT project, which falls under a collaborative Fraunhofer IIS initiative focused on using artificial intelligence, IoT technology and satellite communications in species protection and wildlife research. The manager of the Multimodal Human Sensing group considers it essential "that AI processes the data directly on the sensor, so that no cloud connection is required. This makes it a proper early warning system that can be used to rapidly identify ecological cluster crises, including disease outbreaks, poisonings and other changes to the ecosystem."

Jürgen Ernst, chief engineer at Fraunhofer IIS, developed the test tag for the maiden flight in Berlin zoo. Conchita's test flight demonstrated that the new tag fits and that the camera is correctly positioned on the bird's body for landing. This means that, in the future, vultures will not only be able use the camera to take the most incredible photographs of their flights in the air, but also to capture images of animal carcasses in the savanna. All Ernst has to do now is to adjust the shutter speed of the camera lens to the vulture's own speed as it swoops down. The researcher is also interested in the amount of additional sensors that could fit into the small tag. Animal welfare is paramount, of course, so the sensors must not weigh more than 100 grams. Innovative ▶

Photos: Matjaž Krivic; Jan Zwilling, Leibniz-IZW

back to page 1

The art of fitting a lot of technology into a little space: The sensor must not weigh more than 100 grams.

The micro-transmitter, complete with camera, is attached to the vulture in such a way as to disrupt its natural behavior as little as possible.

sensors will also allow researchers to detect whether the animal the vulture is hopping is a dead elephant or a zebra, without relying on photographic evidence.

To ensure that the tag uses as little energy as possible and that the battery is long-lasting, the Fraunhofer researchers hope to reduce the number of computing operations on the chip to a minimum without affecting its performance. Another goal is to have the AI learn to decode and classify vulture behavior; this means that the camera would triggered when needed, and would not simply record everything at random. Biologist Wanja Rast from the Leibniz-IZW is training the AI that will be used with the vultures in the future. To this end, he is comparing data collected from vultures that are fitted with transmitters with their movements. This way, the AI learns whether, at any given moment, the birds are fighting with each other, preening or resting at a roost — or if they are swooping down to carrion, which is the optimal time for the camera to take a photo.

The researchers still have to wait until the vulture is in an area with a cellular network to receive the data. Florian Leschka, group head for System Design at Fraunhofer IIS, wants to change this using a tag-to-satellite communication system that is not only efficient, but also almost always available. As part of a sub-project on the development of camera tags with sensor-related AI for satellite IoT communication, he is developing a powerful satellite IoT radio module, which can fit into the tag along with the sensors. A cooperation with the start-up Rapid Cubes will help develop satellites that ensure the reliable delivery of messages such as: "Dead animal located here." The plan is to build and launch seven satellites that will form a small network when they circle Earth in low orbit, i.e., at a height of around 400 to 600 kilometers. Vultures in the savanna aren't the only ones who can benefit from IoT satellite communication, says Mr. Leschka. This type of communication could also prove useful for Arctic research or environmental monitoring using marine buoys. Here too, integrated AI creates small information packages that can be received instantly via satellite. "There won't be any more transmissions of large amounts of raw data — just the data extracted by AI, even in areas without a mobile network," explains Mr. Leschka.

Getting their vultures in a row: Falkner Manuel Sembritzki from Tierpark Berlin (left) and Dr. Jörg Melzheimer from Leibniz-IZW.

Readjusting tag settings on a laptop: Head engineer Jürgen Ernst (left) from Fraunhofer IIS fine-tunes settings for the vulture's tag.

"We are developing a technology that can also drive internet-of-things communications in industry."

Florian Leschka, Fraunhofer IIS

The group led by Nina Holzer is working to ensure that AI computing requirements on the chip are as small and energy-efficient as possible. On the other hand, Felix Kreyß and his team at Fraunhofer IIS intend to distribute various different AI algorithm computing operations across several tags. He is head of the SyNaKI subproject, which aims to leverage synergies between natural and artificial intelligence in swarms. If several vultures with transmitters are in the same location, the AI can work separately on the individual tags. This makes use of all of the tags' processing power, meaning that the AI algorithm does not have to limit its prediction accuracy. The SyNaKI approach involves building an ad hoc network as soon as vultures gather, for instance, around a carcass. The individual tags will then be dynamically assigned particular tasks.

Mr. Kreyß is already considering how the technology could be used on other animals. When many animals of the same species come together, it makes sense to distribute tasks to different transmitters. "AI offers a number of advantages for health monitoring of grazing animals, such as its ability to detect unusual behavior, or give an early warning of when an animal is about to give birth," relates Mr. Kreyß.

Vultures may certainly be effective PR agents for this new, cost-efficient AI, but Mr. Leschka has other areas of application in mind. "What we are developing is a technology that can also drive internet-of-things communications and the use of sensor-based artificial intelligence in industry." The advantages of analyzing data in real time on the sensor, without a cloud connection, could enable value creation in new fields of application — for example, logistics, avalanche warning systems and health monitoring that involves where sensitive patient data which cannot be processed in the cloud; not to mention traffic control systems and ensuring optimal soil irrigation in agriculture. ■

Photos: Matjaž Krivic; Jan Zwilling, Leibniz-IZW

back to page 1

It's not just the roads that are packed — with more and more gadgets to cram in, space is also at a premium inside cars. Now, Fraunhofer-Gesellschaft researchers want to fit sensors into headlights.

Photo & Fraunhofer

Go into the light

Cars already have many autonomous features — from cruise control to ensure that the vehicle maintains the correct distance from the car in front to lane assist systems for keeping the car away from guard rails. Attention assist warns fatigued drivers to take their coffee breaks when they need them, while parking guidance makes it easier to slot your car into a space. And in a tight spot, some cars can even hit the emergency break. To make these features possible, car manufacturers have incorporated large numbers of cameras and sensors into the vehicles at various different points.

However, if cars are to some day make their way through traffic safely without a human hand on the wheel, many more sensors will be needed in order to replace human drivers' vision and hearing. A key technology in this context, besides camera systems and radar, is high-resolution LiDAR (light detection and ranging) sensors; by using lasers, this technology can create an extremely precise 3D map of the vehicle's surroundings at lightning speed.

But how can we fit all these high-tech detectors into our cars? A research team made up of scientists from five different Fraunhofer-Gesellschaft institutes have found a smart solution for this space shortage. "We're integrating radar and LiDAR sensors into headlights, seeing as they are there already anyway — and what's more, they're the best place for ensuring optimum transmission for optical sensors and light sources, as well as a dirt-free environment," says Tim Freialdenhoven of the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR. "We're also working on combining the data from radar and LiDAR systems. This will create a lot of added value, especially when it comes to reliability." The Smart Headlight project team is currently building a prototype and they have already applied for a patent.

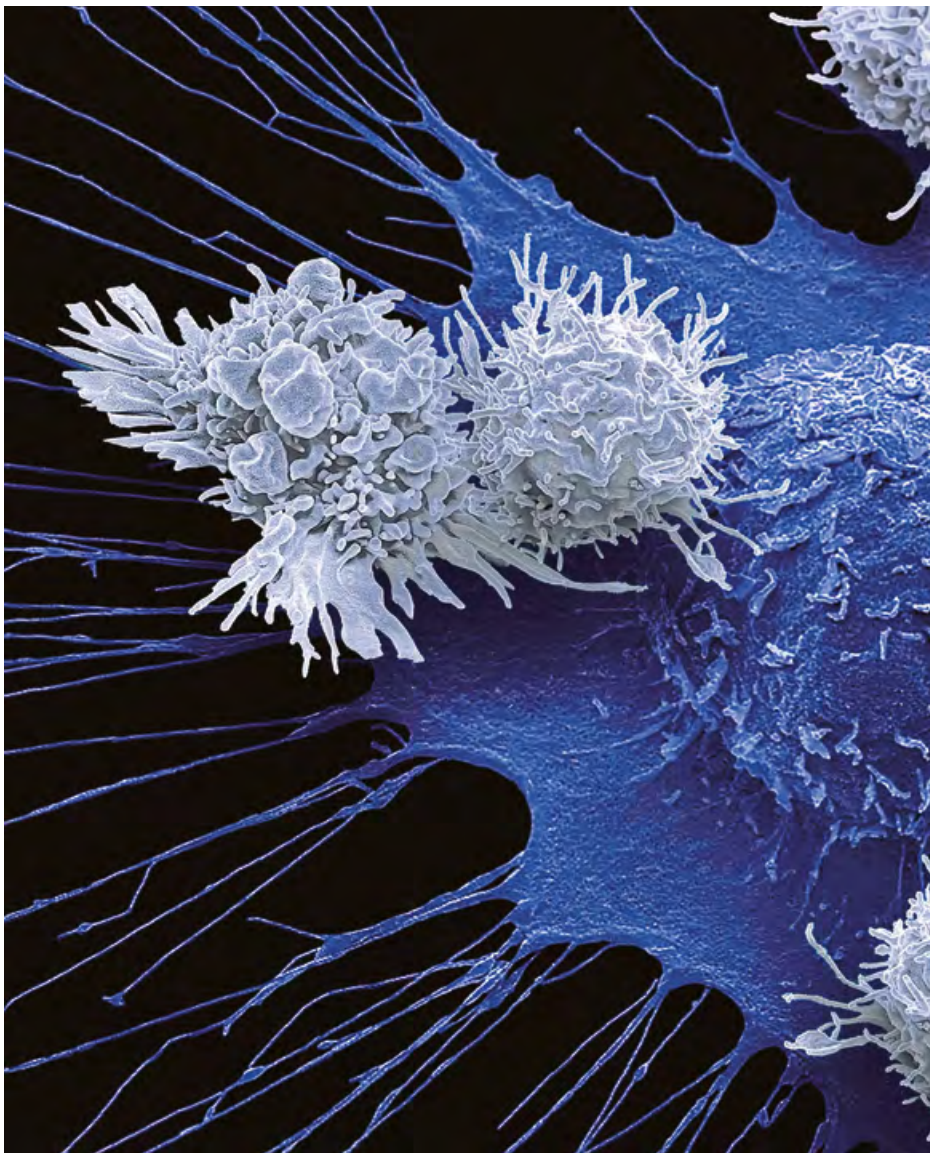
Photo: unikyluckk/AdobeStock

back to page 1

Detecting breast cancer cells in the bloodstream

It's faster, more efficient and safer for patients: With this new type of biopsy, breast cancer can now be diagnosed within just a few hours.

By Dr. Janine van Ackeren



Programmed for growth: a breast cancer cell among white blood cells.

When it comes to our lives, every day counts — every hour, even. For women that suspect they have breast cancer, that makes it all the more torturous when they have to wait days and days for the lab results on a tissue sample from their potential tumor. Can't it be done any faster? At the Fraunhofer Institute for Applied Polymer Research IAP, researchers in the LIBIMEDOTS project run by the "Nanocellular Interactions" working group are aiming to diagnose breast cancer in (almost) real time. With their liquid biopsy, they have developed a non-invasive and exceptionally fast alternative diagnostic method that enables early detection of breast carcinomas, without putting undue strain on patients' bodies.

"We detect breast cancer via tumor cells circulating in the blood," explains Dr. Neus Feliu Torres, a chemist and medical scientist who has been leading the working group at Fraunhofer IAP since July 2020. This is possible because as soon as a cancerous tumor develops in the body, for example in the breast, some of the tumor cells will always make their way into the bloodstream. This is why the researchers at Fraunhofer IAP and their project partners from Spain's Universitat Rovira i Virgili, Universität Hamburg and the University Medical Center Hamburg-Eppendorf, do not look for tumors directly in a tissue sample, but in the patient's blood.

This seemingly circuitous route offers several advantages. For one thing, the earlier a tumor is detected, the better the chances of recovery. The benefits of optimizing early detection and thus expanding the range of treatment options are reflected in the statistics: Since the late 1990s, the breast cancer mortality rate has been steadily decreasing. According to the German Centre for Cancer Registry Data,

Photo: Steve Gschmeissner/Science Photo Library

on average, 79 out of every 100 women affected are still alive 5 years after their diagnosis; after 10 years, the number drops to 67.

Certainty is just a pinprick away

Tissue removal is a minimally invasive surgical procedure but it can still cause pain, and is even associated with certain risks. The new method, however, requires nothing more than a pinprick — the patient only needs to provide a small blood sample. And the new technology is also expected to create advantages for the treatment stage. For instance, it can be used to quickly and easily check whether a treatment that the patient has recently started is working successfully. In this case, there will be a decrease in the number of tumor cells that the test detects flowing through the patient's veins. If the treatment is not working as hoped, the patient's doctors can then switch to a different type of treatment without losing valuable time.

The liquid biopsy in itself is not a new procedure, although it is not yet a standard tool for cancer diagnostics. The procedure has not been used for breast cancer detection at all until now. There are two main reasons for this: "Unlike other somatic cells, tumor cells in the blood are only present at a ratio of one to one million," explains Dr. Feliu Torres. "This makes them extremely difficult to detect." To track these fugitive cells down, the Catalan-born scientist and her research team have developed special magnetic nanoparticles that can be used to enrich the tumor cells. As soon as the cancer cells absorb these particles, they can be basically be gathered up into a concentrated group using a magnetic field.

However, just knowing that there is a tumor somewhere in the body is of limited help to the patient's physicians. Their next step is to determine exactly where the carcinoma is located. To do this, the scientists are using fluorescent particles that will bind specifically to the surface of the tumor cells detected in the blood. If one of them lights up, the researchers know that it is a cell from a breast tumor. The particles glow so brightly that very few cells are needed for tumor detection.

In current liquid biopsy methods, the magnetic nanoparticles bind to the surface of the cancer cells. However, these surfaces offer limited space, and in order to exploit the full potential of cell typing, there must be room for both the magnetic particles and the fluorescent particles. "We are developing magnetic nanoparticles that will be absorbed by the cancer cells. Then we will be able to use the entire cell surface for characterizing the tumor cells," explains Dr. Feliu Torres. As the tumor cells circulating in the blood vary from patient to patient, it is by no means sufficient to use just one type of fluorescent particle. This is why the team uses up to 18 different types of binding particles to track the tumor cells.

This new way of conducting liquid biopsies could soon make the detection of breast tumors more precise and specific, as well as more efficient, cost-effective and above all, faster than the classic method of tissue biopsy. This could ultimately allow patients to gain the most important thing of all: more life. ■

"Tumor cells in the blood are extremely difficult to detect."

Dr. Neus Feliu Torres, Fraunhofer IAP

back to page 1

Resilient networks and fortified systems

Thousands of kilometers of gas supply networks stretch across Europe. The EU project SecureGas aims to make them more secure.

By Mehmet Toprak

In September 2022, leaks in the Baltic Sea pipelines demonstrated the vulnerability of gas networks.

Europe's natural gas network alone stretches across 140,000 kilometers — and it would be impossible to protect this entire 140,000 kilometers of critical infrastructure against sabotage and attacks without leaving at least some gaps. Instead, the goal is to plan the networks in such a way that the consequences of attacks or technical defects are easier to bring under control and the gas network can regain its previous level of performance as quickly as possible. The focus is on resilience. Using newly developed software, the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI in Freiburg can simulate the probable effects of defects or incidents of any kind within the gas network — before they occur. Gas networks are highly complex systems, composed of pipelines, pressure regulators, connectors, valves and compressor stations. The latter are used about every 100 to 200 kilometers along the German transmission system in order to ensure that the pressure in the pipelines remains consistently high. This results in the highest energy throughput possible, while keeping friction losses to a minimum.

The software can simulate various situations, such as the way the network's gas pressure distribution would change if a pipeline were to fail due to damage. In this way, it would also determine the percentage by which the delivery capacity would decrease for each individual gas consumer. This software can simulate tens of thousands of different incidents. "Each scenario includes at least one component failure. If we look at what would happen if multiple components failed simultaneously, we quickly end up with a large number of possible scenarios," explains project manager Jörg Finger. "Doing this allows us assess which defects within the gas network would have particularly serious effects on performance, and which ones would have less serious consequences, before they ever happen." This then makes it possible to draw conclusions as to how the gas should be rerouted or which components should be repaired and in what order.

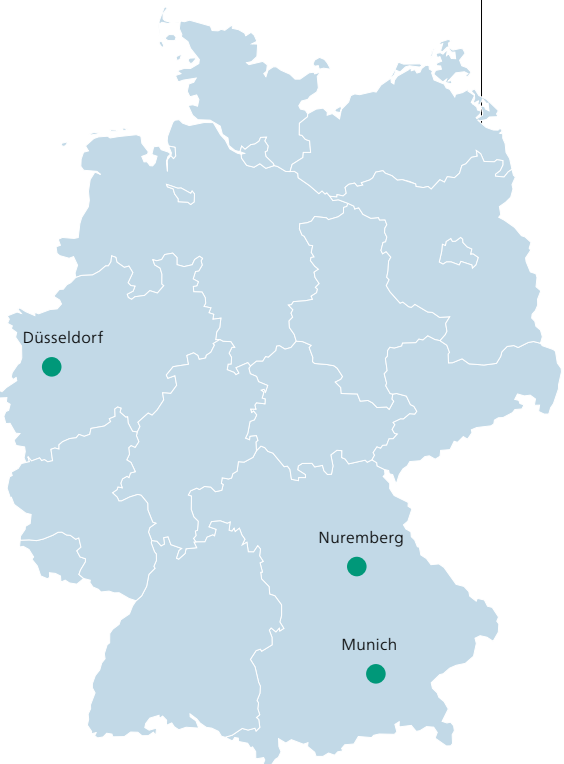
Which parts of the network are at the highest risk of damage — and what can be done to prevent it?

The network operators provide the basic data for the simulations. This includes information on the length and diameter of the pipelines, as well as characteristic values and performance features of numerous other components. Lastly, the software needs data on operating conditions and external influencing factors, such as gas feed-in and withdrawal rates, as well as access to values from measurements. "At Fraunhofer EMI, we are contributing to the project by identifying the points within the network that would cause the greatest damage if they were to fail. However, it will take the network operators' expertise to devise specific measures based on our results — for example, creating redundancies, strengthening protective measures and so on," says Dr. Sebastian Ganter, who, in addition to his leadership responsibilities, was in charge of developing the SecureGas project software. "We provide support in the preventive phase, especially when it comes to planning the expansion of the gas network." The simulation software can even help with the planning and construction stages of a network by simulating all the incidents and failures that could conceivably occur, which naturally also includes cyber- and physical attacks.

The research that Fraunhofer EMI is conducting here falls under the EU SecureGas project, which is being funded through the European research and innovation program Horizon 2020. Launched in 2019, the project aims to introduce a risk-based security management model for gas networks and to design a reference architecture for building, operating and maintaining resilient European gas networks. ■

Photo: AP/dpa

Fraunhofer on the road



Düsseldorf
November 14–17, 2022
Medica/Compamed
The leading international trade fairs for the medical sector

Munich
November 15–18, 2022
electronica
The leading international fair and conference for electronics

Munich
November 23, 2022
Fraunhofer Investment Forum (hybrid)
High-tech founders in search of capital meet investors

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

As of: October. Changes may occur due to the pandemic. Please keep an eye out for information from the event organizers.

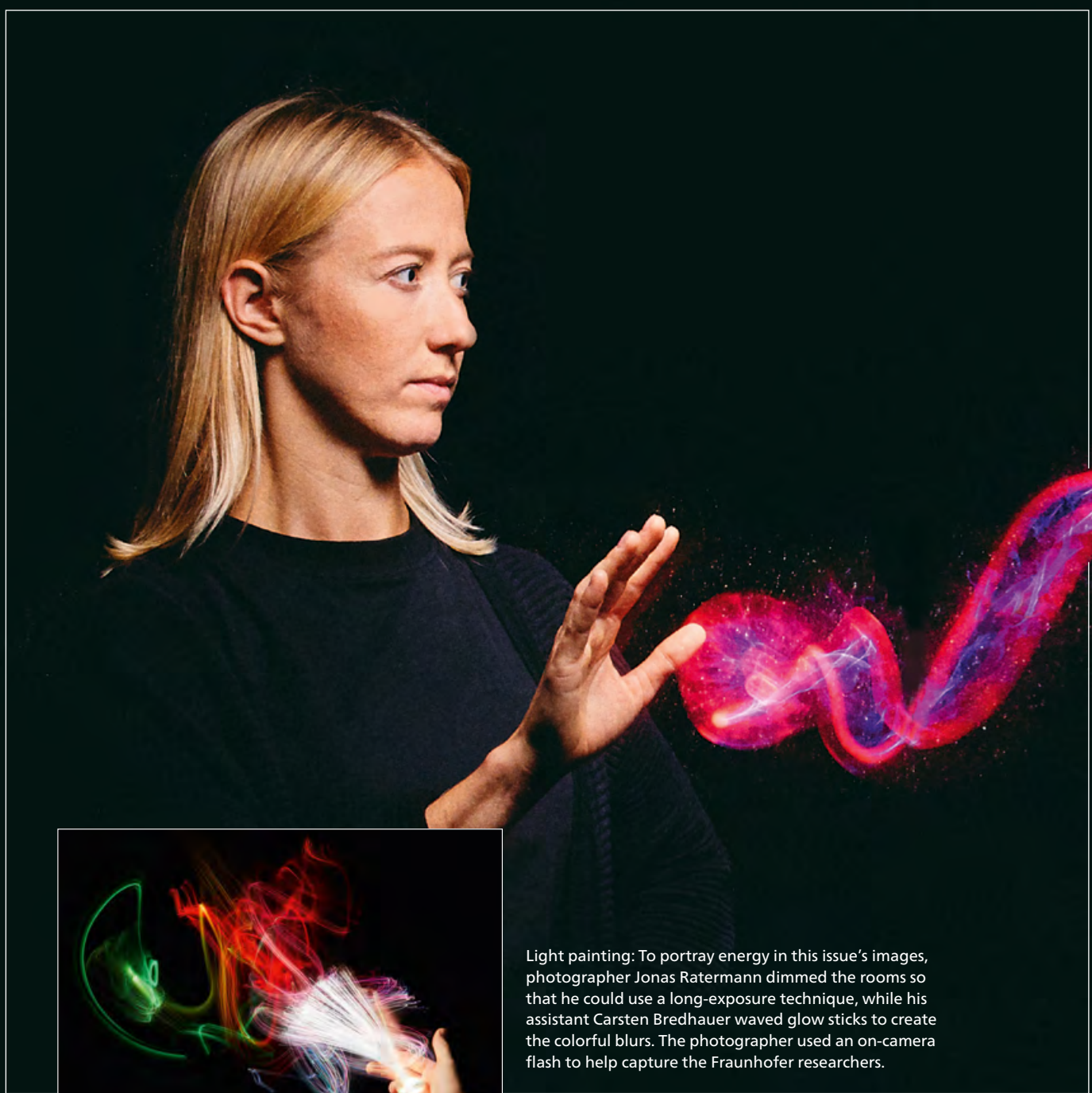
Fraunhofer magazine
The magazine for people who shape the future

Would you like to get the Fraunhofer magazine in your mailbox as soon as it comes out — for free? Order it online directly at **https://s.fhg.de/of**

back to page 1

“We already set up 30 pilot networks more than 13 years ago. Regular peer-to-peer discussions help the businesses involved to quickly learn where they can save energy.”

Lisa Neusel, Fraunhofer ISI



Light painting: To portray energy in this issue’s images, photographer Jonas Ratermann dimmed the rooms so that he could use a long-exposure technique, while his assistant Carsten Bredhauer waved glow sticks to create the colorful blurs. The photographer used an on-camera flash to help capture the Fraunhofer researchers.

Fraunhofer