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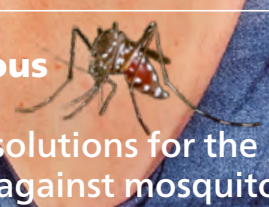
The magazine for people shaping the future

Sovereignty from space
200 satellites to increase security

Better plastics

From environmental crime to biosynthetics

Dr. Benedikt Hauer, Fraunhofer IPM



Perilous pest
New solutions for the fight against mosquitoes

"We need even more research!"
An interview with German Minister for the Environment Steffi Lemke

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Editorial

Excellence and diversity are in our DNA

By Prof. Holger Hanselka

Prof. Holger Hanselka

Plastic is incredible. It has huge potential in terms of its power-to-weight ratio and allows us to carry out highly efficient processes. Thanks to its material diversity and practically unlimited possibilities, this malleable, light, durable substance has been enjoying its heyday since the mid-20th century. And in the process, it has created a global environmental problem: 5 billion tons of plastic garbage — the downside to the plastic boom. So should we denounce plastic? In a lot of public discourse, our society is currently leaning toward hysteria. We do not understand, we do not weigh up both sides of an argument and we rush to judgment. That is the point where we really need science and rationality in a very particular way. The cover story of this issue of the Fraunhofer magazine is all about the search for "good plastic." As "the magazine for people shaping the future," it introduces readers to the Fraunhofer-Gesellschaft researchers that are applying all their passion and excellence to transforming the positive properties of plastic with a view to sustainability.

The solution? As is so often the case in situations with complex requirements, there is no single solution. Our teams of researchers are using biobased materials to develop a wide range of solutions such as fiber-reinforced plastics and energy-efficient circular systems with as little material loss as possible. An openness to using new technologies is fundamental here — for Fraunhofer itself, but also for a high-tech, scientific country like Germany. I am delighted that the German Federal Minister for the Environment, Steffi Lemke, also talked about being open to new technologies in an interview in this edition of the Fraunhofer magazine. "It goes without saying," as she puts it, that this approach will lead us to adopt technologies that achieve our goals in the most economical way possible. "Without independent research and research institutions like the Fraunhofer-Gesellschaft," Ms. Lemke says in her interview, "knowledge- and fact-based policy-making would be impossible." And the German Federal Minister for the Environment gives a clear answer to the question on how scientific solutions can be implemented more quickly: "Through direct dialogue, for example."

As the new president of the Fraunhofer-Gesellschaft, of course I would be glad to engage with this discourse at any time. It is up to politicians to set objectives, just as it is up to politicians to give researchers the framework they need to find solutions to achieve these objectives. It should not and cannot be up to politicians to dictate every little detail of how we will achieve those goals. Putting blinkers on researchers benefits no one. We do not need bottlenecks that restrict us. We need to turn the funnel upside down so that thought, research and the search for solutions can be extended in every direction.

Germany has always managed to develop incredible ideas. This country can be proud of that. Our Fraunhofer-Gesellschaft can be proud too — with 30,800 employees in 76 institutes and research units, we have been playing a reliable role in the German scientific scene for almost 75 years. Diversity is our DNA, and it is with and through this mindset that we are creating new opportunities for Germany and Europe. Let us work together to achieve this.

Sincerely,

Prof. Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer/Markus Jürgens

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Dr. Matthias Beier of SPACEOPTIX GmbH and Dr. Henrik von Lukowicz of Fraunhofer IOF (right) are aiming high with their new satellite technologies.

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Communications are being stretched to the limits during international military exercises. Mandatory standards will reduce the strain.

86 The coffee of tomorrow

Researchers believe Germany's favorite drink could taste quite different in the future.

According to the UCS Satellite Database, there are currently 6,718 satellites in orbit. A good 50 percent of these belong to SpaceX's Starlink network, meaning that the private American enterprise operates the largest satellite fleet in space. Europe is striving to achieve more independence from Elon Musk in its communications — and Fraunhofer is providing the necessary solutions (from p. 38).

50%

Front and back cover photos: Hilde Harshagen, Thomas Straub, Stefan Thomas Kröger/laif
Content photos: Hilde Harshagen, Stefan Boness/VISUM, Thomas Straub, Martin/Le Figaro Magazine/laif, Fraunhofer/Piotr Banczerowski, Siegra Asmoel/dpa

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Brief report

Better protection for personal data: Fraunhofer researchers are securing ID documents against quantum computer attacks.

Certified quantum-safe

The PoQuID project is aiming to make counterfeit-proof identity documents, even in the age of quantum computing. Identity cards and EU passports issued in Germany contain an electronic chip that stores not only the holder's name, height and eye color, but also their photo and two fingerprints. The chip is intended to make the document counterfeit-proof.

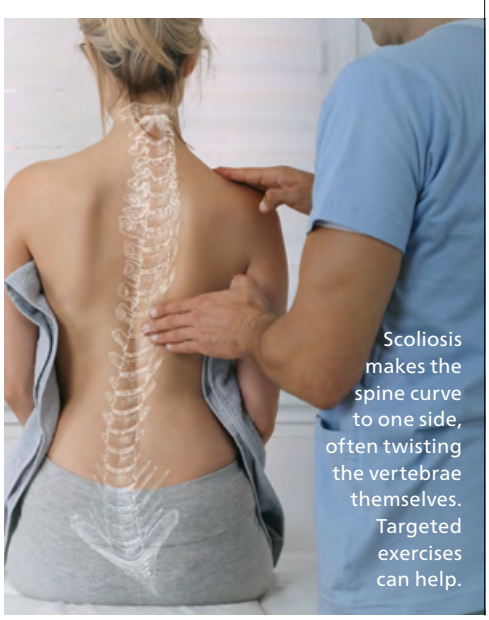
The Fraunhofer Institute for Applied and Integrated Security AISEC joined together with the Bundesdruckerei security printing company and semiconductor specialist Infineon for this project to develop cryptographic protocols that can withstand even quantum computer attacks. "We have adapted and further developed Extended Access Control, the current standard cryptographic protocol for passports, to make it quantum-resistant and ensure it can run effectively even within the limitations of the security chip's resources," says Prof. Marian Margraf, head of the Secure Systems Engineering department at Fraunhofer AISEC. These protocols are suitable not only for electronic border controls, but also for online identification.

Prof. Margraf is now calling for these to be brought to the market sooner: The first effective quantum computers should be available from 2030 onward. But the international standardization process alone will take at least five years — and previously issued identity documents can remain valid for up to ten years. ■

Digital support for scoliosis therapy

Researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU have worked with partners to develop a digitally aided scoliosis therapy system. iScoolio guarantees comprehensive patient monitoring, real-time feedback and long-term assessment of therapeutic success. The iScoolio app provides visual feedback to reassure patients that the have done their therapeutic exercises correctly at home. In addition, its digital user profile and gamification elements boost motivation. Patients wear a vest equipped with sensors while doing their exercises. These sensors track movements and monitor breathing, so there is no need for a camera system. Additional modules make it possible to monitor other factors, such as the strength applied while carrying out the exercises. Measuring of the center of pressure (COP) provides another diagnostic point of reference for assessing therapeutic progress.

Scoliosis, a three-dimensional structural deformity, is the most common spinal disorder among children and adolescents in Germany. It is treated through daily therapeutic exercise and, in more severe cases, a back brace. ■



Scoliosis makes the spine curve to one side, often twisting the vertebrae themselves. Targeted exercises can help.

Intelligent automated remanufacturing

In the Desire4Electronics project, the Fraunhofer Institute for Manufacturing Engineering and Automation IPA is working together with ten partners on automated disassembly processes for remanufacturing small electronic devices. Machine learning techniques are used to rapidly recognize types of devices and joining methods and assess them with the help of images and process data. This provides a basis for researchers to develop multi-tools that can easily release various connections when dismantling small electronic devices. The aim of developing automated dismantling methods is to establish remanufacturing processes in industrial countries and make remanufacturing profitable — this will contribute to greater sustainability in terms of production and consumption.

Each year, Germany generates a per capita average of 19.4 kilograms of scrap electronics — and this figure is rising. Small electronic devices like toasters, hairdryers, robot vacuum cleaners and robotic mowers in particular are made up of multiple components containing valuable substances such as copper, polymers and lithium; these products are still functional and could be remanufactured. This process is currently very time-consuming and expensive. This process, which is usually performed manually, is very time-consuming and expensive, making automated dismantling a key contributor to the circular economy. ■

TVs, smartphones and other electronic devices often end up in the trash, even though remanufacturing would give them a new cycle of use.

Better organization of voluntary support

When the chips are down, professionals need the support of volunteers.

An interdisciplinary team that includes the Fraunhofer Institute for Open Communication Systems FOKUS is developing an app to coordinate the deployment of volunteer helpers in disaster situations.

KatHelfer-PRO contacts volunteers as quickly as possible and assigns them tasks based on their skills and availability. In the case of a crisis or disaster, the system uses a special placement algorithm to automatically match supply and demand. This takes account of factors such as maximum working hours and rest periods, capacity in areas of deployment and traveling time. KatHelfer-PRO provides helpers with precise information about the type and location of their deployment, along with any accompanying details. To avoid inconsistent, technically incompatible local solutions, the team is working on a nationwide digital system that can be flexibly integrated into other systems. ■

Photos: Norbert Buchholz, Albina Mihajlo/AdobeStock, Ramon Espelt/Westend61/mauritius images, Katharina Garrecht/Federal Agency for Technical Relief

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Sunlight generates electricity while cyclists near Freiburg enjoy some shade.

Cycling under a solar roof

Europe's first cycle path with a photovoltaic roof has been launched in Freiburg, Baden-Württemberg. The Fraunhofer Institute for Solar Energy Systems ISE is renting this PV system and using the green energy generated to power some of its laboratories. The researchers are collecting and evaluating data on irradiation and power generation. They aim to use the findings of the pilot project to develop new photovoltaic solutions for urban areas, and so help to drive the energy transition.

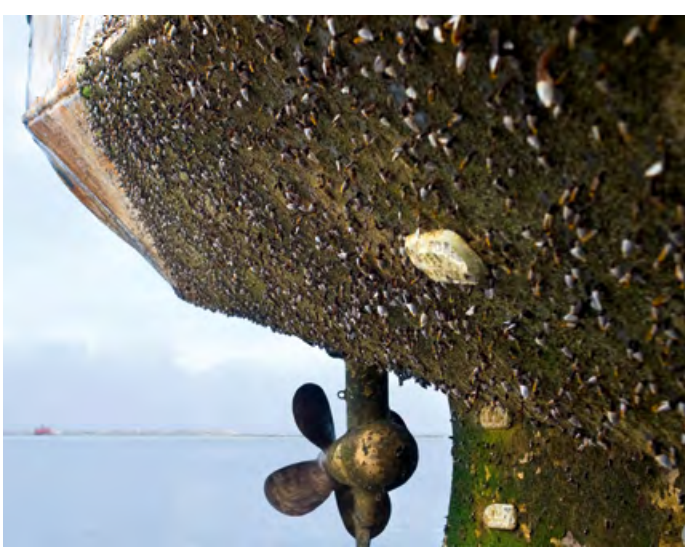
The cycle path, which runs alongside the Freiburg exhibition center, is covered for around 300 meters with 912 transparent photovoltaic modules that generate around 280 megawatt hours of electricity per year. This is equivalent to the needs of about 200 households. The partners in this project are the energy provider badenova-Wärmeplus, which planned and constructed the system, and the city of Freiburg, which provided the site and financed the project through the city's climate protection fund. ■

Lasering off biofouling

Researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM have been working with partners to develop an efficient, environmentally friendly procedure to remove mussels and algae from the hulls of ships.

Laser radiation is used to kill off this growth, known as biofouling, below the water line without damaging the hull's coating underneath. The water current then washes away the dead mussels and algae. This process has already been successfully tested in practice.

Biofouling increases a ship's flow resistance — which raises fuel consumption and CO_2 emissions. Marine fouling can also introduce non-native species into foreign ecosystems, where they spread and cause considerable disruption. Ships can be banned from docking in harbors due to biofouling. ■



Fouling on hulls is more than just unsightly. A new laser procedure should help.

Editorial notes

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A second chance for cacao

The fruits of the cacao tree are vulnerable to pests. To reduce crop losses, Fraunhofer researchers are seeking out opportunities to make use of damaged beans.

Every year, some 20 percent of the worldwide cacao harvest falls victim to harmful fungi, viruses or bacteria. Diseased fruit is either disposed of by the cacao farmers or mixed into healthy fruit, which reduces the quality of the cacao and the chocolate made from it. The Fraunhofer Institute for Process Engineering and Packaging IVV has joined a German-Brazilian consortium to find alternative uses for these supposed rejects.

The Damaged Beans project is primarily targeting the cosmetics industry. Fungal diseases alter the melting properties of cocoa butter, which is also used in personal care products. It softens at room and body temperature. While this is not ideal for chocolate production, it is an advantage in cosmetic applications. Changes in the composition of amino acids and proteins in damaged cacao beans also enhance their gelling and thickening properties, so these fruits could replace environmentally damaging acrylates in cosmetic products, for example. The cacao tree reacts to microbial attacks by generating more secondary plant materials with antioxidant and antimicrobial properties, which can in turn boost the stability and shelf life of creams, shampoos and similar products.

This project, funded by the German Federal Ministry for Economic Affairs and Energy, aims not only to save damaged cacao beans from the trash, but also to improve the circumstances of cacao farmers worldwide by providing opportunities for new applications. It will also broaden the portfolio of sustainable ingredients used in the cosmetic industry at the same time — a win-win-win all along the value chain. ■

The best cacao beans are used to make chocolate. But the rest can be put to other clever uses.

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Title

Better with plastic

Plastic has gone from being a valuable material to a trash problem. But as we can't go without it, researchers are pulling out all the stops to make this multi-purpose material more sustainable.

By Beate Strobel,
Photography: Hilde Harshagen

Fascinated by plastic and its possibilities: Andreas Keller, Fraunhofer IZFP.

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Simon, six, has a decision to make: the soda can or the yogurt pot? The empty water bottle, the chocolate packaging or the torn-open chips bag? At the Fraunhofer Institute for Process Engineering and Packaging IVV booth at the Munich Science Days event, Birgit Faltermayr has lined up all kinds of trash — but what belongs in the bag for recyclable packaging, and what goes in the recycling can? Hesitantly, Simon picks up the yogurt pot and looks questioningly at the scientist. "Bingo," Ms. Faltermayr says approvingly. And plop — the yogurt pot disappears into the bag. Easy peasy, right?

But when it comes to plastic, unfortunately nothing is simple anymore. This material's heyday, stretching from the mid-20th century, was based entirely on one promise: that with its practically unlimited possibilities in terms of shape and properties, and its durability, low weight and cheap price, plastic would make a lot of things simpler, lighter and cheaper. For decades, it seemed as though this promise could be fulfilled unconditionally. The world became more colorful, products became cheaper and safer, and industrial processes became more efficient. Since the 1950s, plastic production has grown by an average of 8.4 percent per year; over 8 billion tons of plastic have now been produced globally.

Since the start of the plastic boom, almost **5 billion tons of waste plastic** have been introduced into the environment and accumulated in open landfills.

However, the issue of what happened to the material after it was used went overlooked. In many areas of the economy, people failed to adequately consider end-of-life models for plastics, as well as the carbon footprint of plastics and composite materials. The environmental consequences have been devastating: One in twenty tons of petroleum are used for plastic production; this industry accounts for 4.5 percent of global greenhouse gas emissions. What's more, the material's recyclability has been ignored in favor of disposable convenience. Since the start of the plastic boom, almost 5 billion tons of waste plastic have been introduced into the environment and accumulated in open landfills.

The United Nations Environmental Assembly wants to introduce an international treaty to mitigate plastic pollution globally; the completion of the negotiations and entry into effect are set to take place by the end of 2024. The UN environmental organization UNEP has now lit a light at the end of the tunnel, and it's sparking hope — a study published in mid-May indicates that it will be possible to reduce global plastic pollution by over 80 percent by 2040. But how?

"The plastics sector is being transformed at a fundamental level," states Prof. Sebastian Scholz, director of the Fraunhofer Plastics Technology Center Oberlausitz at the Fraunhofer Institute for Machine Tools and Forming Technology IWU. This shift is not just limited to the industry — it affects every individual. After all, when we heard the word "plastic," we mainly think of single-use products and waste packaging, but there's a lot more to plastics than just that. And they are everywhere: in our clothes and cosmetics, in cars, airplanes, trains, in the casing of electric devices and in buildings. Even space debris, which is increasing every day, is mostly made from plastic, as many plastics are used to build satellites and rockets. "It's vital that we develop techniques to help make the production and use of plastic more sustainable," says Prof. Scholz.

There is an important question to be researched here: To what extent can fossil-based plastics be completely or partially replaced with biobased materials, without them losing their desired properties? As part of the LaNDER3 network at the Zittau/Goerlitz University of Applied Sciences, several Fraunhofer institutes are working together with numerous companies to conduct research into replacing glass fibers in synthetic fiber-reinforced plastics with natural fibers. The aim is to retain the advantages of glass-reinforced polymer composites (GFRPs) — a high rate of mechanical stability and resistance, as well as low levels of corrosion and low production costs — in these natural fiber-reinforced polymer composites (NFRCs). For example, the use of tow, a byproduct of hemp and flax fiber production, has been tested in manufacturing interior paneling for trains — this material is inexpensive and available in sufficient quantities. "The NFRC components can rival GFRPs in terms of robustness, flow properties and fire resistance," says Prof. Scholz.

To prevent the solution to this problem from just causing another issue, sustainability needs to be considered right from the outset when selecting new raw materials for the plastics of tomorrow. Because if agricultural products were the only resources meeting Germany's ▶

"It's vital that we develop techniques to help make the production and use of plastic more sustainable."

Prof. Sebastian Scholz, Fraunhofer IWU

Prof. Sebastian Scholz, director of the Plastics Technology Center Oberlausitz at Fraunhofer IWU is researching how using natural materials in plastics might make them more sustainable.

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Chemist Dr. Cornelia Stramm of Fraunhofer IVV is working to create safe packaging from renewable raw materials.

"Anyone who feels annoyed about fruit and vegetables being packaged should avoid imported goods and just buy seasonal and regionally produced products instead."

Dr. Cornelia Stramm, Fraunhofer IVV

enormous appetite for plastic, they would no longer be used for food. Plastics can never be allowed to compete with food. In the EnviroPlast project, researchers from the Fraunhofer Plastics Technology Center Oberlausitz are investigating the use of fibrous residual materials, such as straw, waste wood from lumber mills and other organic waste, as fillers. "We are experimenting with materials and playing with processes to develop plastics where over 50 percent of the fillers consist of residual materials," Prof. Scholz explains. "That will decrease production costs, increase the level of sustainability in manufacturing — and capture CO_2 for many years, as these components are generally in use for decades."

At the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt, Dr. Roland Klein is working on the DuroBast project together with partners from science and industry to find a wider range of application areas for bast fibers in NFRCs. "With NFRCs, there is a risk that they will be saturated with moisture from the environment if the component becomes damaged, for example. Not only can this degrade the mechanical properties, but it could also encourage the growth of microbes," explains Dr. Klein. In order to counteract this absorption of moisture, the research team at Fraunhofer LBF uses a type of pretreatment process to fill in the spaces between the fibers with a biobased plastic. It is only in the second step that the project partners combine the reinforcing material with molten thermoplastic and press it into a moldable semi-finished product. Initial tests have shown that the fiber pretreatment process results in a more robust product. "Improving the mechanical properties of this NFRC means that we will ultimately need less material," Dr. Klein says optimistically. This would also decrease the ecological footprint involved.

The issue of materials is particularly important when it comes to plastic products that are only used for a brief time. Making a change in this area could have an enormous impact: Around one third of the plastic used in Germany is in packaging. Plastic has become established in the packaging sector as the material with the best power-to-weight ratio, explains Prof. Jens-Peter Majschak, director of the Fraunhofer Institute for Process Engineering and Packaging IVV and head of its Dresden location. This rather inelegant term refers to the relationship between the mass of the packaging material and the goods it protects. Some plastics and plastic composites have excellent barrier properties, reduce energy and transportation costs and allow for highly efficient processes — and their huge variety of design options keeps both designers and marketers happy.

Plastic packaging is more than just a wrapper, explains chemist Dr. Cornelia Stramm, who heads up the Materials Development department at Fraunhofer IVV in Freising. Across the world, many harvested food products go bad before they reach the market — but without protective plastic packaging, this issue would be much worse. Dr. Stramm even has a good argument for the much-criticized practice of shrink-wrapping cucumbers in plastic film, despite their natural packaging: If these vegetables had to make the journey from somewhere like Spain without a plastic wrapper, they would be wrinkled by the time they reached their destination. When packaged in plastic film, they stay fresh for five times longer. "Anyone who feels annoyed about fruit and vegetables being packaged should avoid imported goods and just buy seasonal and regionally produced products instead," says Dr. Stramm.

Across the world, **far too many food products** go bad before they reach the market — but without protective plastic packaging, this issue would be much worse.

As consumers' environmental consciousness has evolved, more and more producers have come to Fraunhofer IVV with requests for help in developing more sustainable packaging materials. Institute director Prof. Majschak has been seeing a "huge wave of exploration" when it comes to sustainable raw materials such as leaves, grass, mushrooms and algae. For example, researchers at Fraunhofer UMSICHT are currently working on developing foamed packaging made from the biobased raw material starch; from 2025, this is set to replace polystyrene, polyethylene and polyurethane, the common variants of today. In the EU project GLOPACK, 16 European project partners (including Fraunhofer IVV) have developed solutions that allow residual material from fruit, maize and wheat straw processing to be made into biopolymer trays and films that can be composted after use. And in the PLA4MAP research project, scientists are finetuning the idea of manufacturing a tray and a sealing film made from the biobased plastic polylactic acid (PLA). With coatings ▶

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such as proteins or waxes, this packaging will even be able to protect particularly perishable foods like meat and dairy products and baked goods.

Dr. Stephan Kabasci, who is responsible for strategic project development in the circular economy section at Fraunhofer UMSICHT, believes that polylactic acid will play an important role in the search for innovative bio-packaging. "PLA is a very strong plastic, but it's also biodegradable," the chemical engineer explains. "It can also be produced in a way that makes very efficient use of land: From 1 kilogram of sugar, you can produce around 900 grams of PLA." Dr. Kabasci prefers producing sugar from maize: "At the moment, for example, the majority of the sugar extracted from corn starch is being used as high-fructose corn syrup in soft drinks and other highly sweetened foods. If the sugar content in these products was reduced worldwide, it would free up considerable capacity for producing PLA." This would not only benefit the environment, but consumers as well — too much sugar is considered a health risk in many respects.

> "From one kilogram of sugar, you can produce around 900 grams of PLA."
>
> Dr. Stephan Kabasci, Fraunhofer UMSICHT

PLA is a good option for the industry sector, as it can be manufactured cheaply. The food packaging sector is extremely price-sensitive — differences of a few cents can be the factor that makes the industry decide for or against a certain plastic. "Currently, PLA is the only biopolymer that is available in the required quantities and with consistent quality levels," explains Dr. Stramm of Fraunhofer IVV. Its transparency and mid-level barrier properties make it an excellent option for packaging. But until using PLA seems like a financially viable option for the industry, it won't be worth separating out this particular recycling stream. The lack of proper options for recycling also weakens the argument for PLA's sustainability from the industry's point of view. "What we have here is a classic 'chicken and the egg' problem," says Dr. Stramm.

Despite promising research in the area of biobased plastics, we are still a long way from the go al of entirely replacing fossil-based plastic variants with alternatives made from renewable resources. "Besides, biobased plastics are no free ticket to a sustainable future," adds Prof. Majschak. Quite the opposite: "At it stands, they're throwing sand in the gears of the existing recycling chains." This is because "biobased" does not automatically mean biodegradable. For example, PLA is officially considered to be compostable — but for the variants that are durable enough for packaging, this is only possible under very specific temperature, oxygen and humidity conditions. It cannot be done in a domestic composting bin. This creates a huge challenge, as "with the current state of technological advancement, any packaging that is easily biodegradeable would not be able to perform the protective function it was made for," explains Prof. Majschak. In large composting plants, on the other hand, bioplastics take longer to decompose, so they are less financially profitable: Normal organic waste breaks down much more quickly.

For as long as we still need fossil-based plastics, we will need more solutions for increasing sustainability. In the white paper "From #plasticfree to future-proof plastics," researchers at Fraunhofer UMSICHT and the Dutch research institute TNO worked together to investigate how we could strike a new balance between reducing plastic and taking a sustainable approach based on recyclable plastic. The paper suggested four strategies for transforming the plastics economy, which is currently primarily linear, into something as close as possible to a complete circular economy. The aim is not only to reduce the use of petroleum-based plastics globally ("Narrowing the Loop"), but to make the future production of these plastics more energy efficient and environmentally friendly ("Operating the Loop"). In order to slow the cycle down ("Slowing the Loop"), we need to find new ways to extend the service life of plastic products. A completely closed cycle ("Closing the Loop") could be achieved by collecting and sorting ideally up to 100 percent of the plastic that is used, and recycling it into the highest-quality material possible.

Using plastics for longer: Elke Metzsch-Zilligen, head of the Additivation and Durability department at the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt, is investigating which additives can be added to a plastic to improve its stability. "Heat, moisture, UV rays — they all damage the material and impair their desirable properties," she explains. Only with the use of additives can plastics become durable enough for applications such as the electrical and automotive industries. In the Cluster of Excellence Circular Plastics Economy CCPE, six Fraunhofer institutes (including Fraunhofer LBF) have joined forces with industry partners to pave the way for a ▶

Rethinking plastic: Dr. Stephan Kabasci of Fraunhofer UMSICHT is searching for bioplastics that are fit for purpose.

Smarter sorting

Consumers can do their part from home to increase the material recycling rates for plastics and other packaging.

What are recyclable materials? Packaging such as plastic, tin, aluminum and composite packaging (e.g., Tetra Paks). Instead of being thrown out with the rest of the trash, they should be disposed of in a way that allows them to be recycled. This is usually done in household recycling collections or special recycling dumpsters.

The Green Dot is outdated: The rule that only packaging with Repak's Green Dot can go in recycling collections is a thing of the past. Since 2009, Germans have been allowed to put all their plastic, metal and composite packaging in the recycling. In fact, they can put everything made from plastic or metal in there — not just packaging. There's just one exception: electronic devices.

Homework: To make the sorting plant's work easier, take the packaging apart at home, insofar as this is possible and reasonable. Remove bands made from paper or plastic, separate aluminum lids from plastic cups and take the hard plastic lids off PET bottles or Tetra Paks. In the case of cheese or meat packaging or fruit punnets made of plastic, remove the lids entirely and dispose of them separately.

Leave it loose: Don't stack pieces of packaging inside each other, because the sorting system will only recognize the type of plastic on the outside. Likewise, don't stuff any plastic or other recyclable materials into empty cans and throw them out that way.

Cleaning solution: Remove any food residue from the packaging (scrape it clean). There's no need to actually rinse out the packaging or even go as far as washing it with hot water and dish soap.

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circular plastics economy. One key section of the cluster is working to better understand and control the aging and decomposition properties of plastics such as PLA. The CCPE is also focusing on developing more suitable and (ideally) biobased additives that will enable long-term use and ultimately either material recycling or a controlled biodegrading process. "The results of our research here are very encouraging," says Ms. Metzsch-Zilligen.

Additives also play a special role when it comes to reprocessing recycled materials — for example, they can restore desired properties and distribute impurities more evenly in the mixture to avoid unsightly effects on the surface. Or they can be used to remove the frequently unpleasant odor that clings to used materials: If you have ever smelled the inside of a recycling bin, then you know what we mean. The CCPE has developed a method that uses sandwich injection molding to cover bad-smelling old material with a skin of odorless virgin plastic. Special additives in this protective skin prevent the odor being released from the core over the long term — so there is no longer any reason not to reuse this recycled plastic indoors.

53 percent of plastic waste collected in 2019 was used to generate **electricity and heat**. **46 percent** went for material **recycling.**

The SusFireX and Bio-Flammschutz (bio flame protection) projects at Fraunhofer LBF have proven that not only plastics themselves but also additives can be made more sustainable. In these projects, researchers have developed biobased flame-retardant materials using platform chemicals from biorefineries and cellulose (from sources such as residual material flows from paper recycling). These materials help make highly flammable plastics more sustainable and safer. Up until now, the industry has depended on halogen- or phosphorus-based additives, which are primarily produced from fossil raw materials. "The flame retardants we have developed can be easily incorporated into conventional and biobased plastics," explains Dr. Klein. And the good news does not stop there: "If we use certain combinations of biobased and conventional flame retardants, we can achieve promising results even at very low concentrations. That not only reduces the ecological footprint, but also improves the plastic's mechanical properties."

However, even the longest-lasting product will some day reach the end of its useful life and wind up in the trash. What should we do with this plastic, which has usually been manufactured and processed using a huge amount of energy? According to the German Environment Agency (UBA), over half (53 percent) of the plastic waste collected in 2019 was used for energy, i.e., burned in waste-to-energy plants to generate electricity and heat. Meanwhile, 46 percent went for material recycling, the goal being to turn the used plastic into material for plastic production (recycling). Just 1 percent of plastic waste is currently recycled into raw materials, i.e., broken down into basic materials such as oil and gases — a procedure that is still too complex to be financially viable.

In its waste hierarchy, the German Circular Economy Act (Kreislaufwirtschaftsgesetz, KrWG) gives top priority to the strategy of preventing waste; this involves avoiding or reusing plastic products and packaging. However, this is then followed by strategies that help optimize a proper circular economy. The basic premise here is simple: The longer we can keep plastic in circulation, the less new plastic needs to be produced. "However, this means we need to take the whole process chain into account," explains Susanne Kroll, group manager for High-Performance Composites and Circular Economy at the Fraunhofer Institute for Machine Tools and Forming Technology IWU.

Ms. Kroll is one of the coordinators of the Circular Saxony innovation cluster. Launched in 2022, this cluster aims to bring stakeholders from government, science and industry together to make production and utilization cycles more sustainable, and thus bring the circular economy from theory into practice. "Our very manufacturing processes need to be adapted to fit the concept of a circular economy," says Ms. Kroll. This can be achieved, for example, by constructing hybrid structures that consist of different plastics and composite materials in such a way that they can be easily separated after use, which means they do not just end up being burned for energy. Consideration must also be given to how the object will be dismantled, for example, by using detachable adhesive joints. Ms. Kroll calls this approach "design for reuse, repair and recycling."

Reuse must kept in mind from an early stage: In the RE-USE project, four Fraunhofer institutes are already working on producing food and medicine packaging in a way that makes it easier to recycle later. "Much of ▶

"In the RE-USE project, we want to cover pure plastics with a coating such as silicon oxide or aluminum oxide, which acts as a diffusion barrier."

Dr. Benedikt Hauer, Fraunhofer IPM

In the RE-USE project, Friederike Münch and Dr. Benedikt Hauer (both from Fraunhofer IPM) are using smarter quality control to increase recycling rates.

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"The basic idea was to develop a vehicle platform where components could easily be swapped in and out."

Dr. Martin Kausch, Fraunhofer IWU

Making changes on the fly: In the KOSEL project, Dr. Martin Kausch of Fraunhofer IWU, wants to create vehicle platforms that can be reused multiple times.

this packaging is made from plastic composite materials, which provide a reliable barrier that is good for protecting food. Unfortunately, material combinations like these can no longer be broken down into pure polymers, which is necessary for recycling," explains project manager Dr. Benedikt Hauer of the Fraunhofer Institute for Physical Measurement Techniques IPM. "In the RE-USE project, we want to cover pure plastics — preferably ones made from recycled material — with a coating such as silicon oxide or aluminum oxide, which acts as a diffusion barrier." This coating is only a few nanometers thick, explains Friederike Münch, mechanical engineer and research scientist at Fraunhofer IPM: "That's ten thousand times thinner than a human hair. The benefit here is that the plastic can be recycled like a mono-material, as the contamination caused by this barrier layer will be restricted to the per mille range or even lower."

To ensure that this "superbarrier" is not only ultra-thin but also covers the plastic to a sufficient level in its entirety, the team at Fraunhofer IPM has developed an optical sensor that detects the coating and can therefore perform quality control during production. "By using infrared reflectometry, not only can we see which coating material has been applied, but also how thick the layer is," explains physicist Dr. Hauer. "The challenge now is to scale this technology so it can also be reliably, quickly and inexpensively used on a large scale," explains Ms. Münch. Once that has been achieved, the project manager Dr. Hauer can envision a wide range of applications for this measuring technique — such as the production of films for packaging and food containers, and blister packaging in the pharmaceutical industry. Thin coatings, especially of silicon oxide, are also frequently used to optimize physical and chemical surface properties. The new measuring technique can also be used for quality control during production for these coatings.

In project KOSEL, Fraunhofer IWU has demonstrated how the "design for recycling" principle can be applied to automotive manufacturing. "The basic idea was to develop a vehicle platform where components could easily be swapped in and out," explains Dr. Martin Mausch, head of department for Systems and Technologies for Textile Structures. "That's been standard for a long time when it comes to airplanes, trains and trams — passenger airplanes are converted to cargo airplanes, for example." In KOSEL, researchers have developed an open-source, recycling-oriented modular system for an e-vehicle platform, built from particularly durable plastic components. The main modules for the front end, battery box and rear end are connected using fixed interfaces, so individual elements or complete vehicle components can quickly be switched out.

"Approaches like KOSEL are made for the vehicles of tomorrow," says Ms. Kroll. But are there short-term solutions too? In the Dig-CirclE project, which Fraunhofer IWU is involved in, researchers are using digitalization and automation to analyze and evaluate high-performance fiber-reinforced plastic (FRP) composites from sectors such as the automotive and aviation industries. These plastics are then sent for reuse, repair or recycling, depending on their condition. To make reusing plastic a more financially attractive option, the researchers are also developing efficient repair and recycling processes. "Currently," says Ms. Kroll, "recycled materials are often much more expensive than new materials." However, the costs can be decreased through the use of AI-driven diagnostics systems, for example — these can automatically analyze the plastic structures and manage later processes such as recycling.

> "Design for reuse, repair and recycling: Our very manufacturing processes need to be adapted to fit the concept of a circular economy."
>
> Susanne Kroll, Fraunhofer IWU

Artificial intelligence will be a game changer in the recycling process: This is the focus of the AI Hub Plastic Packaging project, a collaboration between the KIOptiPack and K3I-Cycling innovation labs that involves 51 partners from industry, science and civil society. The KIOptiPack team is developing AI-driven tools for designing sustainable products and manufacturing high-quality plastic packaging with a large proportion of recycled material; meanwhile, K3I-Cycling is working to optimize the material recycling process for packaging.

K3I-Cycling is focusing on sorting waste material flows — how thoroughly and precisely can we separate out diverse types of plastics so that they can be fed into single-material recycling flows as far as possible? These days, large sorting plants are using near-infrared (NIR) hyperspectral cameras. "Plastics absorb and diffuse light in different ways," explains Andreas Keller, a scientist at the Fraunhofer Institute for Nondestructive Testing IZFP. "So that acts like a fingerprint for each type of plastic, which NIR hyperspectral cameras can identify within ▶

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milliseconds." However, the NIR sensors are not equally well suited to every kind of sorting task. Black plastic in particular is a challenge for sorting plants. To solve this problem, K3I-Cycling will be using additional sensors, such as the high-speed thermography systems developed by Fraunhofer IZFP, in conjunction with the NIR cameras.

Based on this kind of data for specific plastic types, K3I-Cycling is developing an Artificial Neural Twin (ANT) — this is "a type of digital twin for the plastic that is overlaid with a neural network that can process and manage the stored data and use it to develop new evaluation methods," according to Mr. Keller. Many different factors may play a role in enabling sorting plants to separate material flows extremely quickly and effectively — including the time of year (in spring, for example, there are always a lot of plant pots made from a certain type of plastic) and which city district a garbage truck visited. "For example, the composition of waste in a pedestrian zone with fast food chains is different to that coming from households," explains Mr. Keller. Thanks to the ANT, the sorting plant can know what specifically to look out for ahead of time.

KIOptipack, on the other hand, is working to support the concept of "design for recycling" based on material selection, use of recycled materials, and product design, manufacturing, usage and recycling. This will make it possible to balance the many, sometimes conflicting requirements of creating recyclable products and recycling-oriented processes. Fraunhofer IVV is coordinating the packaging elements of this endeavor — its researchers are focusing on how to increase the proportion of recycled material in new packaging, while still maintaining properties such as product protection, a good visual appearance and other sensory characteristics and allowing for efficient processing, appropriate use and safe disposal in a recycling system. The enormous challenge here is making the required data consistently available and using it at appropriate points along the whole value chain. AI will be useful in this context — whether it is used for characterizing materials, configuring machine parameters or supporting humans through assistance systems.

Mr. Keller says that further down the line, the two innovation labs, KIOptiPack and K3I-Cycling, will combine their solutions and use the ANT to create a feedback loop between production and recycling. The information gathered by K3I-Cycling can then be used to improve the design and manufacturing of products. These products will be easier to recycle, and so will result in higher-quality recycled material — thus creating a self-optimizing system. By enabling effective sorting and recycling, developments such as these could potentially keep significantly more plastics within recycling loops than we can today. "Using the sorting system developed by K3I-Cycling across Germany could save 500,000 tons of CO_2 equivalent per year," Mr. Keller predicts.

A sector in flux: Plastic is far more than just tomorrow's trash, insists Prof. Scholz of the Plastics Technology Center Oberlausitz. If we produce plastic sustainably and work to keep it in recycling loop, it could even make a huge contribution to combating climate change. Unlike materials such as steel or cement, plastic can be produced from renewable raw materials and recycled. Its low weight means it can be transported with less environmental impact, and its durability and stability give it a long service life. "It's not the material itself that's problematic, but rather how we use it," says Prof. Scholz. "And it's very exciting to make a scientific contribution to the transformation in our approach to plastic." ■

What's what? Sustainable plastics summed up

Biodegradable plastic. Plastic biodegration occurs when organisms use the organic material in plastic as a food source. Biodegradable plastics can be made from renewable raw materials (e.g., starch) or non-renewable/fossil raw materials (e.g., petroleum) that have undergone chemical or biotechnological processing.

Biobased plastics. Made entirely or partially from biomass (= renewable raw materials). Using renewable raw materials can increase the sustainability of these plastics.

Bioplastic. Plastic that is either biodegradable, biobased or both.

Compostable plastic. Is biodegradable under certain conditions, within the time frame of a composting cycle. Biodegradable plastics are not necessarily compostable plastics; however, all compostable plastics are biodegradable.

Source: https://www.umsicht.fraunhofer.de/en.html, "Nachhaltige Kunststoffe" (sustainable plastics) glossary (German only)

"Plastics absorb and diffuse light in different ways."

Andreas Keller, Fraunhofer IZFP

Smarter sorting: Andreas Keller of Fraunhofer IZFP is working to improve recycling rates with the help of AI.

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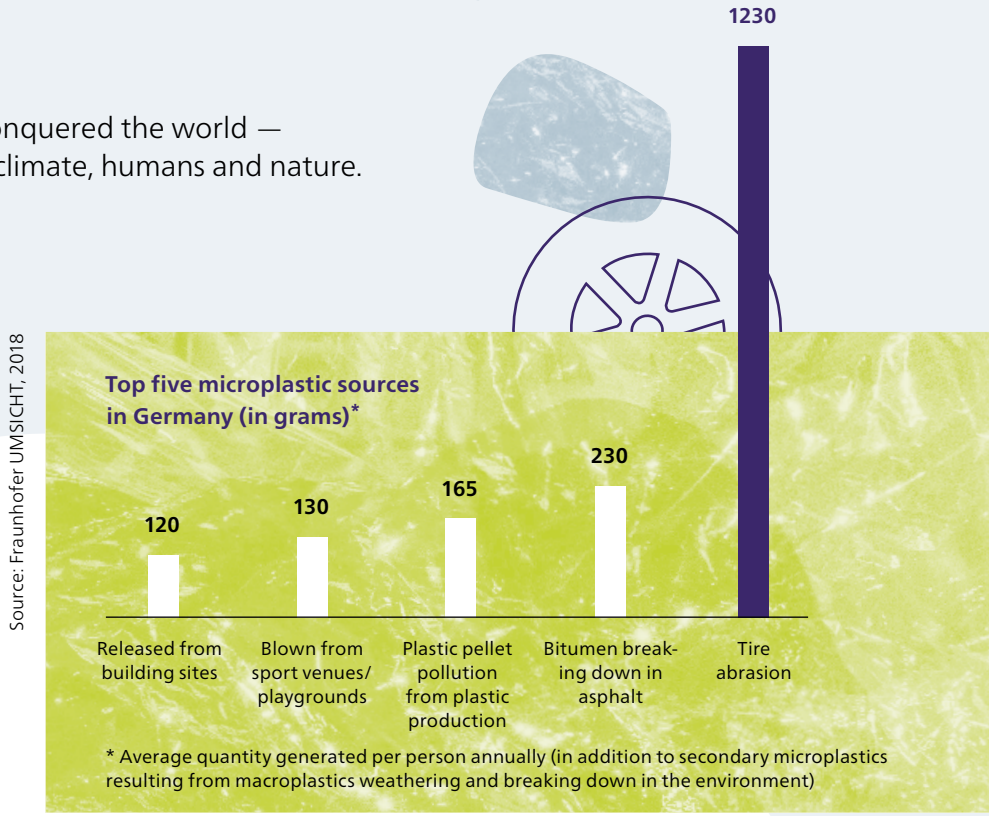
Plastic in numbers

Both a blessing and a curse: Plastic has conquered the world — with some serious consequences for the climate, humans and nature.

Plastic bags:
20 years Time taken to break down in the ocean*



Source: Fraunhofer UMSICHT, 2018

1531 Wolfgang Seidel, a Benedictine monk from Ausburg develops an "imitation horn" (casein) based on milk protein.

1839 Charles Goodyear makes a malleable rubber from natural rubber.

1905 Leo Hendrik Baekeland develops the first fully synthetic plastic, Bakelite.

1911 Chemist Ernst Richard Escales coins the term "Kunststoffe" — the German word for "plastic."

1950 Two million tons of plastic are produced worldwide.

1960 Crude oil becomes the most important raw material for the plastics industry.

Only 60.5 percent* is recycled

* Plastic packaging recycled in Germany, 2020.
In contrast, 95.7 percent of aluminum is recycled, and 88.1 percent of paper.

Source: GVM Gesellschaft für Verpackungsmarktforschung (packaging market research

150 million tons of plastic in our oceans

The largest concentrations of plastic have accumulated in the **five huge garbage islands** in the Pacific, Atlantic and Indian oceans.

The "Great Pacific Garbage Patch" is almost **five times larger than Germany**. However, according to the German Environment Agency, about 70 percent of the plastic trash in the oceans is under the surface of the water.

Source: WWF

We ingest 5 grams of microplastic per week

According to a study by the WWF, the average person worldwide ingests **5 grams of microplastic** per week via their food, tap water and the air we breathe. That is approximately equal to the weight of **a credit card.**

Plastic bottle:
450 years
Time taken to break down in the ocean*

Fishing line:
600 years
Time taken to break down in the ocean*

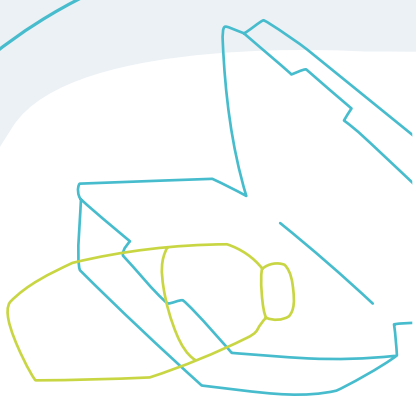
* Source: NABU — Naturschutzbund Deutschland e. V.

1983 At 125 million cubic meters, the use of plastic overtakes steel.

1995 China becomes the fourth-largest producer of plastic, after the USA, Japan and Germany.

2015 Plastic production stands at 400 million tons per year.

2023 According to a UN study, the amount of plastic waste in the environment could be reduced by 80 percent by 2040 — through means such as reducing our use of plastics, recycling, using alternative compostable materials and disposing of plastic safely.



1 billion elephants

Between the 1950s, when plastic was invented, and the year 2015, around **8.3 billion tons of plastic** were produced worldwide. That's equivalent to the weight of a billion elephants.

Source: University of Georgia

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Diagram: Vivian Ellermeyer

3×3 Questions: Plastics

Prof. Maik Feldmann,
head of the Polymer Applications business unit, Fraunhofer Institute for Microstructure of Materials and Systems IMWS

"A significant trend toward biobased plastics."

1 What interests you personally the most about plastics?
The diversity. For a start, plastic is a material that makes our everyday lives easier — often more so than we realize. And plastics can be used in areas of construction where metal wouldn't be as efficient. For example, a plastic-based pressure tank for hydrogen weighs only a quarter as much as a metal one with the same storage capacity.

2 Which trend regarding plastics and sustainability is making you particularly optimistic?
There are two statistics I'm especially optimistic about. The statistic on the bioplastic market from European Bioplastics e. V. shows a significant trend toward biobased plastics. And the numbers from the German Environment Agency (UBA) on material recycling are showing growth there as well; both of these situations are creating exciting avenues of research for us. The global waste issue, greater numbers of environmental laws and rising levels of environmental consciousness among consumers are all sure to strengthen this trend further.

3 What makes a "good" plastic, in your opinion?
A good plastic is one that is ideally suited to the requirements it must fulfill for processing and use, and that makes a durable product while creating the smallest possible carbon footprint. The design and processing methods for the material must be matched to its properties. The raw materials you choose are also important. Ideally, residual or waste materials should be used here. ■

Dr. André Lehmann,
head of the Fiber Technology department, Fraunhofer Institute for Applied Polymer Research IAP

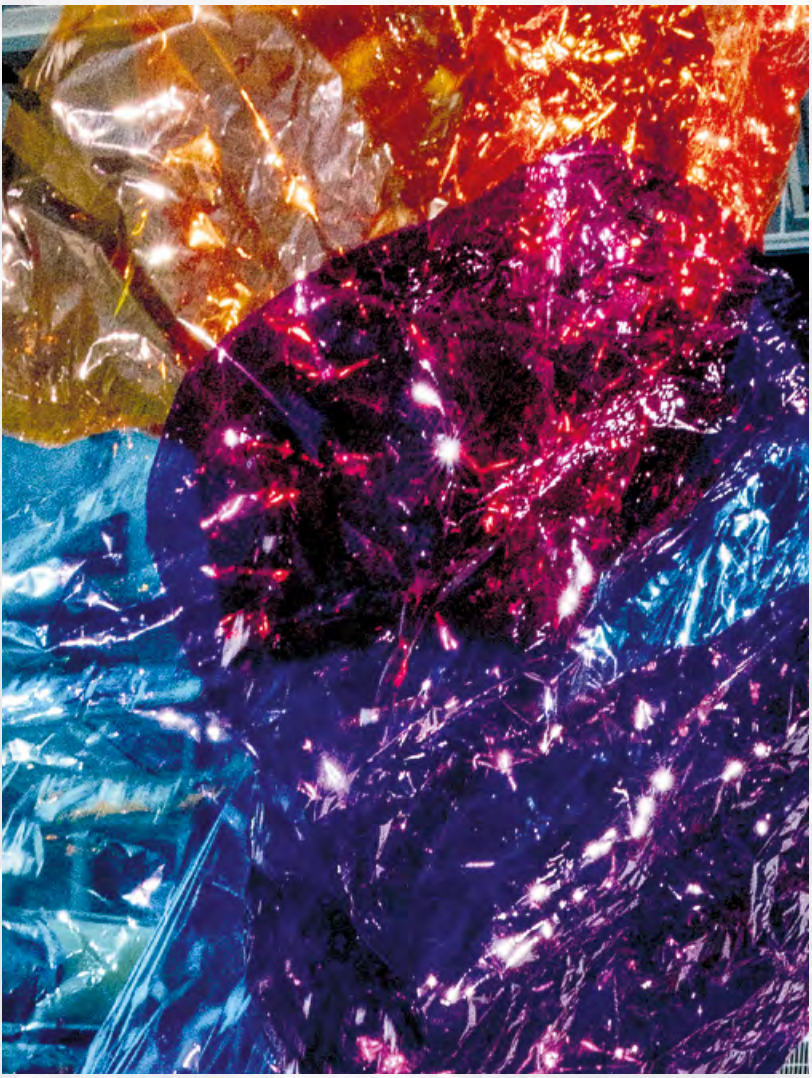
"It's all about making sure the circular plastic economy is energy-efficient, with the lowest possible level of loss."

1 What interests you personally the most about plastics?
I'm interested in the diversity that comes with plastics, and the fact that you can use them to make a nearly endless range of shapes. This is reflected in the wide range of processing technologies and applications that exist for plastic. So THE plastic doesn't exist — there's a wide variety, each tailored to a specific application.

2 Which trend regarding plastics and sustainability is making you particularly optimistic?
I'm optimistic because a variety of material cycles have already been established in sectors such as the textile industry; and due to this, the market share of fibers made from recycled raw materials is growing steadily. PET is ahead here: 15 percent of recycled fibers used annually, equivalent to around 9 million tons, come from PET. However, recycled cotton textiles can also be converted into man-made cellulosic fibers for new textiles. Progress is also being made in terms of research into chemical recycling, which will in turn help to further drive the transition from linear to circular material systems.

3 What makes a "good" plastic, in your opinion?
"Renewable carbon" is a key concept here. It's all about making sure the circular plastic economy is energy-efficient, with the lowest possible level of loss. A good plastic also needs to be recyclable, though that must not affect its functions and quality. This is a huge challenge that we at Fraunhofer IAP are working on together with partners from industry. ■

Photos: S.Bethke, Fraunhofer IAP/Manuela Zydor, Fraunhofer IFAM, Hilde Harshagen



Fantastic plastic: A material with countless possibilities, but also plenty of challenges.

"Plastics work miracles, big and small, in their respective domains."

Dr. Katharina Koschek

Dr. Katharina Koschek,
head of the Polymeric Materials and Mechanical Engineering department, Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM

1 What interests you personally the most about plastics?
Plastics have such a diverse range of potential applications, and it's impossible to imagine daily life without them. The structural and microscopic differences between them may be negligible, but the effect on the resulting material is often enormous. But despite being fascinated by them, of course I can also see the enormous environmental issues associated with plastics. As we develop new materials, and deepen our understanding of the structure and properties involved, we can address these issues and create functioning plastic recycling loops.

2 Which trend regarding plastics and sustainability is making you particularly optimistic?
Germany was one of five European countries to have a recycling rate of over 40 percent in 2020. I see that as a positive step toward a future for the plastics industry where there are no additional fossil resources entering the loop — instead, the loop would be based on renewable carbon to the greatest extent possible. Looking to the future, we need to make further technological advances in areas such as increasing the recycling rate for mixed plastics.

3 What makes a "good" plastic, in your opinion?
I believe most plastics themselves are "good," but I take a critical view of the throwaway culture we have around them. We don't recognize the value in plastics and often forget that they don't just last a long time, but also work miracles, big and small, in their respective domains. By changing our behavior in terms of using and handling plastic more consciously, together with designing materials to be recyclable, we can take plastics from being "good" to "outstanding." ■

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Interview

“We need even more research!”

The climate, droughts, crimes against nature: Steffi Lemke has plenty to deal with. In an interview, the German Federal minister for the environment advocates for true openness toward new technologies. And she reveals how she gets by with little plastic in her own life.

Interview: Josef Oskar Seitz

Minister Steffi Lemke, 55, woman of the house and boss to more than 1,200 employees in the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection on Stresemann-strasse in Berlin’s Kreuzberg district.

Another summer, another new record: In May, it was already 44 degrees in Spain, and Germany was seeing drought by June. Ms. Lemke, what do you think the cities of tomorrow will need to look like, if they're going to be fit to live in?
The cities of tomorrow ideally need to be sponge cities. They will need to be full of green spaces and store rainwater in many different forms. Water reservoirs, green roofs and multifunctional spaces are practical ways to ensure water stays in the cities, and considering the consequences of the climate crisis, this will only become more important in the future. Sponge cities can even provide reserves of usable water for dry periods, and they can create a better buffer for handling extreme weather events such as heavy rain or long droughts. They also provide residents with a better quality of life and are great for protecting biodiversity.

We often talk about waste water that needs to be quickly taken away. But will we need more water supplies coming in, so we can use long-distance pipelines to transport water from wet regions to the dry areas of Germany?
In the future, our aim will still be to have a water supply in the locality as much as possible. That means we need to interlink our water supplies more effectively. In some cases, we will need integrated networks or long-distance pipelines to compensate for differences between regions in terms of how much water is available. The first step for us and the German state governments is to examine the actual need for such systems across the country.

Why is it so difficult for green politicians to win voters' favor, particularly in eastern Germany?
I can only partly agree with this assessment. After all, we're governing three of the five new federal states with great success. At the same time, I also believe we need to do better. The people of eastern Germany have achieved a great deal over the course of their lives: They fought for their own freedom and democracy. Most of them then had to quickly turn their lives upside down, with many experiencing unemployment, or starting to work for West German bosses; a large proportion of my generation migrated to the West. So far, we as the Greens, but also we as society, haven't paid enough attention to these experiences.

Has green politics become the politics of high earners — people who don't need to worry about the costs of heat pumps, solar panels and insulation?
Actually, it's the opposite: It may seem paradoxical to you, but the Greens have always made policies for people that don't yet belong to an interest group. That's young people and future generations that don't have a voice yet. And that also includes people that are particularly badly affected by the climate crisis and environmental pollution: older people, people in small, poorly insulated apartments without a balcony or garden, people living along roads with particularly heavy traffic and people that are finding it difficult to pay energy prices due to the Russian war of aggression and the fossil fuel energy crisis. This is why we advocate for proactive, socially balanced politics with staggered funding and protection for tenants. Clinging to fossil-powered heating would make life prohibitively expensive for many people.

As a minister for the environment, does your private life reflect your mission of protecting the environment?
In my personal life, I manage very well. I still live in Dessau and I'm happy to be so close to nature. I generally commute by train from Dessau to Berlin.

How do you yourself handle the issue of packaging?
I try to avoid unnecessary packaging as much as possible. For everyday use, I have a reusable bottle that I fill with tap water. So when I'm traveling, I don't have to rely on single-use plastic bottles. And in my office, I have a water jug. When I go shopping, I take my backpack or a bag with me.

Plastic production worldwide has doubled in the past 20 years. At a UN conference of 175 member states held in Paris in June, you urged for this production to be curbed. Is that the way forward: recycling plus reduction?
Plastic pollution has reached unprecedented levels worldwide. Without concentrated global efforts and internationally binding limits, this pollution will continue to increase. At the moment, the UN member states are working on a legally binding agreement against plastic waste, which will be signed in 2025. I'm delighted about that, and I'm doing everything in my power to support this agreement. All plastics are made from chemicals that can potentially harm people's health and the environment. In 2022, Germany joined a group of ambitious states that is campaigning to protect our natural resources. We want to make the production and use of plastic more sustainable, create a global circular economy for plastics and ensure that plastic waste is handled in an environmentally friendly way. In short, improving recycling across the world is important, but we can't just combat plastic pollution through recycling alone. ▶

Photo: Stefan Boness/VISUM

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A career in politics at 26
Steffi Lemke became a member of the German parliament in 1994. Before going into politics, she trained as a zoo technician and worked as a mail carrier from 1986 to 1988. She did her high school diploma exams through night school and in 1993, she graduated with a degree in agricultural engineering (specializing in livestock farming).

Arm in arm
At the closing of the 2005 election party conference, foreign minister Joschka Fischer seeks to rub shoulders with the then general secretary. The election ends with defeat for the red-green alliance — Angela Merkel's era begins.

New hope
The 2009 election campaign: Steffi Lemke leads the campaign for Alliance 90/The Greens. Her party gains 2.6 percent. Merkel remains chancellor.

What obstacles do you foresee at an international level?
Working toward a global agreement against plastic waste comes with many challenges: There are over 1,650 participants involved from 169 countries and the EU, as well as 300 monitoring organizations, and the deadline that was set is very tight — just in terms of the formalities involved, a negotiation process of this scale is extremely difficult. I'm very pleased that the negotiating committee in the second negotiating session (INC-2) in Paris showed they can reach collective agreements together on this subject. Some sticking points are expected, including the extent to which the individual measures of the agreement are binding, the interpretation and enforcement of the expanded responsibilities for manufacturers, the question of possibly restricting plastic production and the question of financing.

Which measures are the most urgent?
Our oceans are crucially important to our climate system. They're areas of phenomenal biodiversity, they're food sources and yet they are currently hugely polluted with plastic waste. One of the main issues here is the unsustainable use of packaging materials with short life cycles that get into the oceans via rivers. The international agreement on reducing the plastic problem must serve as a worldwide tool for solving countless challenges. Specifically, I believe it's crucial to have strict obligations across the world that apply to all countries. When it comes to sustainable production and consumption, product design and increasing circularity, for example, the required measures should be put in place at the start and middle of the life cycle. What's more, we need to build up the global capacities that a true circular economy will require. For example, corporations that operate internationally and sell their products in plastic packaging worldwide must be brought to task a great deal more. They need to ensure their packaging doesn't end up in the ocean after use.

Numerous Fraunhofer teams are working to make plastics usable for longer, improve recycling systems and develop new biobased alternative materials. In what areas can this research support your work?
We need even more research to make our overall approach to plastic more sustainable. Biobased alternatives must not come at the cost of food production or biodiversity. That's why I believe we should focus on potentially using by-products from agriculture that can't be used for any other high-value purposes. When it comes to recycling, I believe there is potential for optimization in the areas of recyclate quality, tracing and sorting technologies, and evaluating alternative methods. I also think a great deal of research is required around the much-discussed issue of chemical decomposition processes — both in regard to technologies and how we evaluate efficiency, and in terms of the energy footprint and the quantities of pollution generated.

How can politicians and researchers collaborate so that scientific solutions are put into practice more quickly?
Through direct dialogue, for example. Without independent research by universities, higher education institutes and research institutes like the Fraunhofer-Gesellschaft, knowledge- and fact-based policymaking would be completely impossible. I can't praise researchers and scientists highly enough for their accomplishments. We would be well-advised to harness their work and consider it in our own policy-making.

How do you feel about the idea of openness to new technologies? Do you think it's a fig leaf being used to protect the industry, or is it actually the way we will solve future issues?
I don't have anything against the concept. Unfortunately, people often misuse this phrase to bring technologies into the debate that are obsolete, expensive, inefficient or won't be affordable in the foreseeable future — with the aim of keeping those technologies alive. That's often not in the best interest of our citizens, and yet is sold as supposed freedom. If properly understood, this concept would help create a situation where the technologies that prevail were those that best help us achieve our climate protection targets, while also allowing for maximum financial viability and not triggering any other environmental issues. This means that truly being open to new technologies requires us to take a reality check and do a serious technology impact assessment.

It's been a long time since anything other than the climate and the war made the headlines: Do you feel that there's a lack of attention for the other environmental issues?

"I can't praise researchers highly enough for their accomplishments. We would be well-advised to harness their work."

German minister for the environment Steffi Lemke

Not at all. After all, the world is much more complicated than some exaggerated comments in the debate might suggest. The climate crisis is putting our ecosystems at risk. At the same time, these ecosystems can make a huge contribution to solving the issue, as a form of natural climate protection. And unfortunately, the war in Ukraine is causing massive environmental pollution that the people there are feeling already: contaminated soil, air pollution, water contamination due to events such as the Kakhovka dam blast. And there's the danger of nuclear catastrophe at the Zaporizhzhia Nuclear Power Plant hanging over everything.

The problems are enormous, and the German Federal Ministry for the Environment has one of the smallest budgets at 2.4 billion euros. Is the German minister of finance Christian Lindner saving money in the wrong places?

The basic budget for the German Federal Ministry for the Environment is one of the few that has remained at an almost constant level. That's a good sign, as cutbacks are being made everywhere else — often dramatic ones. And our plan for natural climate protection is in line to receive more money than ever before, with 4 billion euros in financing set to come from the Climate and Transformation fund by 2026.

Natural climate protection constitutes your biggest project. The first measures will be put in place this summer. What's happening there?

In mid-July, we launched the first funding guidelines for natural climate protection in rural regions and in companies. With these guidelines, we're reaching a range of important stakeholders that can help restore and better preserve nature's own climate protection functions. Other funding guidelines will be added in the coming months on capturing and storing CO_2 in peat lands, floodplains and forests. Apart from that, in October, a competence center for natural climate protection will be launched to help quickly and effectively implement the funding initiatives laid out in the Action Plan on Nature-based Solutions for Climate and Biodiversity across the board.

You previously worked as a mail carrier. Who would you like to write a few personal words to today, if you could drop them a line?

I'm delighted that I receive so many letters from schoolchildren in my role as minister for the environment — they have very specific questions about protecting the environment and nature, but also suggest solutions. Unfortunately, I often just don't have enough time to answer them in detail and exchange ideas. ■

Another attempt

Steffi Lemke watches the candidate nominations. In 2013, the Greens lose 2.3 percent in the federal elections with Katrin Göring-Eckardt and Jürgen Trittin. Merkel stays in power.

Onward and upward

Finally: on December 8, 2021, Bundestag president Bärbel Bas swears in Lemke as the new minister for the environment.

An in-depth look

The minister for the environment goes underground in May to learn more about the state of the Asse nuclear waste storage facility in Lower Saxony.

Getting an overview

Before the Oder Conference in June, Steffi Lemke examines the ecosystem from an observation tower. One year previously, there was a mass die-off of fish along the river.

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Tapping into a new lithium source

Deep geothermal drilling is one of the brightest rays of hope for the transition to green heating. It also comes with the positive side effect that it can not only be used to generate eco-friendly electricity and heat, but also to extract lithium for battery manufacturing.

By Dr. Janine van Ackeren

Geothermal systems carry heat from far below the Earth's surface — and soon, they may also be bringing the chemical element lithium (Li^3) with them, thanks to Fraunhofer technology.

Deep geothermal systems seem like something of a magical panacea for our climate-conscious age. Their most attractive feature is their potential for generating green electricity and heat, even to the point of serving as an alternative to heat pumps. The systems bore down to depths of thousands of meters to tap into saline aquifers with a temperature of around 80 degrees; this hot groundwater is then transported to the surface, where it powers electricity generation turbines and supplies many households with heating via district heating networks. But the benefits of geothermal systems don't stop there: The boreholes also represent a new avenue for extracting lithium resources — in Germany, without harming the environment and with very little extra effort. Researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg and the Karlsruhe Institute of Technology (KIT) have teamed up to prove that this goal is technically feasible. "The salty water that gets pumped to the Earth's surface through geothermal boreholes contains around 200 milligrams of lithium per liter," explains Dr. Carl Basler, a project manager at Fraunhofer IPM. "In other words, one borehole should be able to deliver enough lithium for around 20,000 car batteries every year — and that more or less as a side product. In the Upper Rhine Valley alone, it would be possible to set up ten of these facilities."

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Lithium-ion batteries are used on a mass scale in many modern products, ranging from electric cars to smartphones and tablets. These batteries could also play an important role when it comes to electrifying applications during the heating transition — i.e., heat pumps — by serving as storage for the electricity produced by photovoltaic systems. However, as lithium has yet to be mined in Germany, the country is entirely dependent on imports, leaving it vulnerable to all the pitfalls associated with such international relationships. A domestic source of lithium could significantly reduce the pressure in this area.

Researchers at KIT are working to develop the technology required to extract lithium from the water that is pumped to the surface. To do this, they feed the groundwater through a sorbent, i.e., a material that specifically binds the lithium salt, while allowing all the other salts that are dissolved in the water to flow on through unimpeded. If all the binding sites in the sorbent material are occupied, then the sorbent is saturated with lithium, and the team can disconnect it from the borehole water supply and send a desorption solution through instead. This redissolves the bound lithium, which can then be precipitated out of the solution by means of standard processes. The KIT researchers are currently focusing their energies on developing the optimal sorbent material.

Analysis process supports lithium extraction

One important question that crops up in the course of this mode of lithium extraction is: when does the sorbent material reach saturation? After all, the lithium content in the groundwater varies from borehole to borehole, and once the sorbent is saturated, the water will flow on through, taking its dissolved lithium with it. Until now, it has only been possible to answer this question by means of lab-based analysis processes that take around half a day to complete. This is obviously far too long for adaptive control, but fortunately, Fraunhofer IPM has the necessary expertise to speed things up. "We are developing a process that can be used to measure the water's lithium concentration at the outlet from the sorbent in real-time — which allows for extremely rapid feedback cycles. If the concentration increases, then the sorbent material's saturation levels are rising, meaning it needs to be cleaned out," explains Dr. Basler.

For this process, the researchers use laser-induced breakdown spectroscopy, which involves focusing short laser pulses (lasting around 10 nanoseconds each) on the water's surface through a lens. This applies so much energy to the water that some of it forms a plasma — i.e., a gas that no longer consists of atoms or molecules like a normal gas, but rather of ions and electrons — because the laser's high energy ejects the electrons out of the atoms. If the ions capture the electrons again, they emit a characteristic radiation in the process, which allows scientists to extrapolate the type of the atom in question. The researchers can then analyze the spectrum to identify and quantify the elements dissolved in the water. "Based on the ▶

Photo: Falk Heller/argum/imago images

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spectrum, we can see how much lithium is in the water, which also tells us whether the sorbent is saturated and requires cleaning," says Dr. Basler.

The laser-induced breakdown spectroscopy process has been around for quite some time and is used in industry settings to identify aluminum alloys, for example. However, the materials that the process has been used to investigate thus far are all solids. In the case of liquids, things become more tricky — and the hunt for commercial solutions has been unsuccessful. "With solids, the majority of the laser energy is absorbed by the medium, which makes it easy to apply enough energy to the material to ignite a plasma. However, with liquids, the energy is carried much further into the material," explains Dr. Basler. This means that in most cases, the energy is not enough for plasma ignition in liquids. However, by following a sort of "the more, the merrier" logic, the researchers managed it eventually. They created a setup in which a gas layer lies on top of the liquid, so that they could apply so much energy to the liquid via the laser that the plasma is ignited right at the liquid's surface; the plasma then expands through the gas rather than the liquid.

However, that is not quite as easy as it sounds here. The water is subjected to a pressure of 20 bars, that is, 20 times the atmospheric pressure, and the gas must be adapted to these conditions — but this high pressure also influences the generation and expansion of the plasma. Which gases are most suitable? What effect does the pressure have on plasma expansion? The temperature also has an impact on plasma ignition — after all, the groundwater does not run through the system at room temperature, but rather at around 80 degrees Celsius. What's more, if a certain proportion of iron is dissolved in the water, the lines in the analytic spectrum can shift due to what are known as matrix effects. "We will study the matrix effects caused by all elements found in the water and calibrate the system as needed to account for them," says Dr. Basler.

But there are still other challenges to tackle: Plasma expansion often sprays the water beneath away, which results in the spatter hitting the viewing glass that the laser shines through to reach the pressure chamber. The next laser pulse will then be absorbed and deflected, meaning that proper plasma ignition can no longer take place. Consequently, the researchers are working on a setup that will block this spatter effect. They are hoping to overcome all these challenges by the end of 2024, so they can take the next step: testing out the system at an existing geothermal facility alongside the KIT technology that will be used to extract the lithium from the water.

Recycling lithium from used batteries

Given the imminent electrification of mobility and heat generation, lithium demand could soon rise to such heights that even this technology will not be enough to cover it all. This is why the research team is also working on methods of recycling lithium from used batteries as well as extracting it from geothermal water. The German federal government is also driving progress in this area.

In 2022 lithium prices surged by a factor of 10.

Various processes are already being applied in the industry sector in order to recover the materials that batteries contain, such as nickel, manganese, cobalt and aluminum and copper foils. "Unfortunately, lithium is still too cheap to make the recovery process pay off," explains Dr. Basler. However, based on the price trends for lithium over the last year alone, it is safe to assume that this state of affairs will not last for long. In 2022, lithium prices surged by a factor of ten. "The question of recovering lithium from used batteries could become really pressing within a period of around ten years. However, we need to develop the necessary technologies now, so they work when that time comes," affirms Dr. Basler.

The sorbent from KIT has been specially developed for binding lithium — so it should also be suitable for battery recycling. In this process, the battery slurry (a mixture of cobalt, manganese, nickel, lithium, graphite and binding agents) is dissolved in an aqueous solution and passed through the sorbent. It should also be possible to transfer the technology developed by Fraunhofer IPM to this application — and to other approaches, such as processes where the lithium is spun out of an aqueous solution by means of a centrifuge. In short, the process can be used in any situation that involves measuring lithium concentrations in a liquid media — and as such, it has a valuable role to play in driving lithium production in Germany and Europe. ■

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replace

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Knowledge relay

Prof. Manfred Renner, when will ***bioplastics be able to completely replace*** plastics made from ***petroleum?***

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Knowledge relay, episode 9

Prof. Manfred Renner, when will bioplastics be able to completely replace plastics made from petroleum?

Series:
Knowledge relay

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

The primary objective of the European Green Deal is to achieve climate neutrality by 2050 at the latest. The European Commission is supporting implementation of this plan with a catalog of different initiatives. In addition to drafting specific climate protection laws, an action plan is being put in place for the circular economy, as well as a strategy for ensuring product sustainability — the latter is focused on the textiles, construction, electronics and plastics sectors. For this reason, supplies of raw materials for plastics production must be switched to renewable sources (defossilization) as soon as possible. This could help significantly with reducing greenhouse gas emissions, conserving non-renewable resources and strengthening the resilience of the German and European economies.

The plastics sector is one of the most energy- and resource-intensive of all the basic industries where a transformation toward greater sustainability will have a major impact. The greenhouse gas emissions from the plastics industry are currently estimated to be just under 2 gigatons of CO_2 equivalent per year. That corresponds to around two and a half times Germany's total emissions. Depending on which study you read, estimates for the amount of plastic produced by 2050 range from

an increase by a factor of two to a factor of four — and greenhouse gas emissions will increase proportionally.

The following measures for counteracting this trend are under discussion:

1. Using renewable energy in plastics production and processing
2. Reducing the increase in material consumption
3. Switching to biobased plastics
4. Recycling plastic waste

Scenario analyses have shown that each of these measures will curb the increase in greenhouse gas emissions to some extent. But the only way to reduce emissions is to put all four options into practice at the same time, as quickly as possible. Just switching over to biomass as a raw material supply for plastics production would not work on its own. At the same time, we need to consistently apply the R-strategies for the circular economy to plastic products as a matter of priority. This starts with the "refuse," rethink" and "reuse" strategies, which reduce the amount of plastic required by avoiding plastic, redesigning products and services, and adopting business models based on using plastic recyclates — without forgoing any functionalities of the material or products. Methods that reduce the amount of plastic waste we produce include repairing, recycling and other strategies that allow products and components to be used for as long as possible. Waste plastic should be recycled to make quality products to the greatest extent possible.

However, even with a recycling rate of 100 percent, increasing overall demand for material and the fact that some plastic products remain in use for decades — such as construction materials — mean we always need fresh raw materials. In the circular plastics economy, the plan is that these materials will no longer come from fossil sources. In the near future, established production pathways for biobased plastics could be expanded to serve as a supply for these materials and allow us to eliminate fossil sources. However, for this to happen, noticeable improvements must be made to their financial viability by consistently including external costs (particularly those arising due to the climate crisis) in the material price. In addition, we need to further promote technological advancement in bioplastics. The recyclability of these bioplastics can be optimized through innovations in the area of advanced recycling technologies. The advantageous properties of some bioplastics could help support this process. Using recycled materials is an essential factor in successfully establishing a biobased circular economy. This means biobased plastics offer enormous potential for the solution we need to make our world more sustainable.

Once the energy supply has been largely converted to renewable, climate-friendly technologies, it may also be possible to establish process chains based on carbon dioxide. This could then further decrease the biomass needed for plastics production — thus avoiding conflicts with other important biomass utilization pathways when it comes to accessing sustainable biomass, which is also likely to be in limited supply.

However long it takes to transform the plastics industry, we will need more technological innovations and new business models in the years to come. We at Fraunhofer UMSICHT and in the Fraunhofer Cluster of Excellence Circular Plastics Economy are working tirelessly with our partners to make these developments a reality. ■

Prof. Manfred Renner heads up Fraunhofer UMSICHT along with Prof. Christian Doetsch.

Photo: Fraunhofer UMSICHT/Mike Henning

This means biobased plastics *offer enormous potential* for the solution we need to make our *world more* sustainable.

In the next issue:

What is more ***important when it comes to*** food supplies: ***sustainability*** or ***security*** and ***quality?***

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Security

Sovereignty in space

The EU wants to establish its own satellite network by 2027, with the aim of increasing the resilience of the European communications infrastructure and gaining technological sovereignty in space. Achieving this will require novel solutions.

By Mandy Bartel,
Photography: Thomas Straub

Looking into the distance: Dr. Nadya Ben Bekhti-Winkel and Dr. Lars Fuhrmann on TIRA, the space observation radar in Wachtberg. In 15 seconds, the 240 ton antenna can make a complete turn on its axis and track satellites at a distance of 1,000 kilometers to provide high-resolution images of them.

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Coming through? In the antenna testing hall at Fraunhofer IIS in Erlangen, Rainer Wansch tests the characteristics of antennas used in satellite communications and evaluates their performance.

"Onboard processors allow the signals to be processed directly within the satellite. So the satellites themselves become intelligent network components that can control data streams as needed."

Rainer Wansch, Fraunhofer IIS

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"Just as quantum computers are not going to replace smartphones, quantum communication will not replace conventional communication technologies."

Fabian Steinlechner, Fraunhofer IOF

Secured using laser light: Dr. Fabian Steinlechner of Fraunhofer IOF in Jena is researching how tap-proof satellite communications can be achieved using entangled photons.

It began with the internet in Ukraine. When the network collapsed under the force of Russian attacks, nationwide digital communication was restored with the help of a private satellite network. In Europe, relief over US entrepreneur Elon Musk quickly providing help via Starlink soon changed to unease: It seemed no European state was in a position to support Ukraine with this strategically important issue. The war highlighted two problems: How vulnerable terrestrial infrastructure is without backup from space, and how dependent Europe is on third parties when it comes to space technologies and satellite-supported communication.

The EU now wants to change this. By 2027, a constellation of up to 200 satellites should guarantee Europe's sovereignty in space and, by extension, on the ground. IRIS² (Infrastructure for Resilience, Interconnectivity and Security by Satellite) is a large-scale project aimed at not only securely networking critical infrastructures and creating resilient crisis management methods for governments, but also ensuring comprehensive broadband connectivity across Europe, especially in previously underserved regions. The EU wants to open this up to private technological initiatives: Apart from Starlink — which currently has about 4,000 satellites at an altitude of 500 to 550 kilometers, with 8,000 more to come — another supplier active in space is the British company OneWeb, which has 600 satellites. Amazon has announced news of another mega-constellation in the form of its Project Kuiper. China, too, is already planning a network numbered in the five digits.

> "More and more countries want to increase their sovereignty by having their own satellite constellations."
>
> Dr. Nadya Ben Bekhti-Winkel,
> Fraunhofer Aviation and Space Alliance

"More and more countries want to increase their sovereignty by having their own satellite constellations," observes Dr. Nadya Ben Bekhti-Winkel. As acting head of the Space technology area, part of the Fraunhofer AVIATION & SPACE alliance, she has joined 14 organizations ▶

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Dr. Ben Bekhti-Winkel from the Fraunhofer AVIATION & SPACE alliance visits the Fraunhofer FHR radome in Wachtberg, where TIRA is housed.

from five countries in participating in a feasibility and concept study for a European broadband satellite constellation. The goal: to develop, analyze and evaluate new ideas and technologies for this purpose. This involves four key areas: First, robust, resilient communication between the satellites that combines radio signals with optical, laser-based technologies. Second, quantum encryption, to make it as tap-proof as possible. Third, GPS-independent satellite operation, as well as interoperability with existing European systems such as Galileo and Copernicus. "And fourth," adds the space expert, "the scalability of the entire system." The consortium also carried out customer analyses to determine the benefits to state organizations, industry and private households, and to establish the relevant business cases.

Measuring in infinity

By Mehmet Toprak

The journey began on April 14, 2023 at 2:14 p.m. (CET), and it will take eight years to complete the distance of 800 kilometers: The JUICE (Jupiter Icy Moons Explorer) space probe will then arrive at the largest planet in our solar system and spend almost five years orbiting it and its moons. One of the ten measurement instruments on board is GALA, the Ganymede laser altimeter. GALA's receiving telescope was developed at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF located in Jena's "Optical Valley."

The system creates a profile of the surface of Ganymede, Jupiter's largest moon, which has similar characteristics to those of Earth. GALA does this by measuring the transit time of a laser pulse emitted from an altitude of around 500 kilometers from the spacecraft to the surface of the moon and back.

The reflected photons are captured by the telescope and directed to a detector. The various transit times of the reflected laser impulses, which GALA measures to the nearest nanosecond, combine to create a topographical model of the surface of the ice sheet. If oceans exist below the ice sheet, tidal forces would cause changes in its surface profile. With a resolution of ten centimeters, GALA's measurements are so precise, it can detect these changes. This could verify the theory that liquid water lies under the rugged ice sheet, and add impetus to the search for extraterrestrial life forms.

In constructing the telescope's metal mirror, the research team led by Dr. Stefan Risse, head of the Precision Optical Components and Systems department at Fraunhofer IOF, used a special aluminum-silicon alloy, onto which a nickel-phosphorus alloy just 200 micrometers thick was electroplated. This thick X-ray amorphous film is needed for precisely shaping and polishing the surface of the mirrors at Fraunhofer IOF, and ultimately achieving high optical performance and reflectivity. The team use various techniques for this, from ultra-precision turning using diamond tools right up to advanced chemical and mechanical polishing procedures. In addition, a microscopically thin layer of gold is applied using a special evaporation process — gold is an almost perfect reflector for laser light in the infrared spectral range.

It takes ten to twelve months to produce a mirror, and four to five years to develop the entire instrument. These specialized pieces of apparatus are mounted on foundations that are decoupled from vibrations that may occur in and around the building. The production process is also conducted during the hours of night. "A passing bus, a car, even a slamming door within this building would disturb the ultra-precise turning and polishing processes," says Dr. Risse, outlining the effort needed to achieve the highest possible level of precision.

Immense stresses

Mounted on the outside of the space probe, GALA's optics must withstand immense stresses: enormous acceleration forces during launch, frigid temperatures as low as minus 50°C, steep temperature

Photo: Fraunhofer IOF

More numerous, smaller, cheaper — satellites in New Space

These days, profitability is key, even in space: Welcome to the New Space age! While satellite projects were formerly driven and exclusively financed by state bodies, these days we are seeing ever-increasing involvement from private enterprises. Industrial companies and start-ups will be providing the lion's share of the space applications we need — and they will also reap the financial rewards. Rather than large systems with sophisticated technology, New Space will feature small satellites communicating with each other to form powerful networks. "Small satellites are cheaper and quicker to manufacture than conventional large satellites. This means companies can react more quickly to the needs of the market. The possibility of cheaper mass production would enable construction of large satellite constellations for entirely new commercial services and scientific applications. This brings about exciting research questions for Fraunhofer in areas such as intelligent systems, innovative payloads and modern manufacturing processes, right through to application development," says Prof. Frank Schäfer, head of the Space business unit at the Fraunhofer Institute for High-Speed Dynamics EMI, based at the Ernst-Mach-Institut in Freiburg. His institute researches and develops technologies for New Space and has built ERNST, Fraunhofer's first research satellite, which is scheduled for launch in 2024. ▶

> "ERNST offers us entirely new opportunities to research a wide variety of technologies on our own satellite platform."
>
> Prof. Frank Schäfer, Fraunhofer EMI

Producing a mirror telescope for the GALA laser altimeter can take up to 12 months. Work often takes place at night so that as few vibrations as possible disturb the precision manufacturing.

gradients and extreme cosmic radiation. "We had to ensure that GALA stays intact and maintains full performance during its eight-year voyage to Jupiter and its exploration of Ganymede," explains Dr. Henrik von Lukowicz, head of the Precision Systems working group. After meticulous, high-precision manufacturing, followed by vibration and thermal vacuum tests and irradiation in the lab, GALA has proven itself ready for the challenge of voyaging through space and the harsh conditions around Jupiter.

Temperatures up to 430 °C

Another Fraunhofer measuring instrument has already been in space since October 20, 2018. The infrared spectrometer MERTIS (Mercury Radiometer and Thermal Infrared Spectrometer) is traveling to Mercury on board the European-Japanese spacecraft BepiColombo. Its reflective infrared optics, also developed at Fraunhofer IOF, will characterize the minerals and elements on Mercury's surface. Flybys past Venus should slow the spacecraft down enough by 2025 for it to swing into Mercury's orbit. There, too, the instrument will have to withstand extreme conditions: Temperatures on Mercury range from minus 170 °C up to plus 430 °C. Initial test results during a Venus flyby have provided confirmation that the spectrometer is still functioning.

The Fraunhofer researchers have already proven that their space technology can cope with the challenging conditions in outer space: They developed and produced the metal mirrors for the Mid-Infrared Instrument (MIRI) on board the James Webb Space Telescope. This telescope focuses its gaze beyond our planetary system and out into the far distance. MIRI is capable of capturing light that originated more than 13.5 billion years ago in the wake of the Big Bang. Since July 2022, it has been supplying impressive images from distant galaxies. Scientist Dr. Risse is elated: "Of course, we knew about the telescope's capabilities, but this fantastic brilliance and image resolution just keep on amazing us."

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Prof. Frank Schäfer working in earnest on ERNST: Before ERNST, Fraunhofer's own research satellite, goes into space in 2024, it will first undergo top-to-toe testing at the Fraunhofer EMI laboratory in Freiburg — here, the solar module is being checked.

Built with research funding from the German Federal Armed Forces (Bundeswehr), the role of ERNST is to detect missile launches from anywhere in the world from a low Earth orbit. Its built-in infrared camera can recognize the heat emitted by hot rocket engines. However, this nanosatellite half the size of a beer crate also lends itself to other important tasks: spotting forest fires, detecting greenhouse gases and measuring sea temperatures. As a modular platform, it offers important experiential data on how to design a satellite that can accommodate as much productive payload as possible within a small space. "ERNST offers us entirely new opportunities to research a wide variety of technologies on our own satellite platform," says Prof. Schäfer. "These findings are being included in the plans for more small satellite constellations in the future."

Seeing as many small satellites in lower Earth orbits circle the Earth more frequently, constellations of these kinds of nanosatellites lend themselves to Earth observation, which requires as many images of a location as possible — to document local changes, for example. As they are permanently available, they could also guarantee comprehensive internet access if fitted with the right equipment. Compared to the tally of satellites owned by private networks, numbering in the four digits, IRIS², with its approximately 200 individual satellites, is on a more manageable scale. These satellites should be carefully distributed across multiple orbits, as orbiting at higher altitude allows them to cover wider areas.

Loud and clear

In the case of satellite swarms spanning multiple orbits, the most crucial factor is communication with ground stations. IRIS² aims to harness the latest radio and laser-based optical technologies. "One of the greatest challenges when constructing a new satellite constellation is the availability of radio frequencies," says Dr. Ben Bekhti-Winkel. "The electromagnetic spectrum is very limited, and with the ever-increasing numbers of satellites in orbit, it is important that radio ranges from various services do not cause interference for each other. They must therefore be well shielded; compatibility studies must be used to prove that there is no overlap." In Germany, the German Federal Network Agency is responsible for the restrictive allocation of frequencies as well as for regulating them, both within the country and internationally.

Satellite communications must therefore use the available frequencies as efficiently as possible. Rainer Wansch, head of the RF and SatCom Systems department, and his team at the Fraunhofer Institute for Integrated

Circuits IIS in Erlangen, are working on this. These researchers already played a part in the standardization of DVB-S2X, the most advanced satellite communications standard to date. They use beam hopping, a new concept that allows data transmission via satellite to be flexibly adapted to the variable levels of data demand in different areas. "Up until now, a satellite would supply static levels of data to certain areas. Beam hopping means the satellite switches back and forth between different coverage areas — based on a schedule that takes into account the required data rates at a given time," explains Mr. Wansch. "This means one antenna can cover multiple areas — and the transmission capacity is always available in full bandwidth exactly where it is needed." This requires the satellites to be equipped with modular phased array antennas. Their individual beams can be electronically controlled, making them much more flexible than the mechanically controlled antennas that were previously used.

5G integration is crucial

For global cellular coverage to function reliably, satellite communications must be integrated into terrestrial communications such as the 5G network. In the future, user equipment should also be able to directly communicate with satellites — even when there is no terrestrial base station nearby, which has been an indispensable requirement up until now. In the future, depending on whether they have reception, smartphones or even autonomous vehicles could be able to establish a 5G connection either via a terrestrial station or directly via satellite. This flexible combination of fiber-optic and satellite internet would enable complete network coverage across Germany — bidding goodbye to mobile dead spots. In 2021, Mr. Wansch's team of researchers at Fraunhofer IIS used a geostationary satellite in orbit above a fixed location on the Earth's surface to successfully demonstrate the first direct communication between satellites and 5G-enabled user equipment in a non-terrestrial network (NTN).

To trial these NTNs, along with efficient transmission concepts and other satellite technology, radio experts developed the Fraunhofer On-Board Processor (FOBP), a type of satellite communications laboratory that can be booked by those in research and industry for experimental purposes. This flying laboratory went into space this summer on board the communications satellite Heinrich Hertz (H2Sat), and took on the job of processing its digital signals. "Up to now, communications satellites have just acted as relays that receive signals from Earth, amplify them and transmit them to other ground stations, where the signals are processed," explains Mr. Wansch. "Onboard processors allow the signals to be processed directly within the satellites. So the satellites themselves become intelligent network components that can control data streams as needed." As the processor can be adapted to new communication standards from the ground at any time, it lends itself to a diverse range of experiments and applications.

Communicating with light

More and more data, limited radio frequencies — but at the end of the tunnel there is: light! Light can also be used for communication between satellites and ground stations. Transmitting constantly increasing amounts of data at the speed of light across ever-expanding distances through space is one area that optics experts are researching at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. They are developing laser sources for generating light, as well as optical amplifiers to maximize the range of these lasers.

One of their solutions is the wavelength division multiplexer: a device that combines multiple laser beams of different wavelengths. Every individual laser beam with its own specific wavelength represents a single channel, each of which can transmit data and generates 20 watts of power. This multi-channel approach enables high data transmission rates. The multiplexer combines these channels into a single, more powerful signal. Superimposing five channels achieves a total of 100 watts of optical power and thus a very long range. This raises the prospect of an optical link that could reach as far as the moon. Satellites distributed across multiple orbits could use light to communicate seamlessly with ground stations. Researchers are currently working on a system with 1,000 watts of power, which should be scalable up to 10,000 watts in the future. This would make it possible to transmit data from Earth as far as Mars.

Secured via quantum encryption

Light offers one further advantage, apart from range and capacity: Entangled light particles make data exchange particularly secure — which is vital in today's uncertain global situation. Critical information belonging to state or military bodies must be reliably protected from unauthorized access. The EU therefore wants to be among the first to back the principle of quantum key distribution (QKD). This could prove to offer a real advantage over Starlink and other commercial networks. The aim is to supply secret symmetric keys to two partners, no matter how far apart they are. This can be achieved using entangled light particles. The characteristics of these photons are so closely linked that measuring just one of the par- ▶

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ticles also immediately determines the state of the other. Any unauthorized interference immediately breaks this connection, which makes it practically impossible to tap. QKD would secure this communication even from quantum computers, which could well be capable of cracking many of the classic encryption methods before long.

Long-distance, by day or night

Quantum keys can already be seamlessly exchanged over shorter distances at ground level. However, global quantum communication would require longer ranges that could span continents. This remains a challenge — too many of the fragile light particles go astray. At Fraunhofer IOF, Dr. Fabian Steinlechner and his team are working on multiple parallel projects in search of some solutions. For example, they are developing space-suitable miniaturized photon sources the size of a milk carton — these act as a transmitter on board satellites, generating entangled light rays and sending them to Earth. These rays are received at the ground station by optical reflecting telescopes the size of a TV satellite dish. From there, they enter the fiber optic network to be distributed to the receivers. The optics experts are working with eight European and Canadian research partners to further develop quantum communication via free beam into scalable global quantum networks. "In the Hyperspace project, we're creating preliminary designs for transmitting entangled photons over longer distances of 6,000 kilometers and more. This includes, for example, noise-resistant quantum state encoding, as well as hyperentanglement, where the particles are mutually entangled across not one, but multiple characteristics. That could make information transfer both quicker and more efficient."

However, optical communication via satellite faces three hurdles: sunlight, clouds and atmospheric turbulence. These can significantly reduce the quality of light signals or diminish visibility. To receive usable signals even during daylight hours, the quantum experts apply various filters: "Because we know the direction and point in time from which the data signals were transmitted, we can use spatial and temporal filters to distinguish them from sunlight and filter them out," explains Dr. Steinlechner. "In addition, spectral filters allow the spectrum to be narrowed to the relevant wavelengths."

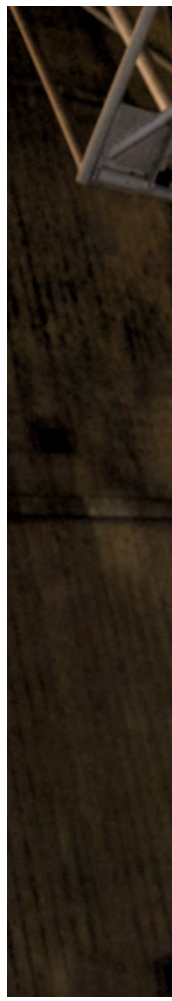
Light rays distorted by turbulence can be corrected using adaptive optics (AO). Picture these like small, flexible deformable mirrors located within the receiving telescopes — they are reshaped using multiple positioning elements to precisely align the light ray so that it can be received by the telescope. These AO mirrors allow the light to be focused even more exactly and directed into a fiber optic cable about two millimeters in diameter. The biggest challenge yet to be resolved is that of clouds, as they often completely block the optical signals. According to Dr. Steinlechner, it could help to include redundancies in the form of other technologies such as radio or diversions to other satellites positioned over cloud-free regions. The quantum keys can also be created in advance so that secure communication is not necessarily dependent on cloud cover.

All of this means quantum communication is still too technologically complex to provide secure universal broadband connections. "Just as quantum computers are not going to replace smartphones, quantum communication will not replace conventional communication technologies," says the researcher. He believes the technology will reach sufficient maturity by 2027, when IRIS² will launched, but only for specific areas of application. For example, European satellites could be used to create a temporary high-security internet for especially security-critical applications or events such as the G7 summit. The research team recently demonstrated how this can be done by carrying out a key experiment as part of the QuNet initiative, which is funded by the German Federal Ministry of Education and Research (BMBF). The experiment involved creating an ad-hoc network between three locations in Jena, through which they were able to establish tap-proof communication.

Sustainability as a competitive advantage

The private satellite networks are still a few years ahead of the European network in their development. However, there is one other area, apart from the application of quantum technology, where IRIS² could still take a pioneering role: this constellation will be more sustainable than others. The plan is to minimize greenhouse gas emissions at every stage of the development process. Light pollution is a problem that has not been adequately addressed to date. For some time now, the night sky has been illuminated not only by stars, but by a great many satellites — and their number keeps growing. The International Astronomical Union is concerned about the impact of satellite constellations, as they reflect sunlight and so interfere with astronomical observations. "In IRIS², we therefore also intend to reduce the visual brightness of the satellites using methods such as special non-reflective coatings," explains Dr. Ben Bekhti-Winkel.

Then there is the enormous issue of leaving behind undesirable legacies: More satellites will potentially lead to more space debris in the form of detached parts, or defective or decommissioned objects. This increases the risk of collisions. According to the ESA, about 30,000 objects



Keeping an eye on conditions in space: Dr. Lars Fuhrmann from Fraunhofer FHR can use TIRA to precisely record the orbit data and rotational parameters of satellites or space debris.

measuring larger than ten centimeters, and more than a million measuring between one and ten centimeters, are currently hurtling around the Earth at speeds of up to 50,000 kilometers per hour. The impact of even one tiny fragment of debris can equal the force of a hand grenade. Researchers at Fraunhofer EMI are conducting laboratory experiments to investigate the effects of such impacts on satellites. They use in-house software to carry out risk analyses with the aim of identifying vulnerabilities right from the satellites' design phases, and building in protective shields. Many manufacturers also equip their satellites with thrusters so that they can evade large pieces of debris and flying objects with measurable trajectories.

To increase sustainability in space, as well as security on the ground, satellites must be able to burn up without trace when they reenter the Earth's atmosphere at the end of their lifespan — this feature must be built into satellites during their construction. The problem is, at an altitude of 600 kilometers, space debris circulates for about 25 years before its velocity reduces to a point where it can burn up in the atmosphere. At an altitude of 800 kilometers, this can take as long as 150 years. France is a trailblazer when it comes to solving the problem of debris: French law dictates that satellites must be disposed of at the end of their mission. ERNST is also working in earnest to protect the space environment: At the end of the operating period, a braking sail measuring 1.6 meters x 1.6 meters is unfurled, meaning Fraunhofer nanosatellites linger at an altitude of 500 kilometers for only a few months, instead of a few years.

Keeping an eye on satellites and space debris

As low Earth orbit becomes more crowded, it is becoming more important that we maintain the most comprehensive and up-to-date overview possible — especially ▶

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considering there is no single worldwide institution or international agreements that regulate or monitor who is sending satellites into orbit, and how many. When it comes to systematic space surveillance, Germany has so far relied on data from US authorities, which may sometimes have different priorities, or choose not to disclose certain information. In recent years, an awareness has grown that in this crucial area, Germany needs to become less dependent on data from third parties. This has led to the establishment of GESTRA (German Experimental Space Surveillance and Tracking Radar), a domestically owned space surveillance system. It uses the most up-to-date radar technology to observe objects at an altitude of 300 to 3,000 kilometers. The German Space Situational Awareness Centre calculates orbit data for all detected objects, which are recorded in the form of a giant roadmap called the orbit data catalog. This catalog offers a basis for assessing any collision risks. Various influences can sometimes cause the objects to change their orbit, so they must be continuously monitored and the map must be constantly adjusted.

"At a distance of 1,000 kilometers, the tracking radar's beam can be trained on an object to an accuracy of three meters. At the same distance, we can simultaneously detect pieces of debris measuring as little as two centimeters in size."

Dr. Lars Fuhrmann, Fraunhofer FHR

GESTRA was developed by the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg, near Bonn, for the German Space Agency at the German Aerospace Center (DLR). It is currently undergoing test operations at the Schmidtenhöhe military training facility near Koblenz, but will be handed over to the DLR as soon as possible. "What is special about GESTRA is its phased array technology," explains Dr. Lars Fuhrmann, head of the Radar for Space Situational Awareness (RWL) section at Fraunhofer FHR. "It generates radar beams that can be electronically pivoted to stretch like a giant fence across a wide area. Any objects that pass through this fence are detected. The radar covers an area of sky of up to 90° x 15°. To contextualize that, the diameter of the moon in the sky, as viewed from Earth, equates to about half of one degree. And area of the GESTRA search fence in the sky is equivalent to around 180 x 30 moon diameters."

GESTRA is also unique worldwide as it is extremely compact and partially mobile — its components can fit inside a few containers. This not only makes it easy to transport the system to other locations to cover other areas of sky, but also makes it scalable. The future could see systems positioned in multiple locations around the world to gather even more precise data by observing the same object from multiple different angles, for example. With this goal in mind, Fraunhofer FHR is collaborating with Hensoldt AG, which wants to convert the space surveillance radar into a system that is ready to go into production and operation.

Space reconnaissance

While it is important to have a comprehensive overview of what is happening in near Earth space, sometimes more detailed information is needed on a particular object — be it an active satellite or space debris. This is a job for the TIRA (Tracking and Imaging Radar) space reconnaissance sensor. This radar system, also developed and operated at Fraunhofer FHR, is housed within a spherical white radome in Wachtberg, near Bonn, about 60 kilometers away from the GESTRA location. As of yet, it is the only system outside the USA that allows a very high degree of precision in measuring space objects' orbits from ground level and produces high-resolution images of satellites.

While GESTRA gives an overview of the bigger picture, TIRA takes a closer look: What are the object's characteristics? Has a satellite been damaged in a collision? How is the object's trajectory or rotation changing? When and how will the object reenter the Earth's atmosphere? To answer questions such as these, the TIRA system uses both a high-powered radar to precisely track the objects and a high-resolution radar to generate a detailed image of the object. Both are integrated into the large antenna, which has a diameter of 34 meters.

Tracking fast-moving satellites or pieces of debris requires speed and precision above all, as these objects usually disappear behind the curvature of the Earth within a few minutes. And TIRA is fast: The system's enormous antenna, weighing about 240 tons, can complete one full rotation within 15 seconds. "That's a world record," says Dr. Fuhrmann. He goes on to explain: "The system combines highly precise positioning and sensitivity. At a

distance of 1,000 kilometers, the tracking radar's beam can be trained on an object to an accuracy of three meters. At the same distance, we can simultaneously detect pieces of debris measuring as little as two centimeters in size."

Missions to retrieve decommissioned satellites

TIRA is also used as an experimental system for developing new space observation techniques, both at Fraunhofer FHR and in collaboration with space organizations such as the ESA and DLR. "Its areas of application range from precise orbit calculations right up to highly technical analyses of suspicious or otherwise interesting satellites," explains Dr. Fuhrmann. "We compile series of high-resolution radar images to investigate factors such as the stability level and rotational characteristics of disabled satellites." To assist with preparations for the first European ClearSpace mission scheduled for 2025, TIRA experts helped with object characterization during the process of selecting suitable objects for retrieval. One possible candidate for a future mission is Envisat, the ESA earth observation satellite, which has been circling through space as a ghost satellite ever since it was decommissioned in 2012. It would take 150 years for it to lose enough speed to independently enter the Earth's atmosphere and burn up. As it weighs eight tons and measures 25 meters in diameter, it would pose a significant risk to other satellites during this period. In the case of a collision, the resulting debris cloud could trigger a devastating chain reaction.

To assess which of the available capture technologies — such as nets or magnetic field technology — are most suitable for capturing such a colossus, as well as deciding on the best way to approach it, the experts are using TIRA to observe the satellite over months and years, meticulously recording its rotational parameters and speed. This data could be used to prepare for a retrieval mission. The goal is to deliberately let the decommissioned satellites burn up, thus ensuring they end their lives in a sustainable manner. TIRA's special features have earned it a great reputation worldwide. In fact, the research team is currently supporting the Japanese space agency with similar retrieval activities.

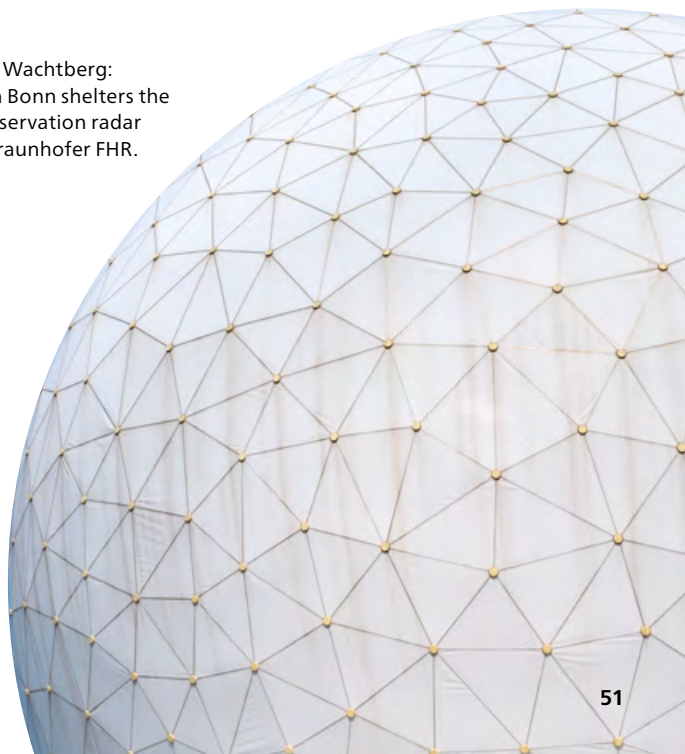
Limits of sovereignty

One other challenge remains largely unresolved: How will the European satellites actually get into space? Since the EU still has neither the necessary modern rocket technology nor the capacity, this is where sovereignty reaches its limits. After the Ukraine war rendered Russian carrier rockets and launch sites unusable, European missions turned to businesses such as Elon Musk's US-based company SpaceX. But despite SpaceX's large number of flights, the waitlists are long. In 2022, Falcon rockets launched 60 times, in contrast to the European Ariane 5, which launched only twice.

While the much-postponed launch of Ariane 6, Europe's most powerful carrier rocket to date, is now scheduled to happen in French Guiana in late 2023, a question still hangs over whether its capacity will suffice for the growing satellite business. The reason is that in contrast to the reusable SpaceX carrier rockets, which can be relaunched, Ariane will remain a single-use rocket for the time being. Sustainability just wasn't on the table during the initial planning process at Arianespace back in 2014.

However, there is hope — many recently founded New Space start-ups are now working with public decision-makers to expand EU space capacity. Even Prof. Schäfer of Fraunhofer EMI is convinced: "In Europe as well as at Fraunhofer, there is a huge amount of know-how around relevant technologies, whether in satellite construction or in communication, quantum and radar technologies. This will help us succeed in establishing our own reliable infrastructure in space and release us from our previous dependency on the USA and Russia." ■

Scan here for the podcast:



A landmark in Wachtberg: The radome in Bonn shelters the TIRA space observation radar operated by Fraunhofer FHR.

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A voice from the business world

Martin Daum, 63, beside the all-electric 19 ton eActros: The electric truck has a 400 kilometer range and is designed for urban areas.

A two-track road to the future

Batteries are the hottest topic of conversation right now — and not just at the upcoming IAA Mobility trade fair in September. Battery-powered propulsion is the number-one technological option for making automotive traffic emission-free. However, trucks are not just big cars.

Martin Daum, CEO of Daimler Truck AG, weighs in.

The commercial vehicles of the future will not only need batteries — they will also need hydrogen. At Daimler Truck, we are well aware of this, which is why we signed a memorandum of understanding with the Toyota Motor Corporation a few months ago. As well as outlining plans to merge our Japanese commercial vehicle subsidies, this agreement also concerns collaborating on hydrogen propulsion. In addition, in 2021, we formed the cellcentric joint venture with the Volvo Group to build one of the largest production facilities for fuel cells in Europe. In contrast to our colleagues in the passenger car sector, we are not pursuing a single technological strategy, but rather heading down a two-track road — and we have a good reason for that.

First of all, trucks are not just big cars. They are capital goods. Our customers must be able to earn money using our products. That means they keep a close eye on costs. And not just the purchasing costs, but also specifically the overall costs throughout a truck's working life.

These costs currently depend very much on the price of diesel — and in the future, they will depend on the prices of electricity and hydrogen. Depending on how these prices develop, it may be more economical for commercial vehicle customers to choose battery or fuel cell propulsion. When it comes to trucks and long-distance buses in particular, energy prices will greatly influence customers' purchasing decisions. However, we cannot predict future price levels — so we also cannot predict the future mix of battery and fuel cell vehicles. This means companies that are not developing hydrogen drives at present could lose out in the future, when the market for hydrogen models may be booming.

One more important thing — in addition to fuel cells, there is another form of hydrogen production: the hydrogen combustion engine. This technology is a good CO_2-free alternative for trucks that have vehicle platforms, such as construction site vehicles, and thus require significantly more energy than is used just for driving. For this reason, we are following current discussions around hydrogen combustion engines very closely. If this concept receives well-founded political support, we will be well prepared and quickly be able to offer vehicle series of this kind.

"Emission-free trucks powered with batteries alone? Every truck stop would need as much energy as a small town."

Martin Daum

- heads up the largest commercial vehicle manufacturer in the world, with 100,000 employees at over 40 production facilities. In May, it was announced that Daimler Truck is planning to merge large parts of its business in Asia with Toyota — and drive the development of hydrogen propulsion and other future-oriented technologies together.
- has been the CEO of Daimler Truck AG since 2019, which split off from the former Daimler AG with an initial public offering in 2021.
- joined what was then Daimler-Benz AG in 1987, after training as a bank clerk, studying business administration and spending three years as a business consultant. In 2009, Mr. Daum became president and CEO of Daimler Trucks North America and increased its market share from 29.6 to 39.3 percent.
- was born on October 28, 1959 in Karlsruhe, and is married with three grown-up children.

A second reason for our two-pronged strategy is the infrastructure. A few facts clearly show what it would mean for zero-emission trucks to be powered with batteries alone in the future. First, if that were the case, every truck stop would require between 20 and 50 charging stations. And every charging station would need to be equipped for megawatt charging. This means every truck stop would need as much energy as a small town.

That type of charging infrastructure is pure fantasy. Providing widespread public access to this amount of charging capacity is simply not realistic. It would overtax power grid expansion efforts beyond all hope of recovery. Just for this reason alone, we will also need hydrogen for trucks in the future — in addition to batteries.

And we must note another fact too: As the consulting firm McKinsey found in a study, when it comes to costs, building two infrastructures is cheaper than just building one. Intuitively, you might expect a different result. But taking an infrastructure that's just based on batteries and scaling it up to an extreme volume is more expensive than scaling two infrastructures — one for batteries and one for hydrogen — up to a medium volume.

The third reason concerns the European continent's energy needs. In order to make Europe more sustainable, we need to completely replace the energy produced from fossil raw materials with green energy sources. The amounts involved are so enormous that we cannot produce them in Europe, where we get comparatively little sunshine. But the good news is, there's more than enough green energy available worldwide. Every day, the Earth's land mass is hit with 15 times as much solar energy as we consume worldwide in a whole year. We just need to capture it and transport it to where it is needed. However, for this purpose, we need a carbon-free energy carrier that can be traded worldwide — and with that, we have now circled back to hydrogen.

So what we can take away here is that we need to develop a hydrogen economy to support the sustainable industry of tomorrow — and there are good reasons to use this energy carrier for trucks and buses too. This is why commercial vehicle manufacturers need to take a two-track road to reach the future. ■

Photo: Daimler Truck AG

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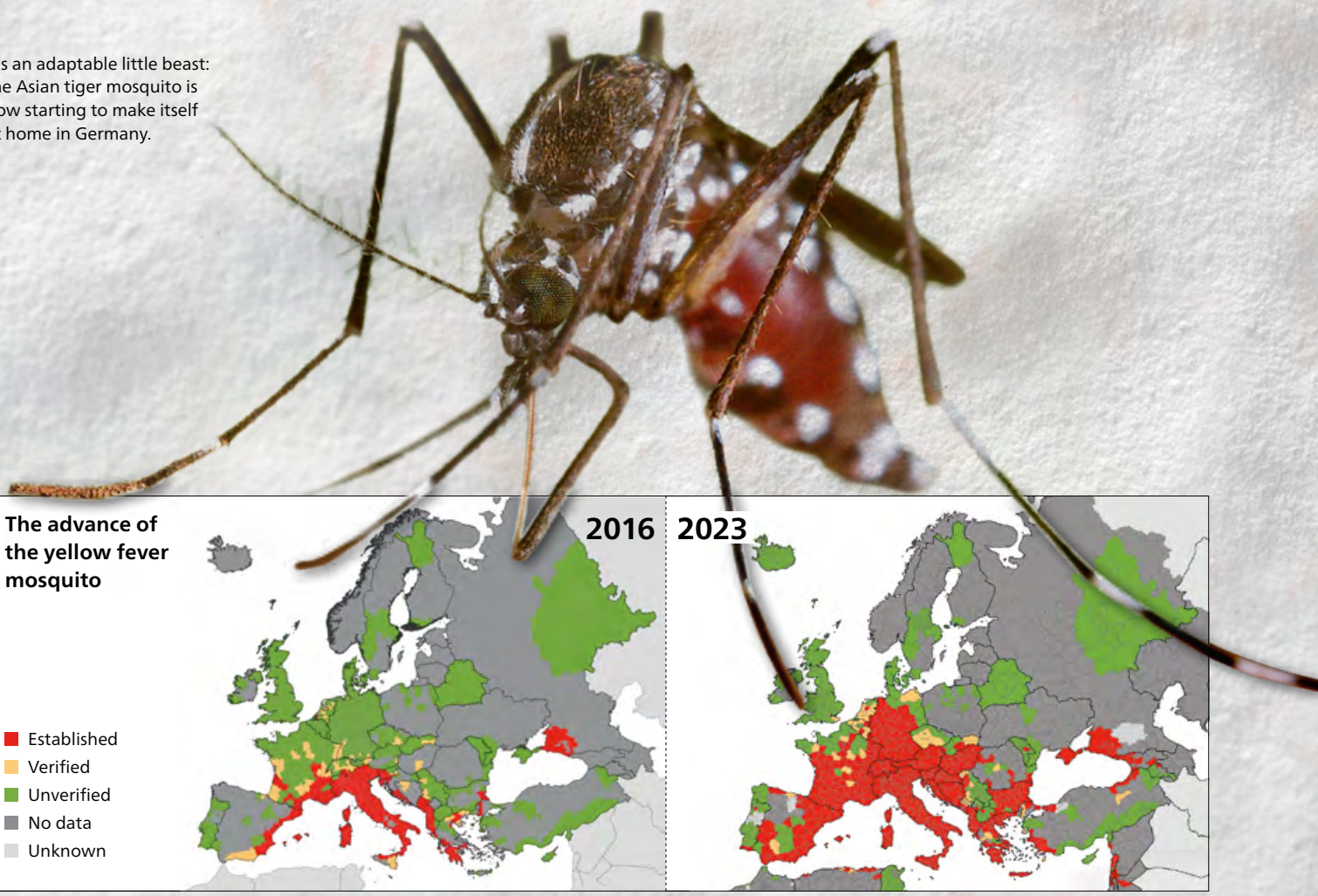
A vicious visitor

Wildlife is a hot topic in Germany, with much ink being spilled about bears, wolves and even lions; however, no creature is responsible for more human deaths than the mosquito. As climate change progresses, these pests are making their way to northern Europe, bringing tropical viruses with them — and we need to be prepared when they arrive.

By Dr. Sonja Endres



It's an adaptable little beast: the Asian tiger mosquito is now starting to make itself at home in Germany.

They travel by plane, truck or ship, they carry dengue fever and Zika viruses and they're here to stay: the Asian tiger mosquito. Although it is originally native to the south and south-east Asian tropics and subtropics, climate change is making many parts of Germany feel quite homey for this particular insect. The scientists in project CuliFo are researching where and how these mosquitoes are spreading, as well as what viruses they are bringing along with them and transmitting to humans and animals. Coordinated by the Bernhard Nocht Institute for Tropical Medicine in Hamburg, this interdisciplinary team has been on the trail of Aedes albopictus, as the tiger mosquito is known by experts, since 2016. Back then, they only found sporadic signs of the insects in the extreme south west of Germany. Now, however, the tropical mosquitoes have reached or become endemic to large swathes of southern, western and eastern Germany.

Since the beginning of this year, the scientists in Germany's largest joint research project on mosquitoes have been benefiting from the assistance of the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig. "In CuliFo, we are studying the spread of these disease-carrying insects," explains Dr. Sebastian Ulbert, head of department for Vaccines and Infection Models. "To do that, we are examining a variety of animals, particularly dead birds, for antibodies that indicate a previous infection caused by a mosquito bite." Dr. Ulbert and his team obtain samples from all over Germany with the help of their colleagues and close collaboration partners at the Friedrich-Loeffler Federal Research Institute for Animal Health (FLI), which is headquartered on the island of Riems.

The researchers' main focus is the Usutu and West Nile viruses. While Usutu virus is primarily a threat to animals, having caused a sharp decline in the blackbird population in the Upper Rhine region during an outbreak in 2011, West Nile virus also presents a risk to human life. The disease was first identified in 1937 in the West Nile region of Uganda, hence the name. Victims of the virus often experience high fevers, vomiting, diarrhea, exhaustion and joint pain. In some rare cases, it can even lead to inflammation of the brain or the lining of the brain and spinal cord — as with tick-borne encephalitis (TBE), which is also caused by a pathogen from the flavivirus family. However, while it is relatively easy to protect yourself against tick bites and so to avoid TBE infections, this is incomparably harder when it comes to mosquito bites — especially as West Nile virus is now being transmitted by the common house mosquito. "The West Nile virus is an all-rounder," says Dr. Ulbert. "It's not choosy when it comes to the hosts that it can multiply in. We are aware of 350 types of bird alone in which it can replicate. This is why the West Nile virus is the most widely spread mosquito-borne virus in the world." Fortunately, the same does not hold true for other members of the flavivirus family, like dengue fever and Zika virus. To date, they have almost exclusively used yellow fever mosquitoes as their host and vector. What's more, these tropical viruses require long, uninterrupted periods of high temperatures in order to multiply in the mosquitoes to such an extent that their bite becomes infectious — another important difference between them and their West Nile cousins, which only need 10 to 15 days where the temperatures do not sink below 20 degrees. This means that the West Nile virus can spread much more quickly.

As all flaviviruses resemble each other closely, the antibodies produced by immune cells as a defense against them are also very similar. Consequently, developing test systems that allow for unambiguous identification is quite a challenge. "The tests that are currently in use often give people a positive result for West Nile virus simply because they have been vaccinated against TBE," explains Dr. Ulbert. He and his team have succeeded in developing tests that can detect antibodies with a far greater level of accuracy. Together with their colleagues at the FLI, the team of researchers aims to improve the testing systems further in project CuliFo so that they can detect the spread of the viruses even more reliably. Their goals include the creation of early warning systems that will allow us to be better prepared for larger outbreaks.

The first outbreak of this nature struck the Leipzig region in summer 2020. Ten people were so severely affected by West Nile fever that they had to be treated in intensive care units, and two of the victims died. "Of course, this was during the coronavirus pandemic, so at the time, no one was interested. There were probably more than a hundred people infected in the city," Dr. Ulbert estimates. At present, he is working with the University of Leipzig Medical Center to retroactively calculate more accurate figures by screening blood donations.

In Padua in northern Italy, the situation is already far more serious. The city experienced an outbreak of the illness last summer, with 200 severely affected patients stretching the local intensive care units to their breaking point. Dozens of those undergoing intensive medical care died. "The case numbers are still quite low for the time being, but they will very probably rise in the years to come, with the areas where they spread expanding within our own borders as well," predicts Dr. Ulbert. The danger is most severe for older people above the age of 60 and people with preexisting conditions. "The at-risk demographics are much the same as those for coronavirus," he explains. "However, unlike COVID, we have neither an effective vaccine nor medications to counter West Nile virus." Currently, all that can be done is to stabilize the patients and hope their immune systems are strong enough to hold out, he adds. Dr. Ulbert and his team are working to change that, and they have already identified a promising vaccine candidate. However, so far, they have not been able to find a partner from the pharmaceutical industry to help them conduct clinical trials. The researchers are also working on a drug that prevents the viruses from replicating in the host cell and could also be used to counter dengue fever and Zika viruses. "It's still too cold for them in Germany," says Dr. Ulbert. "But they will come. They have already reached southern Europe." ■

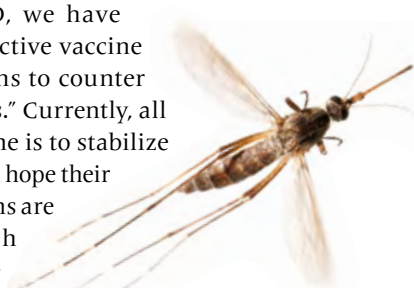


Photo: James Gathany/CDC, Antagain/istockphoto; source for the map of the insects' advance: European Centre for Disease Prevention and Control

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A targeted off-switch

Developing vaccines and drugs to counter tropical diseases is a multi-year process — and with climate change, that time is running out. Nevertheless, it is possible to protect Europe from epidemics by tackling the root cause of the problem: the mosquitoes that transmit the viruses.

By Dr. Sonja Endres

Swatting individual bugs is one thing — when the insects start to number in the thousands, we need better ideas.

When what has so far been Germany's last malaria epidemic struck in the extremely hot summers of 1945 and 1946, the country's main weapon was still dichlorodiphenyltrichloroethane (DDT). This chemical was then a commonly used insecticide, and it was sprayed extensively at the time. Traces of its impact can still be seen today in places like the Schlachtensee lake in Berlin. DDT has been banned since 1972, because it disrupts the hormonal balance in humans and animals and is suspected of causing cancer.

Prof. Andreas Vilcinskas, branch director for Bioresources at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Gießen, is working on a more up-to-date solution for mosquito control. Together with their colleagues at the LOEWE Centre for translational biodiversity genomics, Prof. Vilcinskas and his team sequenced the genomes of various tropical mosquitoes; this information can be used to detect their larvae in water. "By analyzing environmental DNA, we can monitor large areas with relatively high levels of precision. This allows us to detect rapidly growing populations at a relatively early stage, so it's a little like a fire alarm for us. The technique can also be used to verify the presence of viruses," explains Prof. Vilcinskas. It's a good analogy, because a viral outbreak has to be extinguished just as quickly as the source of a fire. "With our 'fire department,' an innovative RNAi technology, we have a targeted method of eliminating the larvae without harming the environment."

The researchers plan to feed the juvenile mosquitoes a specially designed double-stranded RNA that will trigger a natural mechanism used by higher organisms to protect themselves against invasive viruses: RNA interference, or RNAi for short. The principle behind this mechanism is that, unlike animal and plant cells, viruses produce double-stranded RNA. If this form of RNA is discovered in cells, then it is identified as a foreign body and destroyed. However, this process breaks down not only the double-stranded RNA, but also all the body's own single-stranded RNA with the same sequence. Consequently, the associated, complementary gene sequence can no longer be read out and a certain protein can no longer be produced.

Prof. Vilcinskas and his team are targeting genes that are vital to the insects' survival: lethal genes. If these genes are switched off via RNAi, the mosquito will die. "The problem is not finding these genes. Around a third of all the genes that we silenced in the red flour beetle resulted in the death of the insect. However, many of them were far from suitable for our purposes. We can only use a gene if it is susceptible to even tiny doses of the double-stranded RNA." After all, the "bite" that the larvae filter from the water around them is only the size of a single cell.

The packaging counts

The RNA has to be packaged safely to ensure that it does not disintegrate, but finding the right formulation for the protective shell is no mean feat. It must be something that only dissolves when the RNA arrives in the intestines of the larvae, where it can take effect — any earlier is no good, as many mosquitoes and larvae have enzymes for breaking down RNA in their saliva. The formulation also has to be individually adapted to suit its target insect. For example, some larvae float around in the water as they filter out nutrients, but others, like the Asian bush mosquito, prefer to feed at the bottom of the body of water. In their cases then, the RNA particles have to be designed to sink.

The Asian tiger mosquito alone can transmit

20

diff rent viruses.

Prof. Vilcinskas and his team have already notched up one success with the pea aphid. They can stop this particular pest from producing a specific protein that hardens when it makes contact with the host plant's sap flow to form a kind of drinking straw for the insect. Without it, the aphid cannot suck up its food and will starve to death. "The special thing about double-stranded RNA is that we can design it to target specific species, like a precise surgical implement. With pesticides on the other hand, there is always collateral damage."

The urgency of this issue cannot be understated, as Prof. Vilcinskas is quick to point out. The Asian tiger mosquito alone can transmit 20 different viruses that present a risk to human health. "No one in the scientific community seriously doubts that these viruses are coming. We have to protect ourselves and we urgently need environmentally friendly control methods." ■

"With our 'fire department,' an innovative RNAi technology, we have a targeted method of eliminating the larvae without harming the environment."

Prof. Andreas Vilcinskas, Fraunhofer IME

Photos: malerapaso/istockphoto, Fraunhofer/Piotr Banczerowski

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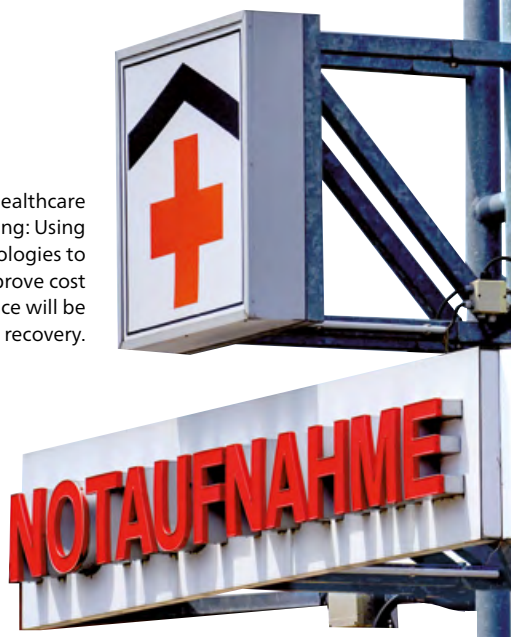
From invention to innovation



The healthcare system is ailing: Using new technologies to improve cost intelligence will be crucial to its recovery.

How sick is Germany's healthcare system? And how can we get it back on its feet? The fight against demographic changes, exploding costs and shortages of skilled workers can only be won with input from the research sphere.

By Beate Strobel

If Germany's healthcare system was a person, it would be lying in the intensive care unit right now. "We'd see a patient with a chronic illness, suffering from a multitude of progressively worsening symptoms," explains Prof. Gerd Geißlinger, director of the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP and Medical Research Officer of the Fraunhofer-Gesellschaft. What's making it sick? "Our healthcare system is spending significantly more money than it brings in," Prof. Geißlinger diagnoses. "In order to bring income and expenditure back into equilibrium, we need something more than short-term solutions that essentially just treat the symptoms — we need a long-term fix." One thing is clear to the doctor and pharmacist: "Germany doesn't just need a climate turnaround, energy transition and a new era. It's also high time we transformed our healthcare system."

In 2022, the statutory health insurance providers ran a deficit of 17 billion euros. The proportion of the gross domestic product (GDP) going to healthcare expenditure is continuing to rise; Germany now has the highest healthcare expenditure in the EU. The majority of health insurers once again increased their rate of contribution in 2023 for this reason. Germany's citizens are paying more for their statutory health insurance than ever before — an average of 16.2 percent of their gross salary.

Prof. Geißlinger is prescribing a course of cost intelligence for the ailing healthcare system: "Research and development can contribute significantly here. As an interface between basic and applied research and the industry, the Fraunhofer institutes could be the driving power behind a transformation of the healthcare system. Inventions need to be transformed into cost-intelligent innovations at a quicker rate, and these innovations need to reach patients at a similar speed."

According to Prof. Geißlinger, an example of a cost-intelligent invention would be one that can detect diseases during an early phase of molecular and cellular immune dysfunction and stop them before the first clinical symptoms occur. In collaboration with the Goethe University Frankfurt and the Karolinska Institutet in Stockholm, Fraunhofer ITMP has helped with the preclinical development of the first therapeutic vaccine against rheumatoid arthritis — a diagnosis that affects around 800,000 people in Germany and results in treatment costs of 15,000 to 25,000 euros per patient annually, if treated conventionally. The clinical trial of this innovative vaccine is currently being carried out through a spin-off (aidCURE).

At present, over half of the 76 Fraunhofer institutes and research units are involved with what is known as the Health Research in 4D: drugs, devices, diagnostics and data. The data component of these four fields is currently the focus of much attention, as the availability of medical data for research and development is a basic requirement for cost intelligence.

Take the Fraunhofer lighthouse project MED²ICIN, for example — a project in which six Fraunhofer institutes have joined forces to create an interdisciplinary research association, under the leadership of Fraunhofer IGD. This project aims to use medical data to not only improve prevention, diagnostics and treatment for individuals, but also allow for intelligent cost management at the same time. They have created a software program that combines as much data as possible on patients' diseases — such as pre-existing conditions, lab results and ultrasound images — and uses AI-based algorithms to analyze it. The system also provides up-to-date clinical guidelines, possible treatment methods and anonymized data on other, similar cases. The result are presented in an interactive dashboard for doctors that not only offers an overview of all the data and treatment options, but also — thanks to the cooper-

Photos: Klaus-Dietmar Gabbert/dpa, Oliver Soulas

ation of a range of university hospitals — shows the results of treatment in other patients. In addition, the system balances the expected success of the treatment against the costs — it can give information on more cost-effective alternatives, for example.

The Fraunhofer Institute for Digital Medicine MEVIS developed the OncoChange software for automatic, efficient and reliable monitoring of tumor progression. OncoChange supports physicians in detecting disease- and therapy-related changes in tumors in CT images and in quantitatively determining their size development; this enables a faster and more accurate generation of findings compared to conventionally used methods. As a result, ineffective therapies can be replaced earlier by alternatives, improving the patients' quality of life or even extending their lives — and saving costs. The OncoChange software is designed to be integrable into already existing clinical software infrastructures — a crucial advantage to bring solutions into application quickly and affordably. Because currently, according to Prof. Geißlinger, "we have a patchwork of individual systems in the healthcare landscape that don't always communicate with each other well." This means tests are sometimes carried out multiple times or incomplete data leads to patients being started on ineffective treatments. Both create equal strain on the patients and the healthcare system. "Doctor's practices and hospitals have not yet been digitalized to the extent we would like," says Prof. Geißlinger. "We urgently need to take decisive steps to address this, even if it costs a lot of money in the beginning. But ultimately, digitalization is one of several measures that will save our healthcare system."

Another crucial tool is automation — in the areas of diagnostics, treatment and care. Wise implementation of robot-assisted systems in relevant areas of the healthcare sector could relieve some of the strain on medical and care staff by taking over routine or physically demanding tasks, for example. This will allow personnel to stay physically fit for longer and give them more time in their day-to-day jobs for their actual work: helping and healing.

In the European research project DIH-HERO (Digital Innovation Hub Healthcare Robotics), the Fraunhofer Institute for Manufacturing Engineering and Automation IPA is contributing its expertise in assistive robotics for medical and care staff. Fraunhofer IPA has already developed a smart care cart that autonomously accompanies staff in hospitals and care homes and independently documents which materials are taken from the cart. This care cart has cousins: a robotic service assistant that can be filled with drinks and snacks and autonomously offers them to patients and care home residents, and a transportation robot that quickly and safely brings care carts and containers to their destinations. However, robotics does not only play an important role in routine tasks, but also more and more in surgical interventions. Robotic-assisted and (semi-)automated surgical procedures using connected systems have the potential to create unprecedented flexibility and precision in the operating room. What is more, when combined with smart assistance systems, they could increase the quality of these procedures while also saving on costs.

> "It's high time we transformed our healthcare system."
>
> Prof. Gerd Geißlinger, Fraunhofer ITMP

Automation also affects the production of therapeutic agents. Producing medicines for personalized cell and gene therapies, which are used for diseases such as acute cancers, is extremely time-consuming, personnel-intensive and expensive. This is because cell therapies, which belong to the category of advanced therapy medicinal products (ATMPs), have been produced manually up until now. Innovative solutions are therefore required to allow these therapeutic agents to be produced in an automated, digitalized and thus more cost-efficient way. In a white paper on the scalable production of ATMPs, experts from multiple Fraunhofer institutes developed modular strategies based on highly automated and fully digitalized technologies; these allow better-quality products to be produced at a higher speed, which results in significant cost savings.

Since 2021, the Fraunhofer Institute for Cell Therapy and Immunology IZI has been working to develop AI-driven ATMP production systems for hospitals as part of the EU project AIDPATH. The aim is to produce CAR T cells tailored to specific individuals — these are genetically altered T cells from cancer patients that are given a special receptor that allows them to recognize and destroy tumor cells. Establishing a facility of this kind directly at the site where treatment takes place will save valuable time and avoid expensive logistics processes. ▶

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The mission: bringing quick, cost-effective medicines to the market and to patients. The method: drug repurposing. This term refers to the search for new applications for medicines that have already been tried and tested in practice. In the EU-funded REMEDi4ALL project, the Fraunhofer Institutes for Translational Medicine and Pharmacology ITMP and for Algorithms and Scientific Computing SCAI, as well as Fraunhofer IZI, are working on a technology platform that allows approved medicines to be evaluated for their suitability for new areas of application.

Medicine production largely takes place in non-European countries. Although this situation has caused repeated bottlenecks since the coronavirus pandemic, Prof. Geißlinger does not believe there is much chance of changing it. "Greater efforts must be made to bring medicine production and research, particularly clinical research, back to Germany and Europe," he insists. "There is a financial component to this: a lot of money is being put into development and clinical testing. If we keep this within the country, it will be good for our national economy."

"However, therapies can also be optimized to make them more cost-effective and avoid unnecessary treatments and the costs that comes with them,' says Prof. Geißlinger. Medicines are often combined, because each one has its own effects, and synergetic or additive effects can achieved by using them together. As part of the MUST treatment study being carried out on psoriatic arthritis patients across Germany, Fraunhofer ITMP has shown that monotherapy using a specific biological agent is just as effective as using it in combination with another drug, as was commonly done previously. This avoids side effects from combining medicines and saves on the costs of unnecessary treatments and monitoring.

Another ongoing problem that Prof. Geißlinger laments is related to the limited possibilities for collecting and using health data from the healthcare system for research and industry. "Israel, the Scandinavian countries and the United Kingdom, for example, are way ahead of us in this area," the Fraunhofer expert says. He therefore believes the development of a health data use act as part of the German Federal Ministry of Health's digitalization strategy will be an important milestone and represent a crucial step forward for research. "We will only be able to keep the research industry alive in this country if we make enable and simplify the use of health data for scientific purposes."

At the same time, Prof. Geißlinger warns against prematurely dismissing the German healthcare system as a failure: "Our healthcare is still the envy of many countries across the world." However, for this to remain the case in the future, we urgently need to make many adjustments, and intelligent system solutions must be developed and put in place. Prof. Geißlinger adds that the healthcare system can only be successfully transformed if this work is carried out across governmental departments. For example, the German federal minister of health, Karl Lauterbach, has emphasized the need for a national heating plan, which shows that healthcare policy and climate change are connected. Maintaining or restoring people's ability to work is not only in the best interest of the healthcare system, but also the climate, education, economic affairs and finance ministries.

There is still a lot of potential going untapped when it comes to interdisciplinary collaboration, particularly in terms of merging research findings from the biomedical and engineering sectors to create system solutions for affordable healthcare. At Fraunhofer, specialists in the areas of medicine, the natural sciences, engineering and computer science work closely together under one roof — loosely following with Arthur Schopenhauer's adage that health is not everything, but without health, everything is nothing. ■

Photo: Van Hope/AdobeStock

Rip-off or real?

Whether it's medicines, aftershave or automobile brakes, product pirates will stop at nothing and are becoming increasingly sophisticated. Consumers will now be able to use their smartphones for a simple check to see if they are dealing with a fake product.

By Andrea Kaufmann

Last year, German customs authorities confiscated counterfeit goods to the value of 435 million euros — a rise of 38 percent on the previous year. The trade in inferior copies is lucrative for criminals, but often dangerous for consumers. Poor quality and problematic ingredients carry high risks. In the SmartID project, researchers from the Fraunhofer Institutes for Applied Polymer Research IAP, Secure Information Technology SIT and for Open Communication Systems FOKUS are developing an innovative labeling system that will make life harder for product pirates in the future. Their technique uses an app and a smartphone camera to quickly and easily check whether a product is genuine. The major advantage here is that the check can be conducted offline and without connecting to a database.

The surface of every package or product has a characteristic texture, formed by random irregularities that arise during the manufacturing process. Researchers are harnessing this unique feature: They examine the individual characteristics of the surface texture, which act like the fingerprints of the particular packaging or product. Researchers at Fraunhofer SIT are developing algorithms to analyze this information. The fingerprints are linked to the product manufacturer's digital signature to make a secure and unique label — the SmartID. "For a fingerprint to be unique, it must contain sufficient representative characteristics that can be reliably recognized," explains Dr. Waldemar Berchtold, a specialist in IT forensics and multimedia security at Fraunhofer SIT. "The area we scan for surface textures currently measures several square centimeters. Within this area, we can identify one million characteristics that can be read by all devices, even in poor lighting."

A team from Fraunhofer IAP are developing specially customized quantum materials that make the SmartID even more secure. These light up in the near infrared (NIR) region of the spectrum and are printed onto the object using a novel ink formulation. SmartID project manager Dr. Tobias Jochum from the Center for Applied Nanotechnology CAN at Fraunhofer IAP explains: "Because we include the NIR spectral region along with the visible region, we detect more surface texture characteristics in the same area." To make the introduction of this process easier, the ink and printing process has been optimized so it can be carried out in the conventional production facilities of the product and packaging industries.

In 2022, German customs authorities confiscated counterfeit goods to the value of

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million euros.

The SmartID is printed onto the packaging or the product in the form of a QR code. "In principle, it is possible to store a secure and unique label in any kind of two-dimensional barcode system. In the SmartID project, we have focused on the QR code, as this has already been accepted among both industry and end consumers," says IT expert André Paul of Fraunhofer FOKUS. The quantity of data required to integrate the fingerprint into conventional QR codes would exceed their storage capacity. For this reason, the team at Fraunhofer FOKUS is working on achieving higher storage capacities without compromising compatibility with classical QR codes. This will make it easier to integrate the technology into existing processes within the entire supply chain.

To authenticate a product, the consumer will be able to simultaneously scan both the QR code and the product's surface using their smartphone's camera. The smartphone's SmartID app will compare the two datasets. If they correlate, this proves the product is authentic. "Since you don't need to use a database to find matches, there is no need for an internet connection," explains Dr. Jochum. "That saves on the cost of installing and operating centralized databases, and has a positive effect on the carbon footprint." ■

Photo: Fraunhofer IAP

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Research prizes

Since 1978, the Fraunhofer-Gesellschaft has awarded-prizes to its employees for outstanding scientific achievements.

Microspeakers

Energy efficiency for in-ear headphones

Our constant companion, the smartphone, could be replaced by in-ear headphones that can be wirelessly inserted into the ear canal. The key to this technology — the integrated microspeaker — has been developed by a team of researchers from the Fraunhofer Institute for Photonic Microsystems IPMS and Bosch Sensortec GmbH.

By Dr. Janine van Ackeren

Dr. Sergiu Langa (left) and Dr. Bert Kaiser (center) of Fraunhofer IPMS want to revolutionize speaker technology together with Holger Conrad of Bosch Sensortec GmbH.

In the beginning, cell phones were just for making phone calls on the go, but now they combine a bank branch, shopping mall, music player, navigation system, television and much more. And the technological development is continuing: In the future, smart in-ear headphones with a direct internet interface could take the place of smartphones. These will have to be very small, with minimal energy requirements; they will also have to allow for low power consumption at a high sound pressure level and low production costs. Microelectromechanical systems, or MEMS for short, are ideal for this purpose. Until now, however, the key to this type of in-ear headphones has been lacking: suitable speaker technology. The technologies currently on the market are not yet suitable for such demanding applications — due to factors such as the required degree of miniaturization, integration capability, cost reduction, production scalability or power consumption at very high sound pressure levels.

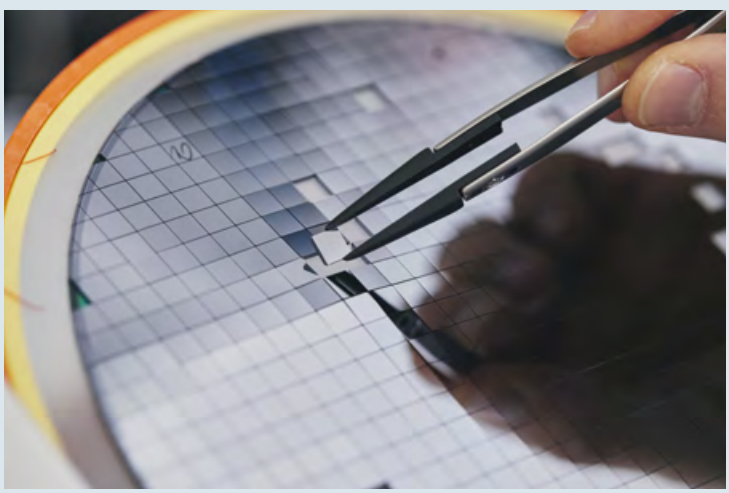
The first functional, economical microspeakers

Researchers at the Fraunhofer Institute for Photonic Microsystems IPMS have now taken an important step toward creating smart in-ear headphones by developing the key piece that they had been missing: mini silicon speakers that can be manufactured using microelectronics technologies and achieve the volume of 120 decibels required by the market without high power consumption. Dr. Bert Kaiser and Dr. Sergiu Langa from Fraunhofer IPMS and Holger Conrad from Bosch Sensortec GmbH are receiving the Joseph von Fraunhofer Prize for their development.

They used two innovative scientific approaches to develop the mini speakers. Firstly, they created a completely new design for the speaker: rather than being based on a conventional vertically deflectable diaphragm, the sound-displacing elements are positioned vertically in a silicon chip. Secondly, they came up with a new drive technology for these elements, the "Nano e-drive" actuators; these allow the sound to be generated. It is almost impossible to separate the two innovations from each other. "With the actuator, an electrostatic lever, we solved a fundamental problem: You can use it to create very large deflections and thus achieve high volumes," says Dr. Kaiser. If you apply a voltage, the lever moves — like an electrostatic muscle. In this way, the researchers were able to achieve large movements with small gap distances. In his dissertation, Dr. Kaiser investigated exactly how exactly to design this lever in order for it to move particularly efficiently and create large deflections. The research team stacked many of these levers vertically in the chip. The levers form a sort of speaker membrane; however, rather than being on the surface, they are inside the body of the chip. When the levers move in response to a voltage, they force the air out of the chip via an outlet opening, which generates sound. "This idea came about through many discussions, including with the director of Fraunhofer IPMS, Prof. Harald Schenk," says Dr. Langa.

To bring the speakers to the market, Arioso Systems GmbH was founded in 2019 as a spin-off of Fraunhofer IPMS. Dr. Hermann Schenk also made a significant contribution to this achievement, in terms of both the technology and the modeling process, during his time at Fraunhofer IPMS and later as managing director of the spin-off. Bosch Sensortec GmbH acquired Arioso Systems GmbH in summer 2022, with the aim of developing cutting-edge products based on MEMS speaker technology for the global mass market. ■

> "With the actuator, an electrostatic lever, we solved a fundamental problem: You can use it to create very large deflections and thus achieve high volumes."
>
> Dr. Bert Kaiser, Fraunhofer IPMS



The sound-displacing elements are positioned vertically in a silicon chip.

All photos: Fraunhofer/Piotr Banczerowski

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Building insulation

Sustainability and affordability with aerogels

We need to lower our CO_2 emissions systematically if we want to achieve our climate targets. Insulating buildings is a key part of this. Now, just when we need it, a sustainable, affordable mineral insulating material that can run rings around polystyrene has arrived on the scene.

It's always the way with superlatives: they get overused. But in the case of the aerogel insulation materials that the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT has developed in collaboration with PROCERAM GmbH & Co. KG, the superlative is far from false advertising: it might actually be the best insulation material in the world right now. It's not just the fact that aerogels are based on the non-critical mineral raw material silicon dioxide that sand is also made of — which means they are sustainable and do not require petrochemical sources. Aerogels are also the lightest solid material in the world — consisting of up to 99.8 percent air — and hold the Guinness World Record for the best insulator. The problem is that aerogels, which were discovered in the 1930s, have been extremely expensive up until now, and producing them has been complex and time-consuming.

Little marvels: The aerogel is mixed into the plaster.

The goal: an insulation revolution

PROCERAM GmbH & Co. KG saw this challenge as an opportunity. Their goal was to mass-produce aerogels in a cost-effective way. In other words, if they could create an affordable, non-combustible mineral insulation material that was a more effective insulator than its fossil-based counterparts, it would revolutionize the insulation sector. To achieve this, they brought experts from Fraunhofer UMSICHT on board. It was a successful move: Within six years, the team had got a new production process for aerogels off the ground that does not use any environmentally harmful chemicals — and scaled it up from the lab to a pre-commercial level. The production costs for the aerogels fell by 70 percent, and manufacturing time from over 10 hours to just 2.5 hours. Nils Mölders and Andreas Sengespeick of Fraunhofer UMSICHT and Christoph Dworatzyk of PROCERAM GmbH & Co. KG will be awarded this year's Joseph von Fraunhofer Prize for their achievement.

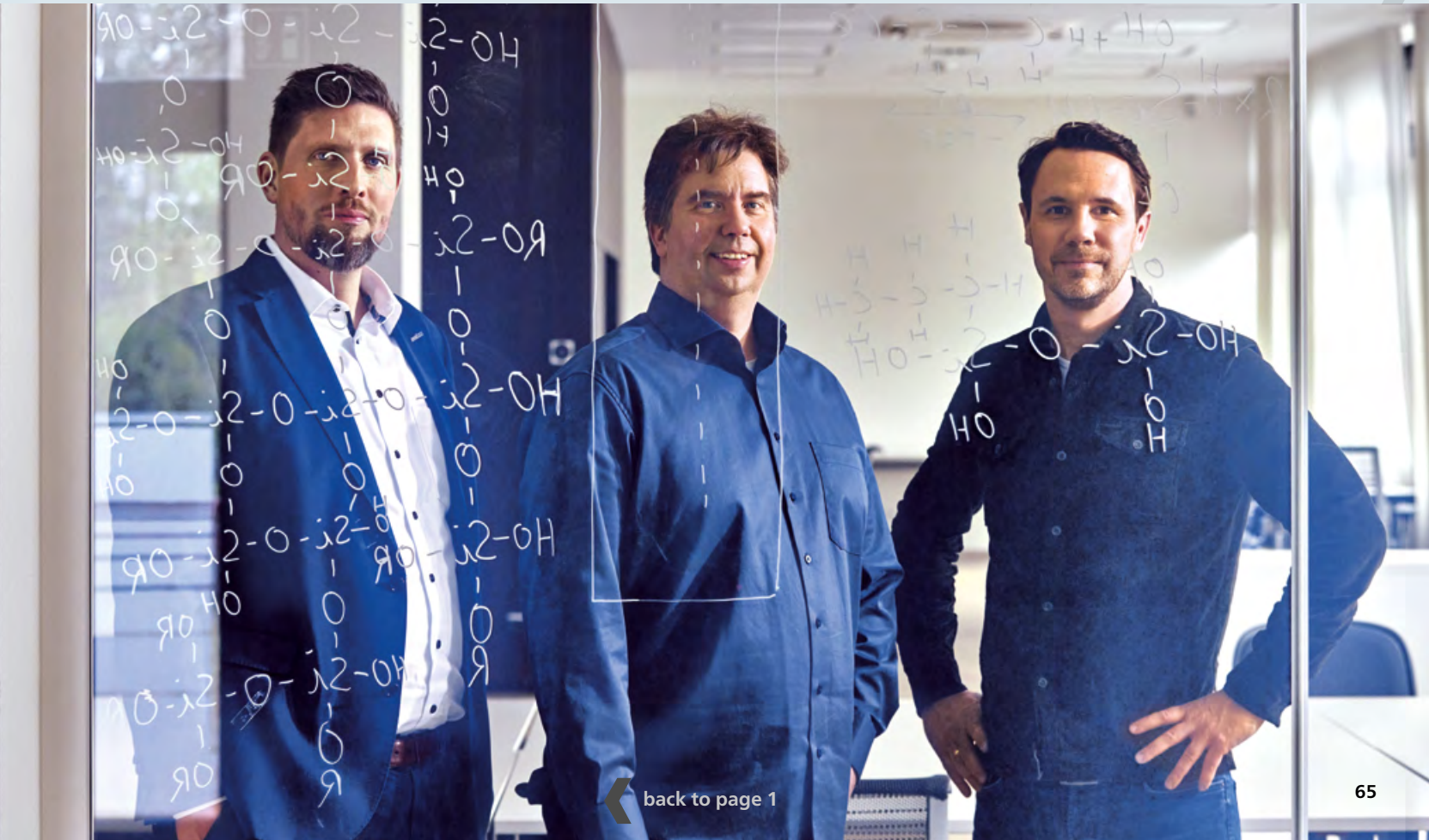
Replacing acids with carbon dioxide

In order to decrease the costs and production time for aerogels at this scale, the research team focused on the production process. Aerogels are typically produced using a sol — a medium containing finely distributed solid particles that has acid added to it to form a gel. Producing 1 kilogram of aerogel requires some 6 kilograms of acid, and these corrosive substances can harm the environment. The gel is then aged, goes through a solvent exchange and is finally dried. "We consistently challenged the existing technological state of the art," explains Mr. Mölders. "Whereas supercritical carbon dioxide, which

is between a gas and liquid in terms of its properties, was previously only used for drying, we use it at every step in the process. That means we can eliminate the use of acids altogether." Even the raw materials meet the sustainability requirement: The researchers tested more than 20 different types of silica sols that were readily available, inexpensive and non-toxic — as opposed to the often expensive established variants.

Mineral plaster is a highly effective insulator

In the final step of the process, the aerogel is broken down into grains 2 to 4 millimeters in size and mixed into a pure mineral plaster so as to be suitable for use as an insulation material for buildings. The resulting mixture has excellent insulation and physical properties for construction, meaning that it outperforms conventional insulation materials such as polystyrene or mineral wool. "The network in our aerogel is so fine that it allows us to stop the movement of individual air molecules, so almost no heat transfer occurs. When mixed into the plaster, the aerogels can reduce thermal conductivity by a factor of two when compared to polystyrene — that is truly huge. So what we have is a highly effective insulating material made purely from minerals," reveals Mr Dworatzyk. This means that a sheet of aerogel material with half the thickness of a sheet of polystyrene can achieve the same level of insulation. And there's another advantage, too: "We only use materials like sand and lime, which can be put back into the circular material economy. If the plaster needs to be removed from the wall in 50 or 60 years, you could use it to make new plaster," Mr. Sengespeick explains. For several years now, this insulating plaster has been used in various prefabricated housing developments to keep out the cold, as well as in a number of listed church buildings and housing estates. The new production process therefore holds great potential both for the building technology sector and climate protection. ■



Nils Mölders (right) and Andreas Sengespeick (center) of Fraunhofer UMSICHT worked with Christoph Dworatzyk of PROCERAM GmbH & Co. KG to develop a solution for climate-friendly insulation.

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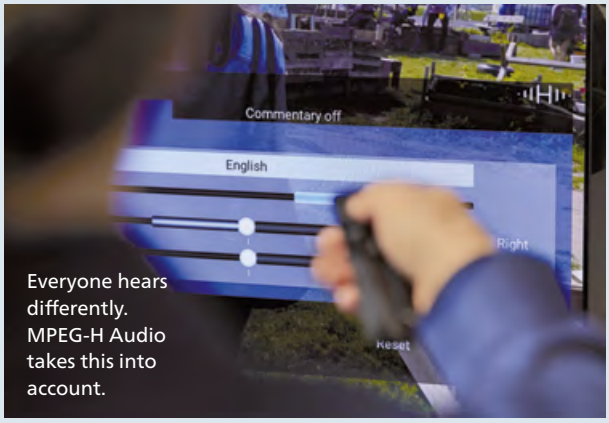
Audio technology

Customized listening experiences in 3D

Whether you're streaming movies, watching TV or listen to music in the car, the MPEG-H Audio system makes it possible to fully immerse yourself in soundscapes and adjust them to your own preferences.

Want to turn the volume of a TV movie's dialogue up or the background sounds down? Select your favorite soccer commentator at the touch of a button? Or turn the drums down a bit while listening to music? The MPEG-H Audio system developed by the Fraunhofer Institute for Integrated Circuits IIS makes it easy to customize 3D sound. Harald Fuchs, Dr. Achim Kuntz and Adrian Murtaza are representing the team that will be awarded the Joseph von Fraunhofer Prize 2023 for developing this system.



Everyone hears differently. MPEG-H Audio takes this into account.

Metadata for personalized sound experiences

The MPEG-H Audio system is bringing three-dimensional sound to more and more playback devices. This Fraunhofer IIS technology uses a process that clearly sets it apart from other 3D sound systems: Instead of using only classic audio tracks, it uses audio objects. These objects — a singing bird, for example — are assigned properties such as position and volume using metadata. These properties are used to determine what is happening to the sound: The birdsong moves in three-dimensional space, becoming louder and quieter. All this information is sent to the playback system, where it is combined with information about the playback environment. Only then are the loudspeaker signals created — in contrast to usual surround formats such as 5.1 or 7.1.

This new approach also allows users to customize their experience: different languages or film dialogue that is easier to understand are sent as audio objects, and the audience can then choose between them. In the case of a soccer game, for example, a producer can even provide the option of placing the commentator's voice at any posion in the room, which can create the feeling of being right in the stadium. "When developing MPEG-H Audio, we made sure that this technical revolution can be integrated into existing systems comparatively easily. This is the only way that we can win over creatives, infrastructure providers and audiences," explains Mr. Fuchs.

MPEG-H Audio: An innovative system from production to playback

The Fraunhofer IIS team has developed a complete system that covers the entire chain, from sound production to transmission through to playback. And it's not just for the broadcast chain: "We want to make sure MPEG-H Audio covers production, transmission and playback for every situation," Dr. Kuntz explains. "This means the MPEG-H Audio system is far more than "just" an audio codec: It comprises production tools, file and transmission formats, and innovative playback methods as well

Adrian Murtaza, Harald Fuchs and Dr. Achim Kuntz (from left) of Fraunhofer IIS are making music more personal.

as software solutions for companies that are integrating the system into their products and a branding program for products that support the MPEG-H Audio system." Another example of one of the many developments around MPEG-H Audio is the immersive, object-based music format 360 Reality Audio from the electronics company Sony. It is firmly established on many streaming services — an album produced with this technology even won the Grammy for Best Immersive Audio Album in 2023.

The end of the test phase

Developing such a comprehensive audio system can only be done with a large team: At peak times, up to a hundred people were working simultaneously on the project, which started back in 2012 — there are currently still around 50 employees. "We needed a lot of know-how from various areas of expertise," explains Mr. Fuchs.

Receiving international support was also important. Industry and technology partners around the world helped make MPEG-H Audio fit for use in a wide variety of environments. The system was first introduced in South Korean television in May 2017. In a further success, Brazil put the technology through large-scale comparative tests in December 2021 and decided to adopt it as the mandatory audio standard for its new television infrastructure. MPEG-H Audio has also been tested a number times in Europe. "This has made it possible for us to adapt the system to existing workflows in the best possible way and integrate it into live and studio production environments," says Mr. Murtaza. The team also developed audio production tools, which enabled the researchers to optimize the system while establishing partnerships in the creative industry, creating demand in the audio sector. All this makes MPEG-H Audio the only open standardized system for the creation, transmission, and playback of Next Generation Audfio content. ■

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Aiming high with new satellite technologies: Dr. Matthias Beier of SPACEOPTIX GmbH and Dr. Henrik von Lukowicz of Fraunhofer IOF (right).

Satellite technology

Sustainable use of water in agriculture

Some 70 percent of our drinking water is currently used for irrigation — and more than half of this unnecessarily, as the ground already contains enough moisture.

In the future, innovative satellite technology will ensure that plants are given only as much water as they need, leading to a more sustainable use of this essential resource. A prototype of the technology, LisR, has already been tested on the International Space Station (ISS). A team of researchers from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and two spin-offs, constellr and SPACEOPTIX, has received the Fraunhofer Prize for Human- and Environment-Centered Technology for this development.

In Germany, it's taken for granted that there will always be enough water available. At least for the time being. Because in the future, this essential resource could become scarce — after all, the Intergovernmental Panel on Climate

Change predicts that, due to climate change, the intensity and frequency of droughts will increase. In addition, the global population is also continuing to grow. It is estimated that, by 2050, the earth will be home to almost ten billion people — and those people will need food. What does that have to do with water? Plenty, as according to the Food and Agriculture Organization of the United Nations, 70 percent of our drinking water is currently used for irrigation. And a particularly scary statistic here is that 60 percent of this water is wasted due to overwatering.

Researchers from Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI and the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, together with the companies constellr GmbH and SPACEOPTIX (both spin-offs of these institutes), have taken inspiration from the founding principle of constellr GmbH to develop the infrared camera LisR — short for Longwave infrared sensing demonstratoR. Following a successful demonstration on the ISS, the findings from the LisR mission will now be used as the basis for building a satellite constellation. In the future, this satellite constellation will measure the land surface temperature from orbit and help adjust irrigation systems according to the level of water actually needed. As early as 2026, this method could save 180 billion tons of water and 94 million tons of CO_2 per year, while supplying plants with the optimal amount of water could increase global harvests by up to 4 percent. This would produce enough additional food to feed over 350 million people. Clemens Horch of Fraunhofer EMI, Dr. Henrik von Lukowicz of Fraunhofer IOF, Cassi Welling of constellr GmbH and Dr. Matthias Beier of SPACEOPTIX GmbH have been awarded the 2023 Fraunhofer Prize for Human- and Environment-Centered Technology for their work on developing the LisR technology prototype.

Measuring the actual land surface temperature

But how does this technology actually help conserve such large quantities of water and CO_2? "From a satellite, LisR monitors the Earth's surface and detects the infrared radiation that the surface emits — i.e., the thermal radiation," Ms. Welling explains. "Whereas other solutions just model the land surface temperature, we take direct measurements of the temperature of the leaf canopy or the vegetation on the land surface. This way, we can precisely assess water availability compared to demand and detect stresses earlier than we ever could before." The evaluation can also indicate how well watered the plants are. If plants are not getting enough water, less water evaporates through their leaves, and that raises the temperature. The level of heat in particular areas of the field can give farmers a clear indication of where the plants need to be watered and where they do not.

The keys to the partners' success in developing the technology demonstrator were their collaborative efforts and complementary expertise, which fit together seamlessly. While Fraunhofer IOF created compact optics that could easily be integrated into the camera module, SPACEOPTIX prepared the necessary freeform mirror optical systems with nanometer precision. For their part, the researchers at Fraunhofer EMI contributed a patented measuring process in which the camera images are used to determine the exact land surface temperature. The task of planning the mission and evaluating the data went to constellr GmbH.

A huge honor for a small system: Testing on board the ISS

Together, the researchers were not only able to rise to the technological challenge, but also to meet the tight deadline: powered by their enthusiasm, they managed to develop and manufacture the demonstrator within a year, and put it through the necessary test runs. "From the ISS, we were able to capture about ten million images, with a resolution of around 80 meters," Mr. Horch is pleased to report. The experts at constellr intend to build on this success by launching 16 small satellites by 2028 — these will be able to precisely measure the land surface temperature everywhere on the planet, with daily frequency, to a resolution of better than 50 meters. ■

Detecting the heat in fields from afar: Cassi Welling (constellr GmbH) and Clemens Horch (Fraunhofer EMI).

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Leveraging synergies: Smart approaches to energy connect electricity generators and consumers in residential districts.

Photo: Hartz, Piranka/istockphoto

On the bright side

The energy transition requires the electricity, heating and mobility sectors to be more closely interlinked — and not just in individual houses, but across entire residential districts. This means new ideas, tools and business models will have to be developed.

By Beate Strobel

Housing is second only to mobility when it comes to being the center of attention in sustainability debates. And for good reason: Around 17 percent of carbon dioxide emissions in Germany come from private households. Conventional methods for heating buildings and providing hot water are the main causes of CO_2 emissions and are therefore fueling climate change. This is because existing homes primarily use natural gas (49.5 percent) and heating oil (24.8 percent) as energy carriers — i.e., heating technologies that use fossil resources.

Up until now, climate protection measures in the public sector have mainly been limited to encouraging people to save energy, renovate their homes to make them more energy-efficient and invest in renewable energy technologies — e.g., by installing solar panels on the roof or putting in a heat pump powered with green energy. Fraunhofer is working on a different approach. "The most important energy sectors of heat, electricity and mobility all come together in residential districts," says Prof. Peter Bretschneider, director of the Advanced Systems Technology AST branch of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB. "Connecting these sectors together in an intelligent way within these districts — and as a result, making more optimized use of the renewable energy generated locally — will be crucial to the success of the energy transition." After all, as the Greek philosopher Aristotle noted, the whole is greater than the sum of its parts.

The Open District Hub (ODH) association has dedicated itself to developing synergistic solutions that create an energy supply for residential districts that is both financially and environmentally viable. The ODH is made up of more than just research institutes such as Fraunhofer — companies from the energy and real estate industries, mobility, IT and consulting and a diverse range of associations and groups are taking part, which shows how many different disciplines are coming together around this issue: there are a lot of stakeholders in the energy transition.

A living lab in Kaiserslautern

The ODH has access to seven reference districts — areas used only for residential purposes and mixed districts with both residential and commercial buildings — to test out its innovative ideas for energy systems integration in the real world. In the Pfaff district in Kaiserslautern, for example, the site of the former Pfaff sewing machine factory has been turned into a living lab. The aim is to build a carbon-neutral mixed-use district here by 2027. Photovoltaic plants are planned for generating electricity, and good connections to local public transportation will provide climate-friendly mobility. ▶

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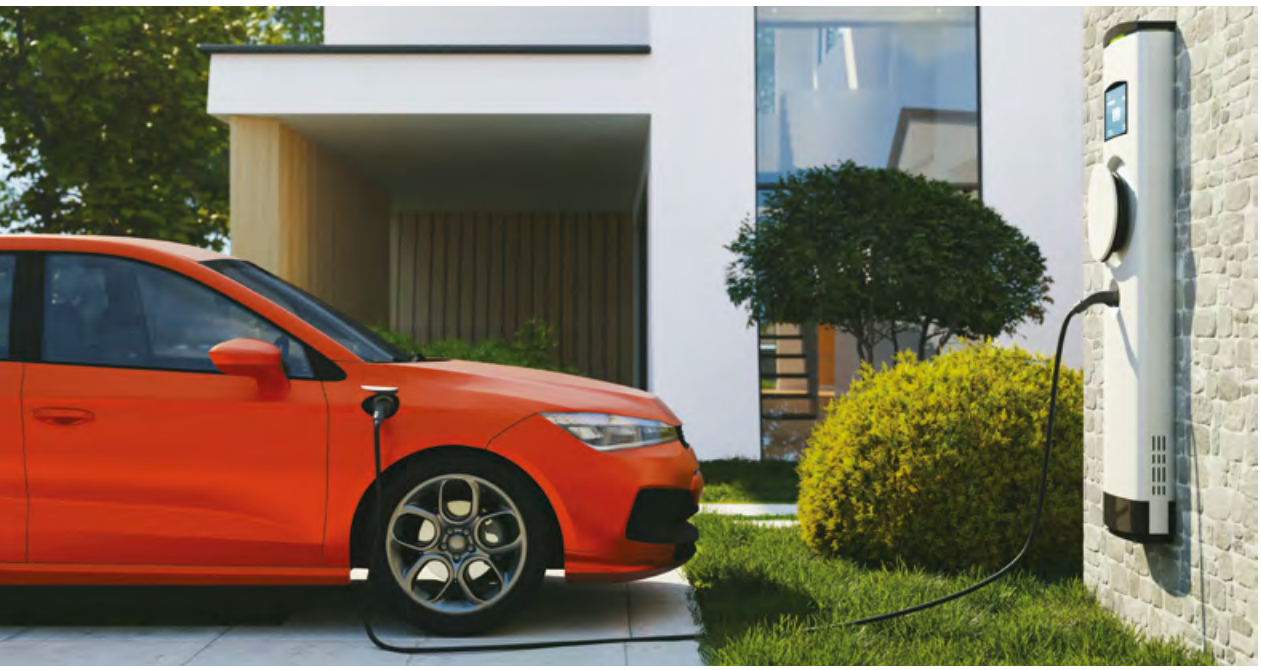

Mobility and flexibility: the electric car is primarily charged when there is enough solar energy available. In this way, the vehicle acts as a mobile energy storage system.

Car-sharing services and charging stations for electric vehicles are also in the pipeline.

Solar panels on the roof, on-site charging facilities: these features are already being planned for many types of buildings, and are currently used predominantly in single-family homes. So what is so innovative about the district-level solutions that the ODH is testing out? Having extra flexibility is critical when it comes to using renewable energy sources — sunshine and wind — in the area where they are generated in the most effective way possible, despite their volatility. For a start, this flexibility can be brought about by connecting the district's energy-dependent sectors — heat, electricity, mobility — to each other and taking advantage of the synergies that exist between cross-sector energy demands and renewable energy provision. This means renewable and carbon-neutral energies can be used not only in the electricity sector, but also for heating and transportation — both these use cases save primary energy from fossil fuels.

Another way the district creates greater flexibility for energy consumers is by offering a greater number of systems that operate in different ways — including energy storage, heat pumps and electric vehicles. This helps to coordinate the supply of renewable energy with consumers' needs in the district. For example, if households need less energy than is being generated locally from renewable resources, charging an electric car during this time will be carbon-neutral. Utility providers can help reduce energy-related CO_2 emissions by both taking advantage of synergy effects and using load flexibility for targeted adjustments in the provision of renewable energy the district.

Another important factor is having the option to store energy, at least in the short term. If there is enough solar energy available because the sun is shining, then the need for space heating decreases proportionally. Ideally, this excess solar energy will be put into short-term storage. However, electric vehicle batteries can also act as mobile electricity storage systems and thus help to keep the grid stable.

There are many systems and many stakeholders involved — and digitalization and automation are indispensable for controlling and regulating these kinds of complex, decentralized energy supply systems. Using intelligent measuring systems (smart meters) to collect data is a basic requirement for efficiently integrating energy systems. The Smart Meter Gateway processes the collected data and disseminates it. All households in Germany are set to have smart meters by 2032.

It is worth transferring responsibility for managing the district to a service provider, due to the amount of time involved in this task. "Integrating energy systems in the locality gives rise to new business models," says Prof. Bretschneider of Fraunhofer IOSB-AST. "As the largest energy suppliers are currently still showing reluctance here, start-ups are using or seizing this opportunity." For example, the company AMPEERS ENERGY, which was launched in 2019 as a Fraunhofer-Gesellschaft spin-off, is using the software and development expertise of Fraunhofer IOSB-AST to offer a range of applications for managing and optimizing energy and data flows within districts. "We provide complete support on the software side to enable simple, comprehensive, scalable implementation of decentralized renewable energy business models," says Dr. Karsten Schmidt, founder and CEO of AMPEERS ENERGY and deputy chair of the Open District Hub association.

More efficient use of solar energy

AMPEERS ENERGY is also collaborating on the Open District Hub's project to develop the district of Bochum-Weitmar.

The real estate company Vonovia owns 232 apartment blocks in this area, with over 1,500 inhabitants in total. As the buildings date back to the 1950s and 1960s, this is an ideal district to represent the many existing buildings that are badly in need of renovation. The Fraunhofer Cluster of Excellence Integrated Energy Systems CINES (in collaboration with Fraunhofer IOSB-AST, the Fraunhofer Institute for Solar Energy Systems ISE and the Fraunhofer Institute for Systems and Innovation Research ISI) selected a part of the district in Bochum-Weitmar to investigate the use of flexible energy approaches with locally based systems. The 13 buildings involved have been fitted with nine photovoltaic systems. Heat is provided via a district heating network; two natural gas condensing boilers, two air source heat pumps and one geothermal heat pump feed into this network. In addition to serving household energy needs, the system also provides two charging stations that each have a charging point for the district's car sharing service.

The results of a short study on local systems as a flexible component of an energy system clearly show the benefit of integrating energy systems and using the same supply structures across different buildings. Simply connecting multiple buildings into one district increases the consumption of locally produced solar energy by 18 percent. Expanding the system to include district energy storage solutions increases this figure by a further 15 percent. However, taking an intelligent approach to district management that includes all possible flexible options increases the consumption of locally produced renewable energy to 78 percent, while reducing carbon dioxide emissions by 19 percent. "If natural gas condensing burners are primarily replaced with heat pumps as a heat source, energy-related CO_2 emissions could actually be more than halved," says project manager Sebastian Flemming of Fraunhofer IOSB-AST. What is more, in this district, not every building needs its own heat pump — multiple houses can share one.

In 2019, the smood ("smart neighborhood") core growth initiative in Thuringia — to which Fraunhofer IOSB and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, among others, provided scientific support — companies in the region and the Thuringian Renewable Energies Network (ThEEN) joined together to develop a sort of toolkit for the synergetic further development of residential districts. When it comes to renovation and modernizing buildings, the aim is for smood to support the entire process chain.

smoodPLAN, for example, provides tools for collecting data on and evaluating the existing building stock. Meanwhile, the GeoHoP project team are developing a process for obtaining geothermal heat in densely built-up urban areas. GeoHeatStorage has contributed a large-scale, yet cost-effective heat storage system that an entire district can use for storing seasonal heat. As part of the EStorage module, researchers from Fraunhofer IKTS developed a fully recyclable sodium chloride battery called Cerenergy that is manufactured using local raw materials and can store electricity from solar plants. Finally, smoodACT serves as the brain of the intelligent district management system: The data required to optimize the system flows into this control center, allowing it to ultimately manage the technical processes in the buildings.

> "If they recognize not just the environmental advantages, but also the monetary benefits, they'll take a different view of the photovoltaics on their roof and the wind turbine up the street."
>
> Sebastian Flemming,
> project manager for the CINES study

This all sounds like it would take a lot of effort and high levels of investment, especially when applied to older existing buildings. "However, if we can use around 60 percent renewable energy in the locality, the investments involved in integrating the energy systems will pay for themselves within around seven years," predicts Prof. Bretschneider, scientific spokesperson for smood. The energy measures help to improve the taxonomy of the buildings — this is an attractive factor for the real estate industry as well. The financial viability of renewable energy supply structures is also closely interlinked with the development of fossil energy prices. 2022 clearly showed that it is difficult to calculate how the costs of fossil energy will develop in the short and medium term, in contrast to renewable energies.

For Sebastian Flemming, project manager of the CINES study on local systems, another factor is important too: Solutions for integrating energy systems in districts have the potential to increase citizen participation in the energy transition. "Tenants often don't feel connected to the photovoltaic system on their roof or the wind turbine they can see outside, because they feel like others are making money from those systems while their own energy costs are increasing," explains Mr. Flemming. "If they recognize not just the environmental advantages, but also the monetary benefits, they will look at the photovoltaics on the roof and the wind turbine up the street differently." He goes on to point out that without acceptance from the German people, we will be unable to accelerate and implement the energy transition to the level required in order to achieve the German federal government's climate targets.

It will be up to legislators to take the intelligent district management solutions out of the living lab and into large-scale implementation. Without a suitable regulatory framework, it will not be possible to scale up the technologies and business models. The landlord-to-tenant models currently used in Germany — where the landlord generates electricity locally from renewable energy sources and sells it to the tenant either directly or through an electricity provider — have proven "too complicated," according to Mr. Flemming. The CINES study, however, has shown that investing in the integration of energy systems within districts makes sense on many levels, says Prof. Bretschneider. "We've shown how it can be done differently, and more effectively." ■

Photo: Hartz, Piranka/istockphoto

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The new black gold

Biochar stores water, nutrients and carbon in the soil for a long period of time. This could help farmers reduce the number of crop failures caused by climate change. However, current manufacturing processes fall short in terms of sustainability. Two Fraunhofer institutes are aiming to change this.

By Kerstin Beckert

Combating drought: Specially manufactured biochar can improve soil quality for agriculture on a long-term basis.

Climate change poses major challenges for agriculture. Heat, high winds and drought reduce the humus content of the soil, which is vital for plants to grow. The compacted earth is unable to store rainwater, which simply flows over the surface. Manure and digestate can provide new nutrients, of course. But without any available moisture, plant roots absorb very little of these nutrients, which in turn reduces agricultural yields.

Biochar can "fundamentally improve soil structure," says Antoine Dalibard of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. This highly porous material contains many cavities. Similar to a sponge, it sucks up water and nutrients, stores them for a long period of time and provides them to the soil and plant roots when needed. "This improves growing conditions" and "builds up the humus layer" over the long term, explains Christopher Kick from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. He warns against using charcoal on the fields in its pure form, however. It needs to be loaded with nutrients before its first use. Otherwise, it will suck away all nutrients from the plants.

Formed at high heat

Fraunhofer institutes IGB and UMSICHT have further developed the thermochemical conversion process in order to manufacture biochar. The process they both use is based on the following basic principle: Residual biomass is heated in an atmosphere without oxygen until it decomposes. A large proportion of the carbon remains in the solid matter, producing high-quality biochar. In the process, highly volatile components also rise with the water vapor, then cool down and condense. In this way, it is possible to isolate compounds contained in this "condensate soup," such as oil, aromatic hydrocarbons, acetic acid and hydrogen. "Our goal is to obtain all the end products in their purest possible form using additional separation processes," explains Mr. Dalibard. The substances that can be obtained from the condensate depend on the pyrolysis procedure used.

Mr. Dalibard is head of the expert group for thermal separation processes at Fraunhofer IGB. To produce biochar, he and his team employ a process known as torrefaction, which uses superheated steam. This mild form of pyrolysis involves heating biowaste to a maximum of 300 degrees Celsius in two stages.

> Biochar can "fundamentally improve soil structure."
>
> Antoine Dalibard, Fraunhofer IGB

During the first stage, most of the water contained in the organic material evaporates (a process called steam drying). The actual torrefaction takes place during the second stage. The energy invested can be easily recovered by using superheated steam, explains Mr. Dalibard, who holds a doctorate in engineering. Thanks to this closed-loop production system, there are also no emissions and no issues with odors. The biochar can be easily stored outdoors, and it doesn't mold.

At Fraunhofer UMSICHT in Sulzbach-Rosenberg, Bavaria, Mr. Kick is known as the "biochar guy." The environmental engineer leads the Processing Thermochemical Conversion Products research group. Their research also includes the project InterPyro, which investigates possible uses for the carbonaceous solid. The charcoal is manufactured using thermo-catalytic reforming (TCR), a medium-speed form of pyrolysis where biowaste is processed for longer than in torrefaction. The temperature is also higher overall. During the initial stage, pre-shredded residual materials are carbonized at 450 degrees Celsius in an anaerobic atmosphere. During the second stage, the biochar itself functions "as a kind of catalyst," according to Mr. Kick, who also holds a doctorate in engineering. The biochar falls into a container "heated to 700 degrees Celsius." The pyrolysis gases are then funneled through this hot bed of charcoal, further improving the quality of the resulting pyrolysis products.

Soil as a carbon sink

Rotting organic waste usually releases methane and carbon dioxide. Biochar, on the other hand, is only broken down very slowly by microorganisms. This means the carbon it contains is stored in the soil over a long period of time. Experts call this a carbon sink. The charcoal's manufacturing process determines how long it remains stable. When produced using torrefaction, it can endure in the soil for hundreds of years; when produced using pyrolysis, it can even last for thousands of years. Applying biochar to arable land can not only improve soil quality, but stores the greenhouse gas CO_2 long-term in the ground as carbon, too.

The residual biomass used to produce the charcoal must be pollutant-free and no longer usable for food production. Examples include residual wood from forestry, organic waste, digestate from biogas plants, green cuttings and horse manure. The starting material and pyrolysis process used can change the composition of the biochar, however, meaning that "we might end up with a different product," explains Mr. Dalibard. Therefore, the researchers need to check at the end of every process whether the resulting product is suitable for use in soil. Additionally, the Federal Institute for Geosciences and Natural Resources (BGR) points out that "negative effects on soil functioning" must be "ruled out." A quality seal could help here — for instance, the European Biochar Certificate (EBC), which is a voluntary industry standard. "We're working on this at the moment," says Mr. Kick. The aim is to facilitate "a decentralized loop, where waste material that is no longer needed is turned into a product that can be used to make the soil fertile again." The processes used by Fraunhofer IGB and Fraunhofer UMSICHT can not only be easily combined, but are also ready to make the leap to industrial use. ■

Photo: Countrypixel/dpa

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Successfully combating internet manipulation

Day after day, millions of messages flood the major social media platforms. Now, the innovative analysis and monitoring tool NewsHawk is helping to unmask online propaganda campaigns.

By Dr. Sonja Endres

How much does a lie cost? 279 euros. That's how much a research team paid for 1,385 fake comments, 13,859 fake likes and 5,808 fake shares on Facebook, Instagram and other platforms. In 2021, NATO commissioned these researchers to examine manipulation on social media platforms. One of the study's findings was that professional opinion-shaping is a thriving business — and a serious threat to democracy. The report urges the legislators to ban the sale of "inauthentic information."

Prof. Ulrich Schade, research group leader at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, explains: "It's common knowledge that targeted influence campaigns exist on social media — to manipulate voters, for example. Being able to identify these quickly and safely has not been possible until now." This is why his team worked together with the Information Visualization and Interaction research group, led by Dr. Carsten Winkelholz, to develop the social media monitoring and analytic tool NewsHawk. This filters, categorizes and clusters posts, and plots the data using visual analytics so it can be understood intuitively. "This way, even laypeople can recognize patterns and uncover fake campaigns powered by botnets."

To start with, the Fraunhofer FKIE teams tested NewsHawk on Twitter. The tool focuses in particular on anomalies in tweet metadata and interactions between different accounts. Prof. Schade describes the process: "We check when the account was set up, how many tweets have been shared since then and who its friends and followers are." If an account retweets content 24/7, there's a very high possibility that it's a bot, i.e, is controlled by a computer program rather than a human. Another indication that an account is a bot is that it doesn't post comments — it only exists to share content and to quickly forward a post online, which creates the impression that many people share the same opinion. In addition, bots often follow other bots, which spreads tweets faster. "What we are seeing is a set structure," says Prof. Schade. Bots also have extremely fast reaction times, with most retweeting content within one hour.

Hundreds of fake accounts set up deliberately

Among other propaganda campaigns, Prof. Schade and his team have been using NewsHawk to investigate those related to the war on Ukraine — and they found masses of them. "It usually follows the same pattern. A prominent supporter of the Russian narrative, such as Sahra Wagenknecht, posts something, and the tweet spreads lightning-fast across the networks we have identified." This form of manipulation is organized: Prof. Schade discovered that just before the Russian invasion of Ukraine in February 2022, hundreds of Twitter accounts were set up. Today, they're used to disseminate pro-Russia views.

NewsHawk enables users to filter the vast number of messages on social media by specific terms. This means the tool can also be used as a warning system that not only identifies campaigns at an early stage, but also detects dangerous events, such as a poison gas attack or a nuclear accident. According to Prof. Schade, "This enables people to react faster, and it buys them time." As a monitoring tool, it can scan social media platforms on an ongoing basis and identify critical messages, making it possible to counter these through communication in good time. This means NewsHawk is of interest to large companies, too. ■

A photo of the hipster pope in a stylish puffer jacket went viral. The only things that give it away as a fake are the cross, which is only hanging from the chain on one side, and a hand that looks unnatural — a common flaw in AI-generated images.

The way many people would like to see the ruler in the Kremlin: There are many fake images in online circulation of Putin behind bars.

Images of Donald Trump supposedly being arrested made the rounds on social media back in March. US journalist Eliot Higgins created and published these in connection with legal cases involving Trump before a New York court.

Nowadays, images generated using artificial intelligence are extremely difficult to recognize as fake. These give fake news more credibility — and increases its reach.

Photos: Pablo Xavier, Eliot Higgins and Malina Vítězslav/all generated using Midjourney V5

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EUROPE

Industrial robots on the lookout

The European collaboration project Sharework aims to equip heavy payload robots with enough intelligence to collaborate with their human operators both efficiently and safely. Researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU have developed a comprehensive modular planning tool for sensing the robot's environment and thus enabling quick, flexible risk assessments during human-robot collaboration. Operating on the basic premise that not all fixed and movable objects or persons in the robotic cell present the same risk of collision, the team divided up the sensing areas in a new way. The robot's environment is detected and categorized via laser-guided sensor technology with a wide field of view, while cameras monitor close-range areas. This setup acts much like extra eyes for the robot, allowing it to assess its surroundings more accurately and act more quickly. Although the robot's movements do still need to be slowed down when humans approach it, the smart environmental detection technology allows for a 25 percent increase in speed. The system has already been tested successfully during live production.

Humans and machines: environmental sensing technology makes for safe collaboration.

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

A new generation of catalysts is set to boost efficiency in hydrogen production.

CANADA

Making hydrogen electrolysis fit for the future

High-powered, resource- and cost-efficient electrolyzers are a vital paving stone on the path to mass-scale hydrogen production. In the German-Canadian joint research project Integrate, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has teamed up with production companies and universities to conduct research on a new generation of anion exchange membrane (AEM) electrolyzers that can meet requirements even in the megawatt range. To optimize this relatively new technology, Fraunhofer IFAM is developing catalysts that will remain stable even in the long term and can be manufactured without precious metals. These catalysts will also maintain high performance levels in dilute alkaline environments. Decisive efficiency factors here include the catalyst material and the structural properties of the carrier substrate, also known as a porous transport layer. Once the material and process parameters, e.g., for the coating process, have been established, it will be possible to design energy-efficient electrodes that are optimized for electrolysis.

Marine farming is impacting water quality. Scientists hope to change that with a new system.

NORWAY

Sustainable aquaculture

In the WeBoat project, researchers from Norway, Belgium and Germany are working on an environmentally friendly technology for cleaning contaminated waste water from salmon farms. To combat lice, farm-bred salmon are treated with drugs. This procedure is carried out in vessels known as well-boats — ships with seawater tanks that have an average capacity of 3,000 cubic meters. At the end of the delousing operation, the polluted waste water is poured back out into the sea. In the future, however, the delousing agents will be neutralized on board the ship by means of a filtration and UV radiation treatment process lasting several hours. To help construct the water treatment system, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS is developing nanoplasmonic optical biosensors. These have a specially adapted surface that makes them highly sensitive to the delousing agent, so that they react with it specifically; this makes it possible to detect the agent and measure its concentration. Real-time monitoring ensures that only waste water that has been tested for and is clear of medication traces is returned to the surrounding seas.

AUSTRIA

Reducing polystyrene waste

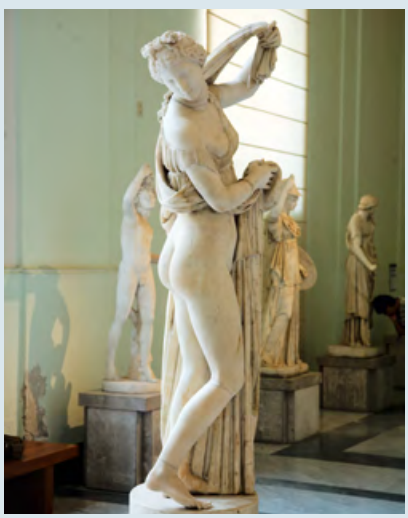
Expanded polystyrene, better known as Styrofoam or EPS, is up to 100 percent recyclable. In Austria, around one quarter of polystyrene construction materials and half of polystyrene packaging is currently recycled — however, it is mostly used as a bulk material, for smoothing out and insulating uneven floors, for example. Researchers from Fraunhofer Austria are working with twelve partners in project EPSolutely to bring about a significant increase in the volume of recycled EPS and to put it into use in new polystyrene products. One key focus area for the project relates to heavily contaminated construction polystyrene that is also loaded with the flame retardant HBCD. The research team succeeded in almost entirely separating the EPS from the foreign components. CreaSolv, a solvent-based recycling process developed by the Fraunhofer Institute for Process Engineering and Packaging IVV, can be used to dissolve the HBCD so that the polystyrene recyclate can be fully recovered.

Construction has to become more climate-friendly — and using recycled materials could help.

ITALY

AI lends a hand with restoration

If only we could see the long-vanished pigments on ancient statues or the true colors of faded historic textiles and paintings — that is the dream motivating researchers in the EU project PERCEIVE, which is focusing on preserving the original coloring of artworks or making what used to be there visible. The Fraunhofer Institute for Computer Graphics Research IGD is developing an artificial intelligence (AI) system that can reconstruct the color scheme of an artwork, show how it has changed over the course of the centuries and predict what it will look like in the future. The AI is trained on data relating to materials and surface textures, historical coloration changes and chemical and physical properties of pigments. It can even guess how the artwork and its colors will look under different incidences of light. The research project was launched with a kickoff event in the National Archaeological Museum of Naples. The goal of the project is to coordinate and optimize art maintenance across Europe. The AI will also be used to enhance virtual exhibitions.



What did this statue of Aphrodite (National Archaeological Museum Naples) originally look like?

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Interoperability as a key to NATO success

NATO members want to work even more closely together in the future. But there is a limit to how well you can conduct common exercises and activities across different military forces if communications and data exchange are not working smoothly.

By Mehmet Toprak

The phrase "interoperable interfaces for data exchange for heterogenous systems" may sound cumbersome. But we're talking about human lives here. Public discourse around modernizing the German Federal Armed Forces generally centers on combat aircraft, high-tech weapons or munitions. However, defense experts are increasingly debating the kind of technology that military vehicles, supply depots and command posts will need if they are to seamlessly transmit and receive data and information and be able to consistently interpret and process it. Interoperability requires functioning technology and common interfaces. A shared understanding of the information and the current situation is equally important — this is the only way to ultimately achieve coordinated action.

"Simulations are used to test the interoperability of interfaces in command and control systems. This allows us to create functional solutions quickly and in a cost-effective way."

Magdalena Dechand,
Fraunhofer FKIE

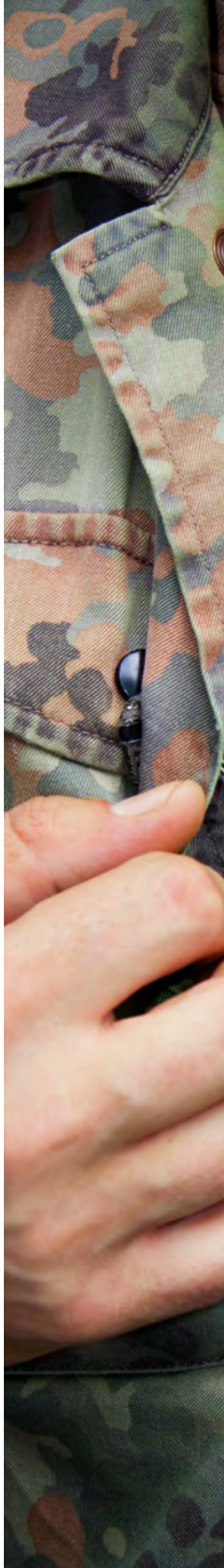
The war in Ukraine is currently demonstrating the ever-growing importance of interoperability and uniform information standards in achieving cooperation among military forces from different nations. In crisis situations, the seamless exchange of information across national borders can save lives.

The Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, which has locations in Wachtberg and Bonn, focuses on this complex topic and all the various factors involved. Fraunhofer FKIE researchers are working on standards, tools and test environments with the aim of advancing interoperability.

In his role as Chief Advisor Military Affairs, retired general Jörg Vollmer, former Inspector of the German Army and commander of the Allied Joint Force Command Brunssum, is advising the Fraunhofer team on this topic. "Over the past decades, many countries have developed their own solutions and neglected interoperability," concludes this veteran of the armed forces, who has spent 44 years in uniform. "Now we must drive it onward. Because without rapid, free-flowing information and data exchange based on common standards, NATO cannot operate successfully."

Data, interfaces, overviews

When creating tactical situational overviews, numerous pieces of information from different branches of the armed forces, or those of allied nations, flow together. If data can be relayed across interfaces more quickly and in a more automated way, the military forces will have more flexibility when it comes to taking action. "This means soldiers in the field are as well protected as possible in dangerous situations, and if weapons are used, they can also avoid collateral damage," explains Dr. Daniel Ota, research group manager at Fraunhofer FKIE.



Internationally recognized: This German Federal Armed Forces sergeant's rank patch also shows his NATO rank code and US insignia.

Photos: Siegra Asmoel/imageBROKER/picture alliance, Fraunhofer FKIE

To investigate the flow of data among a large number of communicating parties, the Fraunhofer researchers have established an analysis and test environment. This platform for testing the integration of complex heterogeneous systems allows actual vehicles or troops to be connected to simulated systems during large-scale tactical exercises. Dr. Ota describes how it works: "There is no need to bring an entire company to the training ground for exercises; instead, training can take place using a single group of tanks, for example, that are supplemented with simulated units — this ultimately generates a complete tactical exercise scenario, essentially." Researchers are continuing to test the interoperability of newly developed devices, such as drones or vehicular sensors, that will be integrated into future systems.

The team at Fraunhofer FKIE is also working together with partners on various international standards, including C2SIM (Command and Control Systems — Simulation Systems Interoperation) and MIP (Multilateral Interoperability Programme). While MIP ensures a common interface for exchanging information between the command and control systems of all participants, C2SIM connects command and control to simulation systems. Project manager Magdalena Dechand explains: "The underlying idea is to use simulations to test the interoperability of interfaces in command and control systems. Later on, the simulation systems are simply removed. In real-life situations, the command and control systems then behave exactly as they did during earlier testing. This allows us to create functional solutions quickly and in a cost-effective way."

Decisions in stressful situations

Technology and consistent standards are only one factor for success, however. There's a good reason why the "E" in the institute acronym FKIE stands for ergonomics — the systems that display, evaluate and forward the complex flow of information must be easy to use, especially in stressful situations. The experts at Fraunhofer FKIE are focusing on reducing complexity: for example, C2SIM uses familiar concepts based on the MIP model.

The human factor also plays a decisive role in relation to other aspects: When different NATO member states, each with their own security norms and interests, try to agree common standards and norms for communication and data exchange, it can be a real challenge. Dr. Ota says: "Often, finding a technically perfect solution is not the greatest challenge. The real issue is reaching a compromise that all partners genuinely accept and want to implement." ■

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Underrated climate protectors: If we can not only preserve peat lands but restore them too, they could play a major role in achieving our climate targets.

Photo & Fraunhofer

More moors

As a famous German poem laments, "How dreadful it is to go over the moor." Peatlands don't have a great public image. But the beliefs we hold about these mystical mummification sites are outdated, as moors have the power to save the climate: Although they only cover 3 percent of the Earth's surface, they store a third of its terrestrial carbon. Every year, peat lands draw up to 250 million tons of the greenhouse gas carbon dioxide from the atmosphere.

However, in Germany, up to 98 percent of the peat land that once existed has been drained and is now mainly used for agriculture. This allows oxygen to come into contact with the carbon stored in the peat turf, which leads to the carbon dioxide being released along with nitrous oxide, an even more environmentally damaging gas. Drained moors are responsible for over 40 percent of agricultural greenhouse gas emissions.

Rewetting former peat lands is part of the German federal government's Nationalen Moorschutzstrategie (national peat land strategy), which was adopted in 2022. However, rewilding measures such as this mean that important agricultural land is lost. For this reason, the Fraunhofer institute for Process Engineering and Packaging IVV and the Fraunhofer Institute for Graphics Research IGD are researching ways to make use of paludiculture, i.e., plants that grow on moors, as part of the Biogenic Value Creation and Smart Farming initiative. In order to make plants such as reeds and cattails into a material for biobased packaging, the scientists are analyzing these plants, developing processing methods, investigating how they interact with other raw materials and carrying out material testing — all in the hope that rewilding former peat lands will pay dividends for both agriculture and the climate. And that soon, we'll see more hauntingly beautiful moors again.

Photo: Thomas Reich, bilderreich.de

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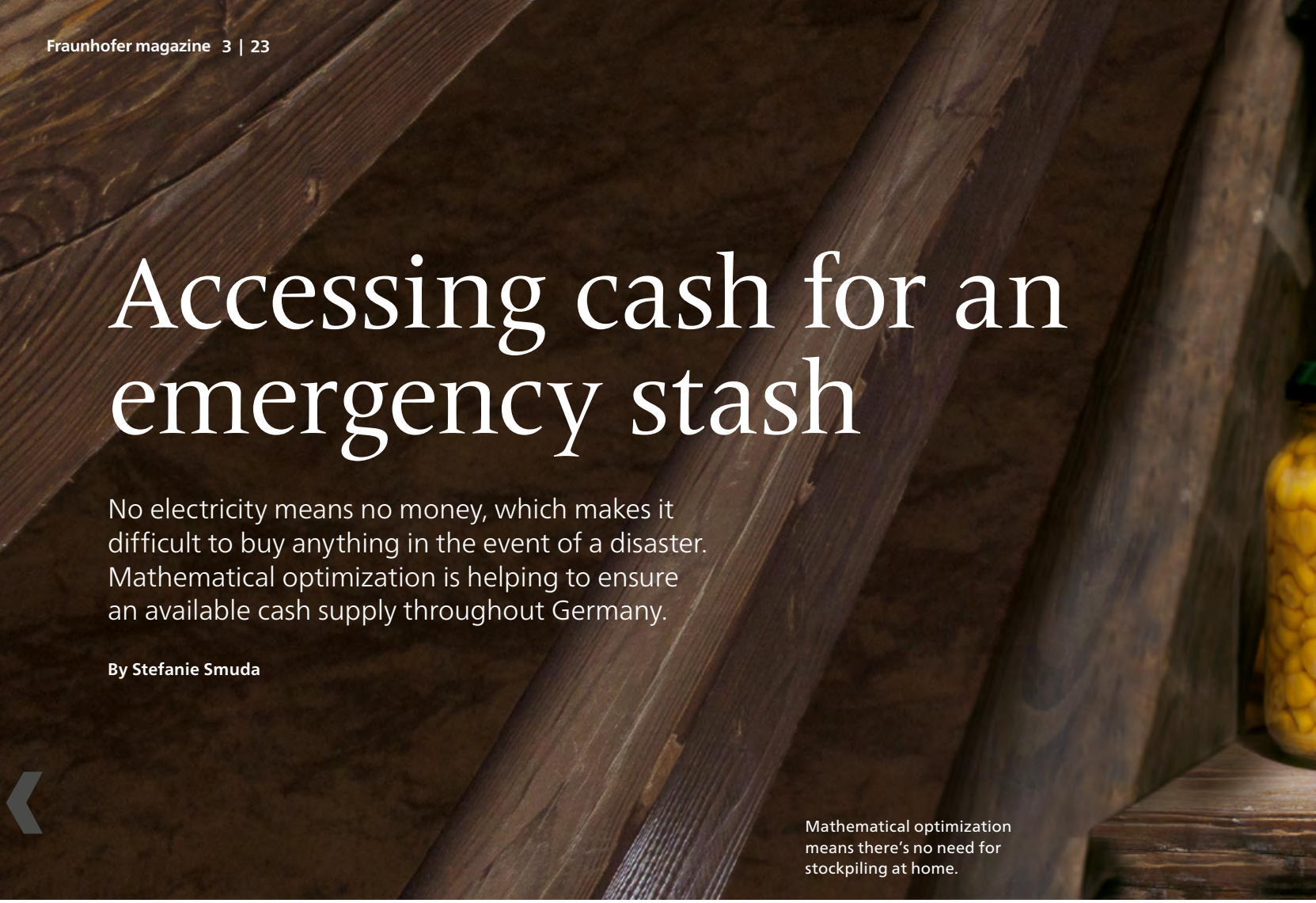
Accessing cash for an emergency stash

No electricity means no money, which makes it difficult to buy anything in the event of a disaster. Mathematical optimization is helping to ensure an available cash supply throughout Germany.

By Stefanie Smuda



Mathematical optimization means there's no need for stockpiling at home.

German people love the jingling of coins and the rustling of bills. According to a survey conducted by the market research company Statista, 72 percent of Germans prefer to pay in cash rather than by card — so they're well prepared for an emergency situation. In the case of a power blackout or IT and communications network failure, not only will electronic payment systems not work, but ATMs won't either. As part of the "Resilience of cash supply — BASIC" project, researchers at the Fraunhofer Institute for Integrated Circuits IIS have developed a mathematical optimization algorithm to maintain the cash cycle.

The scientists worked together with key stakeholders in cash logistics — project partners included Deutsche Bundesbank and the German Federal Office of Civil Protection and Disaster Assistance.

Laura Brouer, deputy group leader for Optimization at Fraunhofer IIS, and her team investigated which banks and ATMs absolutely have to work during a crisis. In the event of an emergency such as disruption to the IT and communications network or a natural disaster, cash is essential so that people can still pay for goods and maintain the flow of economic activity. In addition, people place their trust in cash in times of crisis. They also tend to withdraw more money, which worsens cash shortages. "People don't just hoard toilet paper in a crisis, but cash too," says Ms. Brouer.

72 %
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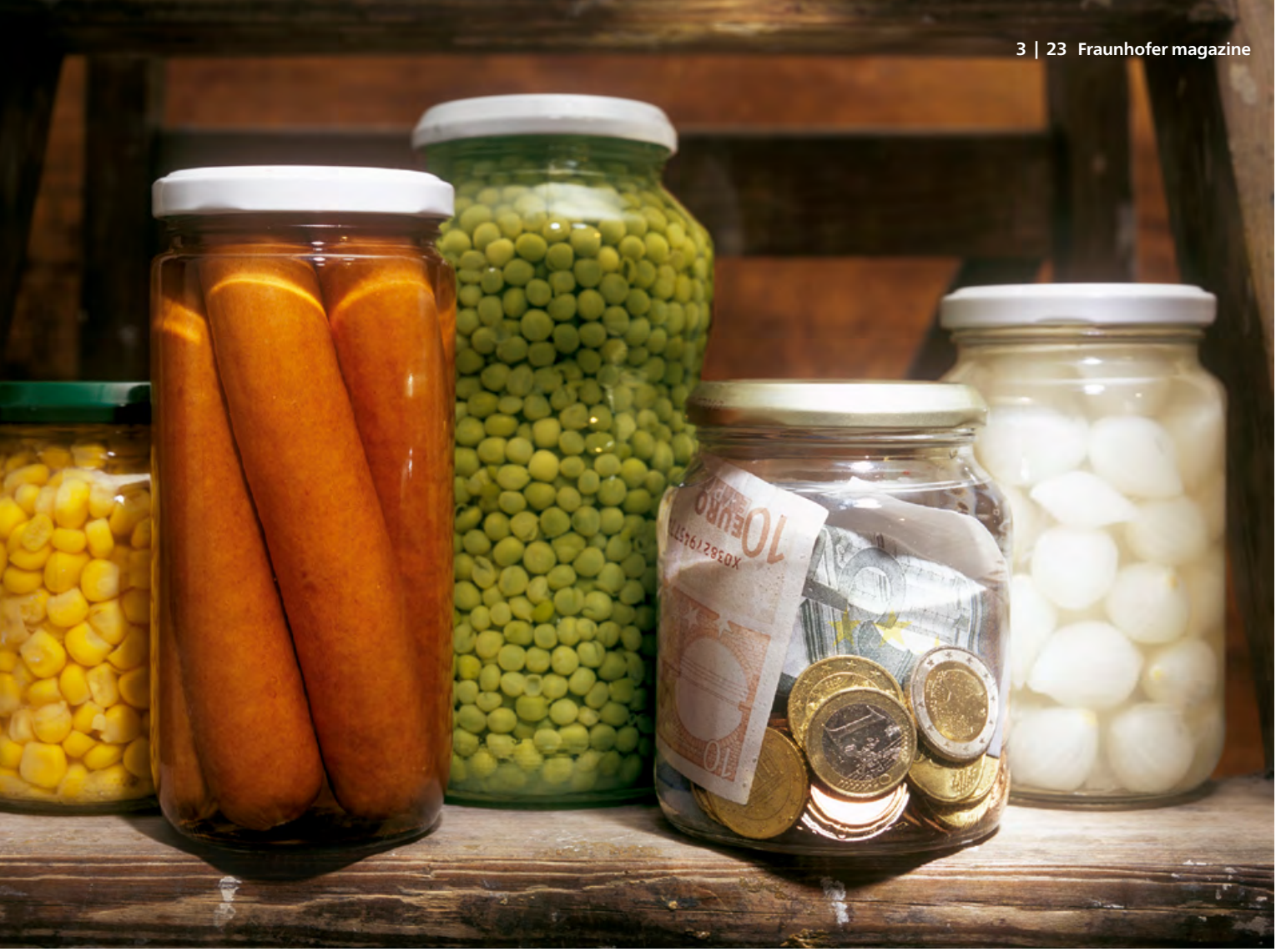
Current contingency plans aren't enough to safeguard cash supplies

Money and cash-in-transit providers already have their own contingency and disaster recovery plans. But these are often not adequately linked with each other, if they are linked at all. This means ensuring cash supplies in the event of an emergency can be difficult. That's where the algorithm developed by the Center for Applied Research on Supply Chain Services at Fraunhofer IIS comes in. Through mathematical optimization, Ms. Brouer and her team have determined



Photos: Wlad74/istockphoto, Thordis Rüggeberg/plainpicture

the cash withdrawal points that would be most crucial in the event of an emergency, as well as the best possible methods for supplying cash.

"Mathematical optimization enables us to take a structured approach to a decision-making problem. If you include all the relevant data, you end up with the optimal solution," explains Ms. Brouer. She illustrates this with an example: "Imagine you want to figure out how to pack your backpack in the most optimal way. For this you need data about your backpack, such as its volume and weight capacity, as well as data about the various items that you want to pack — their purpose, size and weight, for example. You have various options available — such as packing items A and B or items B and C — but there is only one optimal solution, i.e., a packed backpack that offers maximum usability."

In terms of cash withdrawal points, mathematical optimization means the algorithm can choose which ATMs need to work in a crisis from all the infinite possibilities. Stakeholders are then supplied with a map that provides information on which ATMs should be supplied with cash as a priority and/or operated using emergency power generators.

"People don't just hoard toilet paper in a crisis, but cash too."

Laura Brouer, Fraunhofer IIS

The role of a central data directory

Working with a comprehensive, high-quality database is crucial: "To decide which ATMs should have priority, you first need to know which ones exist, and where they are. However, there is no central directory yet," the scientist explains. Her team therefore relied on OpenStreetMap (OSM), a publicly accessible database where geodata is collected and structured by contributors. There's just one downside: The quality of the data depends on how diligent the OSM community is in maintaining the information. However, Ms. Brouer is hopeful that she will be able to use more reliable data in the foreseeable future, as Deutsche Bundesbank is currently working on a central ATM database. ■

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Plant in peril: Regions suited to coffee plant cultivation are shrinking drastically due to climate change.

A nice, hot cup of hope

Climate change is making life uncomfortable for many types of plants, especially the sensitive coffee bush. Researchers are using a new technology to search for more resilient variants.

By Yvonne Weiß

It's Germany's favorite beverage — and Europe's and most of the rest of the world's too. In 2022, for example, Germans drank almost four cups of coffee per capita every day, the equivalent of 167 liters per person annually. The global yearly average for coffee consumption is 42.6 liters per person, and that figure is on the rise. In spite of this, however, the future of the drink is uncertain.

The culprit? Climate change. As temperatures across the world rise, the number of suitable areas for coffee cultivation is shrinking drastically. According to a study by the multidisciplinary scientific journal PLOS ONE, it is probable that more than 50 percent of the optimal productive land for coffee bushes will have vanished by 2050 — and that's if global warming can be kept to "just" 2 degrees. When compared to other crops, the sensitive coffee plant is having a particularly strong reaction to the expected global temperature increases — and the much loved arabica strain is the most vulnerable of all.

Fortunately, Joelle Claußen, a group manager at the Fraunhofer Institute for Integrated Circuits IIS, has an idea that could guarantee a secure future for the coffee bean. Her theory is that phenotyping could allow scientists to understand the plant better, and thus ensure that it survives in the long term. Although still very new, this branch of plant research is centered on using novel observation methods to discover how certain plants react to both environmental influences and cultivation. "How does the plant respond to extreme heat? Do the leaf size and root structure change? How do the tubers develop? These are the questions that we want to answer," Ms. Claußen explains.

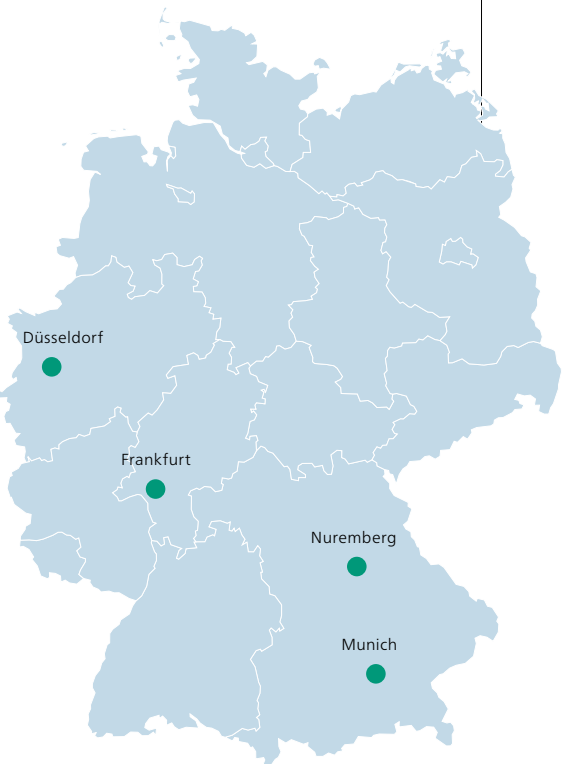
Ms. Claußen and her team are expanding on conventional phenotyping methods at the Fraunhofer Development Center X-ray Technology EZRT: "We are developing and using X-ray technology for phenotyping, which lets us look into the plants and see parts that can't be accessed through optical means alone. This gives us important information, for example, about their root structure and tuber arrangement."

The technology is already being applied with other crops: The researchers at Fraunhofer EZRT are using a climate chamber to subject various plants, e.g., multiple types of potato, to particularly high levels of heat. In this completely controlled environment, the humidity, temperature, CO_2 concentration and levels of light can be regulated with great precision — allowing the researchers to create optimal models of specific climatic zones. By taking a series of X-ray images, the researchers can create a three-dimensional model of the plant that provides them with detailed information on the variant in question.

According to Ms. Claußen, phenotyping could help ensure that coffee plants continue to survive in the changed climate. While the main type of coffee bean sold on the market at present are from arabica plants, there are 124 coffee variants growing around the world — and some of these can handle new environmental conditions much more successfully. And with X-ray technology, it could be possible to identify them in time. "I think that the important thing is to be open to variants," says Ms. Claußen. Everybody's favorite drink might taste a little bit different in the future — but at least it will still exist. ■

Photo: Martin/Le Figaro Magazine/laif

Fraunhofer on the road



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Improving recycling through single-variety plastics:
“The challenge is to scale this technology so it can also be reliably, quickly and inexpensively used on a large scale.”

Friederike Münch (below), Fraunhofer IPM

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