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But Please Put Some Thought into It
Linking AI and robotics

Room for Big Ideas

Start-ups – a plus for society

Amelie Reigl,
Founder
TigerShark Science

Guarding against Cyberattacks
How quantum technology creates more security for critical networks

Natural Heat
Heat pumps, a touchy subject: new opportunities unlocked

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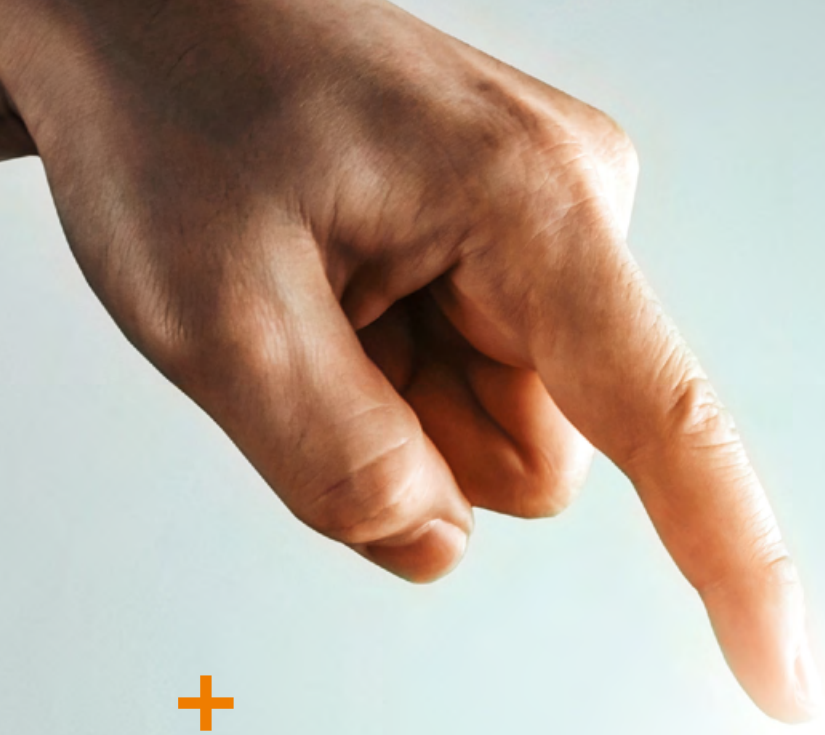

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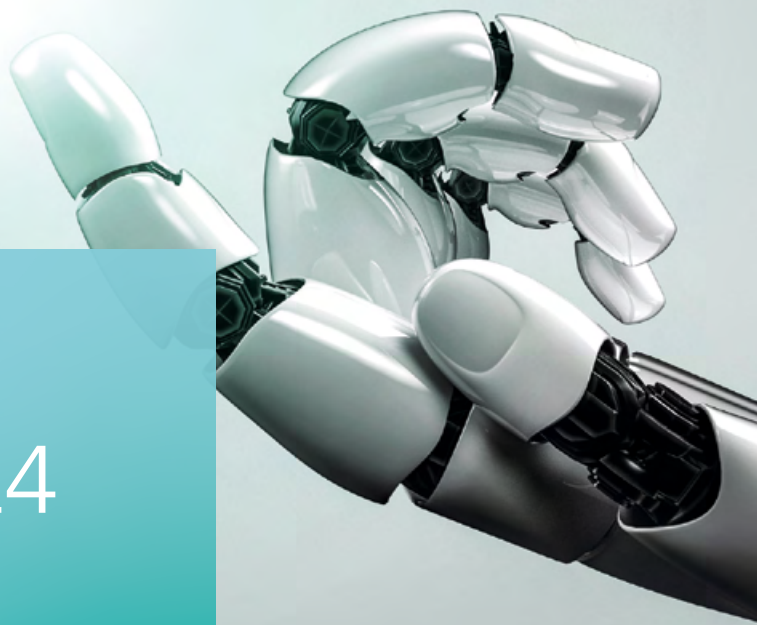

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Editorial

What makes me confident

By Prof. Holger Hanselka

Prof. Holger Hanselka

We are still enjoying late summer, but there is already a certain chill in the air. "The mood in the German business sector further deteriorated in August, continuing the trend from recent months," I read. The ifo Business Climate Index is down for the third time in a row. The 9,000 managers surveyed are pessimistic on the outlook for the months ahead. Those are feelings, but there are also facts to back them up. The German Federal Statistical Office reports that economic output declined by 0.1 percent year over year in the period from April to June. Some even say that the German economy has the "slowest growth in the entire eurozone." There is good reason for all of this, of course. And yet, what I see of Germany is completely different as I go about my everyday life, and especially my day-to-day work.

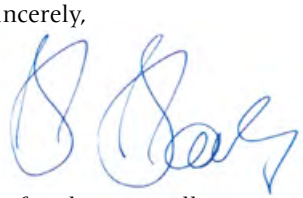
It has been my privilege to lead the Fraunhofer-Gesellschaft in the role of president for the past year. In my first year in office, I have come to know Fraunhofer as a highly agile community full of people who are passionate about what they do. And that is the kind of understatement people expect from Germans. The current issue of Fraunhofer magazine highlights a number of founders who have worked side by side with the Fraunhofer-Gesellschaft to shepherd their ideas through to the actual business creation stage (see article starting on p. 10). One of them is Hunter King, a Canadian who came to Germany to work at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig in 2016. He is still passionate about his work with the organization to this day: "At Fraunhofer, I got to know some of the smartest, most passionate, and most caring people I've ever had the chance to work with, and I loved my time there," says King, now an entrepreneur. "I'm incredible grateful that I can continue my relationship with them," he adds.

Isn't this enthusiasm, this passion, exactly what we need? No one will deny that Germany isn't exactly on the easiest path as a result of the many crises all around us. But haven't we all learned at some point or another that the toughest times are often the most productive and most creative? The Allensbach Institute just recently published a survey asking "what is important for Germany to get ahead, to safeguard a good future for Germany." Fifty-eight percent of respondents in the west of the country and even more, 65 percent, in the east answered, "For scientific advances and innovation to receive support and funding in Germany." Developing innovations and moving scientific advances into real-world application and industry as fast as possible are exactly what the Fraunhofer-Gesellschaft is all about. They are in our DNA. This focus of the Fraunhofer model has been unique in the German innovation system since 1973, and it is what makes Fraunhofer an essential part of that system.

Transfer through start-ups and spin-offs, the subject of this issue's cover story, is one important path, but alongside our core business in contract research for industry, it is only one strand of Fraunhofer's activities. Granted, we are proud that 96 percent of our spin-offs are still active three years on. This is one area where Fraunhofer's close relationship with industry literally pays dividends.

No one knows what the future holds. But one thing is certain: Knowledge and research are the factors that will continue to move us forward, now and in the future. Fraunhofer's passion for knowledge, research, and transfer — those are the factors that give me confidence.

Sincerely,



Prof. Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer/Stefan Obermeier

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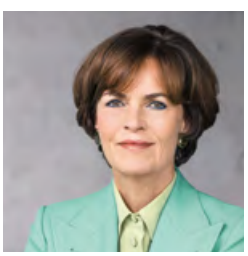

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What's really in the vapor from the many different kinds of e-cigarettes?

44 percent of new founders in Germany in 2023 were female. While full-time self-employment decreased by 8 percent according to the KfW Entrepreneurship Monitor for 2024, more start-ups were created as sidelines (+11%)

44 %

Front and back cover photos: Patrick Runte;
Content photos: Sven Döring, Patrick Runte, Verena Müller / Trumpf, Max Faber / plainpicture, momosu / Photocase, RyanJLane / istockphoto

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Brief report

Quick info: AI-based software brings structure to the tangle of letters.

Harnessing Artificial Intelligence for Administration

Researchers from the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart are studying how artificial intelligence can be used to quickly get the gist of complex documents and simplify administrative processes. The scientists have developed a service platform called Aikido, an AI-based software program that analyzes business documents such as letters and invoices in seconds, extracts key information, and then structures the information.

Aikido even makes short work of significantly more complicated documents, such as the legal texts, medical journal articles, and expert insurance reports. "Our technology uses large language models and rule-based methods to extract the key facts in just a short time and prepare them for users," explains Matthias Engelbach, an applied AI researcher at Fraunhofer IAO.

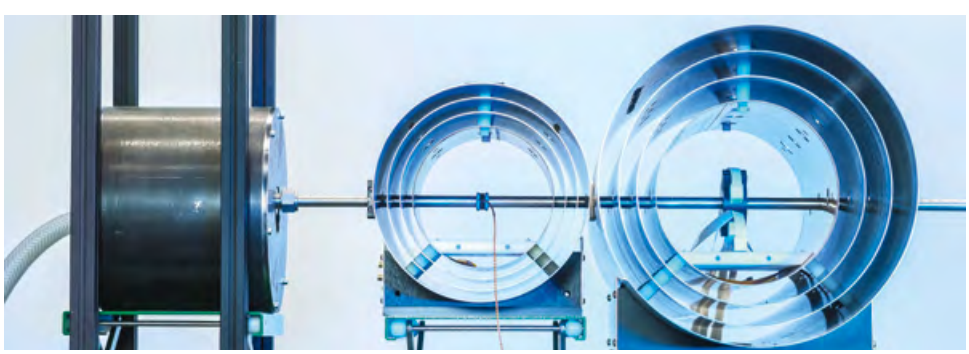
One area expected to significantly benefit from AI-based document analysis in the future is corporate purchasing departments. Aikido classifies inquiries, checks orders, and compares quotes at the touch of a button, saving not only time, but also money and effort. ■

Contactless Measurement of Flow Rate

The Fraunhofer Institute for Physical Measurement Techniques IPM has developed an innovative method of measuring the precise flow velocity of liquids used in industrial production processes, all in a touchless procedure.

The first step is to use a permanent magnet to polarize the liquid. Then, high-frequency pulses are used to reverse the polarity. This creates local magnetic markings in the fluid, which are then logged from the outside of the pipe using highly sensitive quantum sensors as the third step after a certain distance has passed so that the liquid's flow velocity can be determined.

Flowing fluids play a key role in many production processes. Reliable information on flow velocity is a must for controlling processes like these, let alone automating them. ■

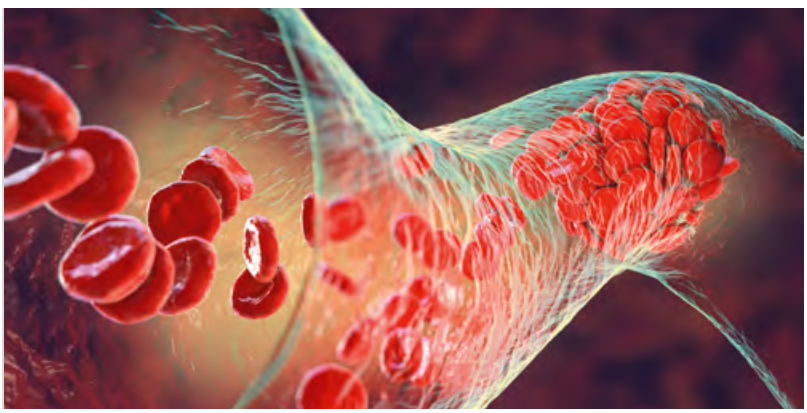


Everything is flowing smoothly — but how fast? A new method uses a magnet and quantum sensors to determine flow speed

Detecting Venous Thrombosis before It's Too Late

A wearable diagnostic device has been developed to help speed up detection of venous thrombosis in the future. The cuff, which has a built-in ultrasonic transducer, monitors the vessels in the lower limbs on a continuous basis. This makes it possible to quickly discover and treat dangerous blood clots that detach from the vessel wall.

The ultrasonic transducer arrays are being developed by the Fraunhofer Institute for Photonic Microsystems IPMS in partnership with Vermon as part of an EU project called ThrombUS+. The researchers plan to use a MEMS-based type of transducer known as a capacitive micromachined ultrasonic transducer (CMUT). CMUTs are viewed as the next generation of medical ultrasonic sensors. Cost-effective mass production means they are widely available. They are also easy to miniaturize with large numbers of channels and feature high bandwidth and sensitivity.



Every year, one in 1,000 people in Germany suffers thrombosis. Men are at slightly higher risk than women.

Some two-thirds of all venous thromboses have no symptoms, which makes them especially dangerous. In about half of patients, the blood clot eventually makes its way to the lungs, where it can cause an embolism. Pulmonary embolisms are fatal in about one-quarter of cases. ■

Better Support for Kids at Childcare Centers

Say something! Researchers aim to use AI to detect language acquisition issues earlier.

How can smart technologies help with early detection of language acquisition issues in the first few years of life? The Fraunhofer Institute for Digital Media Technology IDMT has teamed up with Klett Lernen und Information GmbH (KLI) to study that very question as part of the "Sprechen für die Zukunft" (Speaking for the Future) project.

The research and development work requires speech data on children from everyday scenarios that are as true to life as possible. The scientists used mobile technologies to collect samples of spontaneous speech from children in play scenarios at childcare centers run by Fröbel, a major childcare operator. All of the studies were monitored and supported by teaching staff, and strict privacy guidelines were observed. The recordings can be used to develop and test prospective technological solutions. Among other things, Fraunhofer IDMT is analyzing whether certain features of grammar or vocabulary can be reliably translated into technological algorithms. If so, it would be possible to determine where the child stands in terms of speech and language development later on. The earlier any problems in language acquisition are detected, the sooner support measures can get started — and that is key to getting off to a good start in school. ■

Photos: Mohd Azrin/istockphoto, Fraunhofer IPM, katerynakon/depositphotos, Sandra Roesch/Westend61/mauritius images, Fraunhofer IPM

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Picking Up the Pace of Renovations

A mobile mapping system under development at the Fraunhofer Institute for Physical Measurement Techniques IPM as part of the LaSanGe project aims to detect the energy efficiency of a building by simply driving by. The centerpiece is a multispectral LiDAR sensor that measures not only the building's geometry, but also the thermal properties of windows and facades.

A new sensor will soon provide fast insight into a building's energy efficien .

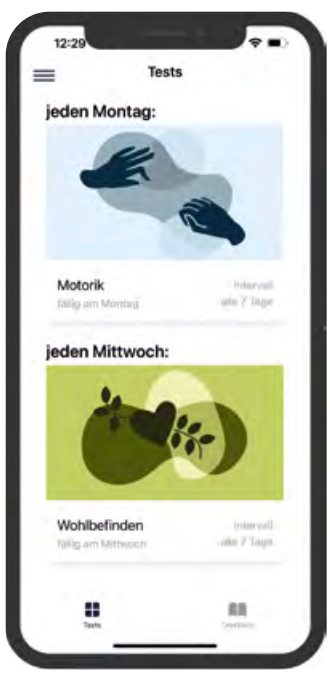
The sensor uses two lasers with different wavelengths to determine the insulating properties of windows. The visual properties of windows are highly wavelength-dependent. The ratio of the backscattered signals allows for a precise assessment of the quality of the windows: coating type, number of glass panes, and so on. The researchers also plan to use conventional thermal imaging cameras. The final result of the measurement is a geometric 3D point cloud, supplemented by parameters relating to the thermal properties of the windows and insulation. These multidimensional data are referenced both spatially and temporally and can be incorporated into geo-information systems. This also makes documenting changes over time both easy and inexpensive. ■

New App Helps with Parkinson's Disease

Researchers from the Fraunhofer Institute for Applied Information Technology FIT aim to help improve the quality of care received by patients with Parkinson's disease. As part of the ParkProReakt project, they are developing a web platform and app used together with wearables to track the progression of the disease, which varies widely between individuals.

"The app, which is named Active PD, is used by patients themselves after an initial familiarization phase. The data collected using the app are transmitted to the web platform, which is available to doctors," explains Daniel Wolferts, a scientist at Fraunhofer FIT.

The patients are asked to perform specific standardized tests twice a week using the app and an Apple Watch, which captures their movements via sensors. The tests look mainly at their motor skills and overall condition, helping to better gauge disease-related symptoms and quickly take appropriate action in response. The concept is being validated in clinical studies with 170 patients over a period of six months. ■



An app could be used to track the progression of Parkinson's disease in the future.

Editorial notes

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

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

Editorial assistants:
Dr. Janine van Ackeren, Mandy Bartel, Vivian Ellermeyer, Meike Grewe, Nina Himmer, Franziska Sell, Stefanie Smuda, Mehmet Toprak, Yvonne Weiß, Britta Widmann

Layout and lithography:
Vierthaler & Braun
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Sven Döring
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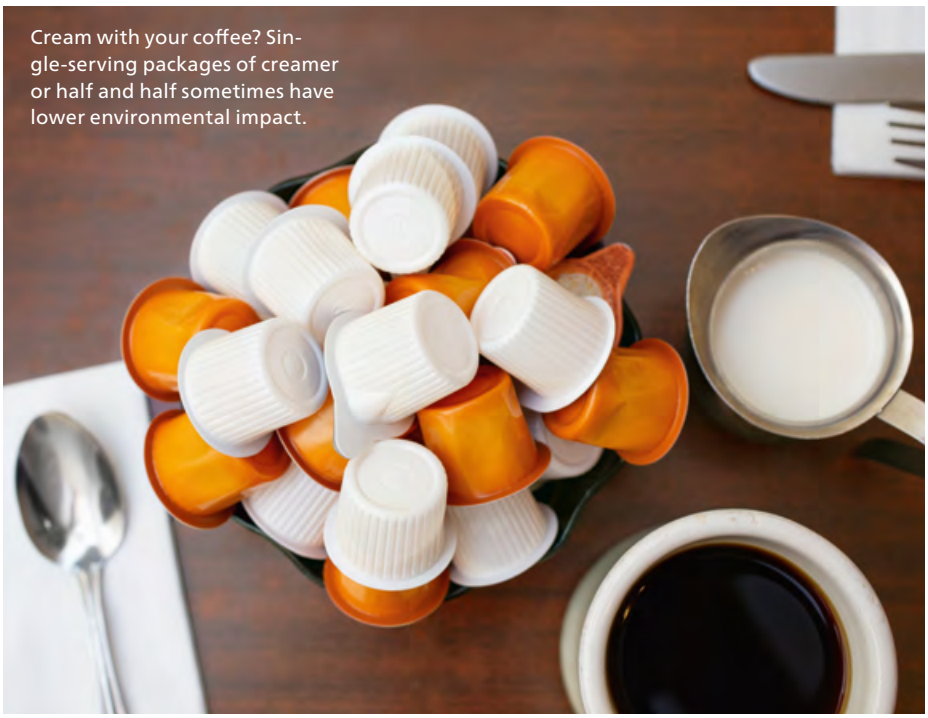

Cream with your coffee? Single-serving packages of creamer or half and half sometimes have lower environmental impact.

Reusable or Disposable?

A new EU regulation calls for the elimination of the small individual plastic packages currently used for coffee creamer and half and half. But is a ceramic or stainless steel pitcher always the greener alternative?

The Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT zeroed in on the environmental footprint to find out. The researchers considered factors such as the environmental impact of food waste, which can play a larger role when reusable systems are used in food service settings, owing to food safety rules. Any leftover perishable products like the milk used for coffee must be disposed of after they are offered to a single customer.

To determine the relevance of food waste, the researchers calculated the break-even point as part of their analysis to show what percentage of milk has to be thrown out for reusable options to have the same carbon footprint as individual packages. They came up with a range of three to 27 percent, with the lowest value applying to individual packages made of polypropylene. Their findings show that depending on the type of package, the single-serving pack may be the solution with the smallest carbon footprint if there is even a small amount of food waste. Dr. Daniel Maga, sustainability assessment group manager at Fraunhofer UMSICHT, comments: "Although the environmental impact of packaging should be reduced as much as possible, the trade-off with food waste always has to be considered as well. Depending on the use case, packages that are designed to be greener, for example by optimizing the choice of materials, may have lower climate impact as an alternative to reusable systems." ■

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Fraunhofer Start-ups

Going up: Biologist Amelie Reigl aims to make sustainable research easier with her start-up, TigerShark Science.

Think New business Act

Germany is a leader in research, enjoying an outstanding reputation worldwide. But the big challenge here, in the "land of thinkers," is how to turn scientific excellence into economic success. Fraunhofer plays a crucial role in this.

By Mandy Bartel
Photography: Patrick Runte

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Innovation starts with ideas, and transfer starts with ambition. Researchers' personal motivation to effect positive change through their work is the most powerful form of leverage in terms of applying knowledge. That is one of the results of a study called "Transfer 1000" published by the Center for Responsible Research and Innovation CeRRI, the Fraunhofer Institute for Industrial Engineering IAO, and Technische Universität Berlin. The authors surveyed 1,000 scientists from across a wide range of disciplines and organizations about their involvement with transferring knowledge and technology. They found that the social relevance and impact of researchers' work is the main driving force and strongest indicator of professional satisfaction for 85 percent of those surveyed — far ahead of factors such as raising their profile or project acquisition.

From lab to launch

Prof. Thomas Bauernhansl believes recognizing and supporting this motivation is crucial. A mechanical engineer by training, Bauernhansl has been the head of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart since 2011. His institute is a leader across Europe in producing spin-offs from its research. Bauernhansl's personal hard work and dedication is one of the reasons. He has been instrumental in driving the strategic establishment of spin-offs at Fraunhofer IPA and has himself supported about 30 spin-offs from lab to launch over the course of his career. The Unipreneurs initiative named him one of 20 outstanding figures in 2023 in recognition of his commitment to spin-offs and entrepreneurship.

"In terms of research as well as technology transfer and start-ups, the most important factors in our success are our researchers and their expertise and motivation," Bauernhansl says. "Our aim is to unleash this potential and actively open up many paths to personal development for people who want to start a business." On a concrete level, he adds, "We must take into account the perspectives of potential users and industry investors right from the planning phase of our research. During our research, we also need to adopt an entrepreneurial mindset and ask ourselves questions such as: What real-world problems can we solve, and for which user groups, with our technology as we compete with others? Can we scale our research findings to an industrial level? Are we meeting the rigorous demands of investors? If we can find answers to those questions for a particular technology, then spin-offs or industrial partnerships are logical next steps."

Europe's share of global investment in **deep tech** has nearly doubled since 2019, up from **10% to 19%**.

So, what Germany needs is ideas, and above all, we also need entrepreneurs to nurture those ideas and put them into action. And that, in turn, is only possible in a functioning transfer system. These days, small start-ups are a primary driver of innovation. Ideally, research activity supplies fresh findings and ideas to contribute to this. Established companies provide support in the form of infrastructure, experience, contracts and investment. Policymakers create a motivational operating environment and ensure that the necessary start-up funding is available. This interplay between the research sector, industry and government turns innovations into success stories. Or that is how it should work in theory, anyway.

From gap to opportunity

A look at what happens in the real world reveals that Germany scores fairly low as a place to start a business, as the German Chamber of Commerce and Industry (DIHK) stated in its August 2024 report on the German start-up scene. Obstacles to entrepreneurship include meager domestic consumer demand, stringent regulations, structural deficiencies, an uncertain environment, high costs and a shortage of skilled workers. Lack of collaboration between established industries, small and medium-sized enterprises and innovative start-ups is another impediment.

In the promising deep tech sector, Europe is especially lagging behind the U.S. on aspects such as entrepreneurship, per capita investment in growth, and IPO value. This field encompasses forward-looking technologies with the potential to radically reshape business models or even entire industries. That includes AI and quantum technologies, along with biotechnology, robotics, and new materials. The U.S. spent some 51 billion dollars on these areas in 2022, compared to just 19.7 billion in Europe.

However, a recent McKinsey study holds out hope. The study, "European Deep Tech: Opportunities and Discoveries," shows that the European deep tech sector is growing increasingly relevant and attractive. Europe's share of global investment in this segment has nearly doubled since 2019, going from 10 percent that year to 19 percent in 2023. Deep tech attracted nearly half (44 percent) of all tech investment in Europe. That's an increase of 18 percentage points in four years. "Deep tech represents a unique opportunity for Europe to restore its somewhat faded innovative strength and competitiveness

at the global level," the McKinsey analysts note. "Achieving that will require targeted cooperation among all stakeholders: universities, research institutions, government and private enterprise. With its long history of engineering and outstanding research institutions, Germany in particular must make a crucial contribution to this shift."

Fraunhofer: a model for tech transfer

One organization bridging the gap between research and industry, with a focus on application as part of its mission, is striving to make just that kind of contribution. Fraunhofer president Prof. Holger Hanselka stresses how important tech transfer is to the organization: "Fraunhofer's mission and fundamental purpose is to ensure the sustainable transfer of scientific findings to the industrial and business sectors. We have a special focus on three areas. First, industrial contracts are our core business, and they are what makes us unique among all scientific and research institutions in Germany. Second, our licensing business encompasses first-class patent families. And third, our innovative spin-offs are based first and foremost on deep tech and IP with lasting value."

This means Fraunhofer's key strength is its close relationship with business and industry: Collaboration with companies on challenges that they cannot resolve on their own is the organization's most important transfer path. Each of the 76 Fraunhofer institutes operates as a business entity in its own right, independently raising two-thirds of its budget from industry and public contracting bodies. In turn, the companies benefit from the researchers' expertise in the form of collaborative projects, cooperation, or awarding of contracts. Licensing of technologies and patents is another way that knowledge transfer takes place. Fraunhofer has almost 3,000 active license agreements at present. Audio or video codecs developed by Fraunhofer institutes in Berlin and Erlangen are an especially popular example. They are used by millions of people each and every day.

The third route by which research findings make their way into real-world application — which is also the most recent, having been established around 24 years ago — is spin-offs from institutes or existing start-ups, which draw on Fraunhofer technology for a competitive edge. "We believe in the fundamental importance of offering conditions, within the existing legal framework, that are conducive to starting new businesses in the area of transferring intellectual property," Hanselka notes. About 500 technology spin-offs have been launched since 2000.

About **500 technology spin-offs** have been launched since 2000.

That makes Fraunhofer a leader among research organizations not affiliated with academia. As for which transfer path is the best one for a given technology, that is ultimately decided by the potential for industrial scaling.

Spin-offs: driving the medium-sized businesses of tomorrow

But technology alone is no guarantee of success. Many innovative technologies fail because they were not developed with the market in mind. Successful execution is crucial. To provide those looking to start a business with comprehensive support from the initial idea to the spin-off, Fraunhofer has implemented coordinated transfer programs and licensing terms that are friendly to start-ups. Fraunhofer Venture's activities provide extensive support to both spin-offs from the Fraunhofer institutes and collaborative arrangements with external start-ups. As one example, the CoLab tech collaboration program brings deep tech entrepreneurs and established start-ups together with Fraunhofer researchers. The Match platform developed internally at Fraunhofer is used to find the right technology from around the world of Fraunhofer for founders' product visions. The partnerships between start-ups and Fraunhofer gain access to the necessary structures and know-how and to a comprehensive network so they can bring their new ideas and technologies to market.

The AHEAD program offers financial and methodological support for Fraunhofer's own spin-off projects, providing methodological and substantive support to accelerate the start-up path and give new businesses financial breathing room. The three-stage transfer support program is structured to work like a business incubator. Its goal is to validate business models and prepare teams and Fraunhofer technology for the start-up and commercialization phase in less than 24 months. Effective and impactful workshops, coaching, an internal project budget of up to 150,000 euros, and a large partner ecosystem made up of investors and industry players combine to help business ideas mature and get potential entrepreneurs ready to start their business and enter the market. This approach is a success: 96 percent of Fraunhofer start-ups are still active on the market three years after they are first founded.

To provide optimal support for development of new business ideas and start-ups, Fraunhofer Venture and the AHEAD program team work with a community that is well versed in deep tech and includes business angels, investors, business ▶

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schools, and the venture units of other non-university research institutions.

In addition to providing support for the start-up process, Fraunhofer itself can also get involved if the founding team wishes. In this area, Fraunhofer has built an extensive network with early-stage investors, alongside close collaboration with and involvement in the High-Tech Gründerfonds (HTGF), Germany's leading seed investor — thereby also unlocking opportunities for the Fraunhofer-Gesellschaft to invest in select spin-offs as a co-investor (the portfolio currently includes over 50 technology shareholdings). One vehicle that has proven its value is the Fraunhofer Technology Transfer Fund (FTTF), which Fraunhofer and the European Investment Fund launched in 2019 with a volume of 60 million euros with the goal of investing in spin-offs based on Fraunhofer technologies. The investment phase of the fund concluded in 2023. Work is currently under way on the next stage. Overall, Fraunhofer is monitoring the positive follow-up concepts in the German venture capital scene for deep tech start-ups and welcomes the initiatives put forward by the German federal government in this area (Future Fund).

96% of **Fraunhofer start-ups are still active** on the market three years after they are first founded.

Long-term ties as success factor

But should Fraunhofer institutes even be trying to help their best and brightest start their own businesses? Launching a business with Fraunhofer is a win for the founding teams, which gain access to infrastructure, expertise and networks, but it is also a gain for the institutes themselves, as Bauernhansl explains: "Start-ups maintain ties with their institute in a variety of ways, including research contracts, license relationships and collaboration. Spin-offs are our way to offer entrepreneurship as a career step within our own ecosystem." And some founders are also happy to come back to the institute after a successful exit or to start another new business after a period of research. "There are several ways we benefit from this: We exploit, upgrade, and scale technologies that have reached the limits of their research potential for our institute, which helps bring in returns and creates a positive feedback loop with our research findings," Bauernhansl says. "At the same time, we have the opportunity to bring leading entrepreneurial thinkers to the institute, where they can serve as role models for our researchers and intrapreneurs."

Read on for five examples of how these kinds of role models make an impact through their work, what prompts them to take the plunge and start their own business, and how they plan to work with Fraunhofer for the future of German industry and society.

For more information, contact:
Fraunhofer Venture
https://www.fraunhoferventure.de/en.html

AHEAD program
https://www.ahead.fraunhofer.de/en.html

Take a bite? To entrepreneur Amelie Reigl, sharks mainly symbolize strength and efficiency.

Skin Deep

Medical innovation relies on animal testing. Or does it? Planned Fraunhofer biotech start-up TigerShark Science aims to use advanced skin models grown from human stem cells to dramatically reduce animal testing.

By Mandy Bartel

Amelie Reigl likes animals. Two of them in particular. "Tigers stand for power and determination," says Reigl "and sharks for adaptability and efficiency." Together with Dr. Dieter Groneberg and Prof. Florian Groeber-Becker, biologist Reigl is on the cusp of launching her start-up, TigerShark Science. The name, which derives from the founding team's favorite animals, symbolizes strength and agility in scientific research. Power, determination, adaptability and efficiency: all characteristics a start-up needs to develop groundbreaking solutions and market them successfully.

And TigerShark Science is in fact all about animals. Some 1.73 million animals were used for testing in Germany in 2022. The goal of alternative methods is to lower that number. But they are often unable to reflect the complexity of a living organism. Reigl aims to change that. She plans to launch a realistic skin model that features almost all the structures present in human skin.

Greater accuracy and applicability of test results

"Our vision is to improve biomedical research on skin through advanced in-vitro skin models and support ethical and sustainable research," Reigl explains. "In the long term, we plan to use our technology to support personalized medicine and individual treatment options." The highly complex skin model grown from human stem cells is intended to help pharmaceutical and cosmetic companies to achieve faster and more accurate test results that are more applicable to humans. This allows for faster testing of active ingredients and their side effects and more detailed research on hair growth, among other aspects. A single model can be used to study how cells in the three main layers of the skin (the epidermis, dermis, and hypodermis) react — a possibility that has not previously existed on the market, and a clear advantage over costly and time-consuming animal testing. TigerShark Science plans to use an automated process to produce the skin models in large numbers inside a bioreactor. They will then be applied to nanofibers using a special method. This will make it possible to grow the models at the air-medium boundary, so the uppermost layer has contact with the air, just like in human skin. The advantage of doing this is that the research findings translate better to human applications.

> "Tigers stand for power and determination, and sharks for adaptability and efficiency."
>
> Amelie Reigl, TigerShark Science

Further development with support from Fraunhofer

Reigl got the inspiration for her spin-off while conducting research at the Fraunhofer Institute for Silicate Research ISC in Würzburg and the affiliated Translational Center for Regenerative Therapies TLC-RT. "While I was there, we saw the possibility of refining and commercializing an in-vitro technology for skin models," Reigl explains. "We took that idea and got started with the AHEAD incubator program at Fraunhofer, which gave us financial support and access to a broad network of experts and mentors. That helped us to fine-tune our business models, plan the right steps for our market launch, and ultimately secure 1.3 million euros in funding through the EXIST Transfer of Research program." The researchers also used the funding and interdisciplinary support they received from the Fraunhofer network to further develop their skin model. Going forward, they plan to add models with immune cells and blood vessels, along with tumor cells, which will help to simulate and study diseases such as skin cancer and fibrosis. Reigl believes the social impact of her work is important: "What I find really inspiring is the opportunity to develop ethical solutions that lead to more effective skin research, so they can also unlock faster improvements in quality of life for patients — all without making animals suffer." ■

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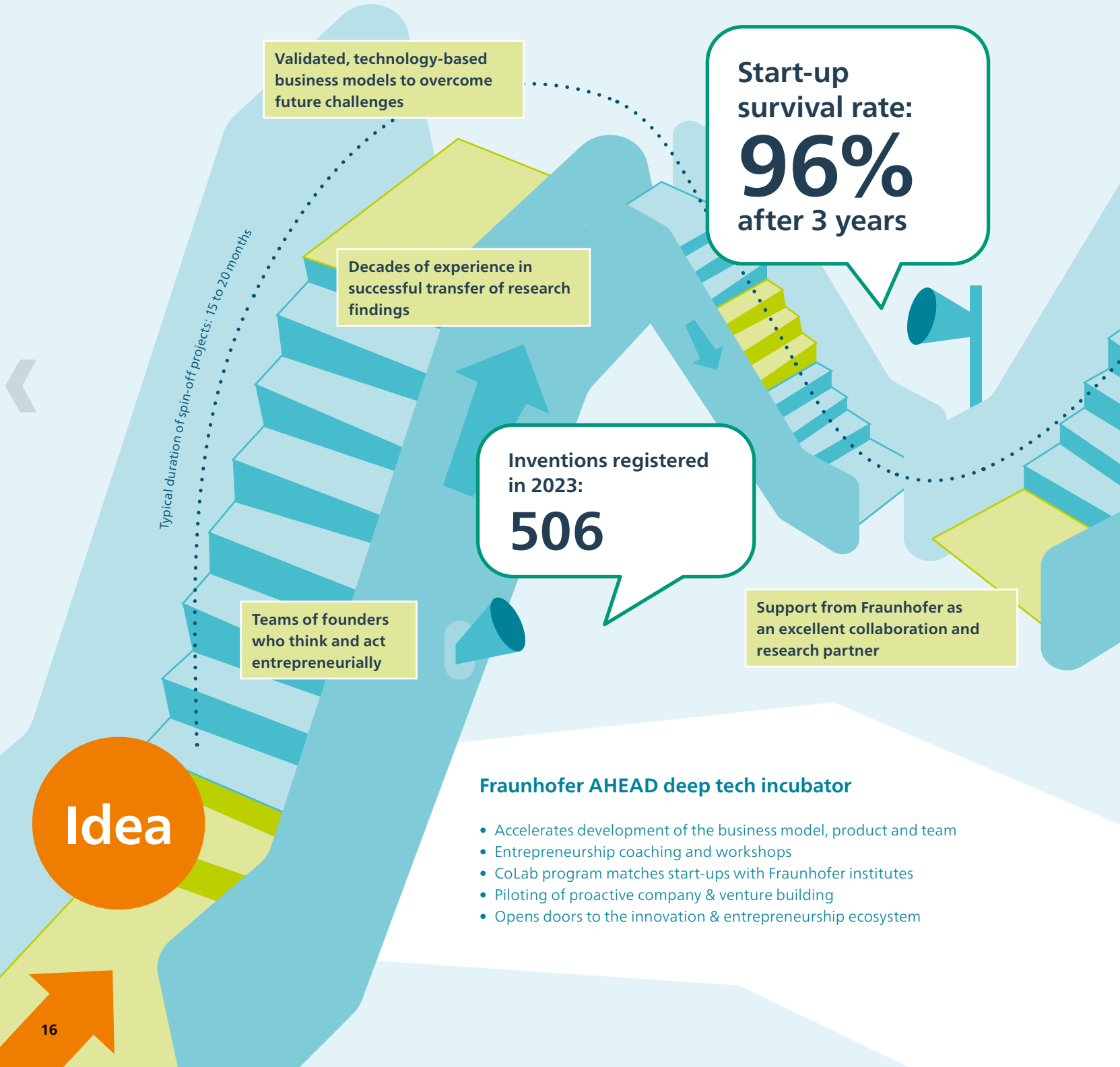
The Fraunhofer Spin-off Path

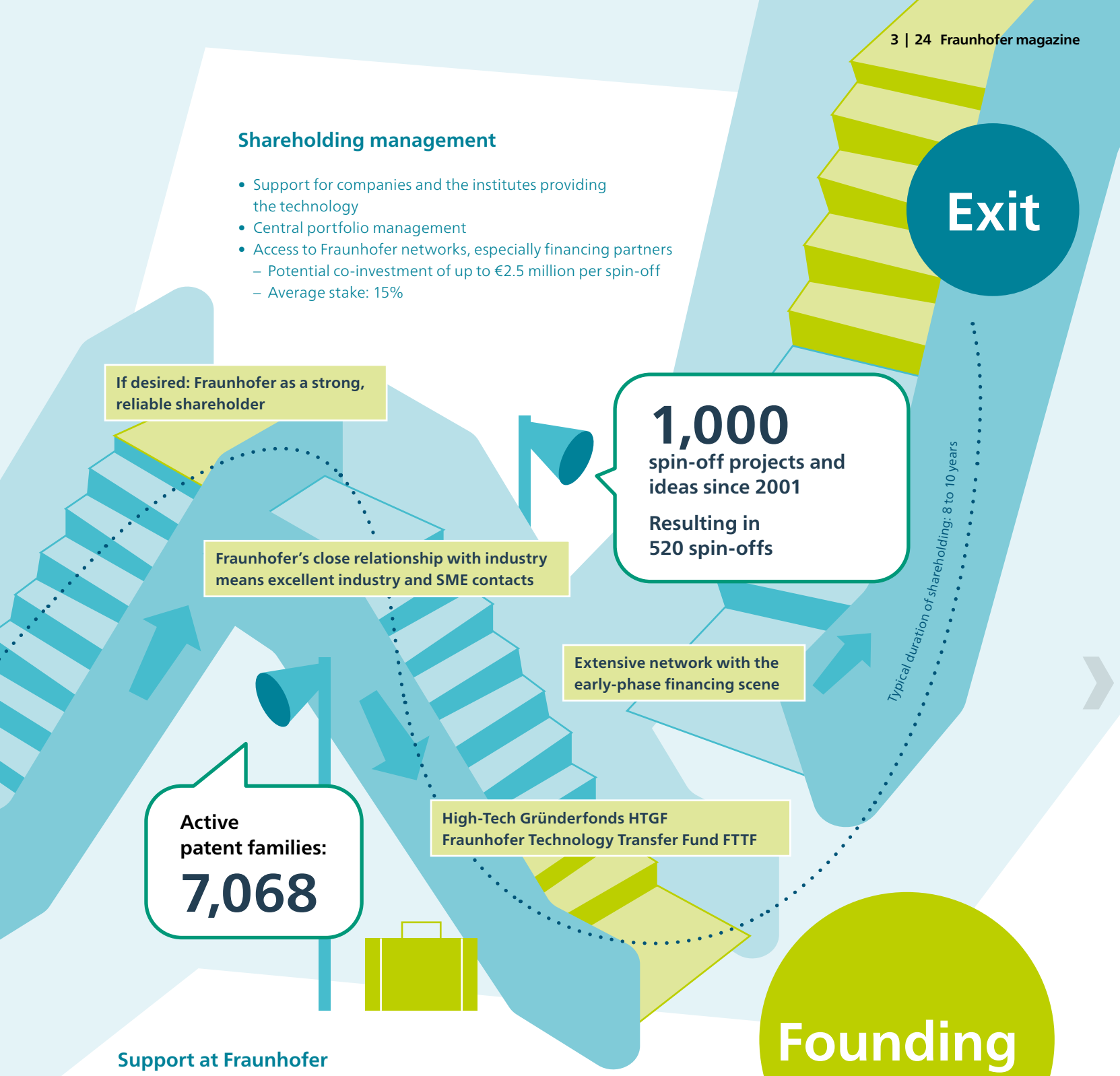


Fraunhofer AHEAD deep tech incubator

- Accelerates development of the business model, product and team
- Entrepreneurship coaching and workshops
- CoLab program matches start-ups with Fraunhofer institutes
- Piloting of proactive company & venture building
- Opens doors to the innovation & entrepreneurship ecosystem

Shareholding management

- Support for companies and the institutes providing the technology
- Central portfolio management
- Access to Fraunhofer networks, especially financing partners
  - Potential co-investment of up to €2.5 million per spin-off
  - Average stake: 15%



Support at Fraunhofer

- Development of business idea and business model
- Building founder team / compliance
- Scheduling
- Protection for intellectual property and licenses
- Use of Fraunhofer logos and infrastructure
- Funding options
- Financing
  - AHEAD support: €150,000
  - FFM — Fraunhofer Supports Management: up to €150,000

Fraunhofer VENTURE

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Leakage Technology

Making hydrogen safer and more efficient to use is Dr. Hunter King's vision. His spin-off, Integrative Nanotech, is harnessing innovative nanotechnology to facilitate detection of leaks in hydrogen systems.

By Stefanie Smuda

The story of Integrative Nanotech starts with a chance discovery. Dr. Hunter King, a Canadian scientist, was conducting research at the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig on materials for micro-electromechanical systems, or MEMS, for use as sensors. "We tried out a lot of different methods, played around with the parameters, and moved beyond known production methods," King explains. In the process, he and his team discovered a novel method of producing nanostructured silicon materials on a large scale. But King was in the middle of writing his dissertation at Fraunhofer IST and working on several other projects at the same time. That meant he didn't fully realize the potential of his discovery until a year later.

After completing his dissertation, King dug into the data and findings from the project and realized that he had developed an innovative nanomaterial with some very special properties. "The new material has an extremely large surface area, so it achieves better performance in gas and liquid sensor applications," he explains. King identified detecting leaks in hydrogen systems as the application with the biggest market potential. His start-up, Integrative Nanotech, focuses on this segment. The long-term objective is to move the hydrogen transportation sector forward into a safer, more efficient future.

Revolutionizing the sensor industry

Hydrogen is viewed as a clean, sustainable and versatile source of energy. But because it is also highly explosive, it is difficult to handle and transport. To target this issue, Integrative Nanotech and Fraunhofer IST plan to work together to develop leak detection solutions with the goal of improving standards and making equipment more reliable. The move should also help to make operational procedures safer. "We want to bring nanomaterials out of the lab and onto the global market, revolutionizing the sensor industry," King says.

> "At Fraunhofer, I got to know some of the smartest, most passionate, and most caring people I've ever had the chance to work with, and I loved my time there."
>
> Dr. Hunter King, Integrative Nanotech

Building on the nanotechnology, the researchers plan to develop the next generation of gas sensors for large-scale industrial use. The benefits include high performance, larger production volumes, and lower costs compared to conventional methods of producing nanomaterials.

The company's proprietary technology also offers faster ways to unlock the functional capabilities of nanomaterials in detecting many different gases. The sensors can be used to locate leaks of hydrogen and gases containing nitrogen and in applications such as environmental monitoring (CH_4, etc.). This opens up a wide range of potential applications, such as in fuel cell vehicles or at hydrogen filling stations.

Advancing product development with Fraunhofer expertise

King was supported in starting his business by Dr. Volker Sittinger, Daniel Stoll and Tino Harig from Fraunhofer IST. They helped during the early phase of technological development, for example. "I might have had the idea and the passion for the subject, but the discovery wouldn't exist if not for Fraunhofer — there wouldn't have even been an opportunity to make it in the first place," King points out.

Fraunhofer IST and Integrative Nanotech signed an exclusive license agreement in May of this year. The agreement gives the spin-off, which is based in Canada, access to the Fraunhofer institute's infrastructure and expertise in thin film processes and production systems and in process scale-up. "In terms of our growth and exploring new markets, we think Fraunhofer IST is in a key position. Thanks to its comprehensive expertise and its technologies, we are able to accelerate product development," King says.

Fraunhofer has set a high benchmark in King's view: "Whenever I talked to friends or family in Canada, I told them all about the incredible people I was lucky enough to work with every day," he explains. "At Fraunhofer, I got to know some of the smartest, most passionate, and most caring people I've ever had the chance to work with, and I loved my time there. I'm incredible grateful that I can continue my relationship with them." ■

Accelerating the future: Dr. Hunter King aims to support the hydrogen sector with his spin-off, Integrative Nanotech.

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A Thirst for Data

Dr. Alanus von Radecki helps cities and municipalities harness the power of data, accelerating the digital transformation across the whole of Germany.

By Nina Himmer

Two souls in a single breast? It's a real-world phenomenon, not just a concept from Goethe's play Faust: Dr. Alanus von Radecki, who works at a start-up in Berlin, is both a sociologist and an engineer. He is driven on the one hand by what makes people tick and how their behavior can be influenced. On the other, he wants to illuminate how technology works in detail. In line with these divergent interests, von Radecki's company straddles the line between these worlds: How can technological solutions be designed in such a way that society really uses them?

That was the original question that led to the creation of the Data Competence Center for Cities and Regions (DKSR), which was spun off from the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart in 2021. Since then, DKSR has been helping cities and regions to build digital infrastructure. "Our goal is to act as a kind of catalyst for the digital transformation while keeping the added value for people in mind," von Radecki explains. How can administration be made more efficient? Cities more livable? How can tax funds be saved?

Digitalizing Germany sounds like a thankless task. Studies regularly rank the country last in Europe on this point. The 2024 Digital Report also shows Germany lagging behind. Most of those surveyed across business, government, administration and the general public do not expect there to be any major progress on that front anytime soon. "It's definitely a big challenge," von Radecki admits. All of Germany's states, cities, and municipalities do their own thing, which leads to a patchwork of different digital solutions. Some are still living in the era of faxes and paper files, while others get tangled up in issues of privacy and data protection or are practically paralyzed by a fear of making mistakes. Von Radecki tends to view the situation as inspiring action: "I love the challenge, and I hope to do more than just churn out paper with my work. I want to be a part of transforming the system in the real world."

Focusing on potential, not problems

That is a typical thing for him to say. Von Radecki has always been someone who enjoys thinking of tomorrow and beyond, a person with vision. He spent years in charge of Fraunhofer's Morgenstadt (city of the future) innovation network, focusing on urban issues of the future. That same desire to shape the future and focus on potential rather than problems is also clearly apparent at DKSR. The center has a lot to show for the three years it has been on the market so far. Its clientele includes more than 80 cities in Germany and other countries. The shared mobility concept used in Cologne was optimized by collecting information on all e-scooters and bike share bikes. In Deggendorf, Bavaria, a project has been launched to improve flooding preparation by linking data from precipitation sensors and flood retention basins with weather forecasts and information on soil moisture levels. In Augsburg, data helped with traffic calming in the city center. And in Aarhus, Denmark, an entire city district is currently being overhauled to produce more energy than it uses. DKSR is building the entire data infrastructure for this, including aspects such as the supply of electricity.

> "Our goal is to act as a kind of **catalyst for the digital transformation** while keeping the added value for people in mind."
>
> Dr. Alanus von Radecki, Data Competence Center for Cities and Regions (DKSR)

Pioneering work with pragmatism

There are a vast number of ideas and examples, most of them closely linked with questions of sustainability and quality of life. "I view data first and foremost as a tool for comfortable, convenient, safe, and sustainable life beyond the digital transformation," von Radecki says. "Thinking in terms of data and working with data is something administrative agencies aren't used to yet." For many, the first step is to take inventory. What data do we have? How can we structure, use, and share it? What problems can it be used to address? Von Radecki knows that sometimes, the main things a particular vision requires are pragmatism and patience. "We're talking about huge system-level transformations here. That kind of thing doesn't happen from one day to the next."

But that pioneering work is exactly what motivates him: "This is an important subject, and we have a chance to make a real difference." Von Radecki says he also owes that outlook to his time at the Fraunhofer institute, where he was surrounded by people with innovative ideas and a desire for a different and brighter future. "It really inspired me and confirmed that I was on the right track in starting a business." ■

Finding answers to questions about the future of cities: Dr. Alanus von Radecki relies on smart data management.

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Breathe Easy

Dr. Felix Wiegandt aims to improve premature infants' chances of survival with an innovative inhalation therapy.

By Nina Himmer

Lena is tiny. Each of her hands is about the size of an adult's thumbnail, her bald head is barely bigger than an orange, and her tiny arms hang slack by her sides. She is wrapped in a diaper, a pacifier in her mouth, not making a sound. Dr. Felix Wiegandt, a biomedical engineer, often tucks her into his pocket to bring her along to trade shows, presentations, and investor meetings. Why? Because the incredibly lifelike plastic doll is such an excellent illustration of how fragile premature babies really are. Lena is also the perfect way for Wiegandt to demonstrate his innovation.

Wiegandt developed a technology intended to help preemies get off to a better start in life when he was working on his doctorate. "Almost 15 million babies are born prematurely each year around the world, about 60,000 of them in Germany," he says. Globally, 43 percent of infants born before the 23rd week of gestation do not survive. One of the main reasons is that their respiratory system is not yet mature. "In many newborns, gas does not exchange properly in the lungs. Their alveoli — the tiny sacs inside the lungs — downright collapse when they exhale," Wiegandt explains. This leads to shortness of breath, inflammation and scarring in the tissue that can cause issues up to adulthood. "Place a hand firmly over your mouth and nose and inhale through the resistance," Wiegandt says. "That's what breathing feels like for many preemies."

The medical term for this phenomenon is bronchopulmonary dysplasia (BPD), and depending on how severe it is and the child's age, it can be acutely life-threatening or have lifelong repercussions. Intravenous cortisone helps, but it can also cause internal bleeding, high blood pressure or growth problems in the babies' tiny bodies. "The potential side effects are so extreme that this kind of systemic cortisone therapy is not used as a preventive measure," Wiegandt explains. "But we've developed a method of administering cortisone on a much narrower basis, with fewer and less severe side effects."

More medication for delicate infant lungs

The intravenous route isn't the only way to administer cortisone. It can also be inhaled directly into the lungs. In this case, the side effects are much less pronounced because the cortisone is only administered locally. In the current standard of care, premature babies are given a breathing gas with slight positive pressure to help them breathe. Six liters of it cycle through the newborn circulatory system. Simply adding cortisone severely dilutes the medication, however. "Up to 96 percent of it is lost, so far too little reaches the lungs." The now patented Inhale+ technology works differently: "We divert a small portion of the breathing gas out of the cycle, add the medication to that, and then feed it through directly to the baby's nose," he explains. And that brings a whopping 320 percent more of the active ingredient into the lungs.

> "I have the chance to make the world a little bit better. And I'm determined to take it."
>
> Dr. Felix Wiegandt, Inhale+ GmbH

This could be a breakthrough in neonatal care. "Our technology enables very early preventive treatment for respiratory illness with a low side effect profile, so it can help to prevent lung damage and long-term harm and reduce the mortality rate in premature infants." Wiegandt and his three-person team are currently working to further improve their method, for example by synchronizing the release of the medication with the baby's breathing. They are also hoping to make all of the parts smaller and more compact. In addition, the researchers plan to make the technology as easy as possible to use so it can succeed in real-world practice. Their long-term strategy also calls for developing this method for adults as well, such as patients with chronic obstructive pulmonary disease (COPD) or asthma.

Wiegandt had originally planned to become a patent attorney, but his doctoral studies at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM and the development of the Inhale+ technology ultimately set him on a different path. Plans call for a new company called Inhale+ GmbH to be spun off in 2025, followed by a proof of concept study and then, starting in 2026, the clinical trials that are required before any new medical technology is formally approved. The market launch is scheduled for 2029.

"This whole start-up life feels pretty wild right now," Wiegandt says. But he feels well prepared, due in part to the Fraunhofer AHEAD program. How do you draw up a business case? What makes for a good market analysis? How much funding is needed before the market launch? "All that was totally new to me," Wiegandt says. "But now, I can't imagine doing anything else. I have the chance to make the world a little bit better. And I'm determined to take it." ■

Oxygen is life: Dr. Felix Wiegandt aims to help preemies get off to a better start in life.

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Seeds of Change

More plants, less meat, dairy and eggs: The world urgently needs a rethink of how and what people eat. How start-up Sunbloom Proteins plans to make that a tastier proposition.

By Nina Himmer

Sunflowers are her favorite flowers, as it happens. "I loved them even before I started Sunbloom Proteins," Amandine Perez says. "And I can still enjoy looking at them without immediately thinking about nutritional value." Sunflowers are a happy sight, whether growing in a field or arranged in a vase. "Or on your plate!" Perez says with a laugh. Her employer, Avril, acquired the start-up Sunbloom Proteins a little over a year ago. Perez, now the company's managing director, has been advancing its vision since July: "To incorporate plant protein into our diet as casually and with as much versatility and good taste as possible."

Developed at Fraunhofer IVV

To achieve this, Sunbloom Proteins uses sunflowers, which have long been prized in Europe for their oil and seeds. A technique developed at the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising, near Munich, also makes it possible to produce a protein concentrate from the plants. The sunflower seeds are shelled and pressed, the oil is extracted, and then the seeds are dried and finally finely ground. "The final product is a powder with a consistency similar to that of flour, but with a protein content of 60 percent," Perez says. It has a number of advantages over other plant proteins like soy, wheat or pea protein: "Sunflower protein has a completely neutral taste, is light in color, has a pleasant consistency and can be processed in a wide variety of ways." In short, the extract is a sustainable and healthy source of protein that can easily be incorporated into many foods.

The texture of the protein is extremely variable. "We supply a natural ingredient that can effortlessly substitute for meat, dairy and eggs in many products," Perez says, pointing to the product's key benefits. Whipped, like cream or egg whites?

> "A lot of people are curious, so they try **plant-based alternatives.** But they haven't really caught on so far. It would be wonderful to be a part of that transformation."
>
> Amandine Perez, Sunbloom Proteins GmbH

No problem. Dissolved in water? Yes, and with no residue. Dissolved in emulsions? The perfect combination. Foamed, like milk? Pass the coffee! Sunflower seed protein is also a good meat substitute, either with a high proportion of water like in burger patties or emulsified sausages, in plant-based pâté or as dried chunks. "Sunflower protein doesn't have an aftertaste, like pea protein, or give foods an unpleasant color, and it has outstanding texturizing properties," Perez explains. And all that is crucial in making it attractive for broad-based use in the food industry. "We need to give manufacturers maximum freedom to design their products."

So far, it's a winning recipe: Sunbloom Proteins GmbH has grown steadily ever since it was founded as a spin-off of Fraunhofer IVV in Freising in 2017. The goal of the company's acquisition by the global Avril Group, in April 2023, was to raise the profile of plant-based proteins on the market. Sunbloom Proteins continues to work closely with Fraunhofer IVV. "Avril looks for innovative and sustainable solutions to feed people. That's why dialogue with the research sector is hugely important to us."

Products that use the sunflower protein as an ingredient are now on store shelves not just in Germany, but also in France, Italy and Brazil. "We're working on a plant-based chocolate mousse right now," Perez says from her office in Paris. A French native herself, she is following the development of the creamy dessert with an especially critical eye. She laughs, but she's serious: "Enjoyment is really important to me. I firmly believe change is only possible if we can offer really tasty, delicious alternatives without compromising on flavor." She's literally working to "sweeten" the shift for people, if you will.

And she is no exception herself. Like most people, Perez is not a vegan or a vegetarian, but she is concerned about the planet and wants to add more plants to her own and her family's diet. That can be a real challenge in daily life with her four-year-old son. "A lot of people are curious, so they try plant-based alternatives. But they haven't really caught on so far. It would be wonderful to be a part of that transformation." ■

Super useful: Amandine Perez focuses on proteins made from sunflower seeds.

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National electrical grids are a potential target for high-tech criminals.

Guarding against Cyberattacks

Without secure gas systems, electrical grids, and communication networks, our society would grind to a halt. With attacks on the rise, a new research project aims to harness quantum technology to better protect these critical networks against hacking.

By Mandy Bartel

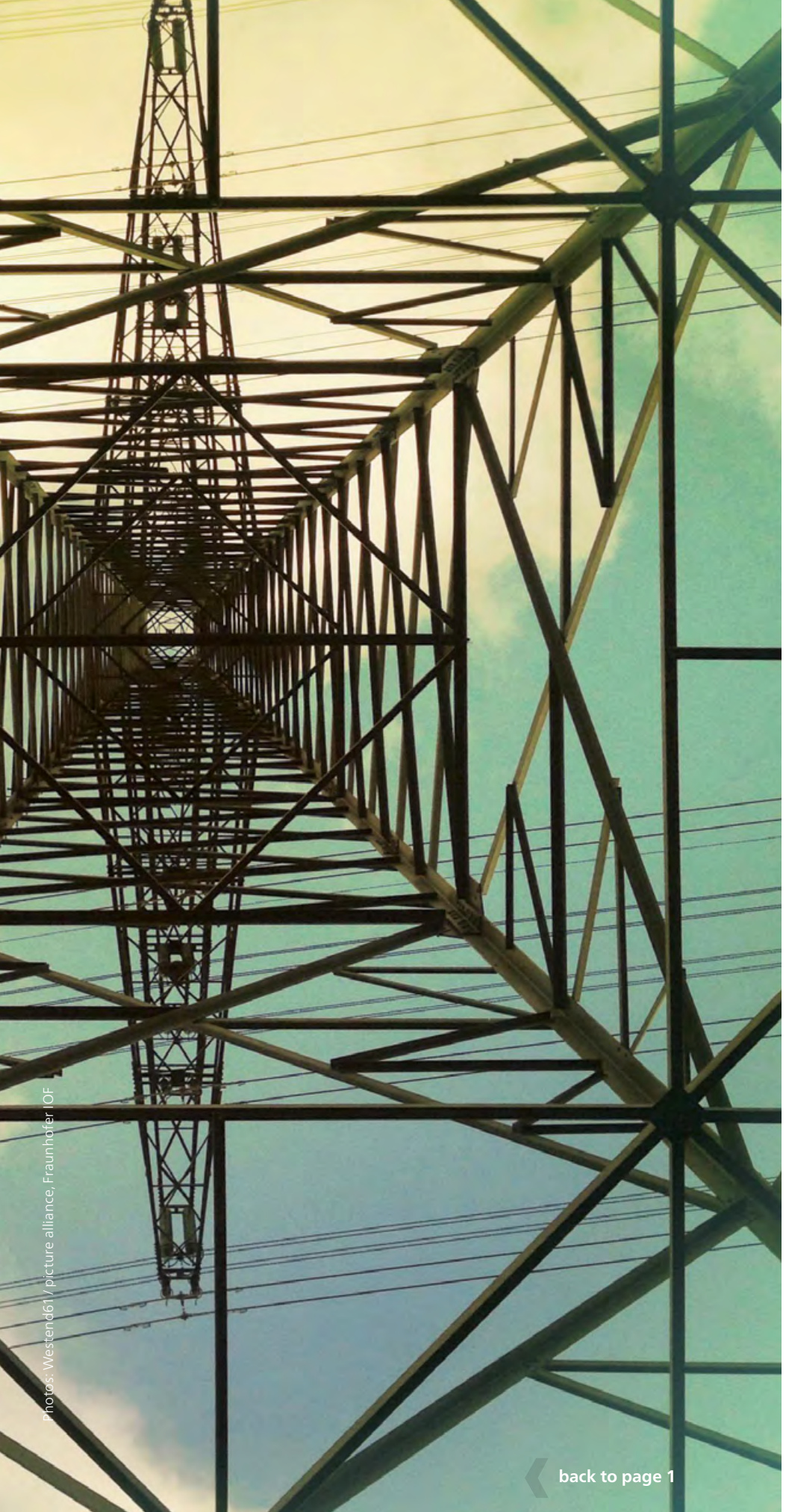
It is a race with many losers. Recent figures show just how quickly cybercriminals are innovating: The Global Threat Intelligence Report from security provider BlackBerry logs 37,000 cyberattacks a day around the world — and that is only the ones captured by its own systems. Over half of them, some 60 percent, target critical infrastructure. In Germany, the German Federal Office for Information Security (BSI) registered more than 400 cyberattacks on critical infrastructure in 2023, a 20 percent increase from the prior year. Energy suppliers and communication networks were especially hard hit.

Researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena have teamed up with partners from industry and the research sector to work on groundbreaking solutions. "Our project aims to revolutionize the security of critical infrastructure through quantum key distribution, or QKD," says Dr. Christopher Spiess, who is in charge of coordinating the MANTIS project at Fraunhofer IOF. The project's name is a German acronym for "Measurement-independent QKD and Secure System Synchronization for Applications in Gas Systems and Critical Infrastructure." It is initially slated to run for a term of three years and has received five million euros in funding.

Quantum technology as key to security

Quantum key distribution relies on principles of quantum physics to create highly secure communication channels. Two parties receive the same random number to use as a secret quantum key for secure transmission. In MANTIS, the quantum experts are going one step beyond to develop chip-based QKD systems that are independent of the measuring devices used. This is called MDI-QKD. "With standard QKD, the receiver's measuring devices are in a secure environment," Spiess explains. "However, if an attacker were to gain physical access to the measuring devices, then the system is no longer secure."

In contrast, MDI-QKD ensures the confidentiality of the exchange of keys even if an attacker has physical access to the measuring devices used to decrypt the quantum keys at the receiver's end. That makes this specific form of QKD an espe-



Photos: Westend61 / picture alliance, Fraunhofer IOF

cially good option for affording better protection against "side-channel" attacks on gas systems and other forms of critical infrastructure. "A hacker can practically have all the measuring devices right in their hands. But access to the measuring devices is useless to them because the MDI-QKD protocol ensures that the measurement information is unusable for the eavesdropper," Spiess says.

Protection over long distances

The work being conducted in the MANTIS project also represents a milestone in bridging longer distances with quantum communication. In contrast to traditional methods, in which the sender and receiver communicate directly with each other, MANTIS introduces a third point — an intermediate station. If the distances are now stabilized with high precision, the setup enables particularly long transmission distances of up to 1000 kilometers in optical fiber networks. The high-loss QKD protocols has limited transmission to just a few hundred kilometers so far.

> "With MANTIS, we're setting new standards in quantum communication."

Dr. Christopher Spiess, Fraunhofer IOF

Spiess believes in the project: "With MANTIS, we're setting new standards in quantum communication. MDI-QKD goes beyond traditional approaches, so it offers maximum security even under extreme conditions." ■

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A voice from the business world

Dr. Nicola Leibinger-Kammüller, CEO of Trumpf SE + Co. KG

Our thoughts are free — and must stay that way.

Excellence in research and innovation form the basis for our industrial prosperity. Intellectual freedom in the sciences and academia is also a litmus test for our society's overall health.

Dr. Nicola Leibinger-Kammüller, CEO and partner at Trumpf SE + Co. KG, makes her case

Are we living in a new counter-Enlightenment era, as some have claimed? It is certainly possible to conclude that we are, given the disruptions of teaching activities at higher education institutions and the personal criticism of scientists we see circulating online. Whatever the issue, from biological sex distinctions to genetic modification of crops, climate change, the coronavirus pandemic, or recent hostility toward Israel and Jewish people in the wake of the Hamas attack on October 7, the discourse on topics where freedom of speech is truly necessary to allow the better argument to win out is increasingly devolving into a shouting match. I think this represents a regression into ideological patterns of thought and deterministic characteristics. It's a far cry from embarking on a better, freer future where we engage with each other without prejudice.

Not a new phenomenon, but still dangerous

Disruptions in the public discourse are nothing new. I have vivid memories of the 1970s, when I was studying humanities. Everyone took a hardline stance toward industry, which was accused of not just exploiting the poorest of the poor (instead of producing broad prosperity), but also causing environmental damage, which was first emerging as a major topic within society. The Seveso Directive was a huge subject.

So it seems even more striking to me that we are now — three decades after the supposed end of history and with many different sources of information to choose from — running the risk of slipping into a new age of irrationality and mistrust toward successful scientific sources. Any view, no matter how outlandish, is aired widely in the media. This leads to a situation in which freedom of speech is being attacked in ways that cannot be countered through constructive argument. Feelings overshadow facts in many cases. And the collaborative and often laborious process of forming knowledge, which is inherent to both science and the humanities, is thrown into question overnight by populism.

So, what should be done? Definitely more than a guest column from the sidelines of the medium-sized business sector can even remotely manage. It goes without saying that we need to be firm in maintaining the standards of freedom of speech, especially in academia. It's also clear that German industry will only stand a chance on the increasingly turbulent global markets if we also allow ourselves to think beyond what is politically expedient, whether that means questions of biology or powertrain and energy technologies, which might not be looked on particularly favorably in this country right now but are in demand abroad.

So, it seems to me that all our thoughts should really start with considering whether we need to relearn how to trust. Trust in scientific expertise that is committed to itself alone, not a political vision. Trust in institutions. Trust in information that has been vetted and filtered in a positive sense.

Those who publicly contemplate whether Germany, as an industrial powerhouse, is heading in the wrong direction on energy policy for ideological reasons, or who, without being forced, move away from important export paths for the future of the automotive sector should not be labeled "skeptics" (let alone "heretics"). Their voices are justified like anyone else's, and we should hear them out.

We are not the center of the world

We won't be able to slow or stop global trends by convincing ourselves we can set the agenda for the technologies of the future. The rest of the world has a limited interest — and, at least as I see it, less and less — in the priorities set here in Germany.

Although the democratic process in Germany may take different paths than our competitors in Asia or the Americas, I also believe science fundamentally means pursuing a question for its own sake. And regardless of practical implementation, maintaining our ability to talk about things, always thinking about new options instead of limiting them, with nothing off limits — and granting that same freedom to others as well. This is a fundamental principle of democracy.

Education and speech, which are founded on tolerance and the ability to listen, are particular expressions of our personality. After all, as scientist and philosopher Max Bense once put it: We won't get around technology by unlearning physics. And excellence can only thrive in a climate of intellectual freedom. ■

"We won't get around technology by unlearning physics."

Max Bense,
philosopher, 1910–1990

Dr. Nicola Leibinger-Kammüller

- Became the head of Trumpf GmbH + Co. KG in 2005 and has served as CEO of Trumpf SE + Co. KG, the successor to Trumpf GmbH + Co. KG, since 2022, heading an organization with more than 19,000 employees and 5.4 billion euros in sales in the 2022/23 financial year. Trumpf is an international family company with more than 70 locations in Europe, the Americas, and Asia.
- Joined the Trumpf mechanical engineering firm in 1984 in the role of public relations officer.
- Studied German and English language and literature at the University of Freiburg, followed by German and English language and literature and Japanese Studies at the University of Zurich.
- Serves as vice president of Stifterverband für die Deutsche Wissenschaft, member of the Senate of the Max Planck Society, and member of the Board of Trustees of the Technical University of Munich.

Photo: Verena Müller/Trumpf

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Improving Safety for Vapers

E-cigarettes are considered less harmful to people's health than "normal" cigarettes. But there is still reason for concern. A new development from Fraunhofer makes it possible to analyze e-liquids from different brands for the first time.

By Britta Widmann

Format and style, technology, flavor, nicotine content: The selection of e-cigarettes and the associated liquids has been growing for years. However, this increasing diversity makes it harder to generalize about health risks. A team of researchers at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM has now developed a patented system that enables testing of the liquids under controlled conditions, so the results are comparable regardless of the vaping model used.

The e-liquids used to produce vapor in e-cigarettes are generally a mixture of propylene glycol, glycerin, fragrances and flavorings, and nicotine. Under Germany's Ordinance on Tobacco Products (Tabakerzeugnisverordnung, TabakerzV), this mixture must not pose a risk to human health when either heated or not. However, for many ingredients, it is completely unknown how they will behave when heated. When the liquids are vaporized, for example, substances that pose no threat when ingested or inhaled in their cold form could break down into other substances with potentially concerning toxicological profiles. Some additives and food flavorings intended to improve the taste of e-cigarettes have also not yet been studied adequately. "Nicotine is stable when exposed to high temperatures. It keeps its molecular structure when heated to 500 degrees Celsius," explains Dr. Stefanie Scheffler, a scientist at Fraunhofer ITEM in Hannover. "Other additives are different, though. One example is sucralose, a sweetener that is also used in e-liquids, or vape juice. Sucralose is sensitive to temperature. It breaks down at just 120 degrees Celsius and forms substances that are thought to be carcinogenic. That's why more and more e-liquid manufacturers are eliminating it from their products."

Vaporized under controlled conditions

Scheffler and her team have developed a portable lab device called EVape that can be used to test e-liquids across the entire relevant temperature range. This was previously impossible for various reasons, including the fact that the temperature inside e-cigarettes varies widely depending on the model and built-in battery, with the result that different e-cigarettes can also produce different fission or thermal decomposition products. While manufacturers are required to disclose toxicology data for the liquids and their emissions, the information is generated using different e-cigarette models with diverse temperature profiles, so the results are not universally valid. Until now, there has never been a test system that covers the entire temperature range from 150 to 350 degrees Celsius. EVape, by contrast, can be hooked up to standard analysis equipment and ensures that the liquid is vaporized under controlled conditions. The results are independent of the e-cigarette used, making them comparable.

> "Sucralose is sensitive to temperature. It breaks down at just 120 degrees Celsius and forms substances that are thought to be carcinogenic."
>
> Dr. Stefanie Scheffler, Fraunhofer ITEM

With EVape, the e-liquids are tested at different temperatures under real-life conditions: "We apply small amounts of the liquid to a hot heating surface, so it instantly vaporizes. Then we suction off the vapor, put it through the analysis equipment, and see what substances are in it. They can be compared against the substances analyzed from before the vaporization process to make inferences about the thermostability of those substances," says Scheffler, describing the testing process. Initial results show that the spectrum of substances found depends on temperature.

EVape thus offers manufacturers ways to rule out potentially harmful substances even before they produce their e-liquids. Beyond that, the researchers also hope EVape will help regulatory authorities monitor the e-cigarette liquids available on the market. Scheffler comments: "We plan to license EVape and make it available to labs, regulatory authorities, and industry. Our goal is for it to be used as a reference device so e-liquids don't reach the market until after quality control using our testing system." ■

Photo: Ryan J Lane/istockphoto

About a third of the German population smokes, and many of them use vapes in addition to "normal" cigarettes or even exclusively.

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Swarming to Protect Countries and People

Drones or land robots can combine into smart swarms. A single human operator is all that is needed to control them. This marks the dawn of a new era in national defense and protection of critical infrastructure.

By Mehmet Toprak

The German military could soon get the reinforcements it so urgently needs. Plans call for robot technology to support the troops and make their jobs easier. Fraunhofer researchers are working on concepts that make it possible for a single human to direct an entire swarm of robots.

The new technology opens up a whole new range of possibilities, as highlighted at the 12th European Land Robot Trial (ELROB) in the German city of Trier in June 2024. Robot systems fielded by 18 international teams competed at the event in disciplines such as reconnaissance, transportation, and evacuating casualties. They were tasked with navigating a dark tunnel, eliminating obstacles, squeezing through narrow doors, making their way up and down stairs, circumventing booby traps, and conducting search and rescue operations for injured persons. The teams came from universities, research organizations, and companies. "The competitions are really fun. People get together in the evenings to share ideas. Some people even go back to their hotel room at night and get out their laptop to work on optimizing their program code for the next competition," says Dr. Matthias Nieuwenhuisen, a researcher from the Cognitive Mobile Systems department at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE in Wachtberg. Fraunhofer FKIE and the German Army Concepts and Capabilities Development Centre co-hosted ELROB.

Nieuwenhuisen specializes in multi-robot systems, also known as "swarm" systems. Germany's Bundeswehr has high hopes for this technology. From aerial drone swarms to groups of robots on land or in the water, plans call for the technology to soon make a crucial contribution to strengthening defense and protecting critical infrastructure. Nieuwenhuisen describes the key advantage: "It used to be that one person controlled one drone or robot. In the future, one person will deploy an entire swarm of these kinds of drones or land vehicles."

The human operator sends a command to the swarm, which could be something like surveilling or exploring a certain area, like a patch of forest or a specific area over the ocean. Once it is off on its mission, the swarm organizes itself, scanning the target area. The robots use cameras, GPS, infrared and thermal imaging sensors in the process and then analyze the incoming data. The swarm detects suspicious objects and reports them to the human operator, who can then decide how to respond.

Retired general Jörg Vollmer, former Inspector of the German Army and commander of the Allied Joint Force Command Brunssum, advises Fraunhofer FKIE in the role of Chief Advisor Military Affairs. "Swarm systems are perfect for surveilling larger areas," Vollmer explains. "They can also handle other tasks, such as helping to evacuate casualties or transport loads." In civilian applications, such as monitoring wind farms, drone swarms could be used to identify a disabled or damaged ship that is coming dangerously close or warn about potential sabotage before it occurs.

The architecture of the swarm

What makes a swarm a swarm? It isn't enough for many drones or robots to simply be operating at the same time. Researchers including cognitive ▶

Proving their value in real-world scenarios: ELROB brings together the world of military robotics from across the globe.

Photos: Fraunhofer FKIE/Fabian Vogel

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"If one aircraft fails, the swarm immediately regroups. The human operator only controls the lead drone."

Jonas Rockbach, Fraunhofer FKIE

scientist Jonas Rockbach from Fraunhofer FKIE are working to answer this question, developing concepts for the communication and command architecture of controllable swarms. "One promising concept is based on one or more controllable drones taking over to lead the swarm and direct other participants by sharing information locally. The other participants could be inexpensive aircraft that can't do much more than fly and forward sensor data. If one aircraft fails, the swarm immediately regroups. The human operator only controls the lead drone." And that means a swarm can be controlled without losing its key advantages: resilience, scalability, and flexibility.

In addition to classic drone jobs such as surveillance and reconnaissance, the multi-robot systems also handle transport missions smoothly. In these cases, a land robot follows a service member and uses cameras, sensors, and GPS to chart the path. Then, when the troops take up a position, the multi-robot system is tasked with bringing provisions, tools, or munitions to them. Finally, a group of mobile robots bring the supplies that have been ordered. Nieuwenhuisen is pleased by the progress he has seen so far: "It's working really well now, even on rough paths where things like fallen branches make it harder to get around."

The Fraunhofer researchers believe intuitive operation is key. To that end, Nieuwenhuisen and his team have equipped a jacket with motion sensors on the sleeves and are using it to control robot arms. Any service member can control the robot systems with just a small amount of training.

Quick detection of radiation sources

Another area where plans call for drones or drone swarms to help in the future is in swiftly detecting sources of radiation like those found in a "dirty bomb." Claudia Bender, a researcher with the Sensor Data and Information Fusion department at Fraunhofer FKIE, is in charge of the project. Bender and her team have succeeded in building a functioning system. Their drones, which are equipped with a gamma ray detector and additional sensors, autonomously scan a certain area while continuously gathering data about the environment and preparing a heat map showing radiation intensity. Plus, the drones do more than simply track the strength of the radioactive signal measured; right from the start, they also calculate probabilities relating to where the radiation source is most likely located. "It already takes us only a few minutes to zero in on a radiation source just a few centimeters across within an area of 160,000 square meters," Bender says.

Fraunhofer FKIE's overarching goal in all these projects is to combine these technologies into a kind of operating system that brings all the various functions, communication standards, file formats, and software modules together in a single user-friendly technology platform. Vollmer comments: "The researchers at Fraunhofer FKIE are aiming to achieve results very fast. After all, time is pressing. The goal is for swarm systems to be capable of supporting humans and protecting them against any conceivable harm not long from now — whether that means in the water, on land, or in the air." ■

Incoming: Dr. Matthias Nieuwenhuisen (right) and the team from Fraunhofer FKIE

Knowledge relay

research for safety

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Incoming: Dr. Matthias Nieuwenhuisen (right) and the team from Fraunhofer FKIE

Knowledge relay

Prof. Beyerer, what can ***research*** do ***for*** our ***safety*** in these ***troubled times***?

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Knowledge relay, episode 13

Prof. Beyerer, what can research do for our safety in these troubled times?

Series:
Knowledge relay

The times we live in have raised **many questions — questions Fraunhofer researchers are working hard to answer.** A specialist **answers a question,** then poses a **question of their own** for the **next expert** to answer — it's a **"knowledge relay."** In this edition, **Prof. Jürgen Beyerer,** head of the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB, answers a question from **Prof. Holger Hanselka,** President of the Fraunhofer-Gesellschaft.

Safety is a highly multifaceted concept. It is considered to exist when overall risk remains below an accepted level. Safety and security can be jeopardized in a variety of ways: physically, chemically, biologically, psychologically, economically, and with regard to information and information technology.

At the same time, safety is an indivisible whole; we are only safe overall if we are adequately safe from natural, technical, criminal, terrorist, and military dangers all at once.

When it comes to comprehensive safety, we also have to consider the time dimension. How do we prepare for risks, what do we do when they materialize, what is the best way to counter the effects of harms once they occur, and how do we learn from these events for the future? This kind of holistic perspective is the subject of resilience research.

The research on civil safety and defense taking place across many different Fraunhofer institutes covers almost this entire spectrum. For naturally occurring risks, for example, our research is producing predictive systems as well as systems that can be used to cope with these kinds of crises and disasters. One example is the SE/EKUS operations management and communication system. It supports spe-

Prof. Jürgen Beyerer, 62, is the managing director of the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB and chair of the Fraunhofer Segment for Defense and Security VVS.

What is the **best way to counter *the effects of*** **harms once they occur, and how do we learn from these events *for the future?***

cial police units in operational preparation, mission management and communication. This award-winning system, which has become established across Germany as a standard, provides web and server technologies along with mobile applications. In this way, forces on the ground can use mobile apps to stay up to date in an emergency.

Potential criminal and terrorist plots must be identified early on so they can be foiled wherever possible. Technologies developed at Fraunhofer can help to investigate and prosecute crimes, whether committed digitally or physically. Risks arising from technical aspects must be countered with suitable design methods, technologies, and protective mechanisms to ensure lasting safety right from the start.

And ultimately, the Russian war of aggression against Ukraine shows that we also need to considerably ramp up our efforts to ensure military safety.

Our defensive capabilities of tomorrow and our strategic sovereignty depend to a crucial degree on excellence in defense research, like that achieved by the institutes that make up the Fraunhofer Segment for Defense and Security VVS.

In Ukraine alone, a third of the country's area is said to be littered with mines. This is making technologies devised by Fraunhofer researchers more and more important. These include ultrawideband radar, which penetrates deep into the ground thanks to its frequency range of between 400 megahertz and 6 gigahertz. And sometimes, a short burst of water is all it takes to disarm booby traps with less risk — the kinetic impulse produced by a pyrotechnics-powered jet of water can destroy mines.

The various aspects of safety are interrelated in that many of the technical and organizational measures involved in guarding against risks and coping with crises and disasters are useful for different aspects of safety at the same time.

Because safety takes so many forms and is such a complex topic, researchers should also truly take a holistic view of the subject. In particular, we should do away with the distinction between "good" and "bad" research on safety and security. The past few years have been a turning point of sorts in showing that this politically motivated division between the civilian and military sides is outdated and no longer produces the right answers to the challenges we face.

Moving away from these narrow distinctions would definitely help to realize many synergies in research so we can make an even more impactful technological contribution toward full, all-encompassing safety. ■

In the next issue:

How can **Fraunhofer contribute *to the worldwide fight*** **to preserve *biodiversity*?**

Photo: Fraunhofer IOSB

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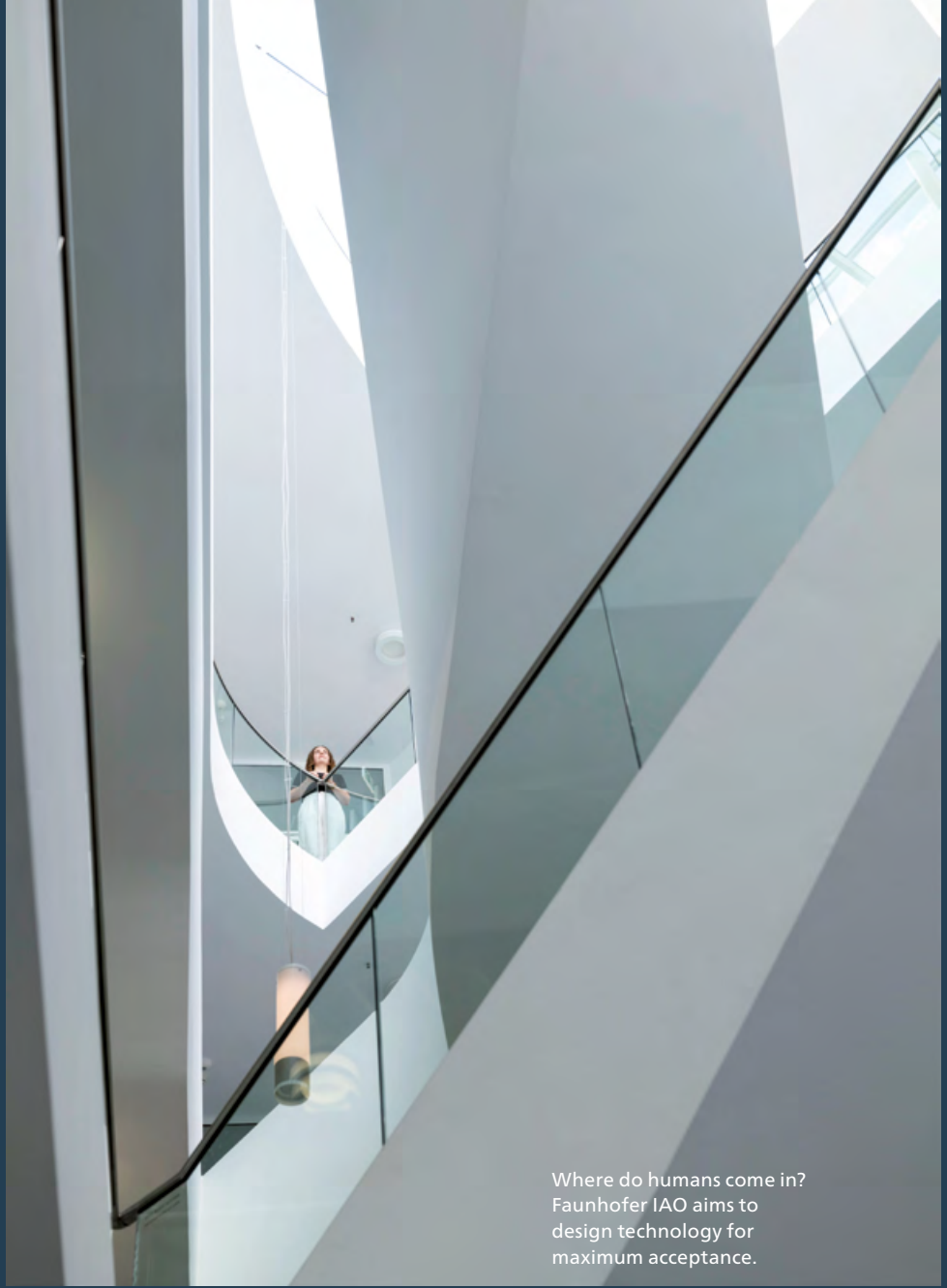
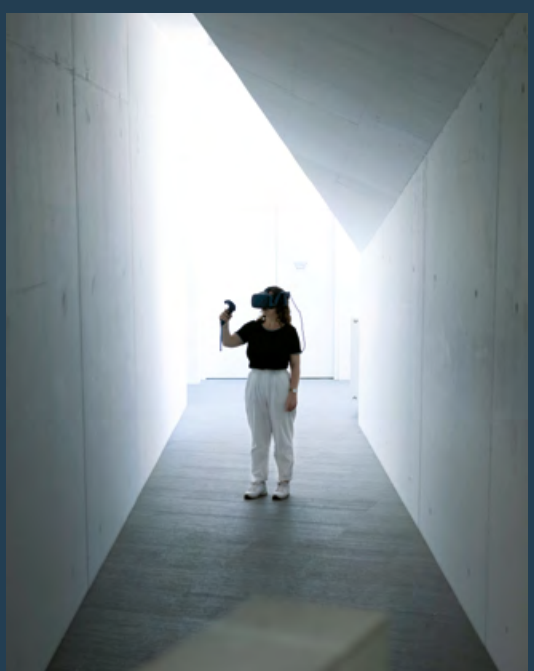
What does the future hold? Engineering psychologist Selina Layer conducts research at Fraunhofer IAO on human-robot interactions.

Does high tech come in a cute version, too? Layer with MiRo-E, a companion robot for older people.



Where do humans come in? Faunhofer IAO aims to design technology for maximum acceptance.



Now with Brainpower!

The next stage in the evolution of technology is coming up: Artificial intelligence is poised to turn robots into all-around self-learners, helping out in industry, logistics, nursing, and private households. Will smart machines radically reshape our lives — and especially our working lives — not long from now?

By Beate Strobel, photography: Sven Döring

How will we work tomorrow? Fraunhofer helps companies harness the power of AI for robotics.

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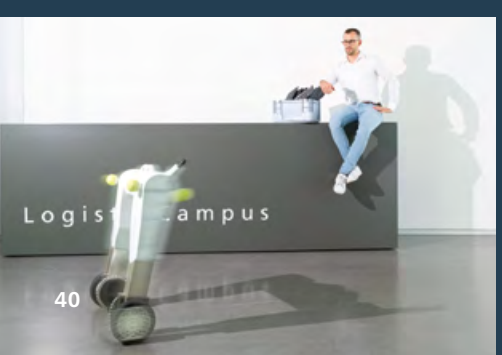
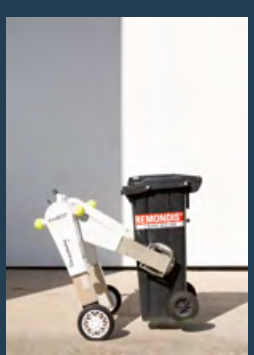
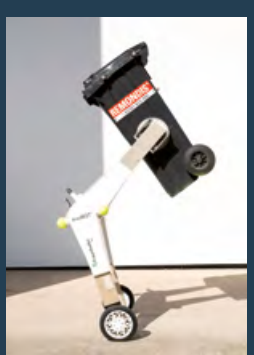
Need a helping hand? The evoBOT®'s job is autonomous transportation of objects.

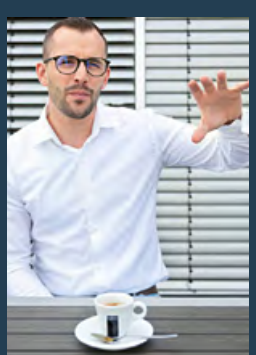
Where does the path lead? Leon Siebel-Achenbach and his team of researchers at Fraunhofer IML deliberately designed the evoBOT® to be modular so it would cover many possible use cases.

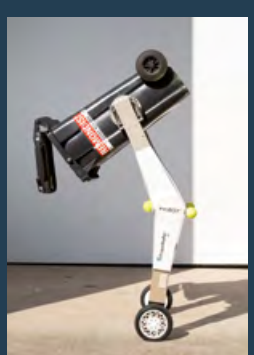
Scan here to watch the evoBOT®'s test drive at the Munich airport.







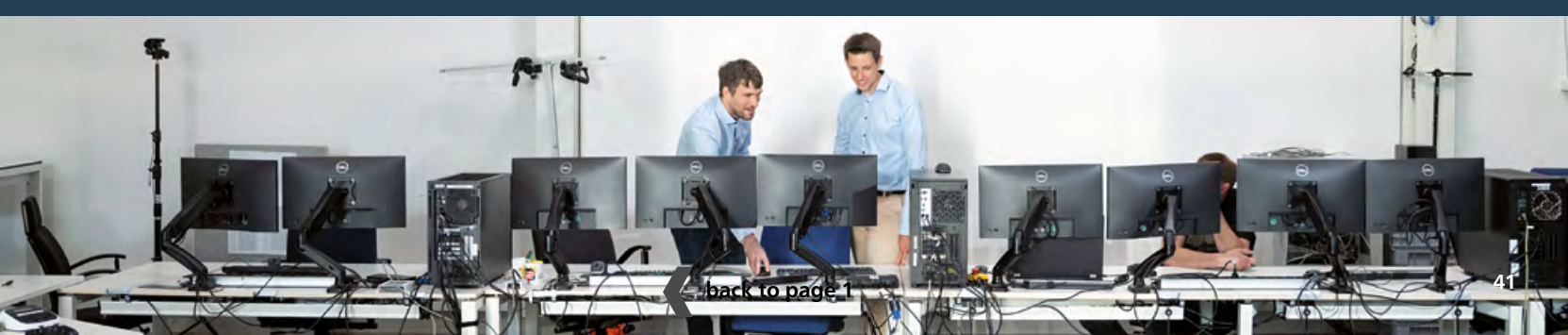




How do AI robots learn? Christian Jestel (below) uses rewards and punishments to train the RoboMaster during simulation exercises at Fraunhofer IML.

Care for some AI with that? Computer scientist Sebastian Hoose (also pictured at top right) developed a portable system called "RAI — Remote AI" at Fraunhofer IML. It equips robots with cognitive abilities.

Packed with features, but that isn't all: Sebastian Hoose's portable RAI — Remote AI system is also a winner for its pleasing design.



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It still has a somewhat alarmingly wobbly gait at this point. But Optimus can take a raw egg out of a carton and place it in an egg cooker. There are high hopes for the broad-shouldered metal bot: Elon Musk, head of Tesla and the official father of Optimus, has predicted — in his usual grandiose style — that humanoid AI robots like Optimus will completely revolutionize the economy.

Optimus is not the only one of its kind. Figure 2, from the tech labs of American software firm OpenAI, can talk and load a dishwasher, while Atlas, from Boston Dynamics, can turn a somersault and complete even a difficult obstacle course. Armar-7, created by the Karlsruhe Institute of Technology (KIT) to provide day-to-day support, can open doors, interact with humans, and prepare small meals. These achievements are spurring higher public expectations for AI-based robotics. Some of today's visionaries make it sound as though the age of Terminator is already upon us.

Many experts at Fraunhofer take a different view. "Developments like Optimus, at Tesla, garner a lot of attention, of course. But the actual innovation is occurring elsewhere. A welding robot might not be as sexy as Optimus, but it already plays a much larger role in industrial production today," says Dr. Werner Kraus, a mechatronics engineer and head of research on automation and robots at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart. "We have big and well-founded doubts that humanoid robots will make a significant contribution to value creation in the next two to five years."

Even so, Kraus agrees that smart robots are a must: "AI needs robotics — and robotics needs AI," Kraus says. This represents the perfect marriage of two strands of research. Until now, robots didn't have the intelligence needed to do more than execute a fixed set of pre-programmed motions. And artificial intelligence, for its part, lacked the body it would need to take action in the real world. "The vision is to have a robot that can really think and take action proactively at some point," Kraus says. "So far, though, we're just happy if we can give a robot a certain level of flexibility in carrying out its tasks, like making it able to grab even objects that it has never seen before."

Bin picking: a well-known issue

A team of researchers at Fraunhofer IPA has been working on teaching robots to pick things up for several years now. Automating the process of "bin picking" is considered a core problem in robotics.

> "AI needs robotics — and robotics needs AI."
>
> Dr. Werner Kraus, Fraunhofer IPA

Many areas of industrial manufacturing generate large volumes of bulk items that need to be sorted and separated as accurately as possible. It is a monotonous, physically demanding, high-cost task, which makes it a perfect candidate to be assigned to a robot instead. But it is also a huge challenge for robots: The bulk of the industrial robots currently used for these jobs utilize laser scanning to be able to at most tell previously learned objects apart.

Artificial intelligence attempts to mimic human cognitive abilities by recognizing and sorting incoming information like Homo sapiens does. However, that doesn't mean it identifies how to solve the problem. In this machine learning method, the algorithm develops a way to execute tasks correctly, but only as part of a simulation. Through training with very large volumes of data, "neural networks" — a subdiscipline of machine learning — can recognize patterns and connections and use them as a basis for making decisions and predictions. And that means they improve over time.

Machine learning can also help deal with unknown objects. In the Deep Grasping research project, neural networks were trained in a virtual simulation environment with the aim of recognizing objects and then transferred to real-world robots. The robot system is now even able to recognize components that are hooked together and plan its grasping motions so it can unhook them. The researchers are also working on automation systems that configure themselves, for example through automatic selection of grippers and gripping poses — "automation of automation", so to speak.

Picking things out of a bin and setting them down somewhere else might sound underwhelming in light of the hopes raised by Optimus and similar robots. But these deceptively small jobs represent huge advances in robotics. Kraus points to what is known in the field as Moravec's paradox: Tasks that seem incredibly simple to us as humans are actually extremely difficult for robots. Or, as Canadian researcher Hans Moravec put it, "It is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility."

The goal of incorporating AI into robotics is to help overcome these challenges, and this is viewed as one of the groundbreaking trends in the digital transformation of industrial manufacturing. Market research firm Mordor Intelligence, for example, forecasts an annual growth rate of 29 percent for the robotics market between now and 2029. Smart industrial

robots can enhance production speed, accuracy, and security, facilitate troubleshooting, and make production more resilient through predictive maintenance.

To support the industrial sector on the way to Industry 5.0, Fraunhofer IPA teamed up with the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart in 2019 to establish the AI Innovation Center "Learning Systems and Cognitive Robotics", an applied branch of Cyber Valley, Europe's biggest research consortium in the field of AI. The goal is to conduct practical research projects as a way to bridge the gap between the technologies involved in cutting-edge AI research and SMEs.

In Magdeburg, the Fraunhofer Institute for Factory Operation and Automation IFF has partnered with companies to create use case labs where the manufacturing sector can present its automation requirements and devise customized smart robotics solutions. The cutting-edge Lamarr Institute, one of five university AI competence centers across Germany to receive ongoing funding as part of the German federal government's AI strategy, is designing a new generation of artificial intelligence that will be powerful, sustainable, trustworthy and secure and contribute to resolving key challenges in industry and society. The Fraunhofer Institute for Material Flow and Logistics IML is contributing in various ways, including with its PACE Lab research infrastructure.

This past July also saw the launch of the Robotics Institute Germany (RIG), which is to become a central point of contact for all aspects of robotics in Germany. The competence network is led by the Technical University of Munich (TUM) and has received 20 million euros in funding from the German Federal Ministry of Education and Research (BMBF). Three Fraunhofer institutes — IPA, IML, and the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB — are all involved. The goals of the RIG are to establish internationally competitive research on AI-based robotics in Germany, use research resources effectively, provide targeted support for talent in the field of robotics, and simplify and advance the transfer of research findings to industry, logistics companies, and the service sector.

Developing purpose-built robots

Robots that are newly joining the team do not necessarily have to walk in on two legs, which is actually not the most effective form of movement according to the current state of technological advancement: too energy-intensive, too slow, too high a risk of falling. "Overall, a humanoid robot would be completely overdeveloped for use in industry and logistics: too many actors, too much freedom, too many motors that aren't even needed for the relevant use case," argues Leon Siebel-Achenbach, an electrical engineer and deputy head of the IoT and Embedded Systems department at Fraunhofer IML. "Instead, we need to build more robots that can deliver significant performance, especially for industries that are already feeling the squeeze from the shortage of skilled workers."

> "Overall, a humanoid robot would be completely overdeveloped for use in industry and logistics."
>
> Leon Siebel-Achenbach, Fraunhofer IML

A creative project team at Fraunhofer IML developed a robot they call the LoadRunner for the logistics sector back in 2019: an autonomous high-speed vehicle that looks like an oversized robot vacuum, moves securely and proficiently at a rate of up to ten meters per second — even as part of a swarm — thanks to smart vehicle coordination, and can join forces with other robots as needed. The LoadRunner can transport loads of up to 30 kilograms, making it perfect for sorting and distribution tasks.

Under the leadership of Patrick Klokowski, the LoadRunner was followed in 2021 by the evoBOT®: "The project's objective is to develop an agile robot for use in logistics that can independently pick up, transport, and actively deliver loads at a height that is also served by humans," Siebel-Achenbach explains. Instead of walking on two legs, the evoBOT® rolls along on two wheels — and is quite nimble at it, too. The evoBOT® is a type of robot known as an autonomous mobile robot, or AMR. It moves based on the inverted pendulum principle familiar from the Segway self-balancing two-wheeled electric scooter. It has "arms" equipped with grippers to the left and right that it can use to lift and transport objects.

At the end of the project, the goal is for the evoBOT® to be able to harness artificial intelligence to recognize and chart its environment and the surface it is moving on so it can move freely around a defined space and avoid obstacles. Camera systems help it to identify and classify load items, so it can lift them correctly, balance appropriately according to their weight, and set the goods down in a different location. "At that point, the evoBOT® could be used completely autonomously as a service robot," Siebel-Achenbach explains. "This would be interesting for fields such as the logistics sector or even in hospital settings, where the robot could be used to transport beds or distribute medications within the facility. We deliberately developed it with a modular approach so that it is maximally scalable in size while also covering as many use cases as possible." ▶

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The new learning paradigm

"AI will let us find new and better solutions for various complex issues, even though we can't understand in detail just how the AI works," says logistics expert Prof. Michael ten Hompel, who retired from his position as head of Fraunhofer IML in April. "That also means we're moving toward a new paradigm in learning."

One visible example of this is the iDEAR project at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg. The project's primary aim is to enhance sustainability by reusing and recycling resources derived from the approximately 54 million metric tons of e-waste generated per year (figures as of 2019). Another central question is what role robots might play in this development. After all, AI-supported robots would seem to be a perfect fit for dealing with end-of-life electronics.

However, high-tech devices are much more complicated to disassemble than to assemble, as there is more to it than joining a known number of parts together according to specified work steps. "Computers are built differently depending on the manufacturer, and there are no longer any instructions for many old devices," explains Prof. Norbert Elkmann, head of the Robotic Systems department at Fraunhofer IFF. "On top of that, you can't see what's going on inside the computer from the outside. That means the robot has to autonomously generate the action for the next step during disassembly."

The researchers are thus on the cusp of a paradigm shift: "Working with a lot of unknowns can't be done with a static program. It requires an adaptive approach," says Magnus Hanses, group manager for cognitive robotics at Fraunhofer IFF. "Whenever you have an activity where a person says they decide on the next action situationally and based on intuition, it gets tough for programmers. But AI can help with that." The objective of iDEAR is to develop automation systems that can respond not only flexibly, but also intelligently — from product identification and evaluation to dynamic cost-effectiveness assessment and through to planning and executing disassembly.

So how do you teach a robot all that? "Training on the real-world system wouldn't be cost-effective, because it takes too long and is also too risky," Hanses explains. "Our approach involves modeling the dismantling process in a simulation. Any number of virtual robots can work in digital space at the same time and at a much faster pace without any safety concerns." This makes it possible to automatically find solution strategies for subprocesses with high variance. To achieve this, data from a digital twin flows continuously into the automated disassembly process in the real world, just as information from the dismantling process is reported back to the digital twin. Human experience is also fed in to further enhance the level of automation. However, Hanses says, AI should only be used where it actually provides added value: "Analytical methods are a much more efficient way to tackle many subprocesses."

> "Whenever you have an activity where a person says they decide on the next action situationally and based on intuition, it gets tough for programmers. But AI can help with that."
>
> Magnus Hanses, Fraunhofer IFF

Bridging the gap between simulation and reality

There are many advantages to learning in the digital simulation — but it also has one vulnerability. The virtual learning environment is never 100 percent the same as the real world. "The challenge for researchers lies in minimizing this 'reality gap,'" computer scientist Christian Jestel explains. There are two possible approaches here. The simulation can either be designed to be as realistic as possible, or it can encompass many possible versions of reality so the neural network learns to generalize and can then find its way around even unfamiliar environments later on.

Jestel's work at Fraunhofer IML involves using what are known as "RoboMasters": robots from a Chinese manufacturer that he breaks down to just the chassis and wheels. These elements are used as a research platform for deep reinforcement learning — essentially, a system of rewards and punishments. In one simulation developed by Jestel, the AI scores more points the faster it reaches a predetermined destination with no disruptions. Points are deducted if it moves away from the endpoint or collides with an obstacle.

"At the start, the AI just tries everything. But in the very next training rounds, it has already learned to avoid the actions that cost it points the last time," Jestel explains. Equipped with the trained AI, the RoboMasters can then make real-world directional decisions autonomously, without any centralized input. This is done based on the input on their surroundings from laser scanners. This training approach could also change the logistics industry not long from now. "Sometimes people will say a RoboMaster is just a toy," Jestel says. "But this project isn't about the vehicle itself. ▶

How close is too close? Prof. Elkmann and Magnus Hanses also focus on the issue of safety during human-robot collaboration in their research at Fraunhofer IFF.

Prof. Norbert Elkmann with the ANNIE assistance robot.

Little helper: Pepper from SoftBank Robotics can respond to gestures, mimics and speech.

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Fraunhofer IOSB develops the sensor technologies and algorithms to help heavy vehicles move around autonomously.

Dr. Janko Petereit works at Fraunhofer IOSB, getting heavy vehicles ready for autonomous work in environments that are dangerous for humans.

What does a robot see? Exploring the terrain with sensors and optical cameras.

It's about the idea behind it. And that idea has the potential to transform many applications for industrial mobile robots."

Plug-in intelligence

Thanks to artificial intelligence, robots are becoming more and more emancipated from humans. Right now, the potential uses for robots like these are impossible to foresee, but that is exactly what computer scientist Sebastian Hoose, who works as a research scientist at Fraunhofer IML, finds so fascinating about this subject. "Everything is so marvelously complicated, with change coming thick and fast and bringing new and exciting aspects with it," he says. To help small and medium-sized enterprises keep up, he is currently working to develop software that can be trained and used as generically as possible. Remote AI, or RAI, can be thought of as AI to go: artificial intelligence in a box that can be simply dropped into conventional transportation vehicles, quickly and easily adding autonomous capabilities and upgrading them with specific attributes. The algorithms in the AI box allow the robot to move around in defined spaces and handle transportation-related tasks. Another advantage to the remote approach is that what individual vehicles learn can easily be shared with other robots or even an entire fleet.

> "Developing an intelligent overall system requires expertise from many different fields."
>
> Dr. Janko Petereit, Fraunhofer IOSB

Upgrading instead of buying new equipment: "RAI makes the technology economically interesting for SMEs," Hoose says. As an additional module, the AI box acts as a kind of bridge between conventional and AI-based robotics. Right now, the remote approach is still limited by the challenge that every transportation robot has a different interface depending on the manufacturer, which means the box cannot simply operate as a plug-and-play solution. "To help with that, we've developed a standard from the RAI side," Hoose explains. Now all that needs to be done during installation is to implement a short piece of code. "There's no way around that unless and until there are industry standards," he says.

Robots for dangerous missions

The AI-based approach to robotics is interesting for two main reasons. First, there are the industrial sectors that are experiencing a shortage of skilled workers. Robot systems can fill the gap there by taking on certain jobs. Second, there are also tasks that are too difficult, cumbersome, or dangerous for humans to perform. These include working on the ground in crisis or disaster situations, at landfills and contaminated sites, or in terrain riddled with land mines. The ROBDEKON competence center focuses on developing smart robot systems for these types of environments that are risky to people. Initiated by the German Federal Ministry of Education and Research (BMBF) in 2018, the center has received about 20 million euros in funding. Fraunhofer IOSB is responsible for the overall coordination of the network. Researchers there have been working for some time to develop various base functions that can add a certain level of autonomy and intelligence to existing robot systems and vehicles, much like the RAI box. ▶

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"We work on really large robot systems," says Dr. Janko Petereit, the group manager for autonomous robot systems at Fraunhofer IOSB, who is also the coordinator of ROBDEKON. Areas of focus include excavators that can be used to retrieve and dispose of hazardous materials or remove contaminated layers of soil without any human operator at all. Petereit comments: "Thanks to various smart algorithms for localization, mapping, obstacle recognition, and movement planning, the robot systems can move around independently, even in unfamiliar terrain, and complete tasks. This enhances efficiency, relieves some of the burden on specialists, and above all, it can reduce accident and health risks when there are jobs to do in hard-to-reach or dangerous environments."

Petereit demonstrated just how well this already works at the BMBF Innovation Forum in Berlin in May. Participants were invited to assign tasks to ALICE, a 24-ton excavator located some 500 kilometers away in Karlsruhe, having it perform missions like retrieving potentially contaminated barrels. ALICE used AI to sense and interpret its environment and perform the tasks completely autonomously.

Fascination for many fields

What many Fraunhofer researchers find especially fascinating about AI-based robotics is the interdisciplinary aspect: "Developing an intelligent overall system requires expertise from many different fields," Petereit explains. And those fields include more than just computer science, electrical engineering, and mechatronics. Psychology, law, and ethics are also involved. After all, intelligent robots, many of them already capable of speech, will increasingly be a fixture of everyday life in the workplace, at home, and in public settings, and that will change the way we look at high-tech devices and how we perceive them and interact with them. The more humanoid their appearance, for example, the more we tend to believe robots are not only intelligent, but also have human characteristics and feelings. In June 2024, a robot administrative officer operated by the Gumi City Council in South Korea ran in circles for a while and then flung itself down a six-foot flight of stairs, immediately sparking theories that the technical failure was actually a robot suicide caused by overwork.

Selina Layer studied engineering psychology, a relatively new discipline. She now works as a research scientist at Fraunhofer IAO, studying the underlying issues in human-machine interactions and how to optimize them. While working on the NIKA project, which focuses on user-centered interaction design for context-sensitive and acceptable robots, Layer wrote her bachelor's thesis on the topic of what robots need to be able to do and how they should behave in order to be accepted by older people as well as younger groups and offer them added value. The project's results were stored as "interaction patterns" in a pattern library, a collection that goes back to research done by Dr. Kathrin Pollmann from Fraunhofer IAO. In the long term, the goal is for the library to help with selecting the right behaviors for a robot and transmitting them to the device, based on the user and situation. "We plan for the pattern library to grow into a kind of basis for designing social interactions between humans and machines," Layer explains.

> The robot's motivations should also be clear so people will accept them as they go about their task: Why is this machine here, and what is it doing?
>
> Selina Layer, Fraunhofer IAO

Layer's current research project revolves around three service robots that are intended for use not in the home, but rather in public settings, where they could be used for tasks such as street sweeping or transportation. Right now, Layer says, machines like these are used primarily overnight in industrial production facilities — when few people see them. Even so, both robots and people need to be prepared for these encounters. "Initial studies conducted as part of our ZEN-MRI project showed, for example, that pedestrians are not very effective at anticipating how and where a machine is going to move next," Layer explains. The risk of "unplanned proximity" is especially high when people are distracted, for instance by conversation or looking at a cell phone. "To prevent collisions, robots need to call more attention to themselves in these situations — but without being annoying due to the noise they make," Layer says.

The robot's motivations should also be clear so people will accept them as they go about their tasks, especially in the early years of the growing "robotization" of the world around us: Why is this machine here, and what is it doing? "If we don't make it clear just what kind of socially desirable job the robot is doing — which can be in the form of a sign posted where it is working or a sticker on the robot itself — there's an elevated risk of attacks, up to and including property damage," Layer explains.

Seventy-three percent of those surveyed for the ZEN-MRI project were afraid they might be injured in a fall after colliding with a robot, for example. Just under half are worried about potential security vulnerabilities caused by problems with

a robot's hardware or software, and nearly one in three people view robots as potential obstacles. These kinds of fears and perceptions contribute to the phenomenon known as "robot bullying," when people attack a robot.

Make it cute — but not too cute

To prevent these kinds of situations and make it easier for people to interact with machines, the RAI box from Fraunhofer IML was given two stylized eyes and two speakers, positioned to the left and right, that look like ears. Two dots vaguely reminiscent of eyes give the evoBOT® a cute, somewhat human appearance. "The point of the friendly design is to lower people's inhibitions about interacting with the robot," researcher Siebel-Achenbach comments. "We achieved better than expected results with the design. Although it's a prototype that still has a few development cycles ahead of it before it's ready to interact properly with people, we're surprised by how open people are when approaching the robot." The principle also works in reverse. The mobile cleaning units used in the ZEN-MRI project were deliberately designed to look nothing like humans or animals to keep from prompting an unconscious desire for interaction.

"Robots aren't all that established in people's everyday lives yet, which is what I think makes research in this area so exciting and valuable," Layer explains. "It's about shaping standards: How will we communicate with robots — and them with us — down the road?"

A question of safety

Industrial robots still operate primarily behind a protective grate or bars. With cobots, which can be used without a protective fence, the subject of personal safety and safety certification is a major factor. But intelligent autonomous mobile robots (AMRs) and humanoid robots achieve new levels of safety and compliance with safety requirements. "The safety question has proven de facto to be one of the most significant challenges when it comes to collaboration between humans and robots in shared work settings," explains Prof. Norbert Elkmann from Fraunhofer IFF. "It is a key reason why reality has fallen short of industry's hopes for fast implementation of robots and cobots in production operations."

A 2018 study by the World Economic Forum, for example, predicted that robots would be responsible for some 52 percent of all hours worked — the majority — by 2025. Elkmann says we are still far from achieving that. Factors include the time, effort and expense involved in planning and implementation and the fact that the process of CE marking for applications involving human-robot collaboration is often very intricate. Mobile robots give rise to a whole new type of challenges: the actions and scenarios that come into play where humans and robots meet are much harder to plan for than is the case with stationary robots. With this in mind, Fraunhofer IFF is taking a new approach: Every action performed by a robot undergoes digital risk analysis and then gets a CE mark. "AI-supported robots that plan and execute their movements autonomously are diametrically opposed to the safety and certification principles we have today, which are the product of deterministic systems," Elkmann explains. "But we'll get there."

> "Industry, and people in general, have high expectations when it comes to intelligent and possibly also humanoid robots — in some cases actually quite excessive expectations."
>
> Norbert Elkmann, Fraunhofer IFF

Fraunhofer IFF works on safety standards for human-robot collaboration that are then reflected in official standards worldwide. For example, researchers at the institute have developed a test system with a pendulum that — with the ethics committee's approval — will enable collision trials with human test subjects to determine the pain threshold: At what point does a collision start to hurt, and where on the body do people experience pain? The levels of stress in relation to force, pressure, and impact energy determined in studies like these can then be translated to verified limits, which will be critically important to the process of designing safe human-robot collaboration. The study's results act as a snapshot of the current state of technological advancement worldwide. The data also enable ultra-precise simulation of physical contact between people and robots. This is a key prerequisite in ensuring that in the future, AI-controlled robots move in such a way that people are not harmed if the two sides come into contact.

"Industry, and people in general, have high expectations when it comes to intelligent and possibly also humanoid robots — in some cases actually quite excessive expectations owing to the latest news from the U.S.," Elkmann says. "Robotics developers still have a number of fundamental tasks ahead of them before products that are truly versatile and make financial sense hit the market. The safety questions will need to be resolved, too. It's really fun to be here supporting and contributing to this development." ■

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3×3 Questions: AI robotics

Dr. José Saenz
Group manager for assistance, service, and industrial robots at the Fraunhofer Institute for Factory Operation and Automation IFF

"We're still far from seeing robots as generalists."

1 What do you see as the biggest misconception about humanoid robots in society?
That it won't be long before they're as powerful and versatile as we might see in a sci-fi movie, and all at an affordable price. Robots are definitely getting more and more powerful, and they can be put to use faster and at lower cost. But we're still far from seeing robots as generalists, just as there's no such thing as artificial general intelligence.

2 Thinking ahead to the year 2050, what role might humanoid robots play in production and home life at that point?
Humanoid robots will first be involved in tasks where the advantages outweigh the high costs. To me, that includes activities in settings where there are dangerous environmental or working conditions, where it isn't worthwhile to develop a task-specific system, or for which there aren't enough qualified human staffers. Examples include service tasks like installing and maintaining offshore wind turbines and jobs in hospitals and nursing facilities, but not in private households.

3 What would a robot that you'd like to own yourself need to be able to do?
Aside from traditional tasks like laundry, ironing, and cleaning, my robot for use at home would also need to be able to handle more sophisticated tasks like sorting laundry (please don't ruin my wool sweaters), finding badminton birdies lost under the hedge (without destroying the hedge), and clearing clogged drains. The robot should need as little space as possible, too. The last thing I want is a robot constantly underfoot when I'm at home. ■

Florian Steinlehner
Head of Division Processing Technology at the Fraunhofer Institute for Casting, Composite and Processing Technology IGCV

"I hope that robots will be part of the solution to the shortage of skilled workers and labor in general."

1 What do you see as the biggest misconception about humanoid robots in society?
Because they look like people, humanoid robots can give the impression of having human intelligence, emotions, or consciousness. That can lead to excessive expectations and to fear. In my view, though, even a humanoid-looking robot is always based on algorithms and data. Robots won't replace people. Instead, they will perform tasks that are too dangerous or harmful for humans to do.

2 Thinking ahead to the year 2050, what role might humanoid robots play in production and home life at that point?
I hope that robots, and humanoid robots in particular, will be part of the solution to the shortage of skilled workers and labor in general and will be used as flexible workers. In addition to complex specialized tasks, humanoid robots are adaptable, so they can work closely with humans and boost productivity. In people's personal lives, robots will come to act as adaptive assistants, playing a key role in environments designed for humans by helping out with household tasks and personalized healthcare.

3 What would a robot that you'd like to own yourself need to be able to do?
To me, a robot should be able to handle multifunctional tasks with flexibility and adaptability. Use as a personal assistant would be really helpful across all kinds of situations in life. To me, that includes routine household, organizing and administrative tasks, help with scheduling, and monitoring people's health. At the same time, the robot should act as an interface with the increasingly smart technology used in the household. ■

Dr. Martin Feistle
Expert on artificial intelligence in production at the Fraunhofer Institute for Casting, Composite and Processing Technology IGCV

"There's no need for industrial robots to have a human appearance."

1 What do you see as the biggest misconception about humanoid robots in society?
The biggest misconception is the assumption that no matter how they are designed, intelligent robots can tackle highly specific tasks relating to society or take over decisions from key personnel. Specifically, there is a widespread misconception that humanoid robots will be able to take on everyday tasks like driving a car without limitations. Their human appearance and ability to take action do not mean they are capable of fully taking over human-related tasks.

2 Thinking ahead to the year 2050, what role might humanoid robots play in production and home life at that point?
Humanoid robots, combined with artificial intelligence, could be used as discussion partners when we are weighing the various factors involved in a decision. By contrast, I don't think humanoids will come to be much of a presence in production environments per se, as there's no need for industrial robots to have a human appearance. In private life, a humanoid might be viewed down the road as a contact person that also handles recurring tasks.

3 What would a robot that you'd like to own yourself need to be able to do?
A humanoid robot like that definitely has to act like a human. Beyond that, it would need to be able to make a to do list of everyday tasks on its own and take care of them situationally. I'm thinking there of things like clearing away a glass that has been used. A humanoid needs to be able to gauge the person's gestures, facial expressions, and tone of voice to see what their mood is like and either step back or lean in to help. That will be crucial to arriving at full coexistence and acceptance. ■

Human or robot? That isn't the question. The Fraunhofer institutes (photo: Leon Siebel-Achenbach, Fraunhofer IML) develop solutions for interaction between humans and technology.

Scan here to see what the robots at Fraunhofer IPA do at night.

Photos: Fraunhofer IFF, Fraunhofer IGCV / Rebekka Amann, Jo Teichmann, Sven Döring

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An Apple a Day

Germany's fruit growers are feeling the squeeze from climate change and rising production costs. How can the future of apple production be made more cost-effective and sustainable?

By Beate Strobel

Apples as far as the eye can see: A walk through an orchard in Germany's Altes Land region in the autumn reveals trees groaning with ripe fruit, their branches bending to the ground. So, is everything going well in Germany, an apple paradise? Sadly, no. "Fruit growing needs to undergo a digital transformation," says mechatronics engineer Frederick Blome, a scientist at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Stade. "AI and smart tools can help fruit growers further increase their yields, even amid climate change, while also using valuable resources like water and crop protectants more efficiently."

Apples are the most popular fruit in Germany, with per capita consumption at more than 24 kilograms a year. With demand so high, the major apple-growing regions in the country — chiefly the Altes Land region, between Stade and Hamburg, and the Lake Constance region — have seen a boom in professionalization over the past 50 years, going from mixed orchard and meadow patterns with tall, labor-intensive trees to dense orchards with up to 20 times as many trees packed into the same amount of land, with shorter trunks and smaller crowns that put the fruit within easier reach for harvesting.

But now, climate change is worrying fruit growers from the Elbe river in the north all the way to Lake Constance in the south. Average temperatures are on the rise, prompting apple trees in the Altes Land region to blossom some three weeks earlier than they did in the mid-1970s. And that increases the risk that the delicate flowers will be destroyed by a late freeze. Apple quality has suffered

> "Fruit growing needs to undergo a digital transformation."
>
> Frederick Blome, Fraunhofer IFAM

Favorite fruit: Some 30 varieties of apples are grown across about 33,100 hectares of land in Germany.

Germans eat more than **24 kg of apples** per capita every year.

Photo: Max Faber/plainpicture

from longer periods of drought, so apple growers are increasingly forced to rely on irrigation technologies. Hotter summers also create more favorable conditions for pests such as the codling moth, whose larvae ("worms") mature inside apples, spoiling the fruit so it cannot be sold. Plus, newer insect pests such as the brown marmorated stink bug, which is native to Asia, are also increasingly making their home in Germany as the climate warms.

Understanding what every tree needs

All of these unfavorable developments call for new responses. With support from the German Federal Ministry of Food and Agriculture (BMEL), researchers began working on the SAMSON (Smart automation systems and services for fruit growing in the Lower Elbe region) joint research project, coordinated by Fraunhofer IFAM, in 2023. They are devising high-tech solutions intended to facilitate the digital transformation of fruit growing. Soon, collecting and analyzing seasonal growing and harvest data could help fruit growers better understand how factors such as climate, weather events, water use, soil care, flowering, and the previous year's yield are interconnected and respond accordingly.

As a first step toward that aim, as much data as possible will be collected over the course of the year. Since March, a tractor with a sensor box mounted on the front has been driving at regular intervals along the apple tree trellises of an experimental field in the Altes Land region. Ultimately, the goal is for a high-tech box unit like this — packed with stereo cameras, a LiDAR sensor for measuring depth, and measuring units to track the tiniest movements and ensure ultra-accurate position location — to support fruit growers with routine tasks around the orchard, automatically and continuously collecting vast troves of data about the trees in the process. This data will be processed by artificial intelligence. The AI will be used to determine things like tree growth, bloom intensity, fruit quantity, and possible pest infestation. Blome explains: "If the AI detects insect pests on a tree, the farm manager no longer needs to take crop protection action on all the trees at once, as they used to. Now, they can treat only the infested trees. That reduces the use of crop protectants." AI is also expected to yield similar benefits in terms of the number of blossoms on the trees. The previous practice was to use chemical agents to thin the blossoms across the board in springtime, but the result can be that either too many or too few blossoms are destroyed on some trees, reducing yield or causing a ▶

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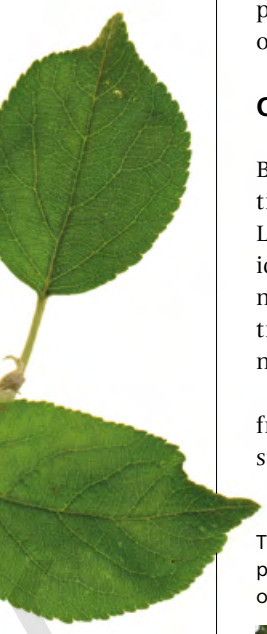
tree to bear too many small, low-quality apples. In contrast, individually determining the ideal blossom count for each tree makes it possible to target the chemical thinning process, which conserves resources, saves money, and optimizes yield.

Orchard gets a digital twin

Beyond individualized actions, large-scale data collection also serves to create a digital model of the orchard. Long-term monitoring of the tree and its fruit can help to identify targeted measures for optimum care. The technical time, effort, and expense should pay off, since apple trees bear fruit for a very long time. They are generally not replaced with younger ones for two decades.

Development of automated water management and frost protection systems and establishment of a weather station network for the Altes Land region are also part of the SAMSON project. Blome explains: "We have two major goals. First, we plan to develop precise prediction models and recommend specific actions to fruit growers based on those models. And second, we also want to increase automation in fruit growing." For example, there are plans to link pumps with a smart farm management system to help automatically adjust irrigation to reflect actual requirements. The intelligent system also provides an early warning to the farm management if there is a risk of a freeze.

So what about farmer's almanacs and gut instinct? Fruit growing operations left those kinds of traditions behind a long time ago. Instead, smart technologies make it possible for them to run their orchards sustainably and with maximum efficiency. In this way, as German federal agriculture minister Cem Özdemir has noted, the results of the SAMSON project will not only benefit Germany's fruit growers, but also be of great interest internationally. ■



The sensor box developed as part of the SAMSON project, which is used to collect and process data in orchards, can be mounted on any tractor.

Photo: Fraunhofer IFAM

Hot or Not?

Germany needs antimony for car batteries, solar panels, and military equipment. Now, China is planning export controls that will cut the metalloid's availability by nearly half. The Fraunhofer Institute for Integrated Circuits IIS worked with an industry partner to come up with a solution, which has already been patented.

By Yvonne Weiss

Color? Silvery gray. Relevance to industry? High. Access? At risk. Antimony is a crucial element of many products. It is used in semiconductors, military equipment such as night vision devices, and car batteries. This status has led places including the European Union and the United States to classify antimony, a type of element known as a metalloid, as a critical raw material. This means that it is of crucial economic importance and at high risk of supply shortages.

Mining operations in China are the primary source of antimony, which has recently put access to this noble metal at risk. The reason? China plans to drastically restrict antimony exports. This could reduce availability by about 40 percent worldwide.

The Fraunhofer Institute for Integrated Circuits IIS collaborated with industry partner GEM Recovery Systems GRS to devise a solution for industry. To that end, the researchers are developing a sensor-based sorting technology that can be used to identify antimony at mining sites. "Antimony is found as a byproduct in places like gold mines," says Alexander Ennen, a department head and expert on raw materials, product development, and recycling at Fraunhofer IIS. He describes the institute's approach: "We plan to use X-ray technology to isolate this substance from other types of rock while at the same time conserving resources like water and energy in comparison to conventional production."

Sensors help to sort rocks

The idea is to have a high-speed conveyor belt carry the unsorted rock, which is then X-rayed using a multi-energy sensor. This special sensor captures data to gain information about the ore's properties. Image processing methods are used to analyze and classify the information after that. This lets researchers find out whether a certain particle contains the desired material — antimony, for example. Then, based on the data collected, the sorting process starts: Special valves separate the rock, and an air jet removes undesired material from the belt.

Photo: Frank Rumpenhorst/dpa

Antimony, a silvery gray metalloid, is found as a byproduct in gold mines.

"The new technology makes it possible to sort out waste from target minerals and achieve what is known as a super concentrate," says Roy Spencer, a geologist from GRS. He explains that afterward, the concentrate alone is sent to a conventional preparation unit, which has been sharply scaled down. This method greatly reduces the volume of material — and with it, consumption of water and energy along with overall investment costs. "International integration of this technology could be a turning point for the material processing industry," Spencer notes.

Initial lab tests have shown that this method can reliably detect antimony. Experiments involving larger volumes of material are planned next. After that stage, this technology could be used at any mine where antimony occurs naturally, meaning outside China as well. The Mopani mine, in South Africa, is considered one of the most attractive yet still unexplored antimony deposits in the West. There are also smaller deposits in Germany, Sweden, and Australia. Ennen comments: "Our sensor-based technology can help with mining the rock, making mines more profitable while also stabilizing production volumes and availability for important materials such as antimony." ■

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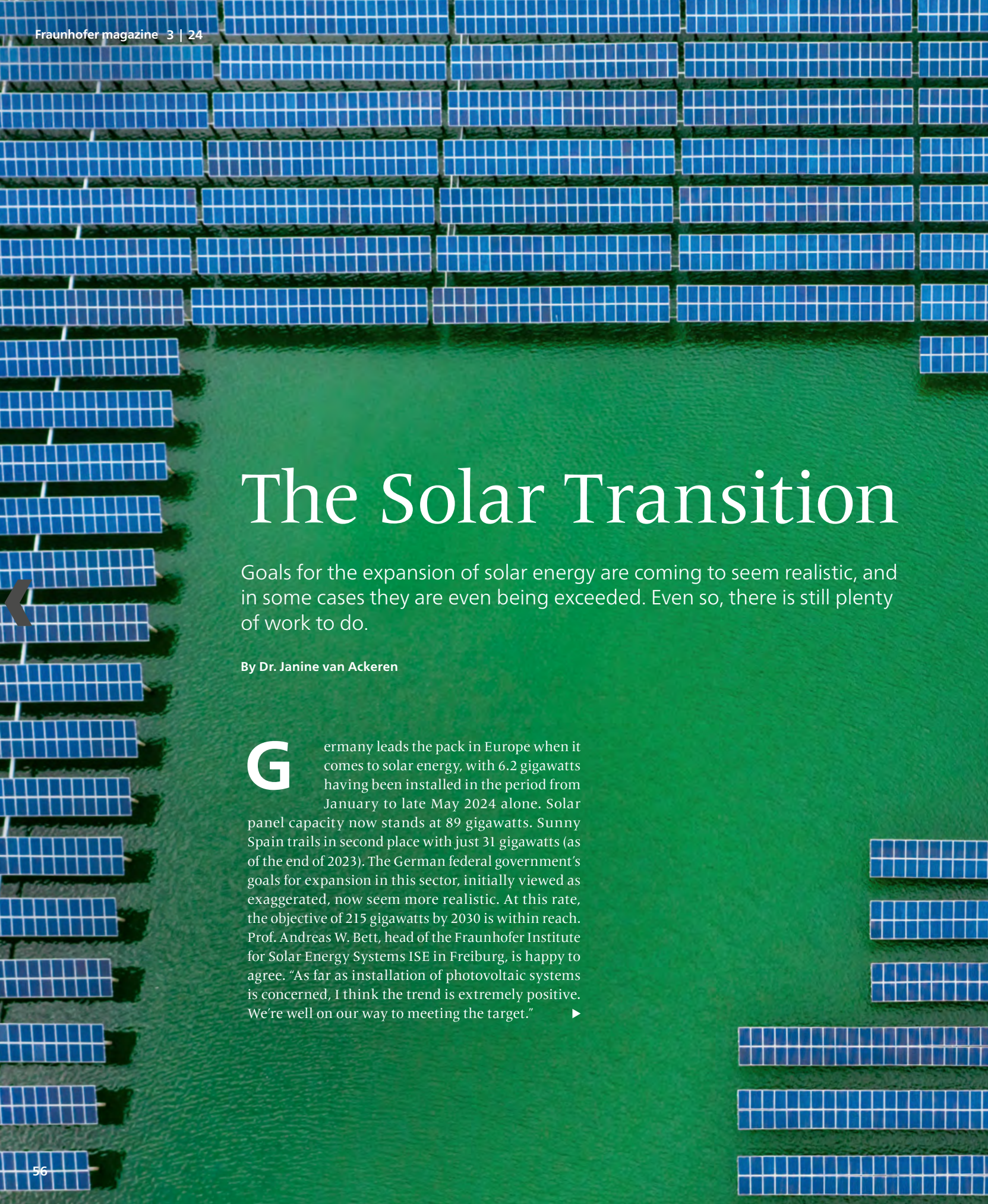
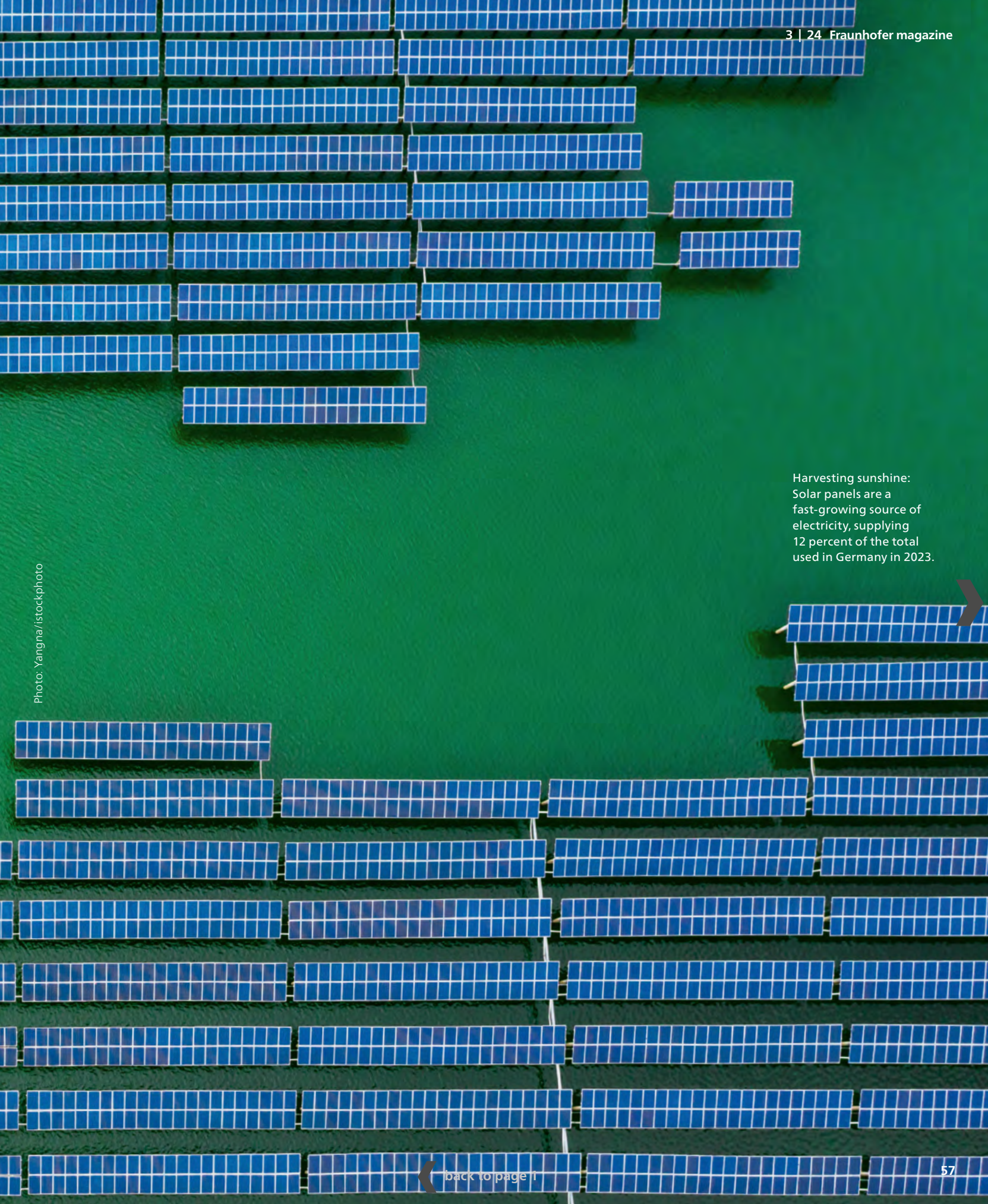


The Solar Transition

Goals for the expansion of solar energy are coming to seem realistic, and in some cases they are even being exceeded. Even so, there is still plenty of work to do.

By Dr. Janine van Ackeren

Germany leads the pack in Europe when it comes to solar energy, with 6.2 gigawatts having been installed in the period from January to late May 2024 alone. Solar panel capacity now stands at 89 gigawatts. Sunny Spain trails in second place with just 31 gigawatts (as of the end of 2023). The German federal government's goals for expansion in this sector, initially viewed as exaggerated, now seem more realistic. At this rate, the objective of 215 gigawatts by 2030 is within reach. Prof. Andreas W. Bett, head of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, is happy to agree. "As far as installation of photovoltaic systems is concerned, I think the trend is extremely positive. We're well on our way to meeting the target." ▶



Harvesting sunshine: Solar panels are a fast-growing source of electricity, supplying 12 percent of the total used in Germany in 2023.

Photo: Yangna/istockphoto

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One factor spurring this positive development is money: The costs of solar panels fell by a whopping 90 percent in Germany between 2010 and 2020 — and are continuing to decrease. The costs of purchasing electricity from solar power plants are also now roughly comparable to those of buying power from a fossil power plant: Solar electricity from large plants operating in the megawatt range costs about 5 to 7 cents a kilowatt-hour, while smaller rooftop arrays run anywhere from 11 to 13 cents per kilowatt-hour. For comparison, electricity costs 3 to 7 cents per kilowatt-hour when produced with coal and 6 to 9 if produced from gas — not including the cost of neutralizing emissions.

The German government's Solar Package I, which took effect on May 16, is intended to further speed things up. The new regulations make it easier to install home solar panels, including on balconies, and also streamline the rules on electricity for tenants. For example, owners and landlords now require a good reason to refuse to allow their tenants to install solar panels on balconies, such as if the structure of the building would be at risk.

Germany also sets records for large-scale plants

Germany is also a leader when it comes to large-scale plants. South of Leipzig, where heavy machinery used to dig for brown coal, the Witznitz solar farm came online in early July 2024. Occupying 500 hectares of space — roughly equivalent to 700 football fields — and delivering peak output of some 650 megawatts, it is the largest of its kind in Europe. Fraunhofer ISE estimates that this is enough electricity to supply about 360,000 people.

But as institute director Andreas W. Bett notes, this positive trend is only one side of the coin. On the flip side, multiple factors threaten to slow the pace of progress. "Worldwide, photovoltaic technology is 98 percent dependent on China," Bett explains. "Right now, Chinese solar panels are being sold in Germany at below the manufacturing cost, a development that is neither sustainable nor healthy for the European Economic Area." The European Union has taken action in the form of the Net-Zero Industry Act (NZIA), which requires 40 percent of the modules installed in Europe to be produced in Europe. However, enforcement falls to the individual member states — something that is proving difficult in Germany right now, for example, owing to the current budget deficit.

Germany is in a good position on the evolution of solar cells and in exploring new potential locations. Fraunhofer ISE is a driving force in this area. "Technological development from the material to the module is a key issue for us. We're working to increase the efficiency of solar panels, lower the amount of resources needed, and make progress on recycling the modules with an eye to life cycle assessment," Bett notes. One major success story from Fraunhofer ISE is MorphoColor® technology, whose developers were recognized with this year's Joseph von Fraunhofer Prize. Drawing inspiration from the colored scales of a morpho butterfly's wings, this technology can be used to produce colored solar cells that are barely recognizable as such. This means the solar elements can even be used as stylish facade accents.

These kinds of modules are developed in the lab, but also always have to prove their value in real-world use. To work on the technology, researchers from Fraunhofer ISE have been spending a lot of time since last year at the three-hectare Outdoor Performance Test Field in Merdingen, where they are supplementing the lab studies with measurements taken under real-world weather conditions. The field is the third of its kind operated by Fraunhofer ISE. The others are located on Gran Canaria, in Spain's Canary Islands, and in the Negev Desert, in Israel. "This way, we can compare the measurements from our accredited labs with the real-life results across these maritime, arid, and continental climates, verify theoretical models, and characterize solar modules faster than before," Bett says. "The measurements also help us predict yields and economic efficiency more accurately."

Make some room!

Germany is densely populated and developed. There isn't much space that would work for large-scale solar farms sitting around unused. With that in mind, researchers are working on options for dual use: solar modules on facades, noise barriers, and farmland. In the PVwins project, researchers from Fraunhofer ISE are developing and studying noise barriers to be installed along major roads and railways in the future, generating solar energy while also damping noise. This parallel function holds out great promise, with potential estimated at about five gigawatts. The teams of researchers are especially focusing on developing solar panels that absorb and dampen sound and testing them in the field. Safe and reliable wiring, cost effectiveness, and feasible operator models are also on the to do list. After the project concludes,

The costs of solar panels fell by a whopping

90 %

in Germany between 2010 and 2020.

the test unit is to be made available to companies for measurement purposes for small-scale advance testing of construction projects.

But dual use on noise barriers alone is not enough to take the total energy flowing from solar installations into Germany's grids to 215 gigawatts between now and 2030 — far from it, in fact. Farmland should also be explored for installation of solar panels. So should solar energy be harvested instead of food? In actuality, both are possible using the same space. After all, not all varieties of fruit and vegetables require full direct sunshine; many plants stop growing if they get too much sun. Bett comments: "Combining solar panels and agriculture, an arrangement known as 'agri-PV' or 'agrivoltaics,' gives us a win-win situation: Crop yield remains the same or might even increase, and at the same time, the space can also be used to generate power."

Grapes, for example, are ripening earlier and earlier as the climate warms. The harvest has already been moved up by six weeks in the German wine region of Baden. The higher temperatures have also brought bigger problems with pests and loss of revenue. So, can solar panels installed over vineyards provide enough shade to protect the vines from the effects of climate change? The VinoPV project is studying that question on the Tuniberg hill in the village of Munzingen. Fraunhofer ISE is among the project partners, participating in supporting research, acceptance research, and long-term monitoring. "The microclimate underneath the solar panels is different, with decreasing issues with moisture and lower mold incidence, so use of fungicides can be reduced. Daytime frost is also less of a problem for the vines," Bett says. This past April, for example, the ambient temperature was measured at negative two degrees Celsius, but it was zero under the panels. And that meant less damage to the plants.

The researchers have had similar experiences at other demonstration sites such as those used for growing fruit. The plants thrive, and there is less of a problem with pests. A team from Fraunhofer ISE is working on another project, APV-Obstbau (Agrivoltaic Orcharding), to study the extent to which solar panels can help protect orchards against hail, thereby preventing losses of quality and crop yield. Bett comments: "There are a number of unanswered questions in agrivoltaics: How does the water drip down from the panels? What does this mean for the soil? Can the water be collected and used for irrigation? We are testing and evaluating the various potential solutions in the field and balancing cost effectiveness with technology."

The agriculture sector seems open to the new approaches: In a study conducted by Fraunhofer ISE and the University of Göttingen, 72.4 percent of farmers said they would be open to the idea of using agrivoltaics on their farms. The main reasons given were that solar would be an additional source of income and would help future-proof their operations. But willingness alone is not enough. "The grid connections are a big challenge. Many of Germany's farms are located on relatively small parcels, so in many cases, investing in a costly grid connection doesn't pencil out yet," Bett explains. There is tremendous potential across Germany's farmland, but tapping into it urgently requires development of low-cost grid connections. That is another task Fraunhofer ISE is working on.

Germany is not the only place where increasing climate resilience in agriculture and minimizing water use is a pressing subject. With that in mind, Fraunhofer ISE is also developing agrivoltaics for worldwide issues. One of their more exotic examples is a photovoltaic tunnel used for shrimp farming in Vietnam. With shade provided by solar panels, the crustaceans can grow on land in closed systems.

Solar power from car hoods

The closer to the consumer the power is generated, the better. So why not use electric vehicle bodies to generate electricity? Mercedes showed that this was possible back in April, with its VISION EQXX car with a long-distance range of 1,000 kilometers — without recharging, to be clear. This was made possible in part by a solar roof made up of 117 solar cells, developed in collaboration with Fraunhofer. Fraunhofer ISE is now building on that experience in the HighLite project with a thin solar cell film for engine compartment hoods that uses the institute's proprietary MorphoColor® technology to match the car's overall color. Technical challenges that emerged in the process include the curved shape and the reverse side of the solar cells, which must be made of sheet metal rather than glass or film. Prototypes with different numbers of solar cells and different cell and wiring technologies have already been built and undergone extensive testing. "Solar cells installed in cars can be used to achieve about 10,000 kilometers of range a year on average," Bett predicts. "That's a substantial contribution when you consider that the average annual mileage for a car in Germany is about 15,000 kilometers." That means solar power is making good progress in Germany. And, perhaps even more importantly, it still has a wealth of potential to explore. ■

"Solar cells installed in cars can be used to achieve about 10,000 kilometers of range a year on average."

Prof. Andreas Bett, Fraunhofer ISE

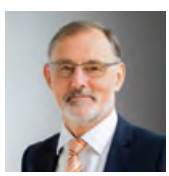

Photo: Fraunhofer ISE

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Tiny Creature, Big Impact

The ingredients that go into pesticides, cosmetics, and pharmaceuticals need to be tested for environmental impact before they are used. Fraunhofer researchers have devised a method of reliably assessing how substances accumulate in the tissue of living creatures — without using vertebrates.

By Yvonne Weiss

More than 1.2 million EU residents supported a citizens' initiative called "Save Cruelty Free Cosmetics — Commit to a Europe Without Animal Testing." The European Commission is already working on a roadmap intended to lead in the medium term to the reduction or even elimination of animal testing as a means of assessing the safety of chemicals. But since these tests are also highly important in order to protect humans, animals, and the environment against potential harm, there is a huge need for innovative alternatives. Researchers at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Schmallenberg have identified one such method.

Their work focuses on a mechanism known as bioaccumulation, which occurs when a substance is ingested or absorbed from the environment and accumulates in the tissue of an organism such as a fish, potentially causing direct harm. The organism that accumulates the substance can also be consumed by other animals, so the substance moves up the food chain. And that means these substances can ultimately also pose a risk to human health.

To avert these risks, European regulations require manufacturers to study whether a chemical substance accumulates in living organisms, and if so to what degree, as part of the official approval process. Only approved ingredients can be subsequently used in products, thereby entering the market and the environment.

Traditional lab tests of bioaccumulation previously required more than 100 fish per substance as test subjects. Fish are especially well suited to testing the environmental impact of chemicals, as their gills are efficient at absorbing substances present in the water. Prof. Christian Schlechtriem, head of the Bioaccumulation and Animal Metabolism department at Fraunhofer IME, aims to replace these controversial tests. How? By using Hyalella azteca, a type of crustacean known as an amphipod that is native to North America and grows to a length of eight millimeters.

The new method developed at Fraunhofer IME, the Hyalella azteca Bioconcentration Test (HYBIT), is based on the same testing concept as fish testing, with one key difference: No vertebrates are used. So

Hyalella azteca, a tiny crustacean, grows to a length of eight millimeters.

Photo: Fraunhofer IME/Klaus-Peter Kappest

if, for instance, a maker of face creams wishes to test an ingredient's environmental impact, the researchers add the substance to an aquarium, along with a group of the tiny crustaceans. Afterward, they measure how the concentration of the substance slowly increases in the organisms' tissue. If the concentration ultimately remains constant, the team transfers the remaining animals to fresh water. Further measurements show how fast the substance breaks down in the tissue, eventually being eliminated from the organism. In this way, the bioconcentration factor indicates whether the substance tested poses a bioaccumulation risk.

The tiny organisms are easy and quick to grow in a lab, but that is not all. Schlechtriem explains that the new approach also yields persuasive results: "Our test method reduces the use of vertebrates like fish, but we can still reliably assess how much a chemical accumulates in the environment."

With scientific support from his colleagues and funding from the European Chemical Industry Council (Cefic) and the German Environment Agency (UBA), Schlechtriem has taken his original idea and developed it into OECD Test Guideline (TG) 321, which applies internationally. That means the new test method is permissible and applicable worldwide. He is already working toward the next objective: "Right now, we are working to further modify the test so it can also be used to assess bioaccumulation of nanoparticles." ■

More than
1.2 million EU residents
supported a citizens' initiative called "Save Cruelty Free Cosmetics —
Commit to a Europe Without Animal Testing."

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Sustainably Gourmet

Cheese made from peas, rapeseed, or sunflower seeds? A team from Fraunhofer IVV is working to create delicacies that can be enjoyed with a clear conscience.

By Dr. Sonja Endres

Vegan cheese isn't much to get excited about these days, at least to hear Dr. Isabel Muranyi tell it. A food chemist at the Fraunhofer Institute for Process Engineering and Packaging IVV in Freising, near Munich, Muranyi has set out to change that. She and her team are working to develop good-tasting cheese alternatives. There is certainly enough demand: One-third of all consumers who responded to a 2021 Statista survey said they were avoiding dairy either entirely or in part, mainly for reasons of animal welfare and climate action, but also due to food intolerances.

The challenges are complex: the diverse flavor profiles, the differences in consistency, the color, the way cheese melts. "We have to really drill down to translate this multifaceted system we call cheese into plant-based ingredients," Muranyi explains. That is why the researchers at Fraunhofer IVV are currently involved in two projects at once in an effort to develop the perfect substitute. The first of them, KäromaVeg, focuses on developing authentic cheese flavor. Conventional cheese alternatives are often made from a mixture of starch and fat, with various flavorings added in. "We're taking a different tack," Muranyi says. "Just like with dairy cheese, we plan to create the flavors naturally, through fermentation."

Photo: Tim Mac Pherson/DEEPOL by plainpicture

To achieve that, the researchers are first producing a type of plant-based milk with a composition similar to that of cow's milk. The starting ingredients are proteins and oils derived from legumes, nuts, rapeseed, or sunflower seeds. The team is also experimenting with adding various microorganisms, such as lactic acid bacteria and fungi, to the plant-based milk. These organisms break down the carbohydrates and cause the mixture to acidify and curdle. At the same time, they also influence the flavor. "For example, we have found that some microorganisms not only neutralize the 'beany' flavor found in legumes, but can even turn it into cheese-like attributes."

Like in traditional cheese making, the fermented plant milk is pressed through a sieve, and the mass is then stored for a time under controlled conditions to allow the flavor and texture to mature. "One key advantage of our method is that we use equipment already present in cheese-making operations today," Muranyi notes. There is no need for costly investments, as the production process remains the same. And that has sparked great interest from the industry. A consortium of dairies, cheese makers, agriculture industry players, and producers of microorganisms, enzymes, and other ingredients is supporting and assisting in the research work.

The Fraunhofer IVV team's first focus is on crafting substitutes for Gouda and the Emmentaler variety of Swiss cheese, both of which are highly popular in Germany. In general, it is easier to achieve strong, sharp flavors than the milky, buttery ones found in cheeses like mozzarella or young Gouda. But the scientists have already devised solutions: "Various microorganisms convert precursor substances made from plant proteins and oils into substances with active effects on flavor, such as diacetyl, which provides a buttery taste," Muranyi explains. Shortening the fermentation time could also help create a milder flavor. On the whole, the maturation process is much faster with plant-based milk than in cheese made from cow's milk. "Parmesan is especially easy to imitate," Muranyi says. Even with over-fermentation — such as if the vegan cheese mass is stored at high temperatures for too long or too many microorganisms are used — the texture and flavor are close to those of the popular Italian cheese, which is often grated.

The Fraunhofer IVV team is experimenting with various nuts, which are especially suitable for producing cheese-like flavors. Which ones exactly is a secret for now, as competition in the cheese substitute segment is fierce. "We use both the protein and the oil from the nuts in our experiments. The microorganisms break them down into amino acids and fatty acids with an active effect on flavor, which makes them relevant to our cheese taste," Muranyi explains. The researchers are also experimenting with sunflower seed and rapeseed oil. "With sunflower, though, we've found we have to be careful, since it doesn't take much to turn the cheese green," Muranyi notes. That is due to the polyphenols that are often present in sunflower proteins, which discolor at certain pH values.

> "Just like with dairy cheese, we plan to create the flavors naturally, through fermentation."
>
> Dr. Isabel Muranyi, Fraunhofer IVV

The second project, Pulse2Cheese, focuses not on the plant-based cheese's taste, but rather how it melts. Inexpensive cheese substitutes melt well on pizza or in casseroles or baked goods, but they are low in nutrients and typically contain a long list of additives. "With our fermentation processes, we can produce cheese alternatives with much greater nutritional value. Our ingredient list is short: proteins and oil from a plant-based raw material, lactic acid bacteria, and that's it," Muranyi says. At the same time, the unsaturated fatty acids derived from plants are healthier than the saturated ones dominant in cheese made from cow's milk. Healthy ingredients are the third most important factor, after taste and price, that consumers of dairy substitutes — who are generally nutrition-conscious — cite as reasons to buy a certain product.

The problem is that the protein-rich plant-based cheese does not melt well when exposed to heat. Instead, it forms a solid lump. The researchers are now looking at ways to add starch to make the protein more flexible, so it bonds to the starch and melts when heated. Legumes are an especially promising starting material. "We've already observed under a microscope that the legume proteins form networks like those found in melting cow's milk cheese," Muranyi says. Legumes can be grown sustainably, plus they are high in protein, which makes extraction efficient as well. Starch can be produced from the residue. The team of researchers is currently working on the optimal ratio of starch to protein and on perfecting the environmental conditions. "The pH value is one factor, and so is salt content. We have to get those right before the starch and protein interact and the whole system starts to flow," Muranyi explains. Once they strike the right balance, it won't be long before a high-quality, sustainable alternative to conventional cheeses is available for pizza and other dishes. ■

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Intelligent Interaction in the Car of the Future

Improving communication between vehicle and driver as a function of the degree of automation is the objective of a Fraunhofer research project.

By Stefanie Smuda

AI tip: It's better to drive yourself on a winding stretch of road.

Warning: If you keep reading now, you may become nauseous on the winding stretch of road. In five minutes we'll be on the highway and it will be easier." Not long from now, statements like these might no longer come from a parent in the passenger seat, but rather an assistance system in the vehicle. In the KARLI project (a German acronym that stands for "Artificial Intelligence for Adaptive, Responsive and Level-compliant Interaction" in vehicles of the future), researchers from the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB and the Fraunhofer Institute for Industrial Engineering IAO are working to optimize communication between vehicles and their drivers. To that end, they are harnessing a wide range of AI applications, depending on the car's level of automation.

The Fraunhofer researchers are joined in the KARLI project by ten partners from industry and the research sector, including companies such as Audi, Ford, and Continental. With vehicle automation levels steadily on the rise, both industry and the research sector are working hard to optimize interactions between vehicles and humans. Researchers currently use a model comprising six levels of automation: No Driving Automation (Level 0), Driver Assistance (Level 1), Partial Driving Automation (Level 2), Conditional Driving Automation (Level 3), High Driving Automation (Level 4), and finally Full Driving Automation (Level 5). "In the KARLI project, we are developing AI functions for automation levels from partial to full," explains project coordinator Dr. Frederik Diederichs from Fraunhofer IOSB in Karlsruhe. "To do this, we are collecting data on driver conditions and designing various human-technology interactions adapted to the relevant level and driving tasks." For example, the system uses a camera-based occupant monitoring system to tell when the driver is distracted or reaches for their cell phone and can then make suggestions or issue warnings, depending on the automation level.

AI "butler" lends a helping hand

The researchers are combining optical sensors for monitoring the vehicle interior with language models to form what are known as vision language models (VLMs). The optical sensors used for in-cabin monitoring are required in Europe as of July 2024 at any rate, thanks to new rules designed to detect driver distraction or drowsiness. These AI-supported sensors gather information on activity inside the car and supply visual data that is then combined with large language models (LLMs) to form VLMs. On this basis, advanced driver assistance systems in (partially) autonomous vehicles can record situations inside the vehicle semantically and respond appropriately. This reduces interactions that could be perceived as bothersome or disruptive

"The interaction in the vehicle of the future is like having a butler who stays in the background but understands the context and offers the best possible support to the vehicle's occupants."

Frederik Diederichs,
Fraunhofer IOSB

Photo: audioundwerbung/istockphoto

by vehicle occupants, thereby increasing acceptance of the technology. "The interaction in the vehicle of the future is like having a butler who stays in the background but understands the context and offers the best possible support to the vehicle's occupants," says Diederichs, the project's coordinator.

The different automation levels give drivers different levels of freedom. The lower the level, the more drivers have to concentrate on the road. By contrast, if the vehicle is operating under partial, high, or even full automation, drivers can turn their attention to other things. For KARLI, the researchers developed various AI applications to meet these objectives. Visual, acoustic, and haptic warnings point out unusual road conditions or safety aspects to the driver. "It will be raining soon, so we need to end automated driving. Please get ready to drive on your own for a while. I'm sorry, but you'll need to stow your laptop in a safe place for now. Safety comes first," is how one such message could be worded. The goal is to prevent the person at the wheel from being distracted at the wrong time.

Another AI tool is tackling one of the biggest problems with passive driving: motion sickness. Studies show that anywhere from 20 to 50 percent of vehicle passengers suffer from this condition. AI features are currently under development in an effort to warn passengers ahead of time by comparing their activities — such as reading, which contributes to motion sickness — with expected acceleration patterns on winding stretches of road. "Generative" user interfaces (genUIs) focus on individualized messages and signals. The nature of the interaction depends directly on the automation level: Short, purely verbal notifications are issued when the driver needs to focus on driving. In autonomous mode, more extensive or detailed tips could also be provided through visual channels.

Diederichs and his team are now also testing initial findings from the research project in practice. To study user needs during driving at high automation levels on the road, they are using a mobile Fraunhofer IOSB research lab based on a Mercedes EQS. The first functions developed as part of the KARLI project could be available in series-produced vehicles as early as 2026. ■

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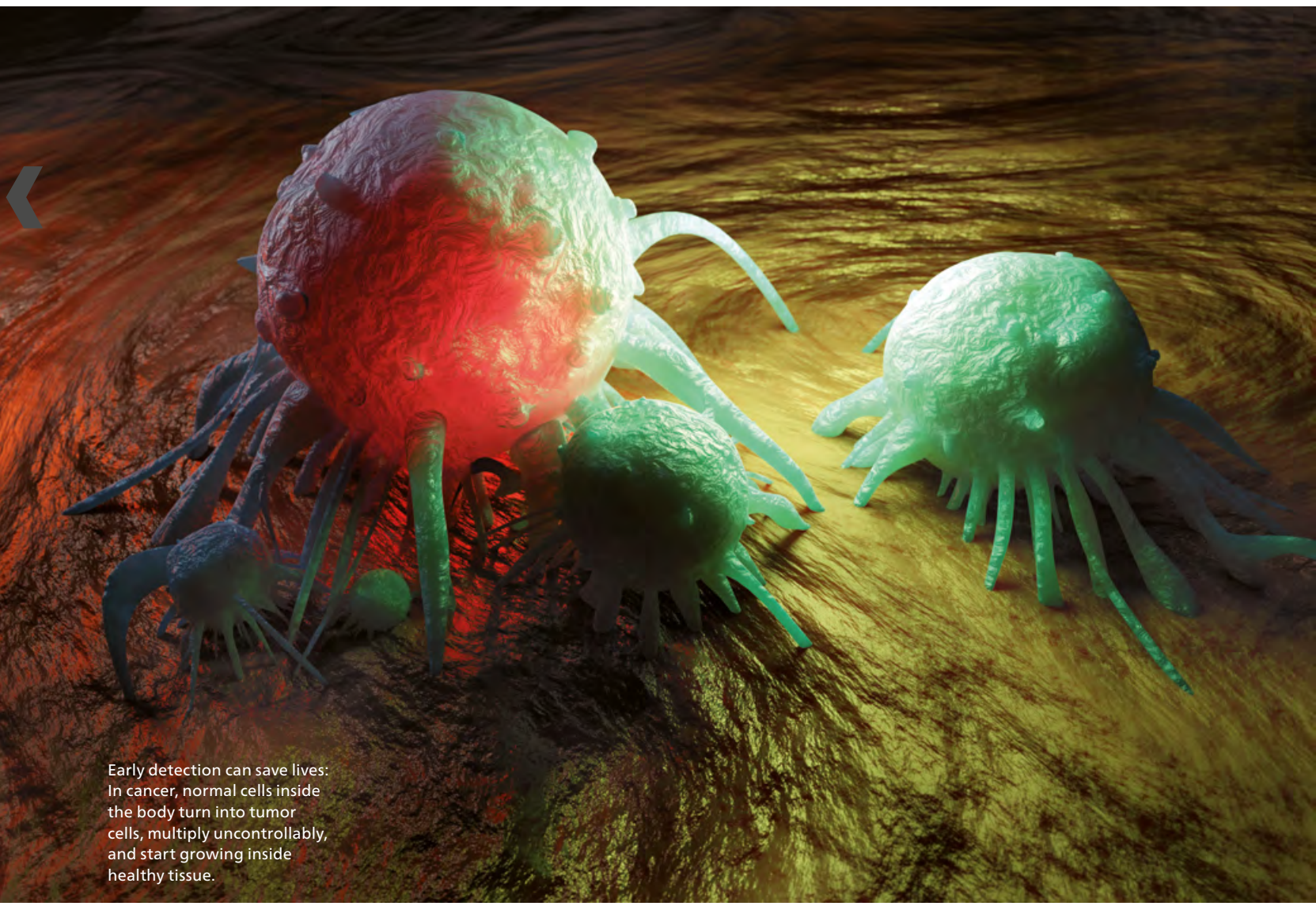
Accelerating the Fight against Cancer

The sooner cancer is detected, the higher the chances of beating it. A new AI foundation model is quick to train, even without much data, while making the diagnostic process significantly more efficient.

By Franziska Sell



Early detection can save lives: In cancer, normal cells inside the body turn into tumor cells, multiply uncontrollably, and start growing inside healthy tissue.

Changes in tissue or circulatory anomalies can be indications of cancer, but they are sometimes difficult to detect in anatomical imaging, especially in the early stages of the disease. Experts can now turn to a new technology for assistance with diagnosis: Self-learning AI systems can help identify these kinds of measurable parameters, known as biomarkers, in pathological images. Researchers from the Fraunhofer Institute for Digital Medicine MEVIS have teamed up with RWTH Aachen University, the University of Regensburg, and the Hannover Medical School to develop a foundation model for this. The resource-efficient model analyzes tissue samples quickly and reliably, based on just a fraction of the usual training data. The team won an award in the international SemiCOL (Semi-supervised learning for colorectal cancer detection) competition based on their research. The model supplied impressive results, especially in cancer classification.

Moving away from large volumes of data and self-supervised learning

Traditional foundation models, like the large language models used for ChatGPT, are trained using large and diverse data sets, supervising themselves as they learn. But for medical image analysis, scant data is generally available, and in fact, the small amounts of data in clinical studies pose a major challenge for the use of AI. In addition, clinical centers differ in how they process pathological preparations and in the makeup of their patient populations — even before the specific form and characteristics of the disease are considered.

All of these factors make it harder to reliably detect existing patterns, and thus diagnostically relevant characteristics. To train AI effectively, this means large volumes of sample images from different origins are typically needed. But each cross-sectional image of tissue is typically several gigabytes in size, containing thousands of different cells but at the same time only reflecting a fraction of the variability described.

Specialization follows solid basic training

The experts at Fraunhofer MEVIS have devised a solution based on supervised pre-training. "We're developing a basic training program for AI modeled on the training that pathologists undergo. After all, they don't have to relearn what a nucleus is all over again in each case. Once these concepts have been covered, they're present as a base and can be applied to various diseases," Dr. Johannes Lotz explains.

In much the same way, the AI model undergoes basic training, learning general characteristics and laws known as tissue concepts from a broad collection of tissue section images presented with various tasks. Combining these tasks gives rise to the large volumes of data needed to train a robust large AI foundation model. Then, as the second step, the concepts that have been learned are used for a specific task. In this way, the algorithms can identify biomarkers distinguishing different types of tumors, for example — all with much less data. "During pre-training, we give our foundation model the image and provide the answer at the same time," explains Jan Raphael Schäfer, an AI expert at Fraunhofer MEVIS. The team also uses an image registration method developed at the institute known as HistokatFusion. This method makes it possible to generate automatically annotated training data from tissue studies such as immunohistochemical staining, thereby using marked antibodies to visualize proteins or other structures. To do this, the information from multiple histopathological images is combined. The experts incorporate these automatically generated markings into the training of their model, which accelerates the process of collecting annotated training data.

> "Because we use so little data, we only need about six percent of the resources."
>
> Dr. Johannes Lotz, Fraunhofer MEVIS

In comparison tests with traditional models that do not involve supervised training, the Fraunhofer researchers use just six percent of the amount of training data. "Because we use so little data, we only need about six percent of the resources," Lotz says. Training takes less time, too: "160 hours is enough," he notes. And that means the foundation model not only adjusts faster to various medical challenges, but is also significantly less expensive than conventional solutions. ■

Photo: Spectral/Westend61/mauritius images

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Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

Plans call for a prototype Hydrocycle to be completed by the end of 2025.

UNITED KINGDOM

Safe, Effective Self-Driving Vehicles

Developing autonomous systems that work safely, with no drawbacks in terms of performance, is a huge challenge for the automotive industry. In the LOPAAS ICON research project, the Fraunhofer Institute for Experimental Software Engineering IESE, the Fraunhofer Institute for Cognitive Systems IKS, and the University of York in the UK have developed new safety standards for self-driving vehicles in particular. The researchers focused on making self-driving cars so safe that they can compete with human operators without severe limitations on aspects such as speed. With its expertise in risk management, Fraunhofer IESE helped to ensure that autonomous systems recognize risks and uncertainties in real time and can respond flexibly to unforeseen situations. One example is reacting safely to sudden obstacles on the road.

The project's findings have been incorporated into international safety standards such as ISO/PAS 8800 and DIN SPEC 92005, which form the basis for safe and reliable use of autonomous systems around the world. These standards enhance trust in autonomous vehicles, unlocking broad-based acceptance on the road and beyond in sectors such as logistics.

Who has the right of way? Reliable safety standards are needed for self-driving vehicles.

CZECH REPUBLIC

Zero-Emissions Easy Rider

Referenzfabrik.H2 at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz is working with Czech Technical University in Prague and other partners to develop a hydrogen-powered motorcycle. The advantage over electric solutions based on batteries lies in the hydrogen bike's greater range and shorter refueling times. The challenge is to integrate an entire fuel cell system, including hydrogen tank and electric powertrain, into the frame of the bike, which is known as the Hydrocycle.

The Referenzfabrik.H2 team is responsible for the system's dimensioning and for packaging, meaning arranging the components to save space. The researchers are also developing new manufacturing technologies for fuel cell production. The H_2 motorcycle is especially interesting for city use, but the goal is to make it usable over longer distances as well.

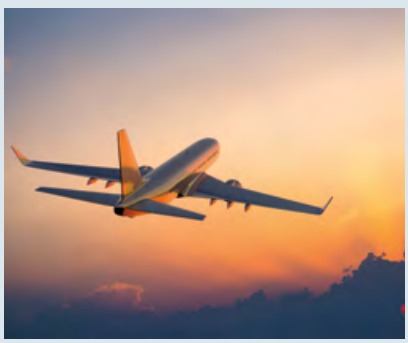
EUROPE

Lofty Aims for the Future

The Fraunhofer Institute for Material and Beam Technology IWS has achieved a breakthrough in aircraft construction under the auspices of the EU's Clean Sky 2 program. As part of the Multi-functional Fuselage Demonstrator (MFFD) project, the researchers developed a method of joining carbon fiber-reinforced thermoplastic (CFRTP) components without drilling or riveting.

For the first time, they succeeded in automatically joining the upper and lower halves of the world's largest fuselage segment made of CFRTP. This was done using the CONTIjoin method, a combination of CO_2 laser technology and highly dynamic beam deflection. Eliminating mechanical joining elements and the duplication of materials found in traditional overlapping or "lap" joints saves time and materials while also reducing weight, making production of commercial aircraft more efficient and lowering its environmental impact.

A new joining process brings greater efficiency to the skie

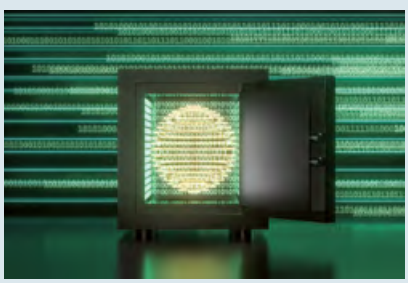


Check it out: A new method takes critical plasticizers out of old PVC flooring

ITALY

An Inside Look at AI

AI as a "black box": unlocking the benefits of g eater transparency.



Many users mistrust AI systems because they do not understand their internal processes. In the XMANAI project, the Fraunhofer Institute for Open Communication Systems FOKUS worked under the leadership of TXT e-solutions, an Italian company, and with partners from all over Europe to develop a platform intended to bring greater transparency to the industrial use of AI.

The task for Fraunhofer FOKUS was to design tools that can import, store, and prepare data and then produce interactive visualizations, knowledge graphs, and explanations in natural language to make AI-driven decision-making processes understandable, even to laypeople. Diagnosis and prediction of machine and production line errors and prediction of customer demand through AI served as practical examples. The platform features open interfaces, so it can be integrated seamlessly into existing IT infrastructures. The project is financed by the European Commission as part of its Horizon 2020 research program.

EUROPE

Critical Plasticizers Neutralized

Polyvinyl chloride (PVC) is a plastic often found in floor coverings. But old coverings contain plasticizers like DEHP, which presents a health concern. Its use is now prohibited. Incineration used to be the only method of disposing of PVC containing these harmful substances. Now, an EU project called Circular Flooring has found a way to recycle these kinds of old PVC flooring sustainably. The solvent-based recycling method, which uses the CreaSolv® formulations developed by the Fraunhofer Institute for Process Engineering and Packaging IVV in partnership with CreaCycle, efficiently removes critical plasticizers. The remaining material meets EU legislative requirements and can be used to produce new PVC floors. The new method can be scaled for industrial use, supporting a circular economy.

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Natural Heat

Heat pumps are a climate-friendly, efficient, heavily subsidized technology — so why is hardly anyone buying them right now? Dr. Marek Miara from Fraunhofer ISE urges fresh trust.

By Dr. Sonja Endres

Ducklings are a natural example of the same heat exchanger principle used in heat pumps. The veins and arteries in their legs are located close together. Warm blood pumped outward from the heart warms up the cool blood from their feet before it flows back into the rest of the body. At the same time, the warm blood cools down, which keeps the feet cold, so they do not freeze in place on icy surfaces.

Photo: Momosu/photocase

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"Heat pumps convert a single unit of electricity into three to five units of warmth."

Dr. Marek Miara, Fraunhofer ISE

He is a leading authority on heat pumps in Germany: For more than 20 years now, Dr. Marek Miara has been studying this technology at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, improving efficiency and conducting studies to prove that heat pumps can be used to heat even unrenovated existing buildings and multi-unit buildings. Miara has been following the discussions surrounding the new version of the German Buildings Energy Act (Gebäudeenergiegesetz, GEG). His takeaway? "The biggest issue is that there has been an unprecedented disinformation campaign that has cost heat pumps a lot of trust with consumers."

And that uncertainty shows up in official figures. Sales of heat pumps have crashed in Germany, with 54 percent fewer units sold in the first half of 2024 than in the same period of the previous year, as the Federation of German Heating Industry (BDH) reports. The federation estimates that a maximum of 200,000 new units will be installed in 2024. That makes the German federal government's goal of 500,000 heat pumps a year seem quite far away.

And yet, Germany's heating systems are a key area of leverage for achieving climate targets. One-third of all energy consumed is used to heat buildings and hot water. Seventy-two percent of all heating systems run on gas or oil, both of which have harmful climate effects. Heat pumps account for just six percent. "At the same time, the technology is sustainable, highly efficient and robust. It has been tested for years, and the government will cover up to 70 percent of the purchase cost," Miara says, shaking his head at the situation.

Heat pumps typically derive 65 to 80 percent of the energy used for heating purposes from their surrounding environment. They work much like a refrigerator. But where a fridge draws warmth out of its interior and emits it outward, a heat pump pulls warmth from its surroundings — typically the air around it, but sometimes also the ground or groundwater — and then uses compression to raise it to the temperature needed for heating purposes. Just like a refrigerator, a heat pump runs on electricity. In Germany, 65 percent of that electricity is now derived from renewable sources, a figure that is rising steadily.

"Even with the high electricity and low gas prices we are seeing right now, a heat pump is worthwhile for consumers, including financially," Miara says. For a standard existing home with an area of about 150 square meters, a low-efficiency air-to-water heat pump can yield annual savings of about 200 euros compared to a gas boiler, he explains. For comparison, the figure in late July 2022 was 3,500 euros. That was when the supply of gas from Russia had been halted in the first year of the war in Ukraine — well before the price of gas had peaked. "My calculations clearly show that as soon as the price of gas rises even slightly, the balance instantly tips greatly in favor of heat pumps." And there is a high risk that gas prices will rise in the future, whether due to geopolitical conflicts, stricter climate action regulations, or simply driven by increasing worldwide demand for limited resources.

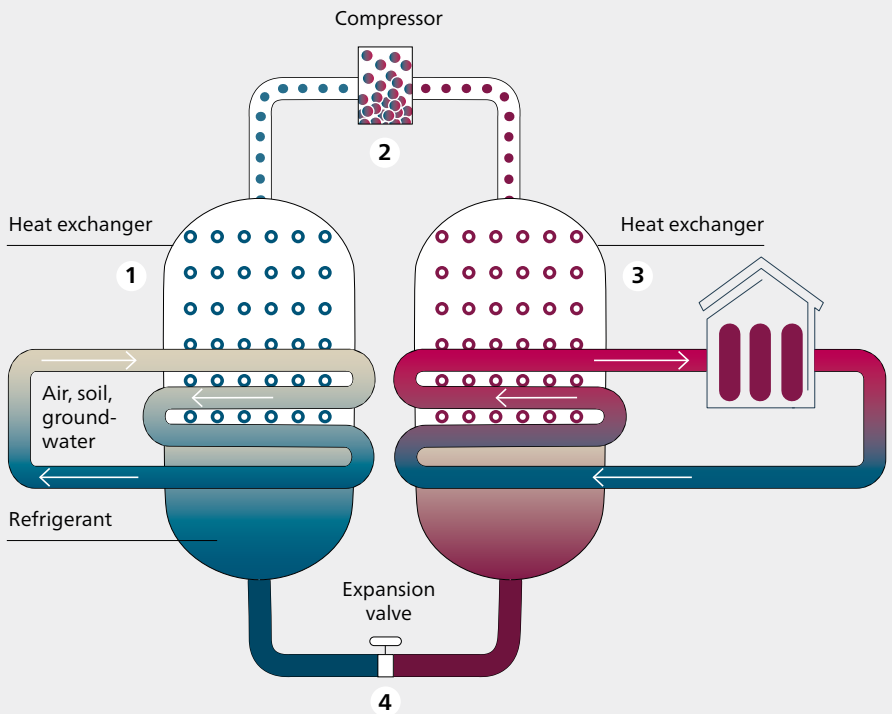
Heat pumps are even greener and more cost-effective when operated using electricity from a home's own solar array, which also eliminates dependence on energy suppliers and fluctuating prices. "Heat pumps convert a single unit of electricity into three to five units of warmth, even in winter," Miara points out. And there's another advantage as well: "Even when exterior temperatures drop sharply, I've never seen a single one of the hundreds of heat pumps we've tested be unable to provide sufficient heat. The most heat pumps are sold in the Scandinavian countries, and as everyone knows, the winters there aren't particularly warm."

To further enhance the performance of heat pumps in the future and allow them to adapt to changing environmental conditions and user habits, the team at Fraunhofer ISE is currently studying heat pumps that are supported by AI. The artificial intelligence analyzes a steady stream of measurement data and optimizes the unit's operating parameters accordingly. The researchers expect that this will unlock energy savings as high as 20 percent.

"Heat pumps are simply the better option, both environmentally and financially."

Dr. Marek Miara, Fraunhofer ISE

Natural alternative refrigerants could also boost the pumps' efficiency. Refrigerants circulate inside a heat pump, enabling heat to be absorbed and emitted. The team at Fraunhofer ISE is focusing on substances including propane for this. With its excellent thermodynamic properties, propane enables significantly



How does a heat pump work?

1. The liquid refrigerant absorbs heat from the air, soil, or groundwater and vaporizes in the process.
2. The compressor compresses the refrigerant vapor, raising the pressure so the vapor heats up.
3. The refrigerant vapor transfers heat to the heating circuit and condenses.
4. An expansion valve lowers the pressure, so the refrigerant cools down to the point that it can absorb heat again.

Source: Bundesverband Wärmepumpe e. V.

higher flow temperatures of up to 70 to 75 degrees Celsius. This makes it especially beneficial for existing buildings that have not been renovated. But even heat pumps that use conventional refrigerants achieve flow temperatures of 50 to 55 degrees Celsius these days and are suitable for heating older buildings. "Eighty-five percent of the units sold last year were intended for existing buildings, not new construction — because it just works," Miara says.

He firmly believes propane will catch on as a refrigerant in heat pumps going forward. Some 25 percent of the pumps installed today already run on propane, which also has big environmental advantages. Its greenhouse potential is 200 times lower than that of R-32, the most commonly used refrigerant today, and 700 times lower than that of R-410A, the second most common one. Both gases face sharp limitations on future use anyway, owing to the EU's F-gas Regulation. "To correct another misconception about this, these refrigerants definitely don't leak into the surrounding air during operation. They flow in hermetically sealed circuits. So that's mainly an issue when the units are filled and during disposal." Consumers who buy a heat pump with synthetic refrigerants today don't have to worry that they will no longer be allowed to operate it at some point. The F-gas Regulation merely forces manufacturers to shift increasingly to refrigerants with lower greenhouse potential or to natural refrigerants.

But propane does have one drawback: It is highly flammable and explosive. As a result, propane heat pumps require additional safety components, and they are generally only approved for outdoor use. However, the researchers at Fraunhofer ISE have managed to solve this problem as well: Reducing the amount of refrigerant to just 146 grams — about five cigarette lighters' worth — also lowers the safety risk. This makes indoor operation possible. The innovative pump generates eleven kilowatts of output, which is enough to heat an average single-family home. Miara believes in this future: "Heat pumps are simply the better option, both environmentally and financially." ■

Photo/illustration: Fraunhofer ISE, Vierthaler and Braun

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Photo & Fraunhofer

Fraunhofer Helps Rockets Launch

Phase-stabilized ammonium nitrate helped the new Ariane 6 launch vehicle take off smoothly from the Guiana Space Centre, also known as Europe's Spaceport, in French Guiana, on July 9. The chemical, which was used in the gas generators to launch the liquid-propellant rockets, originated in the labs at Fraunhofer ICT. "Ammonium nitrate is a relatively inexpensive and readily available substance that reliably supplies the oxygen needed for the combustion process when used as an oxidizing agent," explains Dr. Thomas Keicher, deputy head of the Energetic Materials department at Fraunhofer ICT. "Unfortunately, it also tends to change its crystalline structure at higher temperatures, causing microscopic cracks in the gas generator set. That can cause the gas generator to burn uncontrollably, up to and including an explosion." This means the launch of the Ariane 6 would have been much riskier if not for the phase stabilization achieved by the oxidizing agent.

With this in mind, researchers at Fraunhofer ICT set out to develop a chemical method specifically for rocket fuels and gas generator sets, using additives — nickel oxide, in the case of the Ariane 6 igniter — to maintain the structure of the ammonium nitrate even at higher temperatures. "Fraunhofer patented this invention back in the 1970s, and it hasn't changed much since then, so it's still considered state of the art," Keicher says.

Although the maiden voyage of the Ariane 6 was an uplifting moment in space flight and Fraunhofer ICT played a crucial role in this large-scale European project, Thomas Heintz, Project Group Leader for Particle Technology in the Energetic Materials department at Fraunhofer ICT, comments: "Our institute flew to space, although only in spirit: As soon as Ariane 6 takes off, our job is done."

July 9, 9 p.m. CEST: The Ariane 6 launch vehicle embarks on its maiden flight f om Kourou, French Guiana. It is to fly at least nine missions a year later on.

Photo: ESA-CNES-ARIANESPACE-ARIANEGROUP / Optique Vidéo du CSG

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Storing sunshine for winter

Socking away summer heat: A pilot project aims to repurpose decommissioned mines in Germany's Ruhr area as storehouses for warmth.

By Beate Strobel

When the days are getting shorter again and the coolness of autumn is in the air, it's tempting to want to deposit a few degrees of warmth in a "weather account" for the coming winter months. But there's no such thing as a heat savings account. Or is there?

Stockpiling sunshine is exactly what the WINZER project headed by the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG aims to do by storing heat in abandoned mines in the Ruhr area. The project revolves around a small mine located underneath the Fraunhofer IEG grounds at the Bochum office. In the postwar period, the shallow mine produced coal, but the owners halted operations just a few years later, as the mine was not producing enough. Now, with funding from the German Federal Ministry of Education and Research (BMBF), Fraunhofer IEG has teamed up with Ruhr University Bochum, TU Bergakademie Freiberg, and engineering firm delta h to turn the decommissioned mine into a kind of underground hot water bottle. The idea is to store the solar energy received during the summer there and tap into it during the winter.

The small mine is practically perfect for the innovative project. It is filled with water from 22 to 64 meters in depth, the water cannot leave the caverns. At the same time, it has good permeability and transmissivity, meaning that the rock allows for a flow of water — which stores heat. "The water from the mine is pumped during the summer from the aboveground area, where the temperature is about 11 degrees Celsius, and then heated by a solar array with an output of 30 kilowatts," explains Florian Hahn, head of the Post-Mining Exploitation department at Fraunhofer IEG. "The warm water is then stored in the mine, which also heats the rock around it, making the whole thing like a giant hot water bottle." Then, in the winter, the process is reversed: The warm water is pumped up and through the heat exchanger of a high-temperature heat pump, so it can be used as a source of heat for buildings. Then, after it has cooled back down, the water simply waits in the mine for the next summer.

Looking for optimum conditions

The project follows a roughly seasonal cycle, with the water being heated from Easter to October and then the heat used from October to Easter. The WINZER team is ready and waiting for the next step: Their goal is to feed in 35 megawatt-hours of heating as part of an initial practical test before the end of the year. That is almost enough to heat two single-family homes for an entire year.

The researchers plan to monitor the system closely in the process. How quickly does the temperature spread below the ground? How long can the heat be stored? Does the equipment used show signs of deposits forming or of corrosion? And how do temperatures of up to 60 degrees Celsius affect the surrounding rock and the microbiology of the immediate area? "We can simulate a lot of things in advance, but the reality often ends up looking different," says Dr. Mathias Nehler, the project coordinator at Fraunhofer IEG. "Our goal is to show, at a research scale and with limited storage volume, which conditions are optimal for the principle of storing heat in mine water. And then to scale up the technology to larger mines and for large heat pumps." A recent study performed by Fraunhofer IEG on behalf of Agora Energiewende showed that heat pumps would theoretically have the power to serve all of Germany's long-term needs for heating up to 200 degrees Celsius by using environmental heat and waste heat.

The idea of putting decommissioned mines to use for the heating transition isn't completely new. For example, Stadtwerke Bochum, the municipal utility service for the city of Bochum, has been extracting water naturally warmed to 20 degrees Celsius from the Robert Müser mine

Photo: Frank Wiedemeier/IEG Fraunhofer

Digging deep: A mobile drill was used to open up the mine workings underneath the Fraunhofer IEG campus.

for some ten years now and using it to provide climate-friendly heating for a fire station and two schools. To supply heat and cooling for the MARK 51°7 industry, science, and tech campus, also in Bochum, water from the Dannenbaum mine is pumped to the surface from a depth of 810 meters at a temperature of about 27 degrees, then heated to as high as 48 degrees using heat pumps and fed into the heating network. The water used in the cooling supply comes from a borehole 340 meters deep. It is pumped at a temperature of about 16 degrees Celsius, and then heat pumps are used to cool it to ten degrees. In this way, water from the mine is to provide more than 75 percent of the heating and cooling needed by customers in the immediate area going forward.

> "Our goal is to show the optimum conditions for storing heat in underground mine water."
>
> Dr. Mathias Nehler, Fraunhofer IEG

The WINZER project is taking a new approach in doing more than just using existing heat, instead using solar energy or alternatively industrial waste heat to heat the water pumped from underground. This new idea could also be of interest for former mining regions around the world. Germany's Ruhr area can act as a blueprint of sorts here. "Not only are there a lot of unused mines here, but we also have one of Europe's biggest district heating networks," Hahn notes. "So the conditions are favorable for approaches like connecting a waste-to-energy plant — which produces a lot of waste heat, after all — with a mine used for storage, so the stored heat can be used to cover peak loads during the winter." There are two key ▶

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requirements if that is to happen, however. Not only will the monitoring of the WINZER project have to produce positive findings and indications of where optimization is possible, but the existing bureaucracy will also have to prove to be open to the technology. It took Hahn an entire year just to clarify the legal and regulatory aspects with the various agencies involved and finalize the authorization agreement with the owner of the small mine underneath the Fraunhofer IEG grounds. "We've set a new precedent here," says Hahn.

> "The heating transition will be impossible without solutions for storing heat, adapted to local conditions."
>
> Florian Hahn, Fraunhofer IEG

From permanent damage to permanent benefit

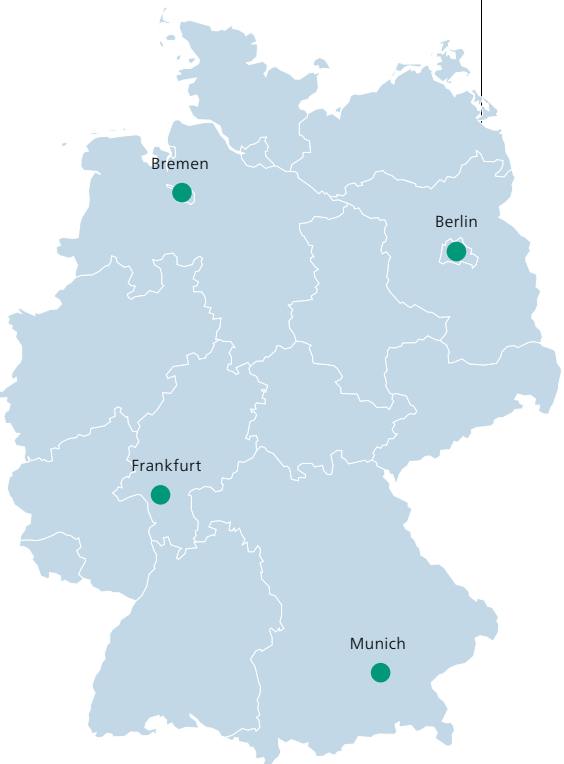
The effort may be worthwhile from both an ecological and economic standpoint. While renewable energy is making up an ever-larger share of the electricity supply, the supply of renewable heat and cooling is lagging behind. Right now, more than 50 percent of energy in Germany is used to provide heat and cooling, with renewables accounting for just seven to 12 percent. Among other things, there is a lack of ways to store surplus solar heat in the summer. "Using solar heating and mine water as a storage medium can help balance out seasonal differences in supply and demand," Nehler says. Hahn adds, "Our goal is to take the permanent damage caused by mining and turn it around into a permanent benefit. That way, the negative impact can be used for positive added value."

Currently, Hahn and Nehler are presenting the WINZER system to a number of interested representatives of municipal utilities and district heating network operators. "The energy crisis sparked by the war in Ukraine has brought a sea change in how people are thinking about municipal heat planning," Hahn explains. Industry is also looking for new avenues of decarbonization. Using underground mine water to store heat may be just one piece of the puzzle when it comes to storing heat — but it is one that fits perfectly in places like the Ruhr region and the former mining regions of Saxony and the Ore Mountains. "We need storage capacity to carry renewable energy over from day to night and from summer to winter," Hahn says. "The heating transition will be impossible without these kinds of solutions for storing heat, adapted to local conditions." ■

Many small-scale mines were dug in the Ruhr area in the postwar era (photo: Museumszeche).

Photo: Horst Ossinger/dpa

Fraunhofer on the road



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Dr. Hunter King,
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