Fraunhofer
4 | 21

Fraunhofer

The magazine for people shaping the future

"Stronger support for research!"
An interview with minister Stark-Watzinger

We have the energy!

Sun, wind, heat — ready for the transition

Dr. Andrea Herbst, Fraunhofer ISI

From the heart
Research with its finger on the pulse — new technology and treatments

The cars of the future
Mobility of the future
More diversity on our roads


Fraunhofer
Save the new date:
Sept. 28 – 29, 2022
The Quantum Breakthrough
FUTURAS IN RES, Berlin
The second-generation quantum technologies have already resulted in an increasing number of practical applications and bear a high innovation potential for the years to come. Our invited international experts from research and industry will present you the latest R&D advancements and applications in the visionary areas of Quantum Imaging & Optics, Quantum Communication, Quantum Sensing and Quantum Computing. Find out more: www.fraunhofer.de/fir2022

Editorial

Pioneers of change

Prof. Reimund Neugebauer

The future and the changes required to shape it successfully are part of our DNA at the Fraunhofer-Gesellschaft. With almost 30,000 employees across 75 institutes, this world-leading organization for applied research is responding to the current challenges that industry and society are facing. These include issues relating to climate-neutral research operations, as well as aligning the organization's focus with mission-oriented research that aims to address major societal challenges, namely climate change, health and increasing the impact of the organization on industry and society.

Already well-equipped with the expertise of its institutes, the Fraunhofer-Gesellschaft is also creating the necessary conditions through the Fraunhofer Agenda 2030. With our high-profile service areas, we aim to guarantee excellence in knowledge transfer as well as participation in publicly funded, large-scale projects and research infrastructure. In view of the tasks that lie ahead of us and the growth in our volume of research topics and capacity over the past six years, in the future, the Fraunhofer-Gesellschaft will bring in another research-focused executive board member so as to focus systematically on research infrastructure, construction, procurement, digital transformation and the development of a knowledge-management system.

In relation to climate neutrality, the Fraunhofer-Gesellschaft has itself pledged to become climate-neutral by 2030. To achieve this target, harmful greenhouse gas emissions will need to be reduced by at least 55 percent and offset through compensatory measures. By 2045, Fraunhofer will meet the challenge of reducing greenhouse gas emissions to almost zero. The establishment of a Fraunhofer living lab for climate-neutral science is designed to provide organizational support for the implementation of this extensive transformation process.

Applied research and its associated economic, ecological and social impact are the hallmarks of the Fraunhofer-Gesellschaft. To support the German economy during and after the coronavirus pandemic, this year, we are once again investing over 70 million euros of special funding in 30 cross-institutional and systemically important research projects that will boost innovation in industry in the long term. For small and medium-sized enterprises (SMEs), Fraunhofer has launched the KMU-Akut program with a funding volume of 10 million euros.

Alexander von Humboldt described knowledge and understanding as the wealth of his native land, calling them a substitute for the goods that nature has provided in too meager a measure. Although he made this statement 150 years ago, in his work entitled "A Sketch of the Physical Description of the Universe," it applies to the situation in Germany equally well in 2021. Germany's "wealth" does not lie in raw materials, but in knowledge and understanding.

Let us use this knowledge together to bring about organic change that is of benefit to everyone. After all, to borrow an expression from Alexander von Humboldt once again, ideas are only of use when they come to life in many minds.

Sincerely,

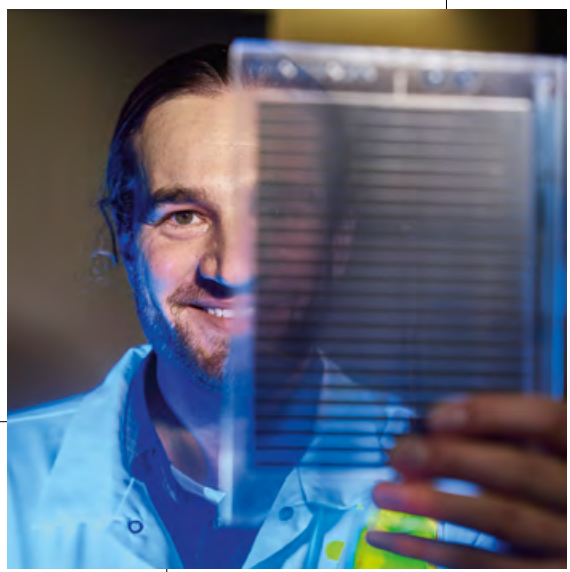
Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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

Photo: Fraunhofer/Bernhard Huber

back to page 1

Contents



32
Where is Emma?

Suddenly, a child vanishes. What now? Fraunhofer helps police search operations with a newly developed messenger app.

68
The whole world is wearing masks

Every month, the world uses 129 billion face masks. Fraunhofer researchers have cracked the challenge of recycling them.

51
Glittering beauties

Diamonds will only shine if cut and polished. Fraunhofer is using math to help out.

47 percent of the German population can already picture themselves buying an electric car, according to the social sustainability barometer 2021 ("Soziale Nachhaltigkeitsbarometer 2021") — despite deficiencies in the charging infrastructure. This representative study showed that around half of the respondents are ready for the transport transition. However, it must be affordable.

47 %

Cover photographs: Johannes Arlt, istockphoto; Content: Johannes Arlt, Heinz Heiss, Mecklenburg-Vorpommern State Chancellery, Sylvio Dittrich/DML-BY, Iconeo, Yves Herman/Reuters/dpa

back to page 1

Brief report

Leaves could provide climate-neutral energy — and could also be used as fertilizer.

Putting leaves to better use

Leaves rot slowly, but burn well. For this reason, researchers at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT plan to use them to generate climate-neutral energy in biomass furnaces. Even the ash could be recycled, since the nutrients it contains may be suitable for use as fertilizer.

During the fall season, trees in German cities and municipalities shed between 620,000 and 740,000 tons of leaves, which is more than the total volume of waste generated annually in Cologne, a city of one million inhabitants. Timely removal of leaves by street cleaners is essential to ensuring that streets and sidewalks do not become slippery and gutters do not become blocked. Usually, the accumulated biomass ends up in composting plants. The problem is that this uses up the capacity of these plants for a relatively long period of time.

An alternative recycling solution could be incineration. However, this is made difficult by the inhomogeneous composition of the leaves, with soil deposits, stones or sand causing contamination. Up to 50 percent of the ash does not come from withered leaves, making it difficult to use as fertilizer later on. Furthermore, the moisture content varies depending on the weather, and the quantity of leaves fluctuates greatly depending on the season. To ensure the consistent availability of a cost-efficient and sustainable fuel, the LaubCycle project is therefore investigating appropriate treatment and storage procedures. ■

3D model helps save lives of premature babies

In premature births that occur before the 35th week of pregnancy, the lungs are not yet fully developed, leaving the airways prone to complications. Dr. Claire Fabian of the Fraunhofer Institute for Cell Therapy and Immunology IZI, together with her colleague, Dr. Mandy Laube of the University of Leipzig, has created an innovative three-dimensional cell culture model, known as an organoid, of the premature lung. It is designed to facilitate the development of new therapies and drugs for premature babies and to make animal testing redundant.

Organoids replicate essential aspects of the structural tissue organization and organ function and can be used to model developmental and disease processes. The new 3D model shows the prenatal development of the lungs and makes it possible to examine organ development and improve vital functions for premature babies.

Where there is a risk of premature birth, cortisone is usually used to accelerate the maturation of the lungs.

A fetal lung development disorder can have serious clinical implications for newborns, such as acute respiratory distress syndrome or bronchopulmonary dysplasia, a chronic lung disease that can lead among other things to a persistent increase in oxygen requirements and increased respiratory infections. ■

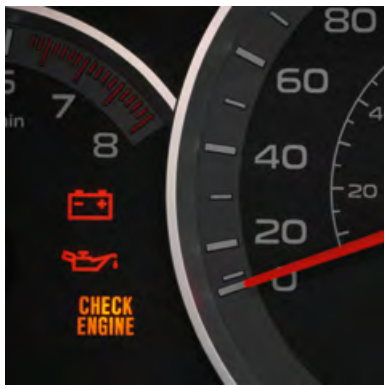
Porcelain art from a printer

Using an innovative 3D printing process, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS has succeeded in restoring valuable exhibits from the world-famous Dresden porcelain collection. This collection was established at the start of the 18th century by Augustus the Strong. For several years, he was the only person in Europe who knew the secret of how to produce this exotic material from China.

This new method devised by Fraunhofer IKTS will make it possible to restore porcelain in a way that is more faithful to the detail of the original and makes it more durable than before. Currently, restorers must either manually fashion the necessary small parts from porcelain or switch to non-durable plastics if they want to use 3D printers. "It will now be possible to print materials that are of higher quality or even true to the original, such as porcelain," explains Dr. Tassilo Moritz, who headed up the RestaurAM project at Fraunhofer IKTS.

"The results are outstanding," confirms Heike Ulbricht, a restorer at the Dresden state art collections (SKD). "This process has the potential to become an important addition to the restoration of valuable art objects made of porcelain." She also hopes it will encourage digital communication between national as well as international art collections, since vase fragments need to be scanned prior to 3D printing. In future, museums could compare the resulting 3D data to similar damaged exhibits at other locations. ■

The new process made it possible to perform a faithful reconstruction of the broken trunk on the historic elephant-head vase.



Low-friction motors and gear mechanisms can significantly improve energy and environmental auditing.

As smooth as it gets

Researchers at the Fraunhofer Institute for Material and Beam Technology IWS are working on the development of motors and gears that are almost frictionless. Due to a reduction in friction and waste heat, improved ultra-hard carbon coatings should give electric bicycles more range per battery charge or help industrial machinery to operate more energy-efficiently, for example.

The basic idea is that engineers add foreign atoms, such as boron, to the carbon layers in the motor, where there is already very little friction. The foreign atoms then combine chemically with certain lubricant molecules in the motor to generate super-lubricating interfaces during operation. In comparison to today's solutions, they are expected to reduce friction in the motor by half. The researchers estimate that lower-friction motors could save up to two terawatt-hours of energy per year in Germany alone, and therefore approximately 520 kilotons of CO_2. This is approximately equivalent to the energy consumed by 800,000 two-person households annually. The first super-lubricating motors from the "Prometheus" research project are expected to be used in production vehicles from 2025 onwards. ■

Photos: Chris Lawton/unsplash, Adobe Stock, Adrian Sauer/porcelain collection, Dresden state art collections (SKD), istockphoto

back to page 1

Editorial notes

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

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

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

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

Editorial assistants:
Dr. Janine van Ackeren, Mandy Bartel, Christine Broll, Meike Grewe, Sirka Henning, Michael Krapp, Dr. Monika Offenberger, Tim Schröder, Franziska Sell, Mehmet Toprak, Britta Widmann

Layout and lithography:
Vierthaler & Braun
Cover image and "Energy" cover story photography: Johannes Arlt
"In the right direction" photograph:
Heinz Heiss
Printed by:
hofmann infocom GmbH, Nuremberg

Find Fraunhofer on social media:

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

Climate neutral
Print product
ClimatePartner.com/11586-2110-1015

MIX
Paper from responsible sources
FSC® C022647

"Strong financial support is needed"

Interview

For the first time since 1965, the Free Democratic Party (FDP) is in charge of both the Ministry of Finance and the Ministry of Research in Germany. The new Minister of Research, Bettina Stark-Watzinger, talks about her ambitions, her curiosity and her plans for research in Germany.

Interview: Josef Oskar Seitz

Bettina Stark-Watzinger, 53, was sworn in as Federal Minster of Education and Research on December 8. Prior to her career in politics, the economics graduate was managing director of what is now the Leibniz Institute for Financial Market Research.

Ms. Stark-Watzinger, your motto is: "The future belongs to those who take action." In terms of the future, which tasks will you tackle first as Minister of Education and Research?

Bettina Stark-Watzinger: As a coalition, we are keen to make more progress, and education and research have a key role to play in this regard, as they are the most significant catalysts for progress in our country. It is my ambition to build on what has been achieved so far and to proceed quickly with launching the projects in the coalition agreement that are in my area.

The coronavirus pandemic has exposed the need for modernization in the education sector. It is therefore of particular importance to me that the Digital Pact for Schools is fast-tracked and bureaucratic hurdles are removed. The German Federal Training Assistance Act (Bundesausbildungsförderungsgesetz, BAföG) is to be reformed and the dependency on parents reduced. And with our "Startchancen" program, we aim to provide additional support to those children and young people who need it most. It is only through research and transferring results into practice that we can address these various challenges. Action is needed in the areas of top-class research, data and the relevant institutions.

Prior to your political career, you were the managing director of a research institute. What have you taken from that role to your new job?

During that time, I gained a deep insight into the daily work of researchers and developed great respect for the work they do. Their curiosity continues to inspire me every day. I have resolved to maintain this level of curiosity, too. As an economist, it was only natural for me to work in financial research, where I feel at home. In addition, I have experienced firsthand how challenging it is to make research possible in the first place, to guide it to a successful outcome and to ensure that it is financed in a sustainable manner. This will be of benefit to me now as Federal Minister of Research. For example, it is important to me that a balance is struck between base funding and project funding. Base funding must not be sacrificed in favor of project funding.

We are about to go from the year of crisis that was 2021 into 2022, a year that is again starting off with a crisis. What role do you expect research to play in making Germany more resilient?

There is already outstanding work being done here in the field of science, ranging from health to labor to climate research. First of all, however, it is our responsibility in politics to make our society more resilient, and I mean that in the broadest sense. Resilience is not just about quickly and successfully coping with a specific pandemic situation or extreme weather event; it is about making Germany as a whole more resilient. This applies to the supply of energy and raw materials and of course also to global competitiveness in general. This is the only way for us to safeguard our future viability and opportunities in the long term. That is

why the new German federal government plans to further extend the sovereignty of Germany and Europe in this regard. We want to be able to overcome this crisis and future crises quickly and in a responsible manner. Research can help us to do so by identifying risks as early as possible, devising possible solutions in advance and putting these solutions to the test. My expectation is that research will continue to provide the basis on which we make evidence-based political decisions, even when under enormous time pressure in ongoing emergency situations. It is therefore very important to me to direct research funding towards making promising innovations feasible, starting with basic research, followed by applied research and extending to experimental development. An important prerequisite for this innovative strength is an openness to technology. Also, during the pandemic, we were able to find a scientific solution quickly because we were able to draw on relevant basic research. We therefore want to continue to provide extensive support for self-initiated basic research that is driven by scientific curiosity.

"I have experienced firsthand how challenging it is to make research possible."

Bettina Stark-Watzinger

My aspiration is for us to become world leaders and even attain Nobel Prize standard. Emerging green technologies that provide climate-neutral energy sources and enable resource-efficient management will play a key role. I expect us to achieve scientific breakthroughs here in the coming years that will make Germany a global pioneer of technology in the areas of climate, energy and the circular economy.

It seems like congratulations are in order: Now that the FDP is in charge of both ministries for the first time since 1965, you're on good terms with the Minister of Finance. Why does research need increased financial support?

In view of the challenges facing our country, such as digitalization, changing demographics and climate change, strong financial support is needed for increased innovation, competitiveness and climate-neutral prosperity. That is why we have ring-fenced a target of 3.5 percent in the coalition agreement. I would like this support to be used to achieve the scientific advances that we urgently need.

We can also use it to create opportunities. I see a particular need for action in terms of achieving our climate and sustainability targets. Furthermore, international competition will continue to intensify in key technology areas such as artificial intelligence or quantum technologies. Germany needs to and wants to become a significant player in this changing global landscape and to further expand its technological sovereignty at a European level. We want to leverage the global visibility that Germany has gained through the development of the first mRNA vaccine to become the leading location for biotechnology internationally. However, we cannot generate this support for research through extra funding alone. By carrying out regular and comprehensive impact reviews, we will also assess the effectiveness and efficiency of government measures in general and create new opportunities for growth.

For the FDP — and for the Fraunhofer-Gesellschaft, too — climate protection and economic growth are not mutually exclusive. The transition of the energy and transport sector and the circular economy are once again the hot topics for our research institute in this issue of the Fraunhofer magazine. What do you plan to do to speed up the application and transfer of research findings to industry?

Germany is in a good starting position. However, we need to significantly improve the link between science and industry and the transfer of results into practice. For me, this transfer is not a one-way street leading from academic research to industry, but a continuous loop. This means that those whose job it is to apply the research results at the end or to refine prototypes should be involved in the research process from the start. These people may be experts from industry but could also be professional users such as doctors, or private users, i.e. ordinary citizens.

One area of priority will be the establishment and development of the German Agency for Transfer and Innovation (DATI), which fosters social and technological innovation, in particular at universities of applied sciences and in small- and medium-sized universities, in collaboration with start-ups, SMEs and social and public organizations, among others. We will continue to create innovative regions based on the British model and to avail of and expand the scope of activity provided for by national and European law. In this context, I am committed to a mission-based research policy that involves all stakeholders at an early stage, particularly the eventual users of the product. We will take advantage of the opportunities afforded by digitalization and leverage the potential of data in a targeted manner. Federal innovation funding should be made consistently available for societal, social and ecological innovation projects. ■

Photo: Thomas Trutschel/photothek/imago images

back to page 1

Title

How can we harness solar energy without emitting excessive quantities of CO_2 when producing the solar cells? Lukas Wagner of Fraunhofer ISE is doing his best to find out.

We have the energy!

The energy transition can be done — and with solar, wind, hydrogen and geothermal power, there many ways of getting there.

By Dr. Janine van Ackeren, Photos: Johannes Arlt

back to page 1

The weather has turned cold in Germany. Winter is closing in and the message is clear: Energy is precious — and like all precious things, it has a cost. Drivers are feeling the truth of that, as steep price increases pummel them at the fuel pumps. In fact, everyone who wants to stay warm in their own home is feeling it. Gas prices have soared, leaping by more than 400 percent in the April to November period alone. But the pressure to introduce smart energy management and saving technology is not the only thing that's growing. Thanks to its significantly lower prices, renewable energy is giving individual consumers ever more opportunities to cover their energy needs in a cheap, eco-friendly way. For the community as a whole, however, the climate is what's at stake here. According to the target laid down in the German Climate Protection Act (Klimaschutzgesetz, KSG), Germany is to become a climate-neutral country by 2045, meaning that its net emissions balance would have to be reduced to zero. The act also set an intermediate target of reducing green house gas emissions by at least 65 percent in comparison to 1990 by the year 2030. There is some good news: "We can achieve climate neutrality by 2045," says Dr. Andrea Herbst. "But it will take serious effort," the research fellow at the Fraunhofer Institute for Systems and Innovation Research ISI is quick to add.

In collaboration with more than 50 researchers from various institutions, Dr. Herbst recently published a study for the Ariadne project, focusing on Germany's path to climate neutrality by 2045. In brief, the study found that renewable electricity, green hydrogen and green e-fuels are set to become the most important energy carriers. Furthermore, renewable energy production must be expanded massively by 2030. Then, it would actually be possible to eliminate our use of coal as an energy source by 2030 — something the government parties laid down as an "ideal" target in their coalition agreement.

The researchers analyzed six different scenarios for achieving our climate targets, using four technological focus areas: direct electrification, hydrogen, synthetic e-fuels such as methane and an energy mix. In addition to Fraunhofer ISI, various other members of the Fraunhofer Cluster of Excellence CINES participated in the study, including the Fraunhofer Institute for Solar Energy Systems ISE, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE and the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG.

> "We can achieve climate neutrality by 2045. But it will take serious effort."
>
> Dr. Andrea Herbst, Fraunhofer ISI

The targets are ambitious. Industrial CO_2 emissions would have to be reduced by 57 percent by as early as 2030. "High-temperature processes involving furnaces and steam generation are especially challenging, and so are the emissions that are ▶

A bright future: Dr. Andrea Herbst takes a closer look at Germany's path to climate neutrality in a study for the Ariadne project.

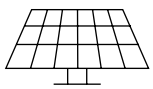
back to page 1

produced by chemical reactions during the processes," explains Dr. Herbst, who is heading up the Ariadne work package on the industry transition. This means there is an urgent need to make investments and replace old plants with new plants before their time runs out. What's more, the industry sector must switch over from previously cheaper energy sources to initially more expensive, sustainable sources such as electricity or hydrogen. This will only be possible if the regulatory framework is significantly expanded, going far beyond the measures that have currently been agreed on and implemented — to be precise, this expansion would have to cover CO_2 pricing, research and investment funding, closing the profitability gap and regulatory law. Another important factor is that electricity and hydrogen must be available around the clock and in sufficient quantities. "Security of supply will play a major role here," says Dr. Herbst. The targets for the heating transition are also quite a stretch. By 2030, the annual building renovation rate must reach 1.5 to 2 percent, five million heat pumps must be installed and around 1.6 million buildings must be newly connected to district heating networks. In short, to make Germany climate neutral in less than 25 years, the new German federal government must hit the ground the running in a lot of areas.

The Fraunhofer Cluster CINES went further in exploring the question of how the energy transition can succeed and conducted an energy system analysis — resulting in seven recommendations for the new German federal government. For example, the experts advised creating a clear framework for the industry sector, which would in turn serve as a means of enabling companies to invest in carbon-neutral production technologies. They also recommended developing possible means of carbon capture and storage, and pointed out that sharply accelerated expansion in wind and solar energy would be the core element of the energy transition.

The sun

"If you assume that humanity as a whole will opt for the cheapest alternative, then you'll reach the conclusion that photovoltaics are going to become the most important energy source," says Dr. Jan Christoph Goldschmidt, who has worked at Fraunhofer ISE for many years and recently became professor of experimental physics at the University of Marburg. "In the long term, around half the electricity for the entire world must come from the sun." That means by 2050, we must have installed a photovoltaic capacity of 20 to 80 terawatts, and by 2100, we will need 80 to 170 terawatts." By way of comparison, a nuclear power plant has a capacity of a little more than a gigawatt, which is 0.001 terawatts, so the resources required for this expansion of worldwide photovoltaic capacity will be significant. Fraunhofer ISE and the Potsdam Institute for Climate Impact Research have conducted a new study to highlight this shortcoming, but they found that this rapid increase in photovoltaic capacity is in fact possible. However, it will require more efficient manufacturing technologies, as well as the infrastructure for recycling the old photovoltaic systems. "To reach this target, we must work at full tilt to install solar cells in their current form, while simultaneously driving innovation forward," stressed Dr. Goldschmidt. The development of solar cells has involved a number of learning curves, with not only costs but also energy requirements for manufacturing and silver consumption continuously dropping.



The worldwide energy generation capacity of photovoltaic systems is growing rapidly, jumping by 38 percent a year on average. Although the global installed capacity was only 100,000 kilowatts in the early 90s, solar power had already reached **a capacity of 700 million kilowatts by 2020.** If this growth continues, the installed capacity will reach **around 60 billion kilowatts in 2035.**

However, by 2100, it's possible that photovoltaic manufacturing will require more glass than is currently produced worldwide. The supply conditions for metals like silver could be critical. The best case scenario would be for total consumption to remain around the current level of 2860 tons per year — provided the rate of innovation remains the same. The study also offered some encouragement in the context of energy requirements for manufacturing. The energy consumed in producing photovoltaic systems is expected to level out at around 4 percent of the solar cells' power output, which is about the same proportion as the energy consumed in producing power from fossil fuels.

However, this will also require some innovative developments. If many photovoltaic modules are manufactured using power generated from coal, this would use up a significant amount of the CO_2 budget. In fact, not all photovoltaic systems are made equal when it comes to their "ecological rucksacks." "Photovoltaic modules produced in the EU represent a 40 percent saving in CO_2 emissions when compared to modules imported from China," explains Dr. Holger Neuhaus, head of department

at Fraunhofer ISE. This figure came from another study by Fraunhofer ISE. But in 2019, 76 percent of all solar cells and 71 percent of photovoltaic modules were produced in China.

The basis for the study came in the form of a cost calculation tool developed by Fraunhofer ISE. The tool covers each individual step in the manufacturing process, from raw silicon through wafer production right up to manufacturing the solar cells and modules. "We were able to clearly determine how much energy is required to manufacture a specific module and how big the 'ecological rucksack' is in various different countries," explains Dr. Neuhaus. "The main thing that makes a difference here is the energy mix that the respective country uses. While China generates a large portion of its energy by burning coal, Germany now obtains more than 50 percent of the necessary power from renewable sources." By contrast, the process of transporting the cells from China to Germany results in an emissions increase of only 3 percent. The carbon footprint will also vary depending on the type of solar cell. For example, manufacturing frameless glass-glass modules emits 7.5 to 12.5 percent less greenhouse gas than manufacturing photovoltaic modules with backsheet films. If the much longer service life of the glass-glass modules is taken into account, then the reduction in CO_2 emissions can even reach 22 to 27 percent. However, there is one thing that must be emphasized as a result of these studies. Of course, the manufacturing process means that solar cells are not entirely emission-free, but these emissions are still 40 times lower than those produced when extracting and burning lignite.

However, rather than contenting itself with theoretical studies, Fraunhofer ISE is also developing the technologies needed to maintain the rate of innovation. For example, by making the contacts in the cells thinner, the researchers have reduced silver consumption by around 20 percent and increased efficiency by 1 percent. The Fraunhofer spin-off HighLine is continuing to advance this technology, while the ISE spin-off PV2plus has replaced the silver contacts entirely using copper contacts. With this approach, the amount of copper recycled in Germany alone would be sufficient to cover the future global demand for solar cell production. NexWafe, another company built on Fraunhofer ISE technology, is working on energy-efficient manufacturing of photovoltaic modules. Using an innovative production process, it has succeeded in manufacturing silicon wafers — the heart of every photovoltaic cell — far more efficiently than was previously possible.

As if on cue, an innovative technology that could reduce the "ecological rucksack" of solar cells manufactured in Europe even further has appeared on the scene — printed solar cells made from perovskite, a double salt that consists of one organic and one metallic salt and can be crystallized from a solution at room temperature. "The CO_2 from the manufacturing of the glass substrate is the only emission produced when manufacturing perovskite solar cells — that's only an eighth of what's required for even the latest silicon technology," reports Dr. Lukas Wagner, a scientist at Fraunhofer ISE. Perovskite solar cells also come with lower costs. A module factory in Germany would be 80 percent cheaper than a conventional silicon photovoltaics factory and the solar cells themselves would be 50 percent cheaper.

Although the suitability of perovskite for use in photovoltaics was only discovered by accident in 2009, the metal-organic compound is already competing with the top-tier materials. "Today, perovskite solar cells have already reached a higher level of efficiency than most established technologies — only monocrystalline silicon and GaAs (gallium arsenide) remain a bit more efficient," enthuses Dr. Wagner. So what is it that makes perovskite so special? It's produced from a solution that is very easy to handle and forms a very thin crystal film — 300 to 500 nanometers to be exact. By comparison, silicon is 180 micrometers, i.e. 180,000 nanometers thick. As such, the perovskite solar cells are very material-efficient to manufacture. "At Fraunhofer ISE, we're developing printable solar cells that can be applied to a glass plate using a screen or ink-jet printer — roll-to-roll procedures can also be used," Dr. Wagner explains. "Our vision is that we will use established processes from the vehicular glass industry for manufacturing perovskite solar cells, and so make them fit for mass production. This will allow the German glass industry to move into photovoltaic manufacturing," says Dr. Wagner.

The EU project UNIQUE, which is led by Fraunhofer ISE and involves all the stakeholders in printable solar cells, is pushing the efficiency of these new ▶

"Today, perovskite solar cells have already reached a higher level of efficiency than most established technologies."

Lukas Wagner, Fraunhofer ISE

back to page 1

"The CO_2 from the manufacturing of the glass substrate is the only emission produced when manufacturing perovskite solar cells — that's only an eighth of what's required for even the latest silicon technology."

Lukas Wagner, Fraunhofer ISE

Hope comes in green: Printed solar cells made from perovskite, a double salt that can be crystallized from a solution at room temperature.

solar cells to even higher levels. The long-term objective of the project is to reach excellent efficiency at the module level, with rates of more than 20 percent. "Efficiency records are mostly set using materials that are far too expensive to go on the roofs of houses. By contrast, we're using inexpensive materials and employing processes that would be suitable for capacities of a terawatt and more — such as graphite contacts, for example," says Dr. Wagner, whose research took second place in the energy campus ("Energie-Campus") idea competition by a German foundation for energy and climate protection ("Stiftung Energie und Klimaschutz") three years ago. In addition to the efficiency, the researchers are also working on the stability of the perovskite solar cells. "The hot-spot test had the perovskite community seriously worried for a long time. But now, for the first time, we've shown that it's possible to pass it," reveals Dr. Wagner. In this test, the light to one cell is blocked — as can happen in real-life conditions due to fallen leaves, for example. This sounds harmless, but the cell then operates in reverse voltage and all the power flows through it, which can cause damage.

With the highly stable contact layers used at Fraunhofer ISE, the printed solar cells were not only able to withstand the hot-spot test, but also to reach operational life spans of 10,000 hours — on a German roof, that would be the equivalent of ten years of continuous operation.

Efficiency is a decisive factor for solar cells, but individual silicon solar cells can't go beyond 29 percent — it's the theoretical upper limit for efficiency, this high and no farther. However, if you connect two solar cells to create a tandem cell, it would theoretically be possible to reach up to 40 percent efficiency. With three cells, this could even go as high as 45 percent. If you were to stack an endless number of solar cells one on top of another, then the absolute maximum efficiency would reach more than 85 percent. The reason is that while individual solar cells collect light of all colors, the light is split for tandem cells. It's as if the work were divided up based on the different wavelength ranges. The top cell only "sees" blue light, the one beneath only green, and so on, with each solar cell being optimized for its range of the spectrum.

In the Fraunhofer lighthouse project MaNiTU, Fraunhofer ISE, the Fraunhofer Institute for Mechanics of Materials IWM, the Fraunhofer Institute for Silicate Research ISC, the Fraunhofer Institute for Microstructure of Materials and Systems IMWS and the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS are developing sustainable materials for tandem cells based on silicon and perovskite. This involves applying a layer of perovskite to a silicon substrate. "We expect these tandem solar cells to achieve high efficiency levels at low cost and with low resource consumption," confirms Dr. Goldschmidt. The first step was to screen possible materials to see if they would work in theory. "We took sustainability factors into account right from the outset — so that meant ruling out toxic materials like lead and materials that are not available in sufficient quantities," said Dr. Goldschmidt. Some possible materials have already been identified and various different materials have also already been synthesized. "Things are going well, and I expect us to set a new record in the course of this project," Dr. Goldschmidt affirms.

In the long term, also Dr. Wagner hopes to join his perovskite solar cells together to form tandem solar cells.

To date, silicon-based solar cells themselves have been virtually unbeatable on an individual cell level when it comes to electricity generation costs. However, other solar cell types are becoming increasingly relevant. For example, flexible solar cells could be used to generate electricity wherever silicon modules can't be installed due to their rigid form, like the pillars on wind turbines, curved building facades and — in the case of partially transparent cells — even on window panes, or as solar curtains that provide shade. This would become economically viable once 10 percent efficiency is achieved. By comparison, silicon solar cells have currently reached around 25 percent efficiency. "If we succeed in transferring this efficiency of more than 10 percent from the lab to our roll-to-roll plant, industrial mass production would be within our grasp. The laboratory groundwork and the necessary modifications to the plant were completed in 2021. We could revolutionize the production of flexible solar cells in 2022," says Ludwig Pongratz, a scientist at the Fraunhofer Institute for Laser Technology ILT. He hopes that by 2030, the flexible solar cells could be on the market, making a significant addition to the energy mix in the form of greenhouses or solar awnings.

Researchers at the Fraunhofer Institute for Applied Polymer Research IAP also hope to use large glass facade surfaces for electricity generation in the future. To make this vision a reality, stakeholders all along the value chain, from material and window manufacturers right up to housing companies, have joined forces in CoSoWin, a project funded by the German Federal Ministry for Economic Affairs. Fraunhofer IAP uses nanoparticles to apply a coating to the window panes that collects light, conducts it to the front side of the glass pane and feeds it into an organic solar cell there. "The efficiency is only at 4 to 7 percent at the moment, which is very limited. However, we're proceeding on the assumption that it will be possible to reach 10 percent," says Dr. Armin Wedel, a department and research area head at Fraunhofer IAP.

The wind

Wind energy capacity must be increased by at least 9 gigawatts a year between now and 2030 in order to produce enough CO_2-free electricity for Germany. To achieve these targets, increasing the size and capacity of offshore wind energy plants will be vital — as will optimizing plant operations and reducing downtime. ▶

back to page 1

Wind energy is based on highly advanced plant technology, which is also the result of a plethora of innovative research projects. In the last five years, the Fraunhofer Institute for Wind Energy Systems IWES alone worked on 500 research projects, covering everything from planning processes, development, construction and operation to machine monitoring, repair processes, service life and the removal and reuse of all components.

But it will take even more research to exploit the full potential of offshore technologies. After all, the conditions that these gigantic plants must work in are extreme — salt water, hurricanes with 12 force winds, and waves that tower at 15 meters. And there are other challenges too. Because laying foundations at sea is such an expensive business, the plants are built at the largest scale possible. The largest biggest prototype to date has a rotor diameter of 222 meters and a maximum capacity of 14 megawatts. Before construction, the plants and their components must be tested extensively and under realistic conditions. Fraunhofer IWES has built the necessary testing infrastructure and is assisting the industry sector in testing the latest prototypes and continuously advancing development of their validation methods.

Wind energy is currently the biggest climate-friendly energy source. In 2020, wind farms produced **132 terawatt hours** of electricity in Germany. For the first time, the proportion of wind power surpassed the sum of all fossil sources, with wind supplying the **largest share** of Germany's energy mix. What's more, wind energy plants are particularly effective when it comes to avoiding greenhouse gas emissions.

But extreme storms are not the only challenge for high-tech offshore plants — major risks for the construction of these enormous facilities lurk at the bottom of the sea as well. Objects like boulders on the sea floor are a particularly serious risk, as the foundation structures could hit them during installation. If this results in such severe damage to the structures that they have to be removed and replaced, this could cause direct costs of up to 15 million euros — with additional secondary costs in the multidigit million range. However, that risk can now be significantly reduced thanks to a measurement process developed by Fraunhofer IWES and the University of Bremen. "We generate acoustic signals from an electrical or pneumatic source and transmit them to the ground. If there's an object there, it will reflect the sound — and we can measure that," says Dr. Benedict Preu, Head of the Sub-surface Investigations department at Fraunhofer IWES. Word of this innovative approach got around quickly in the world of wind farm operators. "We already have requests for up to 120 million euros for the next few years, coming from all over the world — far more than we can manage," relates Dr. Preu. Licensing agreements are now being put in place to help meet the deluge of requests. The impact of the technology has even spread to the insurance business. Insurance providers take the Fraunhofer IWES investigation technique into account when calculating premiums.

The IWES also aims to develop the technique further, so that it can detect cables laid in the ground — like the high-voltage cables for transporting power from the wind farms to land. According to government requirements, the position and depth of these cables must be checked once a year, to ensure they do not present any risks to fishing or sharply increase the temperature of the sea floor. However, when using conventional procedures, these checks entail turning off the power cables for up to two weeks. As a single high-voltage cable often carries power from up to ten wind farms, this quickly racks up some serious costs. "With our technology, for the first time, it's possible to exhaustively survey the position and depth of the cables, even during active operation," says Dr. Preu. ▶

"We already have requests for up to 120 million euros for the next few years, coming from all over the world."

Dr. Benedict Preu, Fraunhofer IWES

Bearing our hopes: With rotor blades of up to 222 meters in diameter, wind energy plants need stable foundations. Dr. Benedict Preu from Fraunhofer IWES has a solution that can reduce the construction risks.

back to page 1

Hydrogen

No matter how important electricity generation may be, it won't be enough to make Germany climate-neutral. Because some sectors can only be defossilized through hydrogen — for instance, steel manufacturing. Various high-temperature processes are also depending on hydrogen to get them to their emission-free target.

Hydrogen could play an important role in the energy transition by serving as a means of storing excess wind or solar energy. Electrolysis can be used to produce emission-free hydrogen from water.

Consequently, in addition to expanding renewable energies through electricity generation, there must also be renewable energy facilities dedicated solely to H_2 production, where electrolyzers use (green) electricity to split water into hydrogen and oxygen.

The German federal government recently launched three lighthouse projects that will pave the way toward a hydrogen-based society — at around 740 million euros in total, it is the German Federal Ministry of Education and Research's largest funding initiative for the energy transition. Fraunhofer is also bringing its hydrogen know-how to bear in these projects. The largest of these three lighthouse projects, H_2Giga, is focusing on electrolyzers, with a view to putting an end to manual manufacturing processes and getting automated mass production of electrolyzers underway. The H_2Mare lighthouse project, coordinated by Siemens Energy and Fraunhofer IMWS, aims to harness the energy from offshore wind farms to produce hydrogen directly at the plants. Under the coordination of cruh21, a development company from the AquaVentus project, the Max Planck Institute for Chemical Energy Conversion and the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, the third lighthouse project, TransHyDE, has set its sights on hydrogen transportation. In particular, the TransHyDE project deals with questions such as how existing gas pipelines can be repurposed, what requirement there will be for new hydrogen pipelines and what container-based solutions are suitable for transporting H_2.

One obstacle on the road to a hydrogen-based society is producing sufficient quantities of hydrogen. This will take adequate levels of green electricity, large electrolyzers and various means of transporting the hydrogen — issues that the lighthouse projects, among others, are working on. However, despite all these efforts, Germany will not be able to produce enough hydrogen to meet the high levels of demand that are expected. There is simply no way around hydrogen imports. But realistically, will it be possible to establish this kind of importing infrastructure by 2030? The Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT has joined forces with the German Economic Institute and the Wuppertal Institute to answer this question. The results: "At a technological level, it would actually be possible to reach the target quantities that the National Hydrogen Strategy has set for hydrogen imports in 2030, namely 76–96 TWh/a, but only with (occasionally significant) cutbacks in the areas of sustainability and economic viability. The time frames involved — for engineering issues like converting old pipelines or building new ones, or the availability of ships, and especially the time frames required under planning and approval processes — are also standing in the way of large-scale implementation," says Dr. Christoph Glasner, a scientist at Fraunhofer UMSICHT.

While the Wuppertal Institute studied the selected target countries, namely Chile, Morocco, Spain and the Netherlands, the Fraunhofer researchers primarily concentrated on transporting hydrogen to Germany via pipelines, trucks and ships. How feasible is it on a technical level? Could restrictions stemming from approval processes hinder hydrogen imports? The necessary quantities could be transported by truck, but it would take approximately 1.5 million truckloads a year — not exactly a climate-friendly option. Shipping is also not a viable alternative at least until 2030, since there are still simply no qualified vessels that could transport liquid hydrogen. "Japan is indeed working on a small pilot craft. But, by the time the tests are completed, the approach has been transferred to larger ships and these ships have been constructed, the 2030 deadline could well have elapsed," affirms Dr. Bärbel Egenolf-Jonkmanns, a scientist at Fraunhofer UMSICHT. There's no short-term large-scale solution to be found in converting hydrogen into ammonia or storing it in the form of liquid organic hydrogen carriers (LOHC) either. It is unlikely that the necessary plant technology and harbor infrastructure could be developed by 2030. "In the long term, however, the technological potential for renewable energy in the four countries in the study is high enough to supply Germany with large quantities of green hydrogen," says Dr. Egenolf-Jonkmanns. Until then, the hydrogen will just have to be produced closer to the consumption sites — i.e. in Germany.

The PtX Atlas developed by Fraunhofer IEE is a valuable source of information on future import possibilities: For the first time, the whole world's power-to-liquid potential is on display. PtL is the term used for synthetic fuels that are produced from hydrogen using electricity. Due to the losses incurred during conversion, PtL ▶

A breath of hope: Dr. Andreas Menne from Fraunhofer UMSICHT hopes to make it possible to store hydrogen in the long term and transport it over long distances during importing.

back to page 1

fuels call for extremely cheap, renewable electricity. That means Germany and Europe cannot really compete in this area. "This open, interactive tool allows users to view all the countries in the world, and see what potential they offer in terms of using electricity to produce synthetic fuels. And the map shows the conditions and costs involved too," explains Maximilian Pfennig, a scientist at Fraunhofer IEE. When developing the atlas, the researchers took into account available space, weather conditions, local availability of water, environmental conservation and security of investment. The atlas shows that there are many places in the world where large quantities of the various power-to-X energy carriers could be produced renewably — although that's in the long term.

Ammonia is one of the most promising power-to-X energy carriers. It's a good option for long-distance hydrogen transport and long-term hydrogen storage. "If we assume that in 20 to 30 years, around one third of our energy will be imported as hydrogen, then ammonia is going to be a very important material," says Dr. Andreas Menne, head of department at Fraunhofer UMSICHT. However, at present, the process of converting ammonia back into hydrogen and nitrogen still presents quite a challenge — it takes a lot of energy. Rather than heating the complete reactor to the temperature required for the reaction from the outside, as conventional processes have done so far, Dr. Menne's research team are raising the temperature right inside the catalyst. This makes the conversion far more energy-efficient, while the construction is also simplified. "We believe this will allow us to improve the overall efficiency by at least 20 percent — and in process engineering, that would be a quantum leap forward," Dr. Menne reports. The first prototype, which is set to be completed in early 2022, will be able to produce around 1 kilogram of hydrogen per hour. Ultimately, the researchers' goal is to use this process to provide the imported hydrogen on a decentralized basis, with lower costs than running electrolyzers locally.

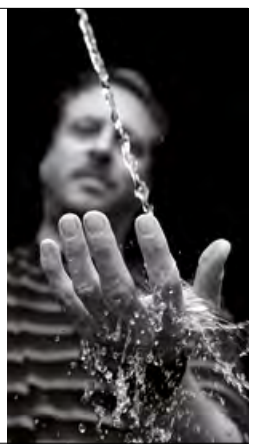
This winter is an ample demonstration of the value of a warm home. Solar collectors could be a solution for sustainable heating. But there is a drawback: They mostly generate heat in summer. In the ZeoMet project, a team at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP has improved one possible means of storing energy for the chilly season, by optimizing thermochemical storage systems. It's a rapidly developing research field. The key to the systems is zeolite, a highly porous substance that can store heat for long periods with virtually no loss. It could allow us to harness the heat of summer even in winter. However, the problem is that so far, scientists have only been able to warm zeolite pellets that are in direct contact with the energy source.

"We coated the zeolite pellets with aluminum — this doubled thermal conductivity after just the first attempt, without negatively impacting water adsorption and desorption. We are currently aiming to increase this by a factor of five to ten by adjusting the coatings," says Dr. Heidrun Klostermann, project manager at Fraunhofer FEP. The institute has developed a special facility for evenly coating hundreds of thousands of pellets with aluminum.

Cooling buildings down can guzzle just as much energy as heating them up. In the year 2016, for example, around 2000 terawatt-hours of energy were required for cooling commercial and residential premises — according to estimates, that amounts to around 10 percent of worldwide power consumption. This amount could triple by 2050. "In existing buildings, if the heat pump — i.e. the heat generator — that is already installed can be operated in reverse to cool the place down, then it would be possible to use the existing heating system for cooling as well," says Sabine Giglmeier, a scientist at the Fraunhofer Institute for Building Physics IBP. This approach would not only eliminate the need to buy new air conditioning systems but might also save on energy.

The team analyzed the solution's potential for two different heating systems, in order to find out whether radiators and underfloor heating could replace air conditioning units. "In the end, we demonstrated that both systems could achieve sufficient cooling capacity depending on some parameters like heating area, type of construction and window surface area," recounts Giglmeier. That means heat pumps with cooling functions could be an alternative to expensive air conditioning systems for existing buildings.

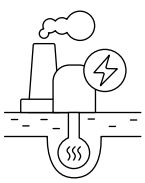
> "If we assume that in 20 to 30 years, around a third of our energy will be imported as hydrogen, then ammonia is going to be a very important material."
>
> Dr. Andreas Menne, Fraunhofer UMSICHT



Geothermal systems

When it comes to climate neutrality, most of the attention goes to renewable electricity generation. "However, the key to the energy transition is actually the heating transition," Prof. Rolf Bracke, director of Fraunhofer IEG points out. After all, generating heat for the industry sector, district heating and buildings takes up 56 percent of annual final energy consumption. By contrast, generating electricity only takes 14 percent of the primary energy. "If we want to be climate-neutral, we have to generate heat from renewable sources. Solar thermal systems will remain a niche option due to the amount of space they take up. And there isn't much room left for expansion in term of biomass either — we can only burn as much wood as we can regrow here in Germany. That just leaves geothermal heating," says Prof. Bracke. The demand for space and hot water heating in buildings alone represents 31 percent of Germany's final energy consumption. Although shallow geothermal energy is used in a significant proportion of new residential construction projects, with percentages well into the double-digit range, and medium-depth geothermal energy supplies many local heat networks in districts, there are few large-scale projects focusing on deep geothermal energy — because the effort involved is far greater. Instead of drilling a hundred meters down as for shallow geothermal energy, deep geothermal energy requires drilling down some thousands of meters, where the water reaches temperatures of 100 to 150 degrees Celsius and only remains in liquid form due to the high pressure. The amount of heat generated by deep geothermal systems would be enough to supply existing district heating networks. This is particularly important in densely developed cities, where it is not possible for every house to tap into shallow geothermal energy. Deep geothermal energy is also a good option for industrial processes, greenhouses, bakeries and paper manufacturers, as they need more energy than residential buildings.

"Deep geothermal energy could supply industrial process temperatures of up to 180 degrees, in combination with large heating pumps, for example — that corresponds to up to a third of the total industrial demand for heat," says Prof. Bracke. It's a combination that Fraunhofer IEG is exploring as well. The research team is working with Fraunhofer UMSICHT to develop a plan for switching a Hagen-based paper factory's heat-intensive paper manufacturing process to a deep geothermal system, complete with a large heating pump. Bio-gas will also be used to supplement any shortfall. "While the upfront costs of a deep geothermal system are much higher than systems that burn fossil fuels to generate heat, the operating costs only amount to 20 to 25 percent of the fossil systems. So, depending on the location, deep drilling will pay for itself in five to 15 years," explains Prof. Bracke. That's why RWE Power AG is considering a deep drilling operation. In conjunction with Fraunhofer IEG, it is developing a geothermal power plant that could supply the Aachen region with renewable heat from 2029. It's an important date, because the last RWE lignite power plant, which supplies Aachen's district heating network, is due to shut down that year. The municipal utilities companies in Düsseldorf and Duisburg, as well as the Düsseldorf airport are also working with Fraunhofer IEG in the field of geothermal heating networks.



The heat energy stored in the earth's crust can be used for heating, cooling and generating energy.

Fraunhofer IEG is adopting an entirely unique approach in the Ruhr region, which is essentially built on a labyrinth of coal mines. "In Bochum, we intend to use the mines for seasonal heat storage, for industrial waste heat for example. We're currently building a demonstrator in the form of a large concentrated solar power plant, which we're using to heat the 20 degree mine water up to 70 degrees. Then, when needed, it can be raised to the district heating temperature of 110 degrees using a large heating pump. This approach, whereby we make use of easily available heat, could become the key to the heating transition for metropolitan areas on the Rhine and in the Ruhr region," says Prof. Bracke hopefully. The large heat pump from Fraunhofer IEG is set for installation in 2022.

Meanwhile, Fraunhofer IEE is campaigning for low-temperature networks. Instead of running at 90 to 120 degrees Celsius, these run at just 40 to 50 degrees. In collaboration with the German Energy Efficiency Association for Heating, Cooling and CHP ("Energieeffizienzverband für Wärme, Kälte und KWK") and various European research partners, Fraunhofer IEE has produced a reference manual showing how these networks could be implemented under a wide range of different conditions. "These low-temperature networks offer many advantages," says Dr. Dietrich Schmidt, head of department at Fraunhofer IEE. "At these temperature ranges, usable waste heat and geothermal heat would be available in much greater quantities. What's more, heat pumps and solar thermal systems are much more efficient at lower temperatures." It also reduces the strain on existing pipes and minimizes transport losses. Across Europe as a whole, the potential savings amount to a total of 14 billion euros a year. If you set yourself high targets, then clearly, you must search for solutions in every nook and cranny — not only looking to the heavens for sun and wind, but also down below, deep within the earth. ■

back to page 1

3×3 Questions

"Creativity that transcends"

Dr. Benedict Preu,
Fraunhofer Institute for Wind Energy Systems IWES

1 Are you optimistic about the success of the energy transition?
That would be a definite yes! We may have started too late and too slowly, but the most important thing is that energy transition efforts have really taken off in the last few years. Overall, this issue will continue to need our full focus for the next two to three generations.

2 Have you faced any challenges that seemed insurmountable but that you eventually managed to overcome?
We are still facing the almost impossible task of how to translate complex geophysical measurements into conclusions that can be used by engineers. The only way to avoid misinterpretation is for both sides to work together with patience and understanding. Otherwise, we will be unable to harness the full potential offered by cross-disciplinary collaboration.

3 Do we need to change our way of thinking?
Once upon a time, individual specialists drove breakthroughs and technologies that transformed society, but those days are behind us now. The technologies of the future will be developed by diverse, interdisciplinary teams and networks. To foster this cross-disciplinary creativity, we need to create new structures that focus on collaboration within a framework that is built on trust, and more importantly, respect. ■

"Slowly but surely, we're showing it's possible!"

Lukas Wagner,
Fraunhofer Institute for Solar Energy Systems ISE

1 Are you optimistic about the success of the energy transition?
Yes, yes I am. The question is, how long will this transition take us? We are already under time pressure to ensure man-made climate change is kept under 1.5 °C.

2 Have you faced any challenges that seemed insurmountable but that you eventually managed to overcome?
Perovskite has some impressive properties. So, perovskite is a semiconductor whose crystalline structure is held together by ionic rather than covalent bonding. This presents a number of advantages. For example, very high quality crystal layers can be easily created using printable fluid. On the negative side, ionic bonds break down easily. A few years ago, when I first started researching perovskite, I had concerns about whether these solar cells could ever be stable. But slowly but surely, we're showing that it's actually possible.

3 Do we need to change our way of thinking?
Many of the global issues we face today have arisen precisely because it is so difficult to think outside of the box. Clearly, an important aspect here is to ensure that the many, very specific issues relating to the energy transition are systematically placed in the wider context of our global challenges. And finally — and for engineers, physicists and chemists focused on the natural world, this is most important — we are not just facing a climate crisis, we are also experiencing an alarming loss of biodiversity. So for each technology we develop, we also need to ask ourselves the question: What impact could our technology have here? ■

Photos: Johannes Arlt

"An important signal for other sectors"

Dr. Andrea Herbst,
Fraunhofer Institute for Systems and Innovation Research ISI

1 Are you optimistic about the success of the energy transition?
I am convinced that the energy transition can be achieved successfully, despite the challenges that lie ahead. For the decades between now and 2030, it is vitally important that we set the right course for the future through renewable energies, infrastructure development, scaling of carbon-neutral processes to industrial level, heating transition and the retrofitting of buildings, as well as the electrification of road transportation. For this transition to be successful, politics, industry and society must work together as one.

2 Have you faced any challenges that seemed insurmountable but that you eventually managed to overcome?
My research is focused on energy transition within industry. Process-driven emissions from the steel, cement and chemical industry account for a large portion of emissions, which result from chemical reactions in production processes. For a long time, reducing these emissions was considered technically challenging if not completely impossible. However, the development of hydrogen-based, carbon-neutral processes in the steel and chemical industry has shown that a significant portion of process emissions can be avoided in the future — provided we can succeed in building up the required production capacity. The use of carbon-neutral processes to develop these products can also send an important signal to other industry sectors right across their value chains and thus accelerate their transformation.

3 Do we need to change our way of thinking?
It is important that we all rise to the challenges we are facing in the area of energy transition — be these technology-based, economical, social or environmental. Furthermore, we must understand that concerted action is now necessary — pushing things down the line is no longer an option. ■

back to page 1

Interview

“Research has already achieved great things”

She believes renewable energy can make her region more attractive to the industry sector: an interview with Manuela Schwesig, Minister President of Mecklenburg-Vorpommern.

Interview: Josef Oskar Seitz

Staying cool in Kühlungsborn (Baltic Sea): Manuela Schwesig, 47, has secured her second term as Minister President — with the SPD’s second-best election results in Mecklenburg-Vorpommern in history.


Photo: Gabo/Bild-Zeitung

It feels as though we're stuck in a loop. From the first to the fourth wave of the virus and from lockdown to the government's "emergency brake" measures, everything seems to be on repeat. Ms. Schwesig, do you think Germany is capable of learning?
Manuela Schwesig: We are still dealing with a dangerous virus. So unfortunately, we have to implement special protective measures to combat the coronavirus this winter as well. Certainly, some things should have been handled better in recent months. For instance, we should have picked up the pace for booster shots sooner, since vaccination offers the only route out of the pandemic, in my opinion. But I don't believe there's anything we could have learned from the past waves of infection that would have allowed us to get through this winter without any cases of or worries about the coronavirus.

At the beginning of the year, we had a shortage of vaccines. Now, toward the end of 2021, we have a shortage of public willingness to get vaccinated. Why does it seem to be so difficult for some people to trust research?
The vast majority of people have done everything they could to contain the pandemic. They followed the coronavirus regulations and got vaccinated as soon as they could. Frankly speaking, I have little understanding for the people who can get vaccinated, but haven't done it yet. The facts convey a clear message. The rate of coronavirus infections among the unvaccinated is significantly higher, and the danger of serious illness is much greater too. It's hard to explain why some people ignore these facts. What is completely unacceptable are the verbal attacks on the very scientists who have been advising us to the best of their abilities for almost two years now.

What do you want from research?
I think that research has already achieved great things in terms of the coronavirus. Developing more effective and safer vaccines in less than a year is a huge accomplishment and our most powerful weapon against the pandemic. Another important area is the development of medications that are effective against coronavirus.

"Our new state government has set the goal of covering our entire energy demand using renewable sources by 2035."

You once said that contrary to the statistical possibilities, you got cancer. Revealing this was a direct appeal to young people to get vaccinated. Did having the illness change you?
Yes, it did. I'm more humble, and more grateful. I now know the importance of family and friends, more than ever before. To this day, I'm still moved by the get-well wishes I received from members of the public. Our health is our greatest asset. I want to repeat my appeal: get vaccinated. Take responsibility for yourself, and for others.

Did your own experience of bodily infirmity teach you anything how the political system deals with illness?
I can only speak for myself here, of course — I received all the support that was possible, both in the hospital and the physical rehabilitation facility, and for that I am very grateful. So, of course, I am aware that our health system is good, but also that there's room for improvement. Everyone has the right to expert treatment and excellent care, and we intend to keep campaigning to make this a reality.

"Involved at the grass-roots level" is how you described yourself and other Minister-Presidents during a talk show recently. In what ways does the perspective of a state politician differ from the federal, Berlin-based view?
In recent months, we have often had the impression that federal politics in Germany ▶

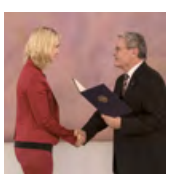
back to page 1

1989

A major turning point
The end of the GDR brought profound changes for Schwesig who grew up in Seelow, Brandenburg as Manuela Frenzel. She remembers her father's unemployment following reunification as a "decisive turning point."

1990

Movie career
"Forbidden Love" was filmed before the fall of the wall, and shown afterwards. She auditioned for the leading role, but got a supporting role as a romantic rival instead — meaning that she didn't have to film a number of explicit scenes.



2013

The road to Berlin
After holding portfolios for health and for employment as a state minister in Mecklenburg-Vorpommern, Manuela Schwesig entered federal politics in 2013. In the picture, Federal President Joachim Gauck presents her with the letter of appointment for the Federal Ministry of Family Affairs.

is too distant from the reality lived by most people. I'm optimistic that this is changing. No matter where I am, people talk to me and tell me about their concerns, whether big or small. Our citizen contact department receives many letters and emails from people describing their problems and making requests. These are all huge challenges.

Ms. Schwesig, you were once on your way to becoming an actor. In 1989, you auditioned for the leading role in the movie "Forbidden Love," but got the supporting role. Did that hamper your ambitions?
No. I had a lot of fun with it at the time, and Julia Brendler, who played the main role, is a successful actress today.

As Minister President of Mecklenburg-Vorpommern, a state with 1.8 million inhabitants, you're now playing a supporting role on the political stage. Isn't it time to start thinking about the federal level? The weekly newspaper Die Zeit has been marveling at the "Schwesig phenomenon" — at how going from the federal government to state politics has actually increased your success. Even the Frankfurter Allgemeine Zeitung, a newspaper that does not have the closest ties with the SPD, has lauded your electoral success, saying that this victory proves that you are qualified for greater things.
I am very happy to be Minister President of Mecklenburg-Vorpommern and am delighted to be able to continue in this role following the state elections. And the articles that you've mentioned show that being Minister President is not a supporting role. I can represent the interests of our state in the German Federal Parliament at any time. And I will continue to do so, with conviction.

Let's talk a little about federal politics all the same, and about the coalition agreement. The government aims to generate 80 percent of Germany's power from renewable energy by 2030. Your state has a lot of land area and a lot of wind, but generates little wind energy. How are you going to get the wind turbines going in Mecklenburg-Vorpommern?
Mecklenburg-Vorpommern is one of the trendsetters for renewable energy in Germany. We're generating almost twice as much energy as we consume. Our new state government has set the goal of covering our entire energy demand using renewable sources by 2035. For this to happen, we need to expand the renewable energy sector further. We're focusing on offshore wind energy in particular. I see two major opportunities in the expansion of renewable energy, combined with the development of a hydrogen economy. Firstly, this will allow us to help protect the climate, and secondly it will open up new opportunities in the industry sector. Industry in Germany needs to become more climate-friendly. Locations that can provide power from renewable resources and modern storage technology will be the ones at an advantage.

Almost a quarter of the people in your state are over 65. Is the digital transformation a stumbling block or a solution?
I strongly feel that every home should have fast internet, right down to the smallest cottage. We need fast internet right across the board: not only for companies and creatives, but for families and our older citizens too. Special interest groups and the state government are heavily involved in advancing the media skills of seniors in Mecklenburg-Vorpommern. We shouldn't understand estimate our older generations here either. A good example of the work being done here is the federal project regional digital transformation, Smarte.Land.Regionen, which calls on citizens from certain rural districts, including Vorpommern-Greifswald within our own state, to put forward ideas. There are many domains with great relevance for the future, where expanding digital services can improve the quality of life in rural areas.

How can science help drive digital transformation in your state?
All in all, I think the way that the Fraunhofer-Gesellschaft is getting involved in digital transformation in our beautiful state is fantastic. The Fraunhofer Institute for Computer Graphics Research IGD in Rostock is supporting companies through its research and development work, particularly in terms of software solutions for the maritime industry, the mechanical and plant engineering sector and information and communication technology. It also forms part of the interdisciplinary Fraunhofer-Gesellschaft research group Smart Ocean Technologies, which develops pioneering marine technology and new solutions for utilizing the sea in a more sustainable way at its location in Rostock. I'm very excited by the plan for a

Minister-President Schwesig has some words of praise for the Fraunhofer research group for Smart Ocean Technologies, founded in 2016, as well as the Digital Ocean Lab.

"All in all, I think the way that the Fraunhofer-Gesellschaft is getting involved in digital transformation in our beautiful state is fantastic."

Digital Ocean Lab, an underwater test site near the coastline where materials, modules and entire underwater systems will be tested, evaluated and optimized in a real-world setting. But researchers in Rostock are also looking toward the future of agriculture. The Fraunhofer Center for Biogenic Value Creation and Smart Farming is focused on developing innovative technology and methods for agricultural operations.

People often complain about the amount of empty space in Mecklenburg-Vorpommern. But let's take a moment to celebrate it. When you want to get away from it all during the winter months, where is your favorite place to go?
I have lots of favorite places. I enjoy going to Schwerin with my family. A walk around the Pfaffenteich lake is great whenever I have the time. And I also love the little island the Hiddensee. ■

2014

Reaching for the scalpel
Schwesig visits an operation room simulation at the German Heart Center Berlin together with school pupils as the Federal Minister of Family Affairs. The artificial heart survived the procedure.

2017

Mother of the people
Schwesig hugs her son Julian before being elected as Minister President of the Schwerin state parliament, while her husband Stefan holds their daughter Julia.

2021

Government selfie
Re-elected as Minister-President, Schwesig takes a photo of the new ministers. The SPD had a clear victory in state elections in September, winning with 39.6 percent.

Photos: private collection, scene from the GDR film "Forbidden Love" — source: https://www.svz.de/29677002, imago images (4), dpa

back to page 1

Deep dive: A micro-submarine sets out for the brain

Tiny, remote-controlled robots may soon take on important tasks in the human body. They are steered and monitored using a new imaging process: magnetic particle imaging.

By Christine Broll

The micro-submarine is steered via a neodymium-iron-boron tip.

The device we're looking at resembles a piece of twisted pasta, but reddish-brown and just 3 millimeters in size. We might only notice the light gray tip on second glance. Anna Bakenecker has big plans for this tiny little thing. "We intend to steer this micro-robot through the body using magnetic fields," says the physicist, who works at the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Lübeck. "The plan is it will transport drugs for cancer treatment directly to the tumor or close off aneurysms in the brain that present a hemorrhage risk."

The first prototypes of this micro-submarine, which will float through the body's bloodstream, are currently undergoing testing at the University of Lübeck. To steer the robot, Bakenecker uses the magnetic fields of a scanner that is used for magnetic particle imaging. "Magnetic particle imaging, MPI for short, is an imaging process first and foremost. Its uses include displaying the blood flow through a beating heart in 3D and real time, for example," explains Prof. Thorsten Buzug, managing director of Fraunhofer IMTE and director of the Institute of Medical Engineering at the University of Lübeck. The robots are coated with nanoparticles of magnetic iron oxide, which are also used as contrast agents for MPI. "The nanoparticles have a high level of tolerability and are subsequently processed safely by the body's iron metabolism," Prof. Buzug stresses.

But how can Anna Bakenecker get these robots to move without any power source of their own? "The tip of the robots is made of neodymium-iron-boron, an alloy that is also used to manufacture strong permanent magnets," explains the physicist. If you set up a rotating magnetic field, the neodymium-iron-boron tip aligns itself with the field and the robot starts revolving. Thanks to the robot's special spiral shape, this rotation is then converted into forward motion. The design was modeled on vertical wind turbines that have spiral-shaped blades that wind around a central axis.

Swimming in to save lives

The first field of application Bakenecker has planned for these nimble little robots is closing off aneurysms. Aneurysms are bubble-shaped weak spots in the walls of arterial blood vessel. If an aneurysm ruptures, it can lead to a life-threatening hemorrhage. This is especially dangerous if the bleeding occurs in the brain. At present, the standard treatment involves inserting a small wire mesh into the aneurysm using a catheter. This causes the

"The plan is it will transport drugs for cancer treatment directly to the tumor or close off aneurysms in the brain that present a hemorrhage risk."

Anna Bakenecker, physicist at Fraunhofer IMTE

blood within the aneurysm to clot, which prevents blood vessels from rupturing at this point. Instead of wire meshes, Bakenecker wants to place the robots inside aneurysms to prevent them from bursting. "Using these robots, we could also treat weak spots in blood vessel walls that cannot be reached with a catheter," says Bakenecker. "At the same time, we are working on materials that will expand within the aneurysms, closing them off."

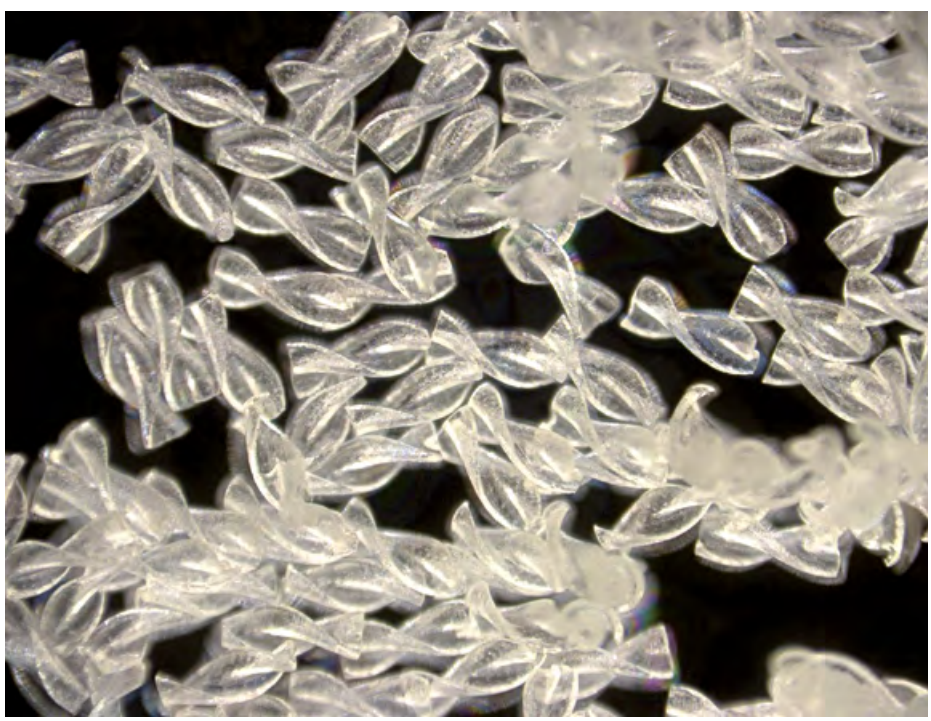
Steering through the arteries with precision

In order to take the first step along the road to application, the physicist collaborated with the department of radiology and nuclear medicine and the department of neuroradiology at the Schleswig-Holstein university hospital. The neuroradiology team used patient data to create a 3D model of a cerebral artery with an aneurysm. The researchers successfully used this model to prove that the robot can actually be steered through the arteries to its precise destination, like a micro-submarine.

Even at 3 millimeters long, the robots are not small enough for the really big tasks, so the team is currently working on size reduction. The dimensions of the mini-submarines need to be reduced to mere micrometers if the robots are to bring therapeutic drugs to hard-to-reach places: to the eye, the inner ear or through fine blood vessels to tumors. "We want to make the robots out of a material that dissolves at its destination and releases the drugs in the process," says Bakenecker. Prof. Buzug is thinking of even more dramatic possibilities. "We could also use the micro-robots to carry radioactive materials that can be activated and deactivated off directly to tumors, thereby enabling radiation therapy with few side effects. We can't possibly envision the full scope of the technology just yet." ■

"We could use the micro-robots to carry radioactive materials that can be switched on and off directly to tumors."

Prof. Thorsten Buzug, managing director of Fraunhofer IMTE



Size comparison: The robot is lying next to a grain of rice.

New, micrometer-sized robots.

Photos: Fraunhofer IMTE

back to page 1

Winter as it was before the coronavirus: First mentioned in 1434, the Striezelmarkt in Dresden is considered the oldest Christmas market in Germany. It attracts roughly two million visitors per year throughout the Advent period — at least in pre-pandemic times.

Photos: Fraunhofer IVI, Saxony police, Sylvio Dittrich/DML-BY

Where is Emma?

It's the stuff of nightmares — a child vanishing without warning. Thanks to close collaboration with Fraunhofer IVI, the police in Saxony have a tool to help direct searches in a more targeted way and quickly narrow down the search area.

By Dr. Monika Offenberger

Imagine a winter without the coronavirus. People would watch the New Year's Eve fireworks, raise a glass to the new year and share embraces. And before that, there would be all the get-togethers over mulled wine and stollen at the Christmas markets in Nuremberg or Dresden. Then, imagine a nightmare scenario striking, right in the middle of the festive atmosphere: Little Emma has disappeared! She was just standing in front of the carousel with her bag of Christmas cookies, but now it's as though she vanished from the face of the earth. You search, and call her name, but still nothing. So you reach for the phone and dial the emergency number.

"A child missing in a large crowd of people is a typical incident for our task forces," relates Jan Hentschel, head of the information and communication department in Saxony's police administration office. "In such cases, we send the next available patrol car there immediately and request a photo of the child from the mother. We send this to all the officers in the vicinity using MePol, the new police messaging app, along with a map that displays the child's last known location. We can also use the map to show our officers' current locations and the direction in which they are headed. In addition, the tool also allows us to estimate how quickly the child is advancing in the crowd and the radius in which they might currently be located. We conduct a targeted search within this area, and as a rule, the missing child is found quickly."

The Fraunhofer Institute for Transportation and Infrastructure Systems IVI in Dresden developed MePol in close cooperation with the Saxon police force for use in standard police services. The Free State of Saxony provided approximately three million euros in funding for the project. To date, the app has been installed on 4300 smartphones operating within a specially protected IT environment and is administered by the Saxon police themselves.

Comparing the old process with the new system effectively shows the extent to which the app has simplified the work of the state's police force. "Previously we spoke to the mother first, of course, and requested a photo of the child," Hentschel explains. "But then we had to take the photo away with us in order to create a wanted poster for the public search. Next, we would send out a radio message with a short description of the person and details of the last known location. Our officers had to remember this information or make notes."

> "A major advantage of MePol is that it connects smartphones with the internal computer infrastructure of our command and situation centers."

Jan Hentschel, Police administration office, Saxony

No photo? No map of the area? No auxiliary functions? And all this in the age of WhatsApp and Signal and all the rest? "As a police force, some of the data we work with is highly sensitive. This means that we must guarantee a high degree of data protection and IT security, so using a commercial service would be totally unacceptable for us," counters Hentschel.

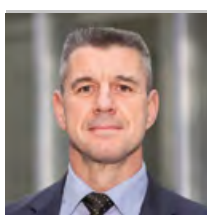
The idea of developing their own communication service was conceived in 2019. On the one hand, it would need to provide the same services as commercially available apps, such as the ability to send and receive text and voice messages, images and videos, and to create groups so all members can keep each other updated at all times. On the other hand, however, it would also have to meet additional requirements specific to the police — for example, operations management, real-time location display, compliance ▶

back to page 1

with legally required deletion deadlines and decision-making support.

The police and researchers worked together closely to develop MePol. They defined priorities, specified requirements and discussed ways of working. "It's an ongoing process in which users in the field and researchers continuously exchange ideas and coordinate with each other. This close collaboration is the key to success," emphasizes Dr. Kamen Danowski, Head of the Strategy and Optimization department at Fraunhofer IVI. Since 2002, his team has been working on new technologies for operations management and secure information transmission in the areas of disaster control, firefighting, rescue services and the police forces. An innovation partnership with the State Office of Criminal Investigation in Saxony was launched in 2013. With more than 20 federal state and national agencies currently participating, this partnership is focusing on developing a solution for special forces whose operations in the fight against terrorism and crime come with serious potential risks. The result of this joint development effort is "SE-Netz," a network for special forces that has been adopted as a nationwide standard and that garnered the 2020 Joseph von Fraunhofer Prize. This technology supports fast, secure and reliable communication across federal states and agencies during special forces operations. "With SE-Netz as a foundation, we were able to develop a solution to support standard police services," says Hentschel.

"We conduct future-oriented research in relation to 3D virtual walk-throughs, drone integration and the use of wearables."



Dr. Kamen Danowski, Fraunhofer IVI

"It's an ongoing process in which users in the field and researchers continuously exchange ideas and coordinate with each other. This close collaboration is the key to success."

Dr. Kamen Danowski, Fraunhofer IVI

The result is a flexible system that connects various servers, end devices and mobile apps, while simultaneously guaranteeing high levels of data and IT security. It can also be linked to the "SE-Netz" tool if necessary. "A major advantage of MePol is that it connects smartphones with the internal computer infrastructure of our command and control centers. This makes exchanging information between our mobile units and operations management significantly easier," Hentschel relates. The core functionalities of MePol include not only information exchange and location display but also intelligent algorithms that calculate the optimal deployment of personnel and resources in a specific case within seconds. Jan Hentschel explains: "Let's say a bag was snatched in Dresden's city center. We know that the incident took place ten minutes ago in front of the Kreuzkirche church and the perpetrator has escaped on foot. Our colleague in the situation center can then identify certain search areas on the map and select the five nearest police cars to route them there. This is another situation where the app could create a visual representation of the target's possible movement radius using its distance/time calculation function. This is a classic tactical challenge in police work, and with MePol, we can accomplish it in a highly effective way."

The new messaging service has been very well received by the police officers on the force, according to Hentschel: "The broad range of functions and ease-of-use have played a pivotal role in this high level of acceptance, as MePol essentially looks much the same as the commercial apps that people use privately. Furthermore, we take on board the suggestions and wishes of our colleagues who use the system every day on an ongoing basis. And here we have a great advantage in that we can implement new requirements very quickly with Fraunhofer IVI."

One of these requirements involved transferring the entire MePol system to the Saxon police force's cloud infrastructure, which was accomplished in 2021. "With this highly available, scalable cloud we have succeeded in taking a major step toward storing our sensitive data securely, without impacting functionality," stresses Hentschel. In fact, it's not only the available technologies that change; the responsibilities of the police force and the threats they face are also constantly in flux. "In police operations, optimized location display, real-time position data for our officers and resources, and the identification of important points and areas are all critical for a successful outcome. To this end, in addition to conventional 2D digital maps, we are also using augmented reality in MePol. We are conducting future-oriented research on 3D virtual walk-throughs, drone integration and the use of wearables," outlines Dr. Danowski. "This is what I believe is our responsibility as Fraunhofer researchers: working with users to develop new technologies and making them available quickly for use by the task forces." ■

Knowledge relay

energy met from renewable

back to page 1

with legally required deletion deadlines and decision-making support.

The police and researchers worked together closely to develop MePol. They defined priorities, specified requirements and discussed ways of working. "It's an ongoing process in which users in the field and researchers continuously exchange ideas and coordinate with each other. This close collaboration is the key to success," emphasizes Dr. Kamen Danowski, Head of the Strategy and Optimization department at Fraunhofer IVI. Since 2002, his team has been working on new technologies for operations management and secure information transmission in the areas of disaster control, firefighting, rescue services and the police forces. An innovation partnership with the State Office of Criminal Investigation in Saxony was launched in 2013. With more than 20 federal state and national agencies currently participating, this partnership is focusing on developing a solution for special forces whose operations in the fight against terrorism and crime come with serious potential risks. The result of this joint development effort is "SE-Netz," a network for special forces that has been adopted as a nationwide standard and that garnered the 2020 Joseph von Fraunhofer Prize. This technology supports fast, secure and reliable communication across federal states and agencies during special forces operations. "With SE-Netz as a foundation, we were able to develop a solution to support standard police services," says Hentschel.

"We conduct future-oriented research in relation to 3D virtual walk-throughs, drone integration and the use of wearables."

Dr. Kamen Danowski, Fraunhofer IVI

"It's an ongoing process in which users in the field and researchers continuously exchange ideas and coordinate with each other. This close collaboration is the key to success."

Dr. Kamen Danowski, Fraunhofer IVI

The result is a flexible system that connects various servers, end devices and mobile apps, while simultaneously guaranteeing high levels of data and IT security. It can also be linked to the "SE-Netz" tool if necessary. "A major advantage of MePol is that it connects smartphones with the internal computer infrastructure of our command and control centers. This makes exchanging information between our mobile units and operations management significantly easier," Hentschel relates. The core functionalities of MePol include not only information exchange and location display but also intelligent algorithms that calculate the optimal deployment of personnel and resources in a specific case within seconds. Jan Hentschel explains: "Let's say a bag was snatched in Dresden's city center. We know that the incident took place ten minutes ago in front of the Kreuzkirche church and the perpetrator has escaped on foot. Our colleague in the situation center can then identify certain search areas on the map and select the five nearest police cars to route them there. This is another situation where the app could create a visual representation of the target's possible movement radius using its distance/time calculation function. This is a classic tactical challenge in police work, and with MePol, we can accomplish it in a highly effective way."

The new messaging service has been very well received by the police officers on the force, according to Hentschel: "The broad range of functions and ease-of-use have played a pivotal role in this high level of acceptance, as MePol essentially looks much the same as the commercial apps that people use privately. Furthermore, we take on board the suggestions and wishes of our colleagues who use the system every day on an ongoing basis. And here we have a great advantage in that we can implement new requirements very quickly with Fraunhofer IVI."

One of these requirements involved transferring the entire MePol system to the Saxon police force's cloud infrastructure, which was accomplished in 2021. "With this highly available, scalable cloud we have succeeded in taking a major step toward storing our sensitive data securely, without impacting functionality," stresses Hentschel. In fact, it's not only the available technologies that change; the responsibilities of the police force and the threats they face are also constantly in flux. "In police operations, optimized location display, real-time position data for our officers and resources, and the identification of important points and areas are all critical for a successful outcome. To this end, in addition to conventional 2D digital maps, we are also using augmented reality in MePol. We are conducting future-oriented research on 3D virtual walk-throughs, drone integration and the use of wearables," outlines Dr. Danowski. "This is what I believe is our responsibility as Fraunhofer researchers: working with users to develop new technologies and making them available quickly for use by the task forces." ■

Knowledge relay

Prof. Henning, when can we ***expect*** the entirety of Germany's primary energy demand to be met from renewable ***sources?***

back to page 1

Knowledge relay, episode 3

Prof. Henning, when can we expect the entirety of Germany's primary energy demand to be met from renewable sources?

Series:
Knowledge relay

The times we live in are raising **lots of questions — Fraunhofer researchers are working hard to find the answers.** A specialist **answers a question,** then poses a **question of their own** for the **next expert** to answer — it's a **"knowledge relay."** In this edition, **Prof. Hans-Martin Henning,** Director of the Fraunhofer Institute for Solar Energy Systems ISE, answers a question from **Prof. Welf-Guntram Drossel,** Director of the Fraunhofer Institute for Machine Tools and Forming Technology IWU.

The German Federal Climate Protection Act has laid down the goal of achieving carbon neutrality by 2045. This means that our energy supply must come entirely from renewable energy sources by that year. Is that possible? And if so, how? First, the good news: This target can still be met. That is, at least, the consensus of a number of recent studies published by the Agora Energiewende think tank, the German Energy Agency (DENA) and several scientific institutions including Fraunhofer and the Federation of German Industries (BDI). But let's take a closer look at some of these results.

First, there is the question of how our energy demand will develop. Demand could develop in a variety of different ways, a fact that is reflected in the wide range of scenarios examined. These include a steady increase in demand due to continued growth in consumption, a higher volume of traffic and a larger amount of living space per person. However, they also foresee a possible decrease in demand owing to shifts in social behavior such as in the area of mobility. These all come with considerable consequences: The lower the energy demand, the easier it is to meet it with renewable sources. However, despite the differences in the predicted developments, each of the

Prof. Hans-Martin Henning is the director of the Fraunhofer Institute for Solar Energy Systems ISE.

All the studies agree: The rate of *reduction in greenhouse gas emissions* stipulated by the German Federal Climate Change Act can be achieved, but it will require a great deal of effort and *quick implementation*.

scenarios studied by all the authors assumed that primary energy demand will be significantly lower in 2045 than it is today, decreasing by 30 to 58 percent compared to the 2019 pre-pandemic figure of 3557 terawatt-hours.

Electricity for warmth and mobility

The most important reason for this assumption is that use of electricity for heating and mobility will increase significantly, which will be far more efficient in terms of energy consumption. So while a gas boiler, for example, can achieve a conversion efficiency of 100 percent at best, 1 kilowatt-hour of electricity can provide three to five times as much energy for heating via a heat pump.

In addition to the direct use of electricity, all the studies also reached the clear conclusion that certain uses — for example, industry processes, modes of transport that cannot run solely on batteries and power supply in areas with low solar or wind resources — still require material energy carriers such as hydrogen produced by means of renewable electricity, or liquid energy carriers and chemical raw materials produced using hydrogen. However, the studies differ significantly in their projections regarding the quantities and future import share of these energy carriers. They also disagree on how much installed capacity will be required for the most important converters of renewable energies by 2045.

If we take an average of the figures from the various scenarios, this would mean increasing installed capacity for photovoltaics (current value: 58 gigawatts) and offshore wind (current value: 7.8 gigawatts) by around a factor of seven, while onshore wind capacity would have to be tripled (current value: 56 gigawatts). In principle, the area necessary to facilitate this increase is available.

All studies agree that the rate of reduction in greenhouse gas emissions stipulated by the German Federal Climate Change Act can be achieved, but that it is a very ambitious target that requires a great deal of effort and quick implementation. The question of resources seems to me to be one of the most significant challenges. After all, if we are going to accomplish the energy transition on a worldwide basis, as we must, then we will need a huge amount of converters, storage devices and transport systems, which will in turn take enormous quantities of a wide range of materials (such as steel, glass, concrete, copper, and even rare earth metals). This is why the transition to circular value creation also plays a key role in the global energy transition. ■

In the next issue:

My question: What *resource strategies* are necessary for the *global energy transition?*

Photo: Fraunhofer ISE

back to page 1

Transport

In the right direction

The cars of the future need mobility that's fit for the future. The opportunities are huge — and so are the challenges.

By Mehmet Toprak, photos by Heinz Heiss

Vehicles come in all shapes and sizes. As mobility changes, Dr. André Häusler from Fraunhofer ILT sees an opportunity for more diversity on our roads — even if he doesn't believe that every kind of car has the same potential for every purpose. His institute is working to make cars more lightweight using laser-based welding processes. It's far from child's play — unlike the little steam-curved wooden cars that pop up in the photos on the next few pages.

back to page 1

New times, new challenges — and new challengers. E-mobility pioneer Tesla, which launched on the German market in 2013 with its Model S, had reason to celebrate in October. The growth rates for Tesla vehicles registered in Germany were in the triple digits, marking an increase of 482.9 percent. German manufacturers saw a double-digit drop, with the exception of Porsche, which stayed almost stable at just minus 0.8 percent (see interview, pg. 48).

Volkswagen, Mercedes, BMW and Audi have also taken on the challenge of e-mobility. With its research fab for battery production, in which ten Fraunhofer Institutes are involved, the Fraunhofer-Gesellschaft is helping to expand and strengthen Germany's position as a leader in battery manufacturing technology. And yet it will take more than that to ensure Germany maintains this position and doesn't slip down the ranks in terms of environmental rating and reputation.

Diversity — on our roads too

The cars of the future need mobility that's fit for the future. Dr. André Häusler has warned against closed-mindedness when it comes to mobility. The expert from the Fraunhofer Institute for Laser Technology ILT in Aachen believes that diversity in transportation will become a necessity. He envisions different drive methods coexisting harmoniously — depending on where cars are used and what they are used for Need to fill up in five minutes and then drive 650 kilometers? Hydrogen is best for the job. Living in a rural area where charging points are hard to come by? A hybrid model with a combustion engine and an electric motor might be the best option. "In the coming years, car manufacturers won't just have one drive type in their portfolio anymore," says Dr. Häusler. "They'll need to offer a separate solution for every need — hydrogen, electric, gas, diesel and hybrid models."

However, that won't be enough. It's time to rethink mobility. "When it comes to further developing vehicles, transportation systems and technologies, we need to focus much more strongly on solving specific problems and tasks, and less on developing existing technologies further," states Sebastian Stegmüller of the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart. Stegmüller is Head of the

Sebastian Stegmüller believes that if technology does the work, the driver will become more of a passenger and will also be able to enjoy entertainment on monitors. Within his research area at Fraunhofer IAO, he wants to focus more on new solutions and less on developing existing technologies further.

Mobility and Innovation Systems research unit. Together with his team, he tries to distinguish solid, future-oriented innovations from short-lived hypes.

Slimming down for the future: Regardless of the drive type, one simple rule applies. The lighter the vehicle, the lower its energy consumption can be. This is especially true of electric cars, as their heavy battery modules can be problematic when it comes to range. Fraunhofer ILT has developed a welding process based on lasers, whereby high-strength steel can be welded seamlessly and precisely, even in very small spaces. The steel is therefore thinner and lighter, but doesn't lose any of its strength. "We're working on a process in which metal and plastic are welded together. This can be used to manufacture load-bearing components that no longer require connecting elements. That makes them even more lightweight," explains Dr. Häusler, head of the Micro Welding team.

"Mobility is about more than the proverbial concept of getting **from A to B.** When it comes to cars, there are factors that go beyond the purely objective."

Sebastian Stegmüller, Fraunhofer IAO

Dr. Häusler and his team also demonstrate the potential of innovative welding techniques for hydrogen-powered vehicles. Fuel cells are designed for use in trucks, transistors and other commercial vehicles. The high-speed welding process developed at Fraunhofer ILT can be used for tasks such as joining the 200 bipolar plates required for each fuel cell, with a helium-tight join of 1.4-meters in length for each plate. And it does so faster, more efficiently and more cost-effectively than traditional welding technology.

Lightweight, sustainable and safe — this is what drives the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut WKI. Scientists at the institute have been working with their partners HOBUM Oleochemicals GmbH and Porsche Motorsport to develop the "Bioconcept-Car" for the Four Motors racing team. The Fraunhofer WKI experts use the natural fiber flax as a substitute for the expensive carbon used wherever extreme strength is required in the racing world. The flax is processed into a textile-like fabric and then coated with a bio-based epoxy resin. The researchers procure the flax fabric from a supplier. This vibration-absorbing material can be used where the strength of carbon is not necessary, e.g. in the door area, seat suspension or roof lining. "Our project proves that natural fiber-reinforced plastics actually work, even under high stress," explains Fraunhofer WKI expert Ole Hansen. There are also environmental advantages, as the flax plant binds CO_2 and is grown in the region, which saves on long supply routes/lengthy shipping distances.

Compact and connected

As a rule, "cars don't just need new technology — they also need new concepts. They need to become more compact and be connected with other forms of transportation through smart technology," says Monika Beck, who is responsible for Technology Transfer — Wireless Microsystems at the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. Electronics will play a crucial role in integrating cars into future transportation systems. Vehicles are already packed full of ECUs (electronic control units). These ECUs control areas that are critical for safety, such as the engine, gear shift, accelerator and brakes. A modern car will contain between 30 and 150 of these units working together, and all are equipped with processors. However, in terms of supply, the automotive industry is dependent on a small number of manufacturers, but their processors are often too large for certain specific purposes. This is where Fraunhofer IPMS comes in. The institute has developed an IP core based on the open RISC-V architecture, which can be individually customized. "The biggest strengths of the open RISC-V architecture are its modularity and expandability. It enables us to design customized processors," Beck explains.

However, the RISC-V processor also offers another very significant new feature. As the first processor designed for use in cars, it is also available as a safety variant. In this variant, the design is pre-certified as ASIL D ready in accordance with ISO 26262. This standard regulates the development of electronic systems for safety in vehicles, such as certain data streams that are designed to be redundant or predefined actions that are initiated after a component fails. A suitable processor can be used in safety-critical functions such as sensors to make them stable and failsafe. Self-driving cars in particular must have completely reliable sensor systems.

Connection with the outside world and rapid evaluation of data are crucial for these sensor systems. But the vehicles can't complete all these tasks themselves, as they only have limited computing power available. This is where edge computing, 5G and V2X wireless connections (Vehicle-to-X) play an important role (see article on pg. 46). Using additional sensors on the roads to support the vehicle' own sensors is also vital for self-driving cars. For example, from an elevated position such as a streetlight, cameras, LiDAR (Light Detection and Ranging) scanners and radar could monitor hazardous locations such as intersections or specific sections of road. The system collects the incoming data and transmits it via 5G to a nearby edge cloud system, which analyzes the data using AI. This forms a picture of all the road users, including their individual speeds and distance from one another. The system analyzes the traffic conditions using deep learning, transmits them back to the vehicles using 5G and detects dangerous situations. If, for example, a non-autonomous car is on a collision course with an autonomous vehicle, the edge cloud system will detect the danger. It will send a warning via 5G to the self-driving vehicle, which can autonomously correct its course ▶

back to page 1

or perform an emergency stop. This all happens practically in real time.

The only information collected on the vehicles is their vehicle category, position and speed. No information on the owner or number plate is transmitted. It may also be possible to create solutions that don't use any cameras at all and instead work with LiDAR or radar technology. In this kind of smart traffic-monitoring system, it would be feasible to have smart traffic lights that switch intelligently depending on the traffic and, in addition to the visual displays, send their traffic light signals to road users via highly reliable 5G wireless network.

Such systems are currently still in development. Fraunhofer researchers are working hard in field trials to make this vision a reality. They include researchers from the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut and HHI in Berlin. "We're working on further developing cameras, lasers for LiDAR scanners and AI for radar, for use in traffic monitoring, for example. So basically we're working on all types of sensors that are used to identify and locate objects. We're further optimizing wireless technologies such as 5G and we're already working on 6G concepts, which will also enable us to reliably transfer vast amounts of data, in real time. We've even set up a new AI department at the institute to perform smart analyses and further process raw data," explains Dr. Tristan Visentin, Innovation Manager at Fraunhofer HHI.

"I don't approve of bans."

Do cars still have a future in the mobility systems of tomorrow? An interview with Prof. Uwe Clausen, chair of the Fraunhofer Traffic and Transportation Alliance.

Interview: Mehmet Toprak

Prof. Clausen, how can we get cars out of the hot seat in public discourse?
A great deal needs to change there. For example, the whole area of the circular economy needs to improve significantly. Right from the design stage, it's important to ensure that the car's individual components and materials can be recycled later. Automotive engineering needs to switch to materials that are not hazardous to the environment. For example, bio-based resins could be used for certain components such as doors.

So, we're going back to the Trabant with its hardened resin body?
It does have a cult following now (laughs)! We need to move on from the old prejudices against recycled or bio-based materials. Today, these kinds of materials can have an appealing, high-quality appearance thanks to haptic effects. It all depends on how they're processed. Our colleagues at Fraunhofer WKI have shown this is possible with their flax-based components.

Are there other solutions?
There are many exciting custom solutions, including in battery production, intelligent lightweight construction and assistance systems. When these are combined in vehicle manufacturing, it massively boosts the car's quality.

Is everything heading toward electric cars?
It's clear that the automotive industry is increasingly focused on electric cars. If more renewable energy is used for manufacturing and charging, and there are fewer combustion engines on the road, that will have a positive effect on CO_2 emissions.

None of that makes cars sound like an attractive mode of transportation for the future.
There won't be one single car of the future. Cars will be part of a holistic mobility strategy, and will be integrated into complex transportation systems. In the connected mobility vision, everything will coexist — cars, buses, trains, electric scooters, cargo bikes, taxis and pedestrians. Through the Fraunhofer Traffic and Transportation Alliance, which is coordinated by Fraunhofer IAO and Fraunhofer IML, we are actively in-

Dr. Karina Villela and Matthias Koch of Fraunhofer IESE are working to intelligently connect very different forms of mobility, even in rural areas.

Cars of the future: Prof. Uwe Clausen takes part in our Fraunhofer Podcast:

Digitalized traffic control integrates cars, bikes, e-scooters and pedestrians into a comprehensive mobility solution. "The car of the future will be part of a holistic mobility solution and integrated into a complex transportation system," confirms Prof. Uwe Clausen, Chair of the Fraunhofer Traffic and Transportation Alliance (see interview below).

What about often neglected rural areas?

The more options available, the more complex mobility becomes for passengers. Dr. Karina Villela, project manager for Digital Innovation Design at the Fraunhofer Institute for Experimental ▶

volved in the European EIT Urban Mobility initiative in order develop and share better solutions. In addition to the opportunities that digitalization opens up for us, cars need to be constantly reimagined in terms of their full range of components, performance and features and should be designed to form an integral part of sustainable, connected mobility.

Does government need to regulate the market with bans and phase-out deadlines?
I don't approve of that. The role of government should be to provide incentives for development, to give impetus and to create a favorable environment. That's the only way to kick-start competitive innovation for future mobility. Ultimately, the winners will be the ideas and clever concepts that people really benefit from. Technologies that don't work end up disappearing on their own.

What role will comfort and infotainment play?
A very large one. In the context of transportation, man does not live by usefulness alone. Fundamentally, comfort plays a huge role. And when it comes to electrically powered vehicles, we also need to address issues in a new way. Internal combustion engines simply masked a lot of disruptive noises — the quiet electric motor is completely different. We have many ideas in this area, such as metamaterials, which are being developed at the Fraunhofer Institute for Structural Durability and System Reliability LBF. The ultimate goal is to integrate the car into the overall transportation system using 5G wireless technology and AI-driven software.

Institutes such as Fraunhofer HHI and the Fraunhofer Institute for Integrated Circuits IIS are working on this very area. This interconnection will open up many exciting possibilities for more than just cars — there will be mobility service providers with completely new ideas, offering incredible levels of comfort. Just imagine the possibilities if you could use your self-driving car as a mobile office! Today, engineers and designers at car manufacturers need to set to work and develop these concepts. At Fraunhofer, we're doing just that.

One area your research focuses on is logistics. Are there technologies that play a role in private mobility?
Definitely! Within the massive trend toward autonomous driving, there are solutions for both freight and passenger transportation and by carrying out projects in each other's sectors, we and our partners are learning from each other. We're seeing more online retail and innovative last-mile solutions, from packing stations to cargo bikes to autonomous delivery robots. When private individuals want to buy or use a car, more logistics services in the consumer sector are allowing greater flexibility, for example in terms of vehicle size.

Will the automotive industry remain the most important industry in Germany in the future?
There are a lot of indications that it will — but as part of a far-reaching structural transformation. Car manufacturers must see themselves as mobility providers, and combine mechanical engineering, design, energy systems, software expertise and transportation systems to create an attractive package. ■

back to page 1

Ensuring greater safety in transportation is one of the major issues of the future. Dr. Tristan Visentin from Fraunhofer HHI works as an innovation manager, developing all kinds of sensors to identify and locate objects.

Software Engineering IESE in Kaiserslautern, is addressing this issue. To solve the problem, she has created a mobility platform as part of the Smart MaaS (Mobility as a Service) project, in collaboration with partners Fiware, Cleopa, DFKI and better mobility. All providers can post their services on the B2B platform, whether for mobility, information or otherwise. This includes taxi operators, shuttle bus operators, e-bike rental companies, public transportation or car sharing providers, hotels or providers of tourist information. This ecosystem brings all stakeholders together on one marketplace — services, information providers and intermediaries.

"We're working on further developing cameras, lasers for LiDAR scanners and AI for radar, for use in traffic monitoring, for example. "We've even set up a new AI department."

Dr. Tristan Visentin, Fraunhofer HHI

All this information is evaluated by a mobility broker. If a customer is looking for the best route for a particular journey, the broker immediately generates a suitable itinerary, including the best means of transportation and transfer options. "Customers can also specify in their inquiry whether they need their trip to be particularly low-cost, comfortable or fast. This enables stress-free door-to-door mobility for passengers," says Villela. She sees Smart MaaS as an opportunity for startups or small businesses with specialist services to promote themselves on the platform.

As part of his KomMaaS project, Matthias Koch, senior requirements engineer at Fraunhofer IESE in Kaiserslautern, is concentrating on rural areas. Here, there are too few options for transportation, rather than too many. The basic idea is to make these few options more accessible and interconnected. That way, public buses could travel through small villages and help people without a car to get mobile. Together with partners, the team led by Koch has developed a suitable web application. If someone needs transportation, they first call the regional public bus service and tell them where they want to go. Alternatively, they can use a smartphone app to indicate their need. The public bus planning team receives this request through the application, and plans accordingly. Providers can now optimally combine individual journeys to specific passengers into a complete route. In turn, the display unit in the public bus shows the driver where passengers are to be picked up or dropped off. In later stages of the planned development, anyone with a private car who is planning a trip to a nearby city will be able to offer other travelers a ride via KomMaaS.

Koch and his team developed the web application with a focus on simple and efficient functionality. "We want to increase mobility for people who don't have their own cars, and improve vehicle utilization at the same time. There's always a social aspect to mobility and transportation, too. When developing networked mobility solutions, we mustn't forget that," says Koch. The public bus trips have already gone through practical testing. Meanwhile, some districts in Rhineland-Palatinate have become the first to signal their interest. All these solutions have one thing in common: people don't necessarily drive their own cars anymore, but rather choose the option that suits them best at a particular moment.

According to the Fraunhofer researchers, the car isn't going to lose its special status. Sebastian Stegmüller believes there are emotional factors at play here. "Mobility is about more than the proverbial concept of getting from A to B. When it comes to cars, there are factors that go beyond the purely objective." Rather than holding less weight in the future, comfort, features and personal space will actually be more important. This opens up huge opportunities for car manufacturer to produce really innovative new solutions." Fraunhofer researchers have already presented a study for this strategy for the future, named Vision PI. The passenger cell is designed based on a shell principle and can be flexibly adapted to the individual needs of the passengers. During the day or while commuting in the morning, the passenger cell can serve as a mobile office for working and for video conferences, for example. The vehicle's HMI (human-machine interface) technologies connect seamlessly with devices such as tablets or headphones, thus enabling an integrated media experience. The route is selected and adapted automatically according to criteria such as network availability, traffic volumes and upcoming appointments. In the evening, in preparation for a relaxing drive home after work, the passenger cell transforms into a relaxation room with darkened windows and wellness features that appeal to all the senses. The use of high-quality materials increases the feel-good factor — think cozy lounge ambiance, rather than the more austere feeling of a cockpit. "While it's horsepower we care about today, in the future we'll be looking for equipment that can be personalized depending on the context, and high-quality haptic features built into the car's interior," Stegmüller believes.

"There's a social aspect to mobility and transportation, too!"

If basic requirements are met such as compliance with social standards in regard to manufacturing, environmental sustainability and safety, there is nothing to prevent cars from remaining personal consumer goods. Prof. Michael Lauster, Director of the Fraunhofer Institute for Technological Trend Analysis INT is optimistic, in any case. "Cars have a long, bright future ahead of them. They continue to be one of the building blocks of individual mobility. However, with the trend toward using rather than owning, cars will serve as status symbols for only the rare few." ■

back to page 1

How well-known illustrator Klaus Bürgle's imagined the future of transportation in 1955. He also thought that self-driving cars would be possible in the future.

Using your smartphone to stay safe on the go

How road transportation communication networks make navigating through traffic faster while also helping to avoid congestion and accidents.

By Moritz Schmerbeck

A tailback around a bend or objects lying on the freeway — road transportation is full of hazards that the human senses often only perceive once it's too late. Vehicle-2-X communication, which transfers information between road users and between the road user and transportation infrastructure, will alleviate this issue in future. The Fraunhofer Institute for Open Communication Systems FOKUS in Berlin has been developing and optimizing this technology for several years to enable real-time information about accidents, construction works, congestion and other hazards to be exchanged between standalone and networked vehicles en route.

Researchers at Fraunhofer are now aiming to make the network available for use by other road users via their smartphone. "Vulnerable road users (VRU) such as pedestrians, e-scooter users and cyclists have a high level of risk when it comes to sustaining injuries in city-center traffic. With our ultra-precise location technology, which can be integrated as a service into any app, we want to compensate for this issue and get users to their destination in a faster, safer way," explains Dr. Ilja Radusch, Director of Smart Mobility at Fraunhofer FOKUS. The hope is that cyclists, among other road users, will be able to feel safer — currently, because of the dangers of road traffic, 44 percent don't feel safe.

Radusch and his team have developed an interface that allows smartphones to connect to the mobility network, which finally makes VRU "visible" within the digital vehicle communication system. For example, a pedestrian walking out from between two parked vehicles into the path of one or more moving vehicles can be easily detected. Approaching cars, bicycles and e-scooters can receive advance warning about the potential risk of collision, and pedestrians can be alerted of danger via smartphone.

Computing outsourced to the cloud

A Mobile Edge Cloud (MEC) is a basic requirement for rapid warnings. It comprises many smaller computing units located on cell phone masts or in phone boxes on the roadside and constitutes the interface that is used to connect to other vehicles as well as to the transportation infrastructure. An MEC is also indispensable for the continuous and exact pinpointing of cyclists and pedestrians. All computing work for safety functions is outsourced to the cloud, which is then accessed via cell phone network. This reduces the load on the smartphone and has a positive impact on its battery life.

In some cases, smartphone GPS data is not precise and can be off by up to several meters. In congested traffic, this difference can be dangerous. Is a pedestrian actually walking right in the middle of a road, or are they just sitting at a bus stop on the sidewalk? This "position error" is created when signals are blocked by buildings or cloudy skies. To improve position data after the fact, researchers at Fraunhofer FOKUS have developed an algorithm that allows GPS data to undergo a plausibility check and be corrected.

Dr. Ilja Radusch explains why reliability is important for creating a high level of acceptance for such apps: "False positive events that occur when a collision warning is triggered in error, for instance, can lead to users switching off the system or deactivating individual functions. Thanks to algorithm tuning, we now have a tool that's truly reliable."

What's more, users can choose to sail through consecutive sets of green lights at the touch of the button thanks to highly precise location technology. Since the transportation infrastructure is part of connected mobility, an app can be used to reach a destination using traffic signal synchronization. This automatically selects a route with fewer stop lights. The app can also tell cyclists whether it's worth pumping the pedals a little harder before the next intersection, or if they should reduce their speed a few hundred meters beforehand. Another important factor for app acceptance among the public is the safeguarding of data privacy — all position data is processed anonymously in every respect.

The next step in ensuring that the ultra-precise location technology developed by the researchers is tried and true involves working together with industry partners to prove that it works. A pilot project in Hamburg allows citizens to try out the mobility network in a real-world street traffic setting for themselves. The Hanseatic city is actively providing support through traffic signal systems with appropriate interfaces, while industry partners are expanding Mobile Edge Cloud capabilities within the urban area and providing smartphone apps. The project presented demos in October at the ITS World Congress in Hamburg — the world's largest event for intelligent transportation and the digitalization of transportation. ■

44 %

of cyclists don't feel safe because of the dangers of road traffic.

Take part in the project run by RealLabor Hamburg and try out Fraunhofer technology today in the port city on the Elbe:

https://reallab-hamburg.de/en

Info video about the technology:
https://www.youtube.com/watch?v= KzaITVkMyUc&t=26s

Illustration: Klaus Bürgle

back to page 1

Interview

“Porsche will be the last to have a steering wheel.”

You’ll be able to drive autonomously — but you’ll want to drive manually. Detlev von Platen, Executive Vice President for Marketing, on the future of a German legend.

Interview: Josef Oskar Seitz

Looking toward the future, but without a crystal ball: Detlev von Platen, Member of the Executive Board — Sales and Marketing at Dr. Ing. h.c. F. Porsche AG.

Mr. von Platen, how far can I drive an electric Porsche at the maximum legal speed of 250 kilometers an hour?
You probably can't drive anywhere at a constant top speed (laughs). Under normal driving conditions, a Taycan's range is a good 350 kilometers, and with our new model, the Taycan GTS, you can reach over 500 kilometers. However, it's not enough to look at this number alone. With the Taycan, we never aimed to become the world champions for range. What's important to us is weight and driving dynamics, as well as a short charging time. We've set standards around the world with our 800-volt technology. The Taycan charges much faster than most other electric cars, from 5 to 80 percent SoC in 22.5 minutes.

Your telephone numbers at headquarters still begin with "911" — however, this year you have delivered more Taycans than classic 911s. Is it time to bring your telephone system into a new era? And what number would you consider switching to?
Actually, in terms of global deliveries, the Taycan was on par with the 911 for the first three quarters of 2021. We are pleased that the first all-electric Porsche has met with such a great response, especially since around 50 percent of people who purchase Taycans are already Porsche customers. That means, while we've struck a chord with our fans, we've also conquered a new target group, namely people who have never driven a Porsche before. We're expanding our fan base with electric sports cars. Regardless of that, the 911 remains our icon. No other vehicle is more closely associated with our brand. That's been the case for almost 60 years. That's why "911" is still our first choice for our telephone numbers.

Do you consider e-mobility to be the future?
At Porsche, electromobility is the mobility of tomorrow. Our focus is on electrifying our models, so we are establishing an extensive range and a position of technological leadership here. For example, we founded the Cellforce joint venture with CUSTOMCELLS, a company that develops and manufactures high-performance battery cells. With Rimac, we also hold a stake in one of the most innovative e-mobility companies. Together with other automobile manufacturers, we launched high power charging as part of the IONITY joint venture, which is now picking up pace. By 2025, the number of charging stations will increase from their current number of just under 400 to more than 1000. Additionally, we are working on an exclusive, Porsche-owned charging network. We also think it makes sense to pursue green e-fuels — these allow traditional combustion engines to operate with a CO_2 output that is almost neutral.

One third of the good 13,000 kilometers of highway in Germany has a speed limit. Or to put it another way, only 2 percent of German roads are free from speed restrictions. Meanwhile, according to a survey conducted this year, half the members of the general German automobile club (Allgemeiner Deutscher Automobil-Club — ADAC) are in favor of speed limits. Is this a bad time to be a sports car manufacturer?
I am against speed limits in areas where it is possible to drive safely without putting others in danger. People should be afforded this level of personal freedom. Speed limits are often used as an argument for reducing the number of accidents. However, accidents are five times less frequent on federal highways than on ordinary roads. Statistically, highways are among the safest roads in the world. That is why Germany's future traffic light coalition government has spoken out against the introduction of a general speed limit in their coalition agreement.

What criteria will decide consumers' choices when buying cars in ten years' time?
For our customers, the brand has always been the number one factor influencing their purchase. We can see that this trend is only intensifying. That is why we are putting a lot of consideration into the question of how the Porsche brand will remain unique and attractive in the future, for example, through emotional connections to the brand that you can't get from other manufacturers. Of course, the aspect of sustainability is becoming all the more important. We want to be at the forefront in this area, as well. We will invest 15 billion euros in electromobility, digital transformation and sustainable production by 2025. Decarbonization is a central field of action in our sustainability strategy — and we're setting ourselves some ambitious goals: Porsche aims to be carbon neutral across the entire value chain and vehicle life cycle by 2030. All of this will play a greater role in customers' decisions in the future.

Photos: Rafael Kroetz/Porsche AG

back to page 1

When will Porsche buyers come to trust autonomous driving — and will the autopilot be able to chauffeur in sport mode?
Our goal is to have the Porsche be the last vehicle with a steering wheel. Our sports cars are geared towards the driver, aiming for dynamism and fun while driving. You will always want to drive a Porsche yourself. Nevertheless, it can be a relief for our customers if, for example, their vehicle can roll along in traffic jams or park independently. It's also conceivable that a car could complete a highly automated drive around a race track, on a course that was previously driven by a well-known driver. This sort of use case would be typical of Porsche.

What is it that makes Porsche so fascinating?
Porsche stands for freedom, independence and an internal drive to achieve goals. This is also expressed by our brand purpose, "Driven by Dreams." It's rooted deep in the history of the company. Our founder, Ferry Porsche, wasn't able to find the sports car of his dreams, so he built it himself. This is the attitude that still drives us today — not just when it comes to building sports cars, but also in a social sense. We want to support people in making their dreams come true, in fighting for their dreams. At the same time, our products play a crucial role. Every vehicle we send out has to be an authentic Porsche. Design, quality and handling are key characteristics.

How can the brand feeling change? How must it change and how will it change?
Porsche has only remained "Porsche" because it has been undergoing a constant process of change. Changes in the product range have often initially given rise to some skeptical questions — for example with our first SUV, the Cayenne, or our first electric vehicle, the Taycan. People asked, "Is that really an authentic Porsche?" But in most cases, once people were able to actually sit behind the wheel, they found that the answer was a clear "yes." All of our vehicles are sports cars. They share DNA with the original design. They feel like a Porsche and have the typical Porsche sound. The same will be true in the future. In addition, the brand feeling is about real experiences, both emotional and unique. For example, we are further expanding our Porsche Experience Center — PEC for short — worldwide. We have just opened new locations in Italy and Tokyo. Our next one, Toronto PEC, will be our tenth.

So what are the arguments for buying a Porsche, in strictly rational terms?
This question has often been answered like so: "We build the vehicles that no one needs, but everyone wants." That's still true today. At the same time, our vehicles excel in how they optimally combine performance with suitability for day-to-day use. A Porsche is much more than a car for a weekend drive. Our sports cars are popular with everyone that wants to combine dynamic driving experiences with practicality in everyday life. Depending on which preference is stronger, our wide range of products enables us to meet every requirement.

What detail do you yourself particularly love?
For me, it's less about details than an overall feeling. I still get it today, even after 20 years at Porsche. Every morning when I hop into my car, I turn on the engine with a little smile on my face. This applies as much to my current car, a Taycan Cross Turismo, as it does to the 911. And to me, that represents the passion we have for our products.

What do you want from research?
The automotive industry is undergoing massive change, a transformation that has not happened in the past 100 years. Autonomous driving and digital networking are dominating the public debate. The car of the future should offer sustainable mobility, as well as being digital and fully networked. Each of these areas require intelligent concepts. This means that we, the manufacturers, must work in close collaboration with science and research institutes, but also with start-ups and new players. We are always trying to start conversations and looking for partners that we can collaborate with to actively shape change. ■

"Intelligent concepts are required in every area. This means we, the manufacturers, must work closely with science and research institutes."

Detlev von Platen, Executive Vice President for Marketing at Porsche

Valuable software

Cutting and polishing have a decisive effect on a diamond's value. OptiRough, a new software, helps to achieve the maximum sales prices for diamonds.

By Michael Krapp

A small mistake in cutting can reduce the value of a diamond by half. Antwerp is known for having the world's best gemcutters.

Raw diamonds do not sparkle and glisten: They look like dirty stones. Only by cutting and polishing a diamond can you reveal its beauty and create a valuable jewel. However, some crucial questions must be answered first: How many gems should you cut from a single raw diamond? What shape and cut should you give them? And how can you get the highest possible carat value? Dr. Jan Hamaekers, Head of the Virtual Material Design business area at the Fraunhofer Institute for Algorithms and Scientific Computing SCAI, is seeking the answers. After being contacted by Dave Oste, director of Tensor Diamond Technology bv in Antwerp, he took up the challenge.

It's all about the money — and lots of it, since the answers to these questions massively influence the sales price. For example, most raw diamonds contain inclusions in the form of small mineral crystals. Depending on their size, they can reduce the value of the diamond. Alongside this, the selling prices for certain cuts on the diamond exchange and their day-to-day fluctuations must be taken into account.

"Cutting and polishing raw diamonds to obtain the maximum sales price involves solving an extremely complex optimization problem," says Dr. Hamaekers. As a mathematician, he approaches the problem in terms of combinatorics: how many diamonds should a single raw diamond produce, and with what faceting? When cutting a stone, the position, rotation, the various shape parameters and quality grade must be considered. Diamond price charts present yet another difficulty here. The price jumps in these charts mean that very small changes to the size or purity of a diamond, for example, have a considerable impact on the market price of the finished product.

A complex optimization problem — and the solution

According to Oste, a diamond specialist, the problem is: "Previous solutions only produced satisfying results as long as no more than one or two gems were cut from a single raw diamond." Another problem with cut planning is that a rough diamond usually has many different inclusions that the cut diamonds should not contain. Therefore, software solutions need to efficiently handle this complexity, especially in the case of multiple stones.

After reviewing various methods and analyzing numerous benchmark examples, Dr. Hamaekers and his team succeeded in developing a solution. "We combined sparse grid methods and genetic algorithms," recounts Dr. Hamaekers. The sparse grid method is particularly well suited to efficiently solve high-dimensional problems.Incidentally, this mathematical technique has also already been the subject of several fundamental papers by Prof. Michael Griebel, institute director of Fraunhofer SCAI.

Genetic algorithms use the principles of evolution to constantly come up with improved solutions to optimization problems. If you want to use genetic algorithms to solve complex optimization problems, the trick is to adapt them to the specific challenges of the problem at hand. The team at Fraunhofer SCAI integrated a module with a combination of these methods into the OptiRough software. Beyond anything else, the new algorithm takes into account that even slight changes to the carat weight can significantly affect the sales price of the diamond. "You stand to gain or lose tens, or even hundreds, of thousands of euros," says Dr. Hamaekers.

Not only does the program suggest an optimal solution, but — seeing as numerous other factors influence the process of cutting and polishing a raw diamond — it also provides a list of various promising candidates from the available selection of raw diamonds. This way, it comprehensively supports planning how to cut and polish the diamond.

Oste gave the Fraunhofer program a positive report. "The Fraunhofer SCAI software has made it possible to significantly speed up and improve the difficult and often protracted planning phase that comes before cutting," he says. "It works well when it comes to inclusions and also factors in combinations of two or more stones." The team is now planning a follow-up project with additional software functions. ■

Photo: Yves Herman/Reuters/dpa

back to page 1

Avatars lend a helping hand to physicians

During the pandemic, the use of faxes among health authorities became a symbol of digital backwardness. The paper economy is alive and well in German clinics, too. However, it is something researchers at Fraunhofer IPA now want to change.

By Dr. Sonja Endres

Allergies? Symptoms? Preexisting conditions? Anyone arriving at a hospital suffering from a physical complaint will likely face into another form of suffering, as they are forced to answer the same questions, over and over again. Despite having filled out multiple forms and provided all of the relevant information when being admitted.

Dr. Langejürgen is working to eliminate these multiple stresses for both the patient and the physician — so all input information can be accessed directly from the ward at the click of a button. "With our digital patient admission system TEDIAS, we not only want to put an end to wasteful paper trails, we also — and more importantly — want to automate the process of inputting basic medical data or measuring vital functions," explains the Head of the Clinical Health Technologies department at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. This should give medical staff more time for what is really important — having an in-depth therapeutic consultation with the patient, attending to their questions and concerns, providing detailed explanations and treating the issue at hand.

Politically, there are signs of change as digital transformation within hospitals finally gains momentum. Through the Future of Hospitals Law (Krankenhauszukunftsgesetz, KHZG) for digital transformation passed on October 29, 2020, the German federal government is aiming to accelerate the pace of change within hospitals, as indicated on the German Federal Ministry of Health's home page. The Hospital Future Fund provides 4.3 billion euros for this purpose — which creates a favorable environment for Langejürgen and his team who work closely with Mannheim University Hospital. Their offices and labs are located on the grounds of the hospital, in the CUBEX 41 building next to the cafeteria. "We are in the thick of clinical operations, which makes it easy to discuss things at short notice, too — we can just meet up over a coffee," Langejürgen explains.

4.3

billion euros
has been provided in the Hospital Future Fund to enable the rapid upgrading of hospital systems.

Funded by the Forum Gesundheitsstandort Baden-Württemberg organization, TEDIAS was developed by the Fraunhofer IPA team to address two use cases initially. Firstly, elective admissions, i.e. the planned admission of a patient in order to carry out a procedure such as a gastroscopy, for example. And secondly, emergency admissions of "walking patients," i.e. emergencies that do not require the patient to be transported to the hospital by ambulance. Langejürgen and his colleagues are initially focusing on patients whose primary symptoms are neurological, such as dizziness, headaches or paralysis. The patient spectrum will then be expanded incrementally. In both use cases, the admission procedure essentially involves establishing the patient's anamnesis, i.e. their previous medical history, and carrying out a preliminary examination in order to record the patient's blood pressure, pulse, weight and height.

Rather than having them sit passively in a waiting room until they are finally called, the idea is for the patient to take a seat in the TEDIAS kiosk area. The kiosk seat is equipped with integrated measuring systems for recording body temperature, weight, blood pressure, heart rate and breathing frequency, etc., i.e. readings that would normally be taken in a preliminary examination. "Ideally, the patient should not even notice what's happening. However, for some readings, they need to get more involved, by attaching a pulse oximeter, for example. That's the little finger clip that records oxygen saturation levels in the blood," Langejürgen explains. From a screen facing the patient, a physician avatar welcomes the patient, provides important information about necessary examinations and treatment and then asks them questions about their medical history, symptoms, personal circumstances and allergies. TEDIAS collates this information and later displays it clearly on a dashboard for the real-life physician. The data is compared automatically and any discrepancies are shown. "For example, a

The TEDIAS patient admission system should help reduce hospital waiting times in the future.

Photo: Adobe Stock

patient may have indicated that they have no further illnesses, yet they are taking antiarrhythmic drugs. In this case, the physician will get an alert to follow up further," explains Langejürgen. In a standard patient admission scenario, it takes roughly 45 minutes to attach measuring devices, input readings and record basic medical data — time the physician can now use for a more detailed consultation. Colleagues on the ward, in radiology, anesthetics or the operating theater will also be able to access this information — and thus be freed up from tedious routine tasks.

"We're planning interfaces for common hospital IT systems," continues Langejürgen, who also confirms that TEDIAS will be an optional offering, with no obligation on the patient side. "Just as before, the previous procedure will still be possible in parallel. We're not looking to replace the physician — we'd never be able to do that — we just want to support them in the best way possible." In principle, the avatar solution will be very user friendly, and even those who are not digitally savvy should be able to access it easily. The virtual physician will be able to manage a dialog independently — and not just in German; in time, it will also be able to converse in English, French, Turkish, etc.

Until the avatar solution is ready for use, patients will be given tablets to allow them to input their medical history data into TEDIAS using digital questionnaires. The input information will trigger certain procedures in the hospital. For example, if a patient had a painful wrist after a fall, an x-ray exam would be requested. In the future, these procedures will be displayed transparently to the patient. "The patient's strong involvement has a positive impact on their satisfaction levels, and on their trust in the clinic," affirms Langejürgen. Rather than waiting passively for two hours in an emergency room, sitting apprehensively, full of concern about the possibility of being forgotten, or not being properly understood when finally called for admission, the patient will feel much better, and will have a clear sense that they are being looked after.

The data that is collected as standard via digital questionnaires also offers the added advantage of being a lot more legible than the often non-standard, handwritten information provided on paper forms. It can be compared, it's comprehensive and the information it provides is of good quality — which are all important prerequisites for enabling automated forms of analysis down the line, for example using AI. The data could also allow physicians to detect the early signs of certain illnesses. Or it could be used to review successful treatments that were applied in the past to patients with the same symptoms, vital-sign readings, and medical history.

The first TEDIAS kiosk is set to be tested at University Hospital Mannheim in summer 2022. Langejürgen believes that rather than viewing this new technology as a cold and impersonal digital avatar, physicians should see it as an opportunity to focus more on their core work — which is to care for and look after their patients. ■

back to page 1

Kevin pulls an all-nighter

To rapidly evaluate millions of PCR tests and swiftly break down chains of infection, lab technicians are often required to work day and night. In the future, Kevin — the mobile lab robot developed by a Fraunhofer spin-off — may well be able to take over the night and weekend shifts.

By Mandy Bartel

Since the start of November alone, German labs have carried out 80.3 million PCR tests — that's 1.5 million tests per week. For lab employees, it's a real test of their endurance. Yet, one member of the lab isn't put out by all the overtime. He never gets tired, doesn't need a break and never makes mistakes — even in the middle of the night. He prints out labels, affixes them to test tubes, transports cell cultures. Monotonous tasks and routine processes are what he does best. Kevin is a cobot, a collaborative, mobile laboratory robot that has been developed at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and at a spin-off company of the institute.

Equipped with a collaborative robotic arm, two cameras, an image processing program and a learning algorithm, Kevin makes his way around the lab with the aid of laser and digital map technology. He is able to flexibly interconnect the different items of equipment and manual workstations and can automate processes without the lab operator having to modify all of the existing infrastructure at great expense. "Kevin bridges the gap that exists between lab processes that have hardly changed over the past few decades and the digital world," explains Tobias Brode, Head of the Medical Engineering and Biotechnology business unit at Fraunhofer IPA and founder of the spin-off. Although modern equipment in today's labs can automate some subprocess steps, the problem up to now has been that they are very often not able to interconnect the individual steps, due to the lack of compatibility. This is the gap Kevin is now closing — his biggest advantage being that he is software-independent. As Brode explains, "The more extensive the level of digitalization, and the more options there are for interconnecting individual items of equipment, the smarter Kevin works."

As a highly specialized transport robot based on Fraunhofer technology, he can lighten the load for his human colleagues; for example, by preparing samples during the night so his lab colleagues can start testing them first thing the following morning. The mobile robot is therefore helping to extend the operating times of expensive lab equipment. This not only reduces costs, it also helps to accelerate the development of drugs and treatments, or ensure the more rapid processing of tests — which can be vital in a crisis situation, and in many cases, crucial to saving lives. Yet, for Brode, one thing is important when it comes to praising Kevin and his special skills: "This is not about robots replacing humans. Kevin and his colleagues have been designed to help humans, so they can focus on individual lab processes that offer real added value." ■

For more information, see:
www.kevinrobot.com

Up to

1.5

million
PCR tests
are carried out
by German labs
each week.

Alone in the lab: This 3D visualization was created in the 3DEXPERIENCE Lab for start-ups using construction data from 3DEXCITE/Dassault Systèmes.

Photos: 3DEXITE, Rainer Bez/Fraunhofer IPA

back to page 1

Administering medication is an important part of outpatient care. Employee rosters are often as confusing as a well-stocked medicine cabinet.

On the hunt for care fraudsters

Outpatient care has become a business worth billions. A new software has been developed to help bring fraudsters to justice — and provide effective investigative support for the criminal police.

By Tim Schröder

Since 1999, the number of people in need of care in Germany has doubled, reaching about four million. Insurance providers for long-term care pay out 25.2 billion euros per year for outpatient care alone — that is, for treating patients in their own homes. The business has its dark side, however. In 2018, the German National Association of Statutory Health Insurance Funds reported a total of just under 7 million euros in damages resulting from care fraud. However, it is essentially an open secret that the number of unreported cases is considerably higher.

The beginning of 2023 will see the release of a prototype for a new software that will speed up investigations into care fraud, making them more secure and, above all, more systematic. It is being developed by the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern.

"Until now, our paper-based systems have left the door open to fraudsters," explains Elisabeth Leoff, Deputy Head of the Financial Mathematics department at Fraunhofer ITWM. Paper-based lists are still widespread in the care industry, with caregivers' itineraries created on an individual basis by each nursing service and printed daily. The caregivers then put their initials on service confirmation documents in order to sign off their billable services. Although these service confirmation documents are subject to certain guidelines, there is no standard nationwide format. This means that, when suspicions arise, bringing the fraudsters to justice is extremely time-consuming for the police. Because of the lack of digitalization, officers have no choice but to compare thousands of itineraries with the service confirmation documents, line by line and all by hand.

30,000 itineraries, nine months of police work

But since different caregivers normally make their rounds on different days, the police have to inspect the itineraries of multiple employees. Even if there are only ten employees caring for ten different patients throughout the year, this can quickly produce around 30,000 itineraries. According to the Saxon Police Force, manually inspecting that many documents would take officers up to nine months. "Until now, this tedious work has been done by highly qualified detectives, who then become unavailable for other tasks," says Dr. Henrike Stephani, Deputy Head of the Image Processing department at Fraunhofer ITWM. Even if the case is eventually taken to court, fraudsters are often only judged for a portion of their crimes. This is because the police sim-

Photo: Stocksy/F1 Online

ply do not have the time to conduct meticulous inspections of a longer period. "That means the care service providers in question are only sued for a few weeks' or months' worth of fraud, even though everyone in the court knows that the fraud has been ongoing for years," explains Stephani, adding that the police cannot employ temporary assistants for the manual inspections, because the cases concern confidential patient data.

The project, which is funded by the German Federal Ministry of Education and Research, is divided into two parts: first, automatic image recognition, and second, analysis of the content. Stephani and her team are responsible for image recognition. They use text recognition programs in some instances, for example, to read sections of itineraries and service confirmation documents. "This is very easy when it comes to printed text in the tables, such as addresses," says Stephani. "But for the handwritten content, we have to find individual solutions based on machine learning. Handwritten time periods present a particular challenge, since the notation can vary greatly." The next step is to compile the information. Then, the data must be assessed, which is something of a speciality for Elisabeth Leoff. "We work closely with the police to learn what content is critical for the investigations. After all, our goal is to create a software system that the police can use independently in their daily work in the future."

> "Our goal is to create a software system that the police can use independently in their daily work in the future."
>
> Dr. Henrike Stephani, Fraunhofer ITWM

AI and legal compliance

One challenge the project is currently facing is that the data must be anonymized before the police can hand it over to the team at Fraunhofer ITWM, thus creating an additional hurdle for the data assessment. On top of that, Leoff and Stephani must make sure the data is being processed in such a way that it can stand up in court. As Leoff puts it, it has to "comply with the requirements of the justice system." Regardless of the artificial intelligence system or algorithms used, the judge must be able to understand what data the analysis is based on and how the results came to be. Otherwise, the public prosecutor has no chance of convicting the perpetrators.

The current project, which is concerned with building a prototype, will end in the beginning of 2023. However, the partners are confident that it will continue. "The police are highly dedicated collaboration partners, so we can safely assume that the project will continue and that the system will be ready to use in a few years' time," says Leoff. In the future, detectives will be able to carry out the entire process independently, from scanning the documents to conducting analyses. The software is designed to be flexible so that it can be easily adapted to the requirements of the respective fraud case.

For Leoff and Stephani, the project is very different from their usual tasks at Fraunhofer ITWM, both because it deals very closely with people and because it involves very personal information that requires a high level of protection, namely care data.

Normally, Leoff's projects see her immersed in the finance or insurance sectors, while Stephani generally focuses on issues relating to industry — for example, in one current project, she is applying automatic image recognition to identify tropical timber that has been traded illegally. That is to say, developing a search tool together with the police in order to save thousands of working hours and fight crime more effectively is something very special indeed. ■

AI fights care fraud — the Fraunhofer Podcast.

back to page 1

Solutions for a healthy heart

From defective valves to constricted arteries, the list of cardiac diseases is long. Experts at Fraunhofer IPK and Fraunhofer IKTS are researching solutions that enable patients to lead long, active lives in spite of cardiovascular problems.

By Britta Widmann

Balloon catheters are being used ever more frequently for drug delivery in patients with heart disease. Until now, the process for coating the catheters has been manual. But now there is hope for increased speed and efficiency.

A pain in the chest, difficulty breathing and an outbreak of sweat — panic! These are typical signs of a heart attack, and coronary heart disease (CHD) is often the trigger. Now, new technology is set to help make this condition less life-threatening.

CHD is caused by calcium deposits that constrict the coronary arteries. This creates a bottleneck, which doctors normally widen using a stent. But in many cases, a constriction builds up in the arteries again, requiring further intervention. That is why minimally invasive cardiac surgery uses drug-coated balloon catheters in lieu of stent treatment. When the balloon is expanded, drugs are transported directly from its surface into the arterial walls, where immunosuppressants and cytostatic agents prevent the vessel from closing again.

The problem is that even today, the process of coating the balloons with drugs is entirely manual. "It's hard to believe," says Gregor Dürre, a scientist at the Fraunhofer Institute for Production Systems and Design Technology IPK. "The procedure is time-consuming and prone to error. There are hardly any specialists with the required expertise." Together with his team, Dürre is researching how the process of coating the balloon catheters can be automated.

At the moment, Fraunhofer IPK is developing an automatic coating machine together with partners InnoRa GmbH and Organical CAD/CAM GmbH. "This would allow us to reduce the rates of rejects and errors, massively increase the sale of balloons and guarantee process reliability," says the researcher.

Constructing the automatic coating machine is challenging. The aim is for the microscopic crystals in the drugs to point outwards in the same direction. This is the only way that the drug can quickly and reliably penetrate the cell walls and have as long-lasting an effect as possible. For this reason, parameters such as the thickness of the layers and the texture of the coating surface play a decisive role. "The balloon catheter needs to transport the drugs into the artery walls immediately. This must occur within a maximum of one minute so that the oxygen supply to the heart is not cut off for too long," explains Dürre. After the drug has been dispensed, the balloon catheter is removed again.

Factors such as kinematics, the pressure applied to the balloon, coating speed, the duration of the coating process and rotation speed impact the crystal structure and, consequently, the construction of the coating machine. The "balloon" part of the catheter is an extremely thin and fragile membrane, and must be coated while expanded. "That is very difficult. The smallest mistakes can lead to a fissure in the 20 to 80 micrometer-thin membrane," says Annika Brehmer, a biotechnologist and colleague of Dürre.

This is what makes constructing a coating unit so challenging. The balloon is stretched on a wire that is rotated by two motors, ensuring that it is coated evenly on all sides. The position of the coating head alters depending on the balloon membrane. An integrated surface measuring device takes care of quality control by constantly measuring the thickness of the layers. The coating process lasts three to five minutes. "In contrast to manual processes, this method allows us to constantly monitor the quality," affirms Dürre. The prototype should be market-ready by the start of 2023.

Putting an end to calcification — but how?

The second-most common form of cardiac disease involves defective heart valves. When a heart valve no longer opens and closes as it should, it often needs to be replaced with an artificial valve. Currently, medical science is trending toward biological replacement — it has the advantage of not requiring patients to take blood-thinning drugs such as Marcumar. But compared to mechanical valves, bioprostheses also have a drawback: They calcify quickly. Biological valves, which are made from the aortic valves of pigs or from the pericardial tissue of cattle, work reliably for a maximum of 15 years. However, crystalline hydroxyapatite is deposited on the valve leaflets, triggering the calcification process. Researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS hope to use new chemical pretreatments to stop these deposits from forming. They are working closely with the Institute of Applied Medical Engineering at RWTH Aachen University and the Meshalkin National Medical Research Center in Novosibirsk, Russia.

"The prostheses are normally pretreated with glutaraldehyde. The fixation agent stabilizes the collagen framework of the prosthetic valve," says Dr. Natalia Beshchasna, scientist at Fraunhofer IKTS. Dr. Beschchasna and her team chose pericardial tissue as the base material for their trials and stabilized it with molecules of the fixation agent. Instead of conventional fixation with glutaraldehyde, they used diepoxide and bisphosphonate. "Glutaraldehyde binds well to collagen, but not to elastin, which is also a component of pericardial tissue. That's why people are looking for alternatives. We decided to use diepoxide," explains the engineer. The fixation was tested with and without added bisphosphonates — medications that affect the bone metabolism and are used to treat osteoporosis, for example.

The results of the in vitro test suggested that diepoxides and bisphosphonates could be a highly promising alternative to glutaraldehyde, thanks to their excellent tissue fixation properties. "Pericardial tissue tends to bind calcium ions, which in turn bind phosphate ions, thus encouraging calcification of the prosthetic heart valve. Diepoxides and bisphosphonates can counteract this long-term complication and inhibit the reaction between calcium ions and phosphate ions," says Dr. Beshchasna. "The perfect prosthetic valve has still has yet to be constructed. We hope that our new chemical pretreatment will bring us one step closer to that ideal." ■

Photo: Stocksy/F1online

back to page 1

Green light for phase 2

Prof. Thomas Thum is one of the important pioneers in the field of RNA therapy. He was the first to successfully test an RNA drug for heart disease in a clinical trial. In January 2021, the cardiologist took on the role of institute director at Fraunhofer ITEM.

By Christine Broll

Prof. Thomas Thum

- was one of the most frequently cited scientists in the world in 2021.
- was awarded the Paul Martini Prize in April. The foundation is committed to supporting drug research.
- has been jointly heading up Fraunhofer ITEM with Prof. Norbert Krug since January 2021.
- was born November 16, 1974 in Hildesheim, Germany.

RNA (ribonucleic acid) consists of a chain of nucleotides.

Thum has succeeded in achieving what many researchers only dream of. He managed to bring a therapeutic drug from the initial ideas stage right through to its use on human patients. The 47-year-old cardiologist still clearly remembers the day it all began. It was in 2005, and he was reading an article in the scientific journal "Nature" that described how miRNAs perform regulatory tasks in the liver of mice. At the time, scientists believed that the numerous short RNA fragments found in cells were simply the breakdown products of longer RNAs, i.e. genetic "waste." Once he was gripped by the idea of developing a new therapeutic approach, there was no going back. A mere 15 years later, he held in his hands the first ever vial of an RNA drug specially developed for treating heart failure.

In the interim, Thum has worked intensively on new RNA therapies, also at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM in Hannover, which he has been heading up with Prof. Norbert Krug since January 2021. One area of focus at the institute is pulmonary fibrosis. Pulmonary fibrosis is a disease that causes a change in the lung tissue and the gradual hardening of the lungs. Thum hopes that RNA therapy can be used to treat the causes of this disease, which has thus far proved incurable. "In parallel, we're now starting to research heart disease at Fraunhofer ITEM, which has traditionally focused on lung disease," explains Thum, who also heads up the Institute of Molecular and Translational Therapeutic Strategies at the Hannover Medical School.

Many variants of RNA can be found in the body. The best known type is messenger RNA (mRNA). Its structure contains a code that serves as a blueprint for proteins. As a COVID-19 vaccination, mRNAs offer the most hope in the fight against coronavirus worldwide. Thum is studying another type of RNA — non-coding RNA, which are RNAs that do not contain any blueprint for protein. "It is known by now that over 90 percent of human RNA consists of non-coding RNA," explains Thum. "A lot of this non-coding RNA is involved in regulating important body functions."

More active in diseased hearts

Shortly after reading the article about miRNA in mice, Thum began researching the role of miRNAs in cardiac tissue. He discovered that certain miRNAs are significantly more active in a diseased heart than in healthy tissue. In hearts where the connective tissue had undergone a pathological change, he found particularly high concentrations of miRNA-21. This led him to the decisive idea: Would it be possible to reverse the pathological change in the connective tissue by inhibiting this RNA?

The breakthrough — anti-miRNA

Working with a collaboration partner, Thum's team developed an anti-miRNA that neutralized the pathogenic miRNA. This was the breakthrough. He was able to demonstrate that inhibiting the miRNA had a therapeutic effect. These sensational findings were patented by the working group and published in the renowned journal "Nature" in 2008. Pharma giant Sanofi is meanwhile testing anti-miRNA-21 in a phase-2 clinical trial in patients with kidney fibrosis.

During their cardiac tissue experiments, Thum's team came across yet another type of miRNA. Called miRNA-132, it stimulates pathological cardiac hypertrophy, which eventually leads to heart failure. In this case, too, a positive, curative effect was achieved by inhibiting the miRNA. It was initially tested on cell cultures, and then in further preclinical studies. This means that anti-miRNA-132 has met all of the requirements for use in clinical trials with heart failure patients.

Around four million people suffer from heart failure in Germany alone. In such individuals, the heart is abnormally enlarged and too weak to pump blood around the body. Patients complain of shortness of breath, water retention and weight gain. "In the last 20 years, little progress has been made in terms of treatment," says Prof. Thum. According to data from the German Heart Foundation, more than 40,000 sufferers die each year in Germany.

By founding the startup Cardior Pharmaceuticals in 2016, Thum was able to make the leap from working in a lab to conducting a clinical trial in humans. Twenty-eight heart failure patients took part in the trial and the results are promising. "We have demonstrated that treatment using anti-miRNA-132 is safe and does not cause any side effects in other organs," says Thum. "Furthermore, we observed an improvement in heart failure markers." Following this positive result, fresh funding has been provided and the phase-2 study has been given the green light. It is due to begin in the first quarter of 2022 and will involve 280 patients in eight countries. ■

4 million people in Germany suffer from heart failure.

"We have demonstrated that treatment using anti-miRNA-132 is safe."

Prof. Thomas Thum, co-institute director, Fraunhofer ITEM

RNA research as a beacon of hope, and more — Prof. Thomas Thum took part in our Fraunhofer Podcast:

Photos: Ralf Mohr/Fraunhofer ITEM, Science Photo Library

back to page 1

The sensor system has already undergone successful testing in a clothing factory.

PORTUGAL

Well-being in the workplace

Researchers at the Fraunhofer Center for Assistive Information and Communication Solutions AICOS in Porto, Portugal hope to promote productivity, ergonomics and psychosocial well-being for employees in the industry sector. To do this, they have developed sensors that analyze workflows, movements and posture in real time. This will also help minimize injury and accident risks. The sensors can be attached to the user's clothing easily, without impeding them as they go about their work. The workers can use a self-reporting sensor to record their well-being. The data is sent to a platform developed by AICOS, where it is evaluated and a visual representation is generated. The system also automatically collects data on the working environment such as temperature, noise level, lighting and vibrations. In the first phase of the project, the Fraunhofer AICOS team analyzed how skilled workers in a clothing factory carried out their tasks. Now, they're planning a follow-up project in the automotive industry.

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

In 2019, the average amount of plastic waste per person in Germany came to 76 kg — and packaging accounted for half of that.

EUROPE

Recycling instead of dumping

The CIRCULAR FoodPack project aims to keep packaging materials in a closed recycling loop. Food packaging mostly consists of different layers of plastic that are inseparably bound together. Because it cannot be sorted, processed or recycled, the packaging usually ends up in landfills or gets burned. However, now, under the coordination of the Fraunhofer Institute for Process Engineering and Packaging IVV, 14 European partners are working together to produce packaging that partially consists of recycled materials and is suitable for direct contact with food. Fraunhofer IVV is optimizing the recycling processes and developing innovative monomaterial packaging with functional barriers for foodstuffs and personal hygiene products. This packaging will meet the high requirements for such products, but will be easier to sort, meaning that it will be more recyclable than multimaterial compounds. Until now, it has not been possible to separate the waste streams for food and non-food packaging, leading to the loss of valuable resources. More than 16 million tons of multilayer packaging are sent to dumps or burned in Europe every year, because it cannot be sorted.

AUSTRIA

Active retirement made easy

The digital world is brimming with resources that would allow older people to determine how they want to live their own lives, whether it's in their own homes or assisted living facilities. Open platforms are free software systems that make it possible to link these digital technologies together — in a way that exactly matches the individual user's needs. The aim of the Vienna-based project PlatformUptake.eu is to promote the development and acceptance of these platforms all over Europe. To this end, the Fraunhofer Institute for Computer Graphics Research IGD has analyzed and evaluated existing systems and set up a comparison portal that care facilities can use to find the optimal platform solutions for their residents. The ideal would be to have a secure, user-friendly digital ecosystem that would supply users with health care and social welfare services or preventative programs and that could be connected to the users' own devices at home.

Digital services do help, but they need to be compatible with each other.

ITALY

It just keeps on going

Carbon-fiber-reinforced plastics (CFRP) are light and stable, and they offer cost advantages in the long term — making them perfect for components in electric cars. The Fraunhofer Institute for Machine Tools and Forming Technology IWU and its partners EDAC and INVENT have developed a CFRP-based vehicle frame including seat structures that can be re-used over a 30-year period and for a mileage of up to 1 million kilometers.

The components are not recycled but rather processed and reused directly. In this "design for reuse" approach, the individual components are designed in such a way that they can be disassembled easily and reused in a second or third vehicle. This intelligent, reusable platform for electric cars was developed as part of the EU project FiberEUse, under the coordination of the Politecnico di Milano university.

Imagine if vehicle frames could simply be reused — with this new development from Fraunhofer IWU, that vision is becoming a reality.

NORWAY

Detecting and avoiding pollutants in water

Our drinking water is at risk of contamination by certain chemicals that are not only poisonous, but also particularly long-lasting and mobile. This contamination can be irreparable, because these persistent, mobile substances (or PMs for short) get through filters and withstand drinking water purification processes. PMs are often used in the manufacturing of functional textiles, but they crop up in the paper industry and pesticides too. In the EU project ZeroPM, researchers from the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM are collaborating with 15 partners under the leadership of the Norwegian Geotechnical Institute to develop effective means of protecting humans and the environment.

The Fraunhofer ITEM team aims to identify and characterize risks presented by PM substances, so they are creating models exploring how humans may be exposed to these substances and how they then spread in the body. By assessing the risks of the toxic effects, the researchers hope to help develop prevention and remediation strategies. At the same time, they want to contribute to efforts to detect and avoid new dangerous materials more quickly in the future.

Natural barriers in the water cycle, such as soil filtration, can't stop PM substances.

back to page 1

A voice from the business world

Stefan Hohm, 49, heads up the IT and Development executive unit as Chief Development Officer at Dachser Group SE. The Kempten-based logistics company has over 30,000 employees and generated a turnover of 5.6 billion euros in 2020.

"Coopetition!"

Open-source over classic collaboration: Companies such as Dachser, DB Schenker, duisport and Rhenus want to use the newly established Open Logistics Foundation to advance the interests of all — they do not believe digitalization can be achieved in isolation.

Stefan Hohm, CDO at DACHSER SE, shares his thoughts

Open source may already seem like old hat to some. At Dachser, we've been using numerous open-source components for software development for quite a while now. We use these components to develop our two transportation management systems for air and sea freight as well as for road logistics. Its success in areas as diverse as server operating systems, web and mail servers, databases and smartphone apps shows how open source has gained in importance.

One of the reasons open source has established itself so successfully across various industries is because of the advantages of standardizing across companies. The case of Linux also shows that the modular operating system is being further developed by software developers all over the world. This means that as users, companies do not become dependent on individual providers. Although there can be a high degree of divergence in terms of quality and cost even with open source, platforms such as GitHub show that the opportunities clearly outweigh the challenges.

The logistics industry also makes use of these advantages — though only to a certain extent. Until now, logistics companies have been trying to gain what they believe is a competitive advantage through proprietary, non-interoperable, standalone solutions. This involves considerable effort, and does not allow for the development of standards. Taking an isolationist approach like this today also prevents the pragmatic networking between partners and customers that is so urgently needed in the modern world.

All market participants in this industry are therefore facing the same pain points. And this is exactly why the founders of the Open Logistics Foundation now want to rethink the "old hat" concept of open source for logistics. Selected software and hardware components are to be made openly available — free of charge — to all stakeholders in the supply chain. This will allow the retrieval of individual use cases from the repository and thus create a directly applicable standard, which will benefit everyone involved. Each company can then build on the freely available components and focus their scarce developer resources on creating and developing their own USP. This helps to increase the level of excellence across the industry. The Open Logistics Foundation and the associated Open Logistics Foundation e.V. are driving the industry's move from knowledge to action.

"All market participants in this industry are facing the same pain points."

It's also very important to me personally to emphasize that this isn't a private club. On the contrary, the foundation's core principles are that it is neutral, independent and open to interested stakeholders from any field related to logistics. This combination of principles should make it possible to move away from classic competitive thinking in this specific field, i.e. to engage in "coopetition," to create actual standards and to drive digitalization together. The technical platform, which enables the corresponding components to be made available to everyone on an open-source basis, builds on European legal standards and values, especially in terms of how the repository is operated. The Open Logistics Foundation also supports the selection of collaborative projects and the assessment of economies of scale.

The Fraunhofer Institute for Material Flow and Logistics IML, and Prof. Michael ten Hompel in particular, made a huge contribution to getting the foundation off the ground — he was there from day one. Without his passion for collaboration in the logistics industry, Dachser, DB Schenker, duisport and Rhenus would never have come together to found the Open Logistics Foundation. I am especially pleased that the involvement of Fraunhofer IML will ensure that science, research and practice will continue to be closely interlinked in the future. The foundations have been laid. Now it's up to the companies to establish a corresponding open-source mindset and identify further use cases. This will only work if in 2022, companies really endeavor to live the communal spirit that we hope the Open Logistics Foundation will establish in the context of driving digital transformation in the logistics sector. We're ready to make our contribution to the platform's success, true to our motto: "Let's get it done together!" ■

Stefan Hohm

- Has headed up the IT and Development executive unit as Chief Development Officer (CDO) since January 2021, and is responsible for IT, research and development, ideas and innovation management, contract logistics and company-wide industry solutions.
- Started out at Dachser 30 years ago as a dual-study student in Frankfurt, and was later responsible for the MIKADO warehouse management system.
- Took over management of the newly founded Erfurt branch in 2004 and the Hof branch in 2008.
- Established a central unit for research and development in 2016, in his capacity as Corporate Director at Dachser head office.

Photo: Dachser SE

back to page 1

No walk in the park: Astronauts Akihiko Hoshide (above) and Thomas Pesquet take a six-hour-and-54-minute spacewalk in September 2021.

Photo & Fraunhofer

Working hard in zero-G

An astronaut once described his work on board the International Space Station (ISS) as follows: "Imagine that you want to unscrew the entire engine compartment of your car and put it back together again correctly. Meanwhile, you're all decked out in thick winter clothes, protective goggles, gloves and a full trekking backpack. On top of that, you're doing the repairs on a pitch-black night, at sub-zero temperatures." The ISS is certainly a fascinating place to work — and in 2022, Fraunhofer will contribute to Earth observation onboard two space missions.

If all goes according to plan, a new type of measuring instrument will blast off for the ISS next February, where it will help measure the impact of climate change on our planet's water cycle. The instrument was developed by the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, and its spin-off ConstellR, while the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and its spin-off SpaceOptix helped develop specialized optics for the tool. This will be followed in July by the launch of the ERNST nanosatellite. Developed by Fraunhofer EMI in collaboration with the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB and the Fraunhofer Institute for Technological Trend Analysis INT, the 12U CubeSat weighs just 20 kilograms and is only half the size of a crate of beer. Perfectly equipped with a cryogenically cooled infrared payload, it will detect rocket launches and so demonstrate to the German armed forces the capabilities of small satellites.

Houston, we have a solution!

Photo: ESA/NASA

back to page 1

The whole world is wearing masks

The world goes through 129 billion single-use masks every month. Researchers at Fraunhofer have developed a sustainable and hygienic closed-loop recycling process for this staple of the pandemic.

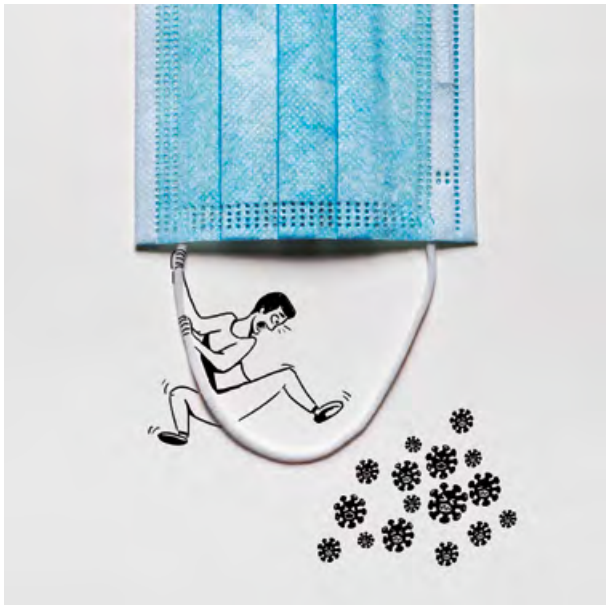
By Franziska Sell

The coronavirus is here to stay, and the whole world is wearing medical masks. Experts estimate that we use 129 billion masks every month. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety BMU has declared that used masks must be disposed of as non-recyclable waste, so that contaminated material can be safely eliminated through burning. But that also means valuable raw materials go up in smoke. Can we recycle these post-consumer plastics, conserve fossil fuel resources, and avoid growing mountains of waste? Researchers at Fraunhofer have found a closed-loop recycling solution for this problem.

"Against the backdrop of the pandemic, the question of disposable masks was on everyone's lips," says Dr. Franziska Auer, group manager for recycling technology at the Sulzbach-Rosenberg branch of the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. Researchers at Fraunhofer joined forces with industry partners and embarked on a project with a highly ambitious aim. Together with specialist teams from Procter & Gamble and the chemical manufacturing company SABIC, they planned to recover raw materials from masks that have been used and thrown away, and reintroduce them into the production value chain.

Thermochemical material separation

"We are experts on chemical recycling," explains Dr. Alexander Hofmann, Head of the Recycling Management



The coronavirus has brought out the creative side in some people — like Steffan Kraft for example. The illustrator from Wiesbaden has come up with his own way of reusing disposable masks.

department at Fraunhofer UMSICHT. The scientist and his team have developed the iCycle process, a procedure used for thermochemical material separation. "Plastics and other organic constituents are broken down using thermal decomposition and evaporated in an oxygen-free atmosphere. This method allows us to separate these materials from the metals or fibers they contain. Contaminants such as pollutants or pathogens are eliminated by the high temperature — ideal conditions for recycling medical masks efficiently."

For the purposes of this project, Procter & Gamble set up specific labeled collection bins in its production and research locations in Germany. It sent the used masks to the team at Fraunhofer for further processing. The team then treated the masks thermochemically in a special pyrolysis facility used for its research, converting them into pyrolysis oil. During the pyrolysis, the plastic is heated in an oxygen-free environment, which breaks it down into molecular fragments. "The oil yield is high. It comes to about 50 to 60 percent. This oil serves as a base material that can be further processed by players in the chemical industry to obtain new raw materials for plastics and masks. When produced via chemical recycling, these have virgin-material quality, so they meet the requirements for medical products as they are," says Dr. Auer, who is delighted with the success.

In the next step, the scientists passed the pyrolysis oil they had just obtained on to their colleagues at SABIC. The SABIC team successfully used it as a base material for manufacturing polypropylene (PP) with quality levels equivalent to new substances.

Finally, the specialists at Procter & Gamble processed the high-quality PP-polymer into a non-woven fiber material. The mask production had now entered a closed loop. The Fraunhofer researchers and their partners had completed project development and implementation in just seven months — from the mask collection phase all the way to production. They stuck to the closed-loop principle in every respect. There are three products of the iCycle process: a solid, an oil and a gas. The latter can be used to provide energy for the process itself.

Genuine closed-loop recycling

"It's amazing that we managed to establish a genuine closed-loop recycling process, that we really are going from a used product back to exactly the same original product, without any loss in quality," says Hofmann. "That is tremendously important, especially in the medical sector and for hygiene products — and it can be achieved through chemical recycling."

Can FFP2 masks also be a part of this loop? Dr. Auer doesn't foresee any difficulties there: "There's nothing to say they can't, because the advantage of the iCycle process is that you can also use it to recycle compound materials that could not be recycled mechanically — because, of course, we break them down into their individual constituents. You don't even have to remove the wire for the nose prior to recycling."

The team at Fraunhofer UMSICHT is now endeavoring to apply the principle of the process for face masks to hospital waste in general. "Mechanical recycling of medical waste has proved difficult due to the high hygiene standards," explains Dr. Auer. "But with our chemical process, we can provide products with virgin-material quality. That is a decisive advantage." ■

Watch how mask recycling is done in a video — the thermochemical process:

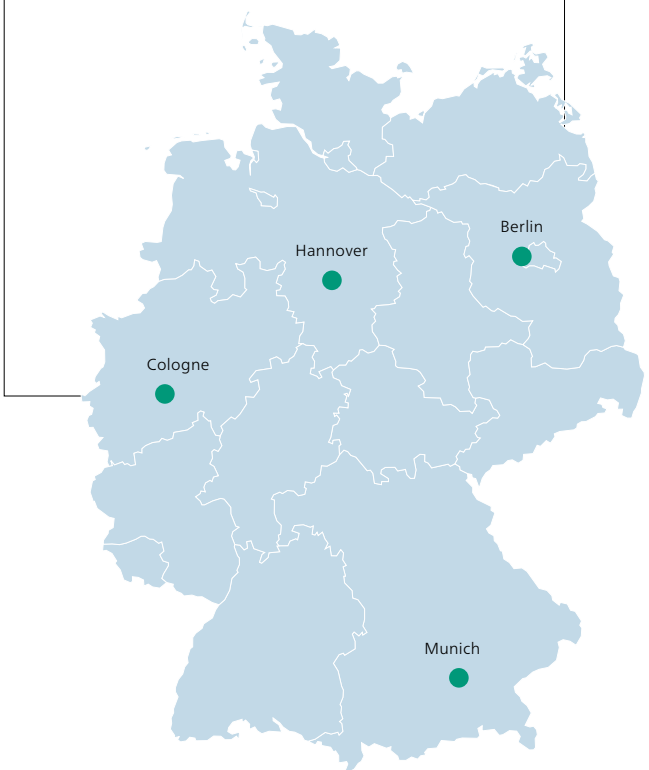
Photos: Iconeo

back to page 1

Fraunhofer

Seasons's Greetings

Fraunhofer on the road



Berlin
April 5–6, 2022
hub.berlin
Europe's interactive business festival for movers and shakers in the digital world

Hannover
April 25–29, 2022
Hannover Messe
The world's leading industrial trade fair

Berlin
April 26–28, 2022
DMEA
The leading event on the digital transformation of health care

Munich
April 26–29, 2022
LASER World of Photonics
The world's leading trade fair for photonics components, systems and applications

Cologne
April 26–29, 2022
Anuga Foodtec
International supplier trade fair for the food and drink industry

Last updated: December. Changes may occur due to the pandemic. Please keep an eye out for information from the event organizers.

Fraunhofer magazine

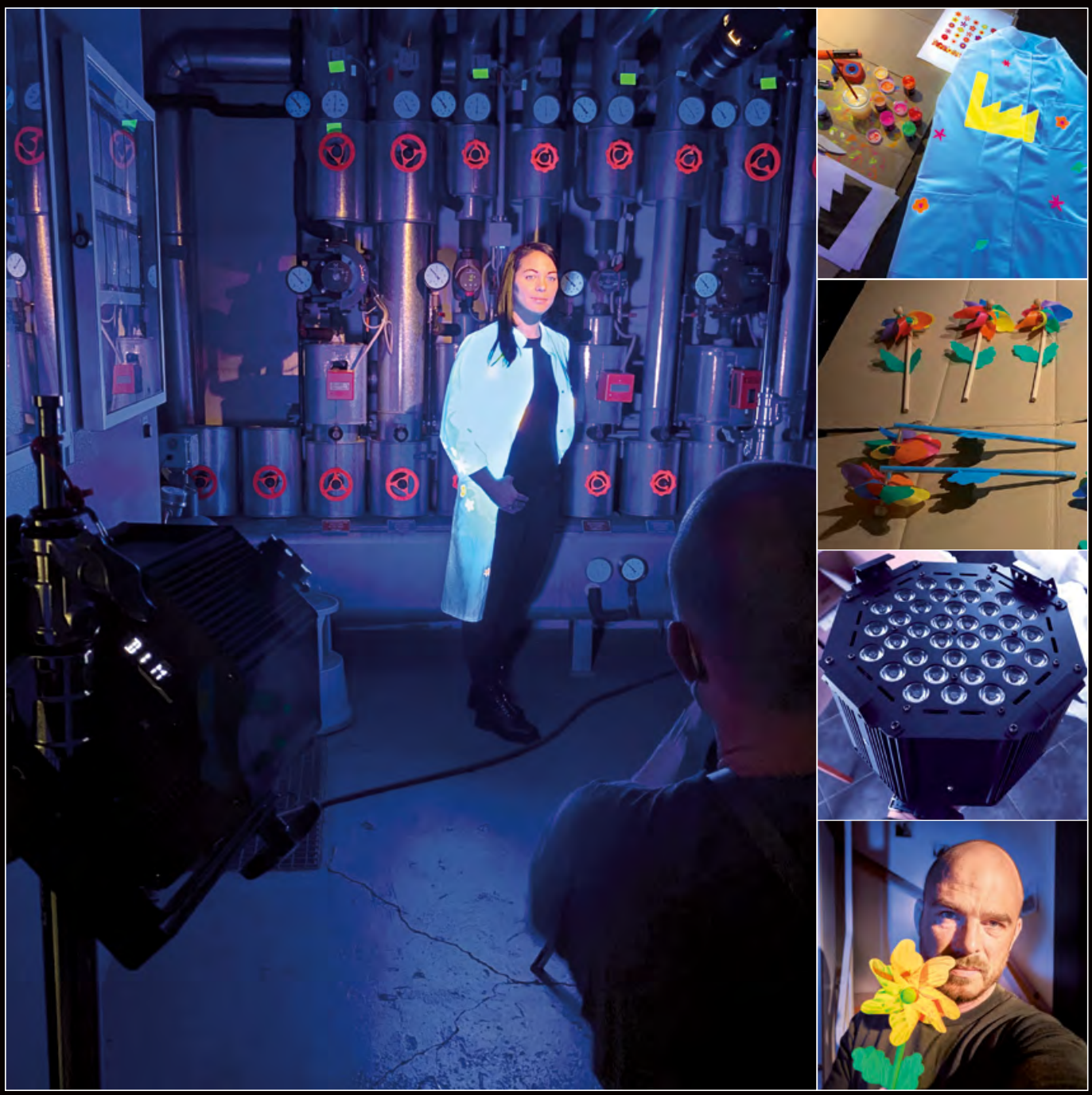
The magazine for people shaping the future

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

back to page 1

"I always try to develop each photograph in collaboration with the subject. When that works, it's a good picture."

Johannes Arlt, photographer



Johannes Arlt (right) brought a 4 kilo lamp with him on his mission to shine a spotlight on energy. What does a photographer have in his bag? A painted lab coat, props and a lot of florescent paint. One of the challenges was to light the subjects' faces in a natural way, without ruining the black light effect — high-precision work that takes a lot of patience.

Fraunhofer