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RESOURCE EFFICIENCY

FORSCHUNG LEBEN

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OPEN SPACE
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To Our Readers,

You've certainly spotted it: We've „re-launched" „RESEARCH AND LIFE", the Magazine of the University of Stuttgart, and incorporated our University's new corporate design. The aim of this new corporate design, which became standard for the entire University of Stuttgart at the beginning of the year, is to make our convictions, our goals, and our services clear and univocal for all the different groups with whom we are in dialogue. We hope to intensify both your interest and your enjoyment as readers with this new design of our research magazine.

In future, a circle will form the basis for a highly flexible and easily recognizable design. It stands both for oneness and also for the diversity and plurality of our university. As in the past, the layout system continues to be stamped by generous backgrounds of white, hard-hitting typesetting, and a clear language of images. We want this new Corporate Design to call attention to our brand name, „The University of Stuttgart" while continuing to highlight the original idea: to embody our creative energy with the impact of „less is more", that is: simplification and clarity.

What hasn't changed is the Magazine's high-quality editorial concept and its goal of underscoring the contents, issues, and problems of society today while informing you about the avenues to solutions which we offer through the University of Stuttgart's wide-ranging research spectrum. In the present issue we take up the explosive topic of Resource Efficiency. For many years, the dominant view in the world of finance and in society was that continued growth is almost synonymous with ever-greater resource consumption. Now, however, as the world's population explodes, the awareness is dawning that affluence, competitiveness and the quality of life essentially depend on a carefully measured, effective and sustainable use of resources.

And now: we hope to catch your interest on the following pages!

Wolfram Ressel
Rector of the University of Stuttgart

Photo: Uli Regenscheit

... Heard in Passing

Photo: HeidelbergCement AG

Dismantling Atomic Power Plants

145 nuclear power plants are currently active in Europe; about one third will reach their normal „retirement age“ in 2025. This poses major challenges regarding safe dismantling and waste disposal as well as how to train the engineers involved. With this in mind, five leading research institutions in Europe have formed the cluster group „Dismantling Nuclear Facilities“. The group‘s aim is to develop dismantling strategies. This includes optimizing both the management of dismantling activities and the dismantling technology which is to be applied. Decontamination and conditioning technology as well as safety precautions for employees, the general public, and natural surroundings are undergoing development. The University of Stuttgart‘s Institute for Nuclear Energy Applications and Energy Systems (IKE) and the Materials Testing Institute (MPA) are helping. The IKE contributes expertise regarding simulated activation of subatomic particles and concrete along with improvements in the safety of wet storage facilities. The MPA will contribute its experience in aging management of nuclear facilities and the approval of transportation and storage containers for radioactive waste products.

CO_2 Reduction in Cement

The cement industry produces 6% of CO_2-emissions worldwide. As part of the European Union‘s „CEMCAP“ Project the University of Stuttgart‘s Institute of Combustion and Power Plant Technology (IFK), together with an international consortium, is studying how to use technologies which could lower CO_2-emissions in the cement industry by 90%. Two thirds of emissions created during the production of this construction material come from CO_2 which has bonded to the initial material and is liberated during the burning (calcination) of limestone contained in the cement raw meal. For that reason, it‘s not enough just to increase energy efficiency.

The technology of „CCS“ (Carbon Capture and Storage) is more suitable. The IFK intends to study two methods. In the „oxy-fuel“ method, cement is burned in an atmosphere of pure oxygen; the off-gas is almost exclusively CO_2 and can be liquefied. In the „calcium-looping“ method, on the other hand, CO_2 is captured and combined with burned lime in a reactor to produce limestone, the raw material for cement.

Lean Construction

With the aim of significantly improving both productivity and resource efficiency in the construction sector, the German Lean Construction Institute (GLCI) was founded in 2014 at the prompting of Prof. Fritz Berner of the University of Stuttgart‘s Institute of Construction Management and Prof. Shervin Haghsheno of the Karlsruhe Institute of Technology (KIT). The GLCI investigates ways and means to improve planning and execution in the construction sector, and with this in mind seeks to apply the basic rules and tools of Lean Management to construction. These rules and tools were initially developed over recent decades in the automotive industry and have become standard in other economic sectors as well since the 1990s. Lean Construction scrutinizes previously accepted building systems, processes and organizational models. By seeking to focus all activities on what is important for the customer and by applying the principle of continuous improvement with less wastefulness, Lean Construction offers the possibility, of putting production processes in the construction sector on a completely new footing.

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ERC Grants in Pairs

Two University of Stuttgart projects have been singled out since March in the form of Consolidator Grants, the generously endowed research prizes of the European Research Council (ERC), with about two million Euros in each case.

Computer scientist Prof. Albrecht Schmidt, Research Director in the SimTech Excellence Cluster, and his Team are studying how the human senses can be technically enhanced and how artificial stimuli and tools supplement them. And Prof. Hans Peter Büchler of the Institute of Theoretical Physics is investigating how photon reciprocity comes about. As his starting point he has taken Rydberg atoms (that is, atoms with specific electron charges) which change their wave functions in the presence of a photon. Including his project, the ERC now supports a total of 12 research projects which are currently underway at the University of Stuttgart.

Prof. Albrecht Schmidt

Photo: Private source

Prof. Hans Peter Büchler

Photo: Ahal Film

ZEISS Research Award for Jörg Wrachtrup

Prof. Jörg Wrachtrup, Director of Physics Institute 3 at the University of Stuttgart, will receive the 2016 ZEISS Research Award for his work on quantum states of foreign atoms in diamonds. He will share the prize of 40,000 Euros with his former colleague Prof. Fedor Jelezko (University of Ulm, Germany). The award is given for outstanding work in the area of optics or photonics.

Central to the research thus honored are diamonds as „building blocks“ for new types of computers. After foreign atoms have been deliberately inserted into the diamond lattice, their quantum states are easily readable even under interference from factors in the vicinity. This would make it possible to process information at very high speeds or transfer it securely. Sensors too can be constructed with such diamonds, and other technical applications are conceivable in areas like medicine and even traffic control. The Zeiss Research Award is Wrachtrup‘s fifth prestigious award within five years.

OUTSTANDING

Photo: David Ausserhofer

RESPONSIBILITY

Photo: Acatech

Ortwin Renn, new Director at the Institute for Advanced Sustainability Studies

Prof. Ortwin Renn, Ordinary Professor for Environmental and Technological Sociology at the University of Stuttgart's Institute for Social Sciences, and Director of the Center for Interdisciplinary Risk and Innovation studies (ZIRIUS), took up his duties as Science Director at the Institute for Advanced Sustainability Studies (IASS) in Potsdam on February 1, 2016 as the successor of Prof. Klaus Töpfer. Renn's goal at the IASS is to study systemic risks which most pose a threat to the environment, the economic sector, and society. He intends to work with the worlds of politics, the economic sector, and groups in civil society to find solutions for bringing these risks under control in a context of sustainable development.

Text Studies in Italy

The Istituto Italiano di Studi Germanici in Rome is one of the most renowned international research institutes for textual studies in Europe. Located in the Villa Sciarra on the Gianicolo, the institute is home to numerous research organizations like the Italian Walter Benjamin Society and the Italian Hölderlin Society. In February 2016, the Stuttgart Research Center for Text studies (Prof. Sandra Richter / Prof. Claus Zittel) signed a cooperative agreement with this famous institute. Central to their cooperation will be the research fields of Digital Humanities and Hermeneutics, Esthetics, Poetry and Textual Theory along with the Analytical and Ideological History of Germanistics.

Photo: Foto: Studi Germanici

COOPERATION

Collaboration for Better Teachers

Many budding teachers experience a shock when debuting into actual practice in the classroom. The reason: up to now, scientific training and professional didactics have been ranked quite differently during teacher training at universities and institutions of higher learning. Now a new alliance entitled „Teacher Training PLUS" is bringing the best of both worlds together. Among those participating are the universities of Stuttgart and Hohenheim, the Pedagogical Academy of Ludwigsburg, the State Academy of the Visual Arts in Stuttgart, and the State Academy for Music and the Performing Arts of Stuttgart.

The joint aim of the partners is to build up a „Professional School of Education" (PSE) and establish a link between the technical disciplines, scientific didactics, and the educational sciences. In addition, the quality of teacher training will undergo scientific analysis and improvement, with greater emphasis on joining theory with practice. Still other activity modules of „Teacher Training PLUS" will look into technical learning in the natural sciences in MINT (mathematics, informatics, natural science and technology) and the areas of inclusive training and heterogeneity.

Photo: Max Kovalenko

A Copernican Energy Revolution

Astronomer and mathematician Nikolaus Copernicus has lent his name to the world's most comprehensive initiative on Energy Revolution research: Germany's Federal Ministry of Education and Research (BMBF) will fund efforts throughout the next 10 years to find trailblazing solutions for converting the world's energy system. The goal is to make so much progress with energy systems that they can provide all of Germany's regions with a secure, stable supply of energy – with equal regard for economic and social aspects. The University of Stuttgart is leading the way in two of four selected projects in this research effort, which is supported with funding of up to 400 million Euros. In the topic area of „Industrial Processes", approval was given for the „SynErgie" project. Its aim will be to create technical and market-related conditions needed for effectively synchronizing German industry's energy needs with a fluctuating energy supply in order to bring about a cost-efficient realization of the Energy Revolution. Secondly, the „ENavi" Consortium will work on „Systems Integration" together with STRise (the Stuttgart Research Initiative on Integrated Systems Analysis for Energy) to study the Energy Revolution as a holistic social process. The goal will be to work out concepts for giving due regard to technical, economic, ecological and social aspects in the development of the future energy system. The aim is to arrive at a socially, ecologically, and economically sustainable Energy Revolution.

Verantwortung. **Chance.** Leidenschaft. Machen.
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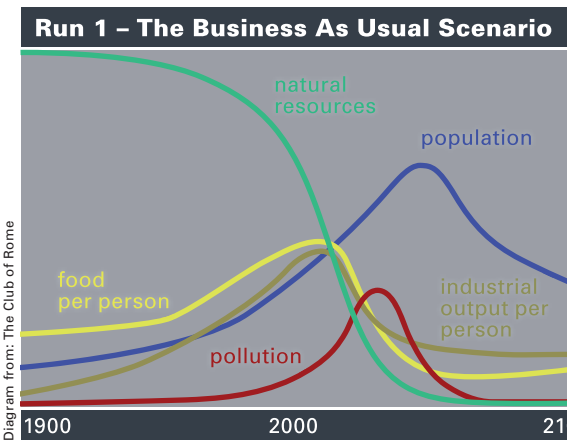
Why „Resource Efficiency“ At All?
Technological development and the political arena must work hand-in-hand.

Physicist and biologist Prof. Ernst Ulrich von Weizsäcker, Co-President of the Club of Rome, is one of the most astute, forward-thinking participants in the debate about sustainability. For years he has said that growth must be decoupled from resource consumption. Here, in a guest comment for RESEARCH AND LIFE, he sketches out some suggestions for improved resource efficiency that will ruffle the feathers of contemporary politicians.

The Club of Rome was made famous in 1972 by its study „The Limits of Growth“[1]. However, the central scenario from this global best-seller was in fact a message of doom and gloom. The earth‘s crust is full of mineral resources, but the richest veins of ore are exhausted first, so that less and less ore is mined from year to year. Even now there is a real scarcity of some chemical elements such as indium, phosphorus and the rare „heavy metals“. Ugo Bardi, a member of the Club of Rome, has shown in a new report[2] that energy consumption and localized impurities per ton of metal have steadily increased over the last decades as a consequence of the undesired but growing ratio of rock to metal.

Recovery rates are catastrophically poor, i.e. less than one percent, for almost all high-technology metals, as Thomas Graedel and his team at Yale University discovered as part of the Metals Task Force of the International Resource Panel.[3] This means that the human race allows itself the luxury of throwing about 99 percent of metals found geologically only in highly diluted form into the waste container after only a single use. Both of these scene-setting statements are intended to serve as a basis for the argument that an improvement of resource productivity is devoutly to be wished – and feasible too. Increasing recycling rates is basically a question of product design and the technology used to separate out technical waste products. The situation with plastics differs from that of metals. Resource efficiency regarding the former means first using plastics for energy efficiency, i.e. thermal insulation and lighter-weight automobiles and airplanes, and secondly increasing the longevity and reuseability of plastics. It goes without saying that toxicity must also be considered, for example with regard to fire and recycling. Polystyrene, long hailed as ideal for thermal insulation, is now regarded more critically, among other things due to the toxicity of substances used for incendiary protection. On the other hand, Professor Bouten in his remarks on page 66 gives examples of the vast complexity and wonderful potential for practical application of polymers and the plastics derived from them. My own political proposal for increasing resource efficiency is somewhat original and goes against the grain of today‘s political machinery. I dare to say that the potential for increased resource productivity is absolutely gigantic. A quintupling



The standard scenario from the global bestseller „The Limits of Growth“. Note above all the green line, showing the steep drop in availability of natural resources.

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[3] International Resource Panel. 2011. Metal Stocks and Recycling Rates. (Lead author: Thomas E. Graedel). Nairobi: UNEP; ISBN 978-92-807-3182-0.

is the least that we should aim for today.[4] And in the long run, a 20-fold increase is conceivable. Sad to say, technology is making almost no progress in this direction. And one reason for that is that the availability of resources has steadily increased throughout the centuries. Exploration as well as the pumping, excavating, transportation and refining of raw materials has simply become more and more efficient, so that each ton of metal or other raw materials has become steadily cheaper.

Raw Materials Prices as An Adjustment Screw

Viewed ecologically, this trend must be termed very negative, and we need to take political action against it. The best solution in my view would be a political decision to continually increase prices paid by the end user for raw materials. To ensure that this does not lead to social friction or an unintended flight of industry, it would be necessary to carry out these increases very gradually, ideally in strict proportion to efficiency gains made during the previous year. By definition, the average cost of energy or mineral-based services in that case would not increase. A special arrangement could also be found for low-income persons in view of their living needs. And an agreement on „supply neutrality" could be worked out for resource-intensive industries: the fees charged to highly sensitive industrial branches for energy and minerals would then be returned to those branches – measured by the amount of added value or full-time jobs.

This would create a „ping-pong" effect between resource productivity and resource prices. It would be the same ping-pong which has now gone on for more than 100 years between work productivity and wages and has resulted, for example, in a 20-fold increase in work productivity, making us more and more affluent. But today, a further increase in global work productivity – for example through digitalization – is not desirable under all conditions (except those of competitiveness), whereas an increase in resource productivity could become a matter of survival.

Ernst Ulrich von Weizsäcker

Photo: James Badham

A quintupling of resource productivity is the least that we should aim for today."

Prof. Ernst Ulrich von Weizsäcker
Club of Rome

[4] Cf. Ernst Ulrich von Weizsäcker, Karlson Hargroves et al. 2009. Factor Five. Transforming the Global Economy through 80% Improvements in Resource Productivity. London: Earthscan. German: factor Fünf. Die Formel für nachhaltiges Wachstum. Munich, Droemer.

Eco Isn't Just Eco
Taking all factors into account shows which products are resource-conserving

Are electric cars better for the environment than those with combustion engines? At what points can industrial production processes save energy and materials? These are the questions that occupy researchers at the Department of Life Cycle Assessment at the University of Stuttgart's Faculty of Building Physics. The aim: to show industry new ways of working that save not only materials and energy but costs as well. The researchers' calculations provide a looking-glass in which society can see where it is wasting resources, doing unnecessary damage to the environment, or flouting social standards.

Probably no question is more controversial in political discussion today regarding traffic and the environment than whether electric vehicles make sense and are useful. True, they travel emission-free; but that alone cannot determine whether they are in fact better for the environment. The reason: just as with combustion-engine vehicles, both their production and the manufacture of their drive systems have an impact on the environment. Conclusive statements can only be made after a detailed analysis on the basis of an environmental balance sheet – or, after drawing up an even more comprehensive, holistic life-cycle balance sheet.

A group of pioneers is already working on this type of calculation: the 23 men and women at the University of Stuttgart's Department for Life Cycle Assessment (GaBi). As early as 1989 they began working out the calculations for ecological life cycles. Since 2006, the Department has been part of the Chair of Building Physics under the direction of Professor Schew-Ram Mehra. The team's expertise and a database built up over the last decades make it possible to perform valuable analyses for the areas of research and industry.

„In our work, we basically analyze flows of recyclable materials," says GaBi Department Head Matthias Fischer. That means studying all materials used in a particular process from the moment they are obtained – for example from a mine in the Congo – to the moment they are recycled at the end of their useable life cycle. The team analyzes processes, products and/or services rendered not only from an ecological but also from the commercial and technical points of view: what goes in, what comes out? How much energy is needed? What adjuvant materials are used? This makes it possible to calculate life cycle costs – not only within a company, but also along the entire value-added chain. „Our goal is to asses the sustainability of every product," says Fischer. In turn, that opens the door to environmentally appropriate product development.

When carrying out life cycle assessment, the researchers determine the impact of a product system on the environment. Five important categories in doing so are the contribution each product or process makes to global warming, to the breakdown of ozone, to summer smog, to acidification and to over-fertilization. „This helps us derive somewhat manageable and non-varying categories of emission impacts from the wealth of emissions and chemical compounds that are available," says Fischer, and he gives an example: carbon dioxide (CO_2), methane and nitrogen monoxide discharged into the air are part of the greenhouse effect because all three gases promote it. For each study, other factors may be added, such as the potential toxicity for humans and the environment, or the country-specific consumption. It doesn't take long for a life cycle assessment report to assemble thousands of parameters. „We record everything," says Fischer. „But we can't decide what politicians think is important at any given moment." At the moment, it's global warming, but in the 1990s it was „summer smog" with high ozone values in the air we breathe. For the Stuttgart

Photo: Ruter-Maxness/Catchlight

Do new forms of technology like this fuel-cell bus really benefit the environment? Life cycle assessment provides answers.

team, it's important not only to identify problems but also to indicate alternatives. „There's always a problem somewhere. The issue is then to solve that problem without creating a new one," says Fischer. „Here's an example from daily life: I use oil heating at home. Sometimes I think about switching to gas, because it burns cleaner. But electric heating would be even better, because there are no emissions at all. But if I also overlook where the electricity comes from, I make a mistake." Which brings us back to the topic of electromobility mentioned at the beginning. „Politically speaking, this is a very ‚high-voltage' issue," says Fischer. „Our aim is to analyze it and then say: „It makes sense for you to go this way or that way."

Daily Data from 56 Hydrogen Buses.

Some of the current projects of the GaBi Department researchers have to do with alternative mobility concepts. One of these is the EU's Clean Hydrogen Project in European Cities (CHIC). This is presently the largest European fuel cell project, with a budget of 82 million Euros. Up to the end of the year 2016, CHIC will test 56 buses with fuel-cell drives in regular bus service in numerous European cities. The University of Stuttgart plays a central role among the 23 research institutes, cities and industrial partners from eight countries which are taking part, as Aleksandar Lozanovski, GaBi Project Assistant, explains. „All the daily data generated by the buses comes together at our institute and is distributed from here," he says. Among other things, the researchers use life cycle assessment to evaluate the buses and to detect other avenues of investigation, for example, finding out how often the vehicles break down during their up to 20-hour rounds, and why. „Such information is important because it shows manufacturers and researchers where further development is needed." By August 2015 the buses had already traveled some eight million kilometers and had saved about four million liters of diesel fuel and more than 6,000 tons of CO_2. A first insight: the buses travel about 25% more efficiently than those with diesel engines. „Looking at it from an environmental point of view, it can be summed up quite simply: the secret is hydrogen production," is how the researcher sums up the preliminary ecological assessment of the buses. „Hydrogen produced with „green" energy makes me much better off than with diesel-run buses. With fossil-produced hydrogen I'm better off in some cases, worse off in others." But in Lozanovski's opinion it will still

Nanomembranes can perform preliminary cleaning of fluids containing foreign matter. Life cycle assessment was used to evaluate the environmental impact of this process.

Photo: Uli Regenscheit

take years before the buses are also more efficient for transportation companies. „A diesel bus costs about 200,000 Euros, while a fuel cell bus at present still costs more than 700,000 Euros – with higher operating costs." But he qualifies this: „Those are only the direct costs. Indirect costs like air pollution and harmful emissions are not included in such commercial computations." But it is difficult to put figures on these contrasting issues: „How can I convert nitrogen oxide or fine-dust emissions in Stuttgart into Euros? That's where a local, emission-free fuel-cell bus would have the advantage."

The Limits of Information

The project nevertheless shows where ecological balance sheets reach their limits: when environmental impact must be weighed against direct costs. After all, this type of calculation makes one thing clear: „Optimizing a product economically does not always guarantee that social standards and environmental conditions will be maintained," as Matthias Fischer puts it.

In such a case, however, the balance sheet can help to formulate political decisions – subsidizing hydrogen buses, for example. The example also shows that the studies can only be as good as the data that go into them. „It goes without saying that we are depending on the quality of the data, the measurements and the information," says Fischer. That is why the GaBi team derives its consumption data, for example, from the automobiles of research institutes rather than those of the manufacturers. It is always important for an ecological balance sheet to transparently document the factors and conditions under which the calculations were carried out, as Fischer mentions. „The more we deviate from this, the less accurate the information." However, he and his research team also use values acquired from industry. Added to this are many statistics and data from searches.

In this way they have at their disposal balance sheet values and individual eco- and life-cycle cost categories for nearly any raw material and substance that can be named. „For example, there may be five different manufacturers of an intermediate product, and they carry out purchases in turn in 20 different raw-material source countries. The advantage: this levels the playing field; but it also makes the entire affair very complex," is how he describes the data problem as an engineer. For that reason, the data records gathered over more than 25 years are the department's crown jewel. After all, the science of ecological life cycle assessment is not to be compared with mathematics or physics, says Fischer. „In some cases, our data are several years s old, so that our ecological balance sheet is actually a retrospective." Experience has shown, however, that this has almost no impact on many calculations. Currently, for example, the low price of oil is giving researchers some headaches: „That makes it difficult for us to propagate the message that we need to be oil-independent in the near future, because someday it will become scarce and expensive."

Battery Materials and Electric Automobiles

With regard to environmental impact, however, the price of oil plays a negligible role, as shown by another project of the GaBi Department's Task Force on Energy and Mobility: the German-French-Austrian project „Electric Vehicle with Range Extender as Sustainable Technology (EVREST)". In that

project, the team studied whether electric vehicles which use a small engine to extend their range (the „Range Extender“, or „RE“) could benefit the environment. On the basis of European traffic statistics, they found that small cars travel an average of 50 kilometers a day, while compact-class cars travel 90 kilometers. That prompted them to calculate whether it would be cheaper and more eco-friendly to install batteries for exactly these distances and use an auxiliary engine for overall ranges of up to 300 kilometers. After all: battery production weighs heavily on the ecological balance sheet of electric vehicles. Upon comparison with conventional vehicles with combustion engines now available on the market, the team came up with a differentiated picture: range-extended vehicles were better regarding their impact on the greenhouse effect, even when charged with conventionally generated electric current. In this respect, they were in fact superior to the battery-electric cars. When „green“ electricity was used, the E-Auto without an auxiliary engine was environmentally more friendly. The picture changed, however, regarding acidification: above all in the resource-rich African countries, the mining and processing of raw materials like cobalt for the battery cell cathodes requires comparatively energy-intensive processes. „That means that the larger the battery, the greater the impact on the environment. The potential for acidification is so great that it cannot be compensated for by service life,“ says GaBi team member Michael Baumann, who is part of the project. Some thinkers have therefore recommended that the „energy-mix“ be created cleanly in the country of origin of these resources and that techniques be developed for using less energy to extract them from ore or for recycling them in Europe.

Benefits for Industry

Projects carried out in direct collaboration with industry show even more concretely than such research studies how life cycle cost analyses can lead to greater efficiency. „Efficiency as I define it means benefit divided by the work required, that is, benefit in proportion to resource-input,“ says Fischer. That means that efficiency can be increased by gaining a greater benefit with the same input or by using fewer resources with the same benefit. Jan Paul Lindner of AG Production materials and Product Systems mentions the NanoMembrane Project as an example to show clearly that efficiency gains are possible above all through the analysis of entire process chains. „If I can pinpoint how much environmental impact I generate at each step, then I can optimize more strategically,“ says this environmental technician. The researchers in the NanoMembrane Project wanted to find out whether it is possible to benefit the environment by means of nanofiltration of impure fluids. They tackled this with coated, porous ceramic tubes with narrow passages. When a fluid to be filtered passes through them, the unwanted substances are filtered out through the ceramic lining. Among other fluids, they tested an organic solvent currently used by a pharmaceutics manufacturer as a medium for synthesizing one of its products. „One option is to dispose of the solvent by burning it. The next option would be to distill out the solvent,“ says Lindner. In that case, only the waste product would need to be burned. Using nanofiltration at the start yields a pre-cleaned solvent and a concentrated waste product. „The distillation is much less work-intensive and time-consuming after prior filtration. The question is: what pays off the most?“ After all: even a combustion system for special wastes, for example, still produces electric current and heat. Nevertheless, the researchers were able to show that: „In this case, all types of re-use are better than incineration,“ and: distillation alone places a greater burden on the environment than is the case with prior nanofiltration.

A robot guides initial cutting of wooden pieces for a lightweight pavilion.

Photo: ICD/ITKE/IIGS

Fischer sums up the results of many life cycle assessments, however, by pointing out that the pivotal point for improvement of resource efficiency does not lie with the chain of recyclable materials itself; rather, it starts with product design. „The design both defines the benefit and has a major influence on the process flow: how much material will be used? And which materials? How will they be joined? Truly increasing resource efficiency means putting an intelligent human being in the designer's seat."

Ecologically, Computers are the Best Woodworkers

The „Wood R3" Project, a final example from the Task Force for Sustainable Construction, shows how designs can be optimized for resource efficiency: it saves resources, it's regional, and – it's done by robots. It brings together the GaBi team, researchers from the University of Stuttgart's Institute for Computational Design (ICD) and Institute of Building Structures and Structural Design (ITKE) to develop innovative wood-planning and production processes. Rafael Horn, who guides „Wood R3" together with Michael Jäger, says, „In product optimization it's important to start even before the product exists. That means introducing parameters into the product development process." As a starting point, they reflected that a condensation of urban living spaces is possible only by building upwards. In turn, that requires lightweight construction techniques. „This is where wood is ideal as a production material," says Horn, who by profession is an environmental technician. Biological models are taken as templates for structural shapes – here, for example, the shell of a starfish. What the result may look like is shown by the Forest Pavilion developed by the project partners ICD and ITKE for the Regional Garden Exhibition in Germany's Schwäbisch Gmünd.

The building consists of countless individual segments. Jäger, the economist, explains: „The modules were made fully automatically by robots." A computer is already busy today designing the geometry of their flat parts with no outside assistance. Humans simply input the contact points of the design, and a robot saws out and turns the parts. „The core element of „Wood R3" is to incorporate sustainability criteria into this optimization process," says Jäger. „This computer-aided planning process then gives us the best ecological variant." Horn specifies: „Technically speaking it is good to make mostly small flat parts, but that requires a longer processing chain, meaning a greater expenditure of energy, and that makes the overall balance sheet very lopsided." When carrying out life cycle cost analysis, the „Wood R3" team also asks not only where processes can be optimized but also looks at the social aspects. This may involve the impact of wood as a material on future inhabitants or the effects of this type of production on value-added chains in the Region – on jobs, for example.

What About Social Factors?

Für Matthias Fischer liegt der große Vorteil der Ganzheitlichen Bilanzierung genau darin, dass auch soziale Faktoren – wie etwa Arbeitsbedingungen – einbezogen werden. „Das ist sicher ein Thema, das For Matthias Fischer, the main benefit of Life Cycle Assessment is precisely that social factors like working conditions are also taken into account. „That is certainly an issue that must and will play an ever great role. We try to bring together both the social dimension and the economic and ecological aspects." For example, the Congo cobalt mines already mentioned not only function with very „dirty" electricity but also the ore there is mined in some cases by children. The full dimensions of this become clear only when the ecological balance sheet is expanded to form a Life Cycle Assessment – and this is the specialty of the research team in Stuttgart. „Our hope is to make the world just a little bit better."

Daniel Völpel

Logical Freethinker
Johannes Kästner studies the details of chemical reactions

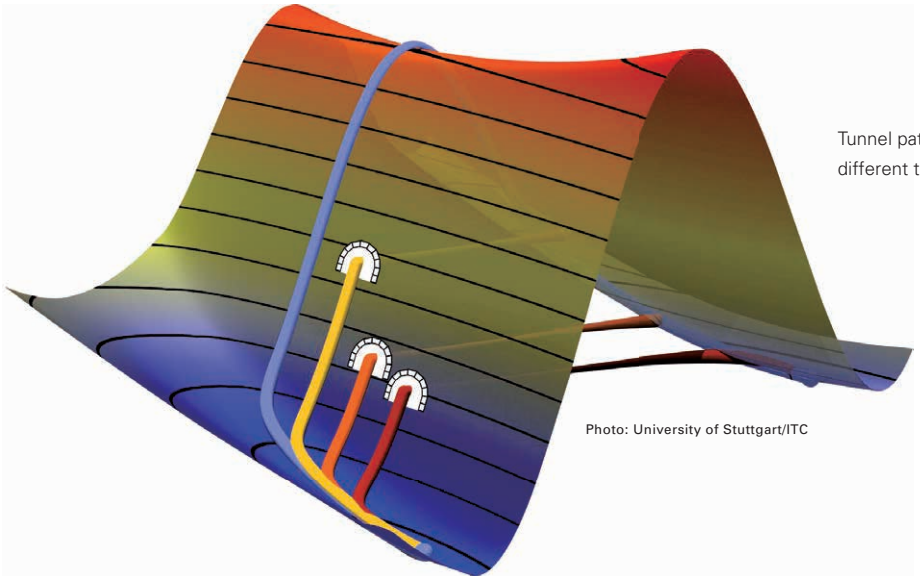
First a junior professor, now a full professor: Johannes Kästner is fascinated by quantum-physical events without which biochemical, chemical, and astrochemical reactions would be impossible. His work tool: the computer. His scientific work brought him a Consolidator Grant from the European Research Council to help him simulate the Tunnel Effect and its role in reaction mechanisms.

Chemistry can be studied even without a laboratory, at least when one asks questions the way Johannes Kästner does. Kästner and his team want to find out why chemical reactions proceed exactly in a certain way. He wants to explain their mechanisms, not on the basis of macroscopic quantities like temperature or pressure, but rather by understanding what happens in their most secret regions. As a professor at the University of Stuttgart's Institute of Theoretical Chemistry, Kastner is looking for answers in the secrets of the quantum world. „Any scientist who really wants to understand why something is this way and not that way always ends up in the world of theory," he says. What especially intrigues him is the role of the „Tunnel Effect" in chemical reactions. Because of their tiny size, atoms and other particles operate according to the laws of quantum physics - and then phenomena like the Tunnel Effect appear: whereas a ball thrown against a wall normally bounces back in everyday life, in the atomic world there is a certain probability that the ball will pass through the wall, that is, it will „tunnel". In that case, the mass of the individual atoms determines the extent to which the „wall" – microscopically speaking an energy barrier – is passable. This is more than hoary theory; its consequences can be observed macroscopically and exploited technically. For instance, without the Tunnel Effect there would be no modern hard disk drives and no memory cards in smartphones – nor would the sun even shine. At the beginning of last year Kästner was awarded a „Consolidator Grant" of the European Research Council in order to study the Tunnel Effect in chemical reactions. This type of grant is given to scientists who reached professorial status seven to twelve years ago and have made a name for themselves in the world of European research. Kästner now has two million Euros, spread out over a period of five years, at his disposal. He explains where it will go: „With theoretical chemists, the money naturally goes for additional personnel and for supercomputer working time, which must be purchased." Kästner's primary working tool, after all, is the computer, his „molecular microscope" as he puts it. „Since the Tunnel Effect in chemical reactions is difficult to study experimentally, we're forced to rely on simulations," says Kästner.

A Child's Dream

Now 38 years old, he is one of those people who even as children wanted to be scientists. „My parents aroused my interest in natural science," he relates, „where you can observe things and draw conclusions. At school as a youngster in Austria, he was interested in everything that had to do with biology, chemistry, and physics. What finally turned him to chemistry is rooted in Kästner's participation in the „Chemistry Olympic Games" for schoolchildren on the regional, national, and finally the international stage. „That brought me together with many enthusiastic schoolchildren and teachers and made me even more certain about what I wanted to do professionally," he says. Kästner began studying chemistry in 1996 at Vienna's Technical University, with a parallel enrollment in physics a year later. He graduated with a Master's Degree in chemistry but did not graduate in physics because he already had the chance to become a physics professor anyway. „So statistically, I'm one of the 50% who break off their physics

Photo: Uli Regenscheit



Tunnel path of a chemical reaction at different temperatures.

Photo: University of Stuttgart/ITC

studies!“ This was the beginning of Kästner‘s peregrinations as teacher and student. To get his professor‘s qualifications in theoretical physics he went to the Technical University of Clausthal and did post-doc studies at the Max Planck Institute for Carbon Studies in Mülheim an der Ruhr with theoretical chemist Walter Thiel, whom Kästner describes as „my mentor and supporter.“ „I was at the MPI for only one-and-a-half years, but it was a very intensive and professionally enriching time,“ he says. Then came the offer of a post-doc position with the possibility of a permanent job in Great Britain, which drew him in 2006 to the Scientific Computing Department of the Science and Technology Facilities Council (STFC). „But it turned out that I had little freedom to do research, no team of my own, and doctoral students were not accepted.“ That made it relatively easy for Kästner in 2008 to accept the offer of a junior professorship at the University of Stuttgart. „I knew the job was temporary, but I had a lot of freedom for research,“ he says. „And there was the chance of a tenure-track, meaning a permanent professor‘s position.“ At the time he was 30. It was to be his fourth job and address change in seven years, and is for now the last. „The first research years are difficult for a young scientist‘s family. I had the good fortune that my wife, also an Austrian, agreed to all the moves.“ Both of Kästner‘s children, now seven and nine years old, were born in Great Britain. „But professionally, a young researcher gains a great deal of new and useful information through such changes of work teams and countries.“ For example Kästner found that he could put the computing techniques he had learned in physics and studied during his doctoral years to good use in chemistry.

The Challenges for a Junior Professor

As a researcher, Kästner waxes enthusiastic about his Junior Professor‘s job. „Many more new and vacant professor positions should be offered as junior professorships with a tenure-track,“ he finds. „That would give young scientists a real perspective.“ It took three years before it was clear that Kästner would be put on the tenure-track. „During that phase everything was up in the air, and there was a lot of pressure,“ he says openly. „A junior professor must quickly come up with publishable results. There‘s no room for research projects whose finish is uncertain or which require a long time.“ Now he has been a Full Professor for Computational Chemistry since 2014, and also completed his official professorial thesis in that year. „Formally speaking it wouldn‘t have been necessary because I already had a junior professorship, but I wanted to keep the option open of accepting offers anywhere in the world. And an official professor‘s title is always an advantage for that.“ Kästner‘s work group now includes five post-docs, three doctoral students, and five undergraduates („who for me are full members of our team“). The team has grown considerably thanks to the Consolidator Grant. „Because of it, as group leader I have more to do with personnel direction and also more objectivity about the research contents of the project,“ says Kästner. „Also, the team members have more personal responsibility for

their work – which is good for future scientists." Thanks to the Consolidator Grant Kästner was able to expand his research activities to the field of astrochemistry, that is, the study of chemical reactions in the depths of the universe. The „Tunnel Effect" plays a major role in extremely cold dust and gas clouds in space because typical „reaction accelerators" like heat or high pressure are mostly absent. „I'm learning a great deal about astrochemistry from our two new team members, and they in turn a lot from me about quantum chemistry." Kästner greatly prizes this fruitful interaction through the collaboration of researchers from different disciplines. His own position is an integral part of the Simulation technology (SimTech) Excellence Cluster. „At Cluster meetings I learn how mathematicians, computer scientists, engineers, physicists and chemists tackle problems with simulations," says Kästner. Due to his training, each of us has his own approach, and that often opens up new avenues to a solution. „SimTech," says researcher Kästner, „is a major reason why I like it so much here at this University."

Michael Vogel

Load-Bearing Gossamer

„More is more:" A truism that's not always true, as seen in the roof of the Munich Olympia Stadium. Perhaps the same effect of hushed reverence could have been achieved with Roman-basilica-like, meter-thick walls. In this case, however, the Stuttgart teams of Professors Frei Otto and Jörg Schlaich created this gigantic space, this imperviousness to weather, and this illusion of „floating" merely with lightweight construction techniques.

Light-weight construction is both sturdy and resource-efficient. Today it is encountered as a design principle in various shapes, colors, and facets. Light-weight airplane and vehicle design has long been a point of traditional emphasis at the University of Stuttgart, where researchers at the ARENA 2036 Research Campus are constantly working on new ideas for the automobile of the future. Currently they are looking at composite fiber materials for series production of vehicles. Less weight means less fuel consumption, stable vehicle bodies and ensured safety.

Their design work takes place mostly at the computer. The images produced by the computers and implemented in prototypes are often reminiscent in beauty and form of shapes found in nature. Ultra-fine fiber structures look like spider webs, platelets come together like honeycombs. But bionics are not always the key here; rather, the similarities emerge spontaneously from the design principle: least weight, least resource-intensive, most stable. All prototypes are thoroughly studied before new developments are to be put into practice. Light-weight construction is by no means made light of!

Ulrich Fries

What does what? At the Institute for Materials Testing, Materials Science and Materials Strength these and other polymer light-weight structures from the 3D-printer are tested for stability.

Photo: Uli Regenscheit

The waterbug Agyroneda aquatica builds a web reinforced from the inside with fibers, allowing it to hold down an air bubble for breathing. This stable design was the inspiration for the University of Stuttgart's Institutes for Computational Design (ICD) and for Building Structures and Structural Design (ITKE) in designing a research pavilion.

The University of Stuttgart

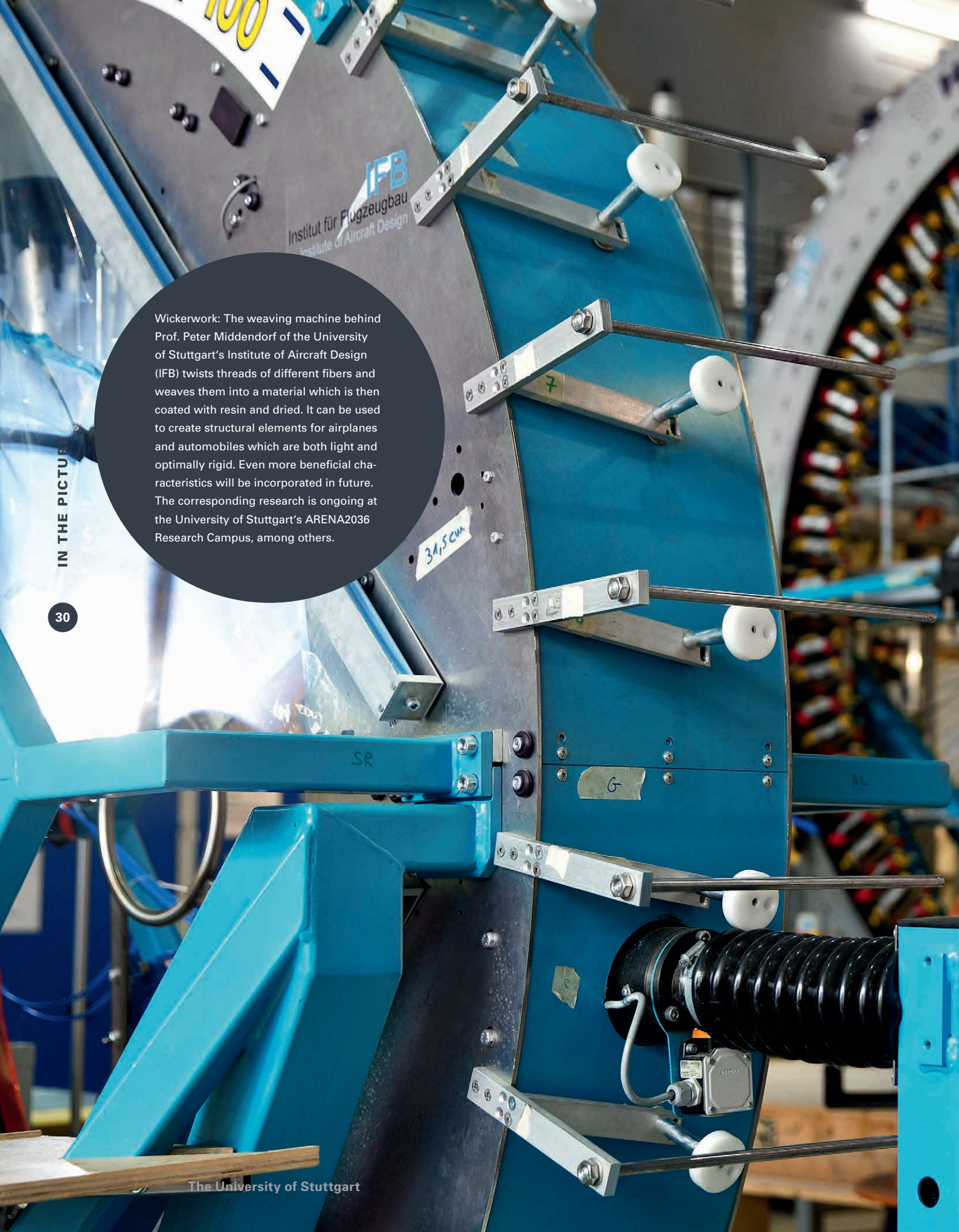
No spider here, but rather a robot has stiffened an initially soft film shell by glueing carbon fibers step by step to the inside. The resulting fiber-bonded shell is highly material-efficient and offers new avenues of design.

Photo: ICD/ITKE

Above the clouds: The solar airplane icaré 2 (at left) and the battery-powered airplane e-Genius fly nearly CO_2-free and energy-efficiently from one record to the next. Their carbon-fiber-sandwich design gives them such a light-weight flight design that they can use even the smallest updrafts - with exactly the same structural stability as a conventional glider.

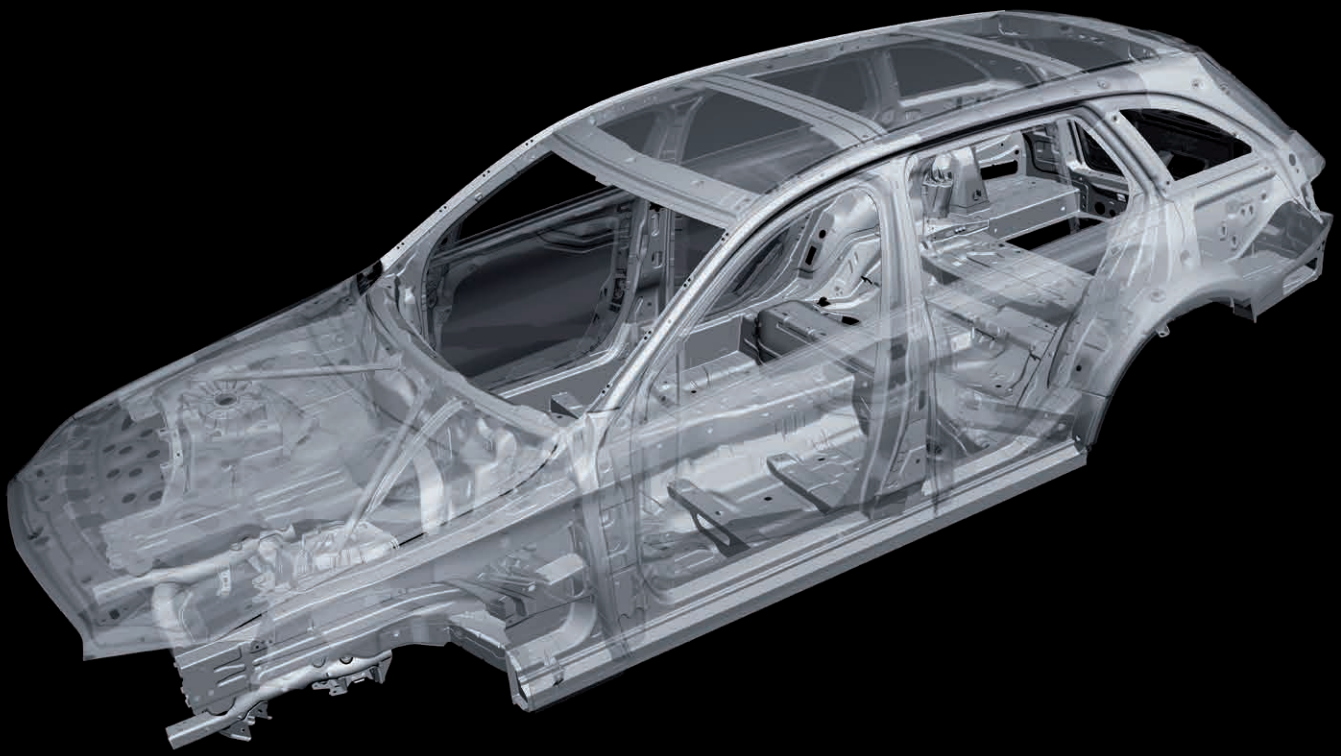
The University of Stuttgart

Photo: icaré 2



Wickerwork: The weaving machine behind Prof. Peter Middendorf of the University of Stuttgart's Institute of Aircraft Design (IFB) twists threads of different fibers and weaves them into a material which is then coated with resin and dried. It can be used to create structural elements for airplanes and automobiles which are both light and optimally rigid. Even more beneficial characteristics will be incorporated in future. The corresponding research is ongoing at the University of Stuttgart's ARENA2036 Research Campus, among others.


Photo: Uli Regenscheit



Ingenious: cast aluminum components, ultra-high strength steels, and different grades of material strength result in a light-weight Mercedes-Benz C-Class design concept for Daimler, an ARENA2036 partner.

Photo: Daimler

Double-down light-weight construction: the drill and rivet end effector developed by Fraunhofer IPA and its partners not only helps process light-weight production materials but is also itself a light-weight unit. The photo shows it drilling through thin piles or stacks of carbon-fiber reinforced plastic, aluminum and titanium for later installation in the outer skin of an airplane.

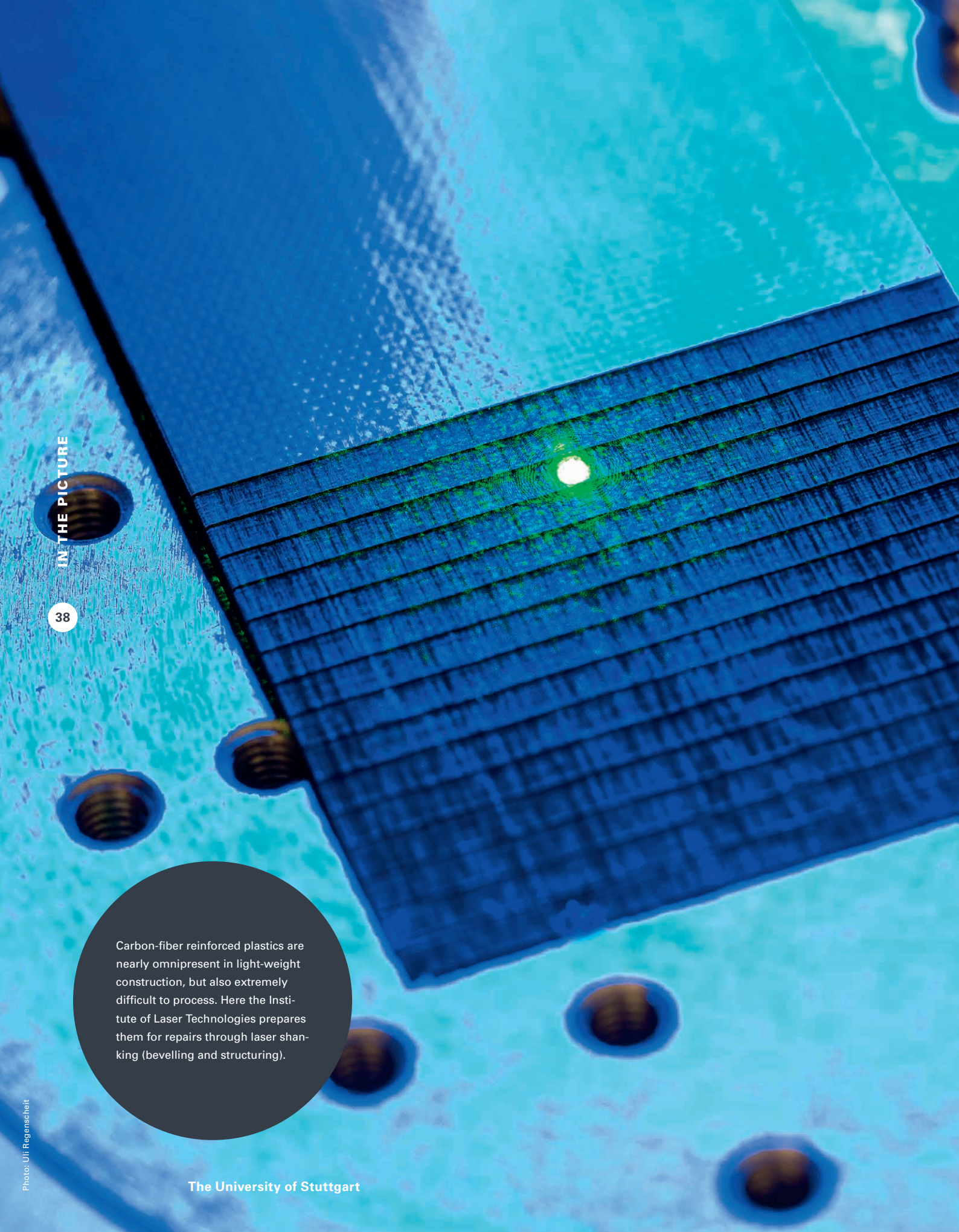
Photo: Fraunhofer IPA/Rainer Bä

Light-weight construction starts right in the planning phase: Clemens Honold and Thorsten Herrmann (l. to r.), of the Task Force on Product Development Methods at the Institute of Engineering Design and Industrial Design (IKTD) discuss methods developed at the Institute for improved light-weight construction design. One important step at this early stage of product development is the analysis of existing structures regarding optimization potentials in light-weight construction.

Photo: Uli Regenscheit

Clamped gossamer: aerospace applications require high-precision structural elements made of light-weight construction materials like carbon fiber-reinforced plastic (CFK), for example, or high-precision geometries which are drilled or turned in a CFK-structural element. This poses major technical challenges for their production. In particular, it is very difficult to clamp them in place, since the gossamer-like CFK structural elements can be deformed by conventional clamping techniques. Now the University of Stuttgart's Institute for Machine Tools (IFW) is looking at a new type of clamping: the photo shows the micro-machining process of a CFK structural element that has been clamped in „frozen" water and is then processed at an air-cushioned microprocessing station.

Photo: Uli Regenscheit

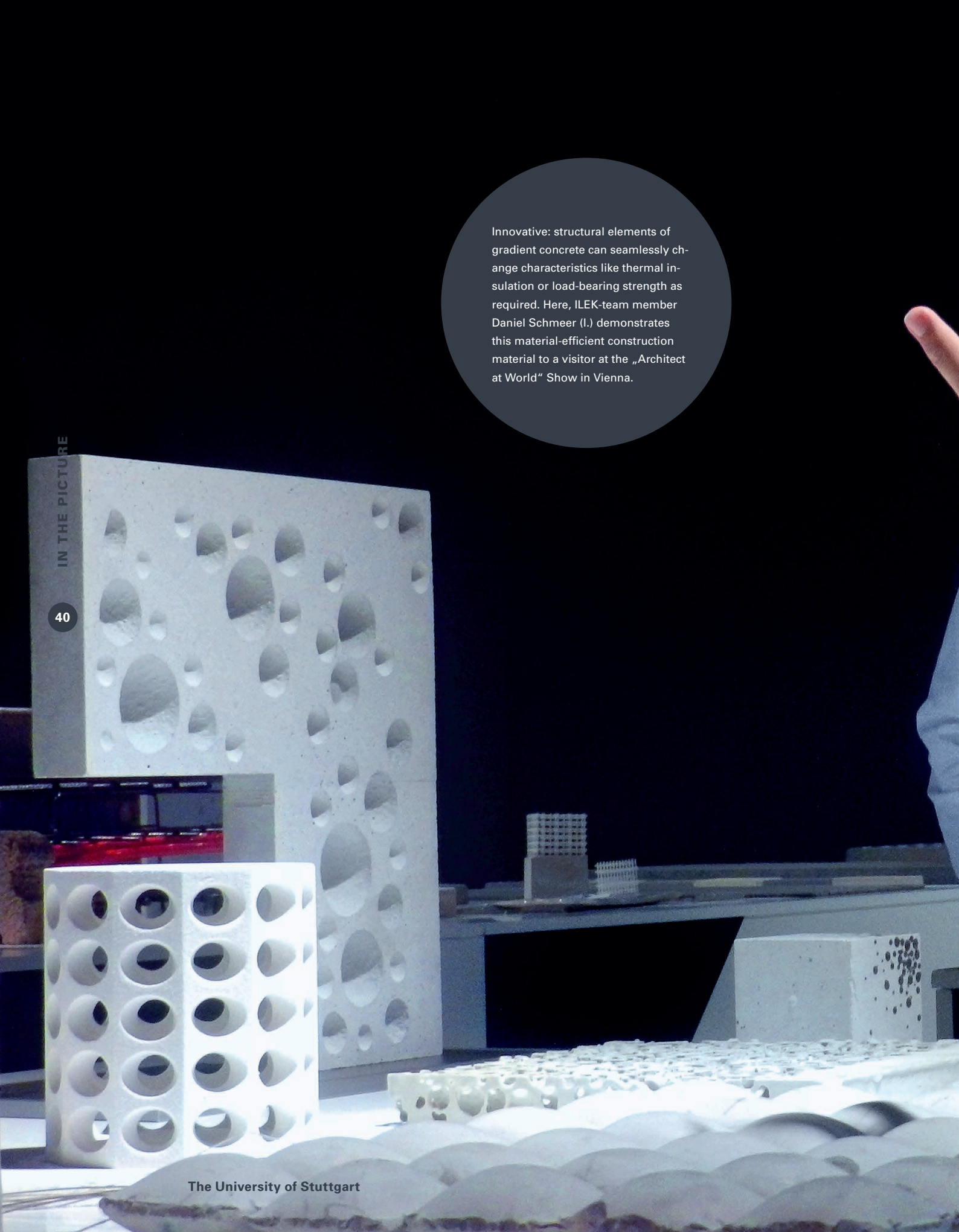


Carbon-fiber reinforced plastics are nearly omnipresent in light-weight construction, but also extremely difficult to process. Here the Institute of Laser Technologies prepares them for repairs through laser shanking (bevelling and structuring).

Photo: Uli Regenscheit

Design is everything, especially in light-weight construction: Here, Evelina Zapala of the Institute of Lightweight Structures and Conceptual Design sets up a foldable textile structure for presentation at the Stuttgart House of Commerce Design Center.

Photo: ILEK



Innovative: structural elements of gradient concrete can seamlessly change characteristics like thermal insulation or load-bearing strength as required. Here, ILEK-team member Daniel Schmeer (l.) demonstrates this material-efficient construction material to a visitor at the „Architect at World“ Show in Vienna.

The University of Stuttgart

Photo: ILEK

Will it hold up? Steffen Keller puts a light-weight construction panel to the test at the University of Stuttgart's Institute for Materials Testing.

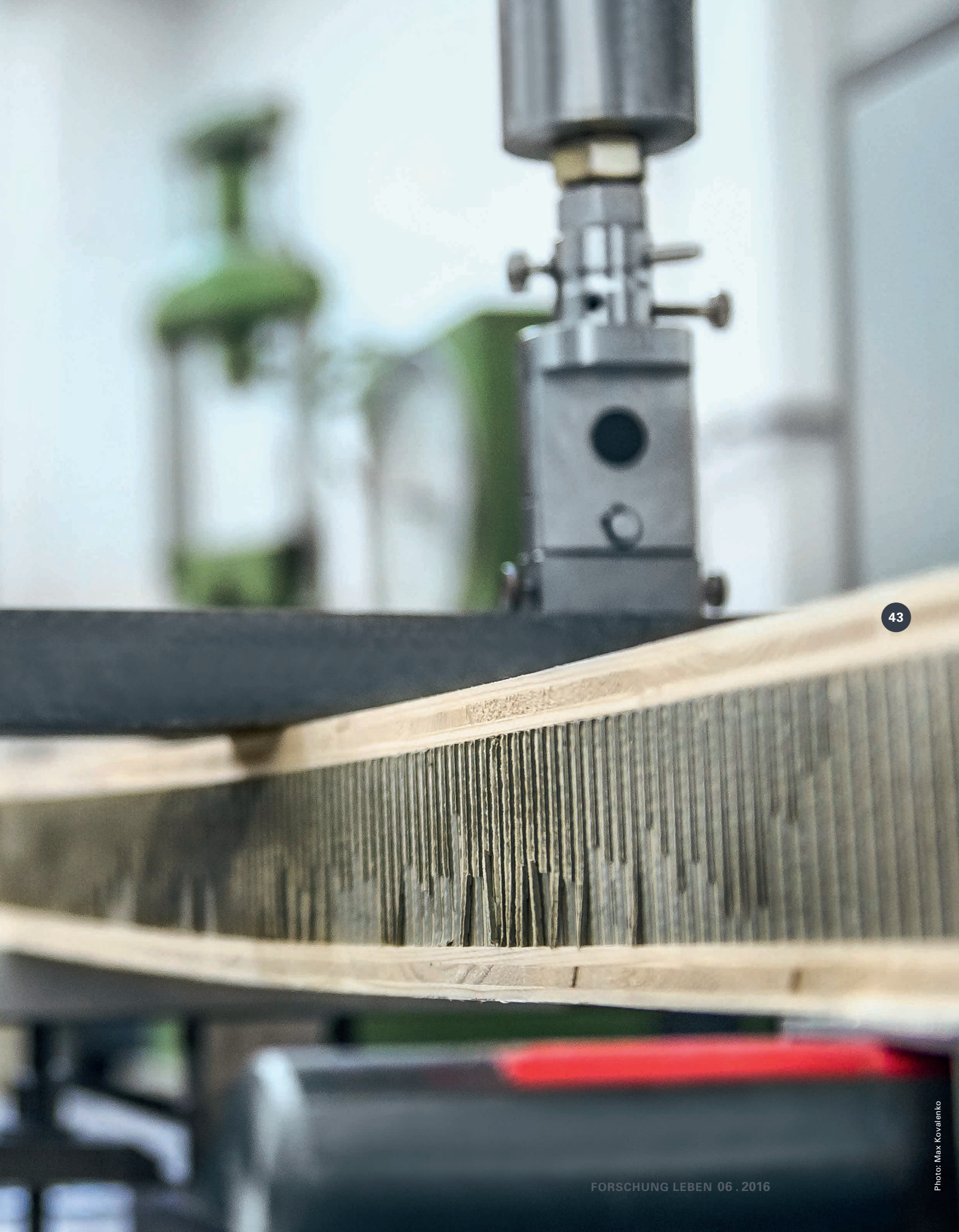


Photo: Max Kovalenko

Extremely high tensile strength, but low density: carbon fiber laminates and other high-performance lightweight construction elements are standard in aerospace and specialized areas like racing cars, but still too expensive for use elsewhere. But the hope is that they will be used more widely in future in the automotive and construction industries.

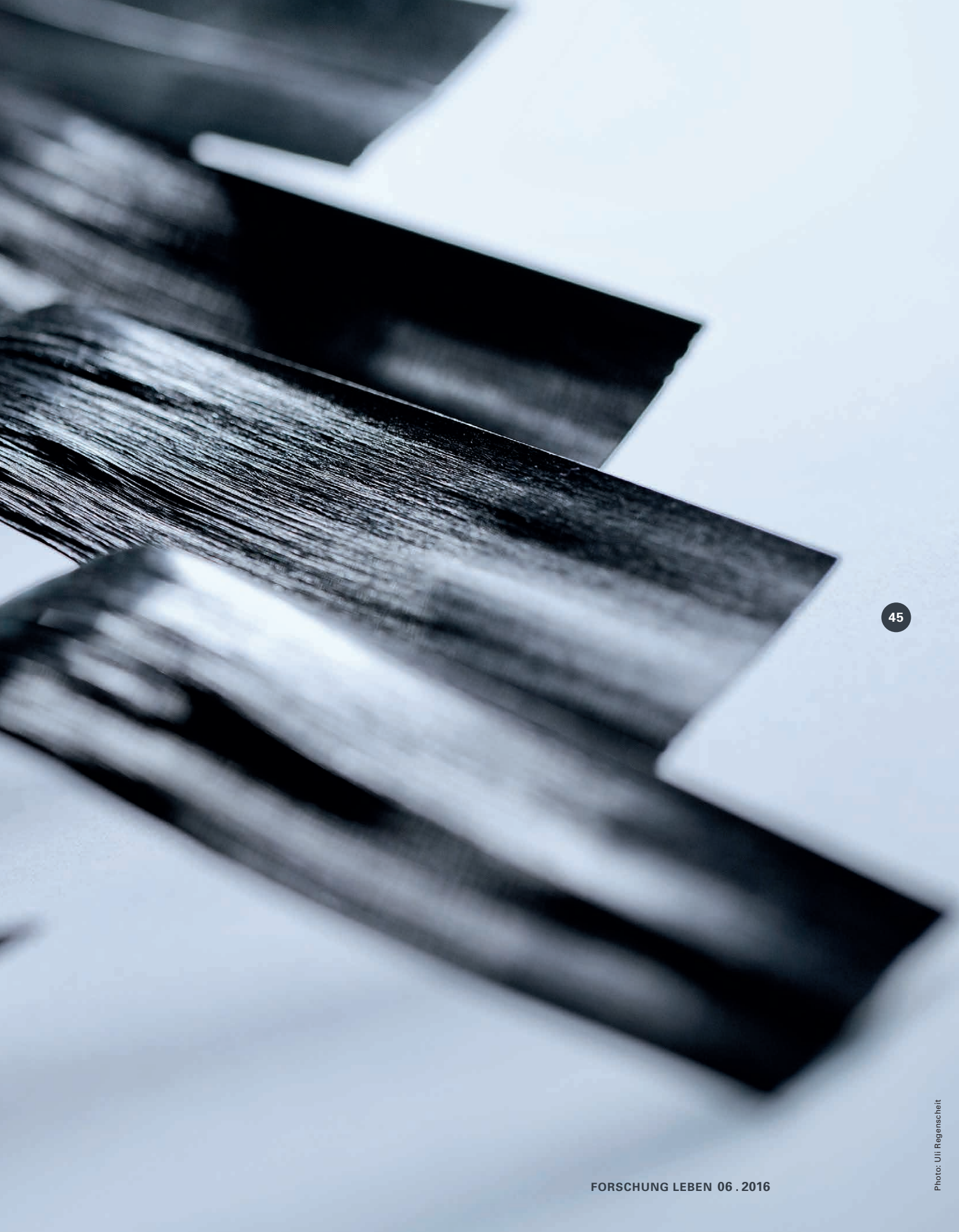


Photo: Uli Regenscheit

Town Meetings in 3D

Participatory urban planning with interactive tools in a reality lab.

Planning an urban area without getting people interested early on can lead to expensive errors and end in dissatisfaction among those who use it. But what tools – including digital ones – are most effective in getting people involved? For the next three years, this question will occupy a research team from the University of Stuttgart's Faculties for Architecture, Engineering, and Social Sciences. Two cities in the Stuttgart region will directly benefit from this project called: „Reality Lab and City: Districts 4.0."

Areas of interest collide when a city asks how to shape a district for the future,: those of the residents, the general public, investors, politics, and civil administration. At the same time, each of these groups has its own particular and specific knowledge about this district: its history, its quality, its location, any functions it may have within the city, its market value – even its climatic conditions. The process of urban planning could be greatly improved if as much of this knowledge as possible could be brought together and the various interests could be balanced in open communication, with fair compromises. Now the University of Stuttgart is working to find this out on an interdisciplinary basis and directly on location in the two cities of Stuttgart and Herrenberg. Concretely they want to find out how such participatory processes can best be organized. The project, called in full „Reality Lab City: Districts 4.0 – Getting People Involved From the Start for Sustained Development in Baden-Württemberg", and funded with about 1.2 million Euros, will look for ways to improve this process through digital visualization. Mike Letzgus, who comes from the Competence Team for Urban Systems Engineering at the Institute of Human Factors and Technology Management (IAT) and is the project's director, describes it as follows: „The cities of Stuttgart and Herrenberg decided early in 2016 which districts are to be developed during the Project." Then, after the participatory processes have been defined, it remains to find and talk to the people who will drive the project. „Then a parallel development of scenarios for the future of these city areas will take place in both cities. One of the central questions of the project is: how can we tackle something today which will become reality only in 10 to 20 years? And a related question is: how do we lay a groundwork for the implementation process with all those involved?" is how Letzgus sees it. By the end of the project, the researchers hope to know which tools and processes used were useful and can be transferred to other projects. The IAT has concentrated its research for years on the city of the future, which also prompted it to work out the overall concept of the „Reality Lab" and form a network of those who work with it. The IAT is also working to develop the new digital formats which will be used in participatory processes.

Creating the required digital models has also brought the University of Stuttgart's High Performance Computing Center Stuttgart (HLRS) into the picture. The Center creates visualizations of reality in a „cave" on the University's Vaihingen campus – a room where virtual, three-dimensional worlds can be simulated. As Dr. Uwe Wössner, Director of the HRLS Visualization Department explains, other studies can be organized out on location with the city population using mobile systems or a kind of 3D-cinema. The Center also has a digital „planning table" for grouping small models of buildings and moving them around. The Cave then immediately displays the changes in 3D to illustrate what structures would look like in the area. „The idea is to carry out changes interactively," says Wössner. This makes it possible to see and „feel" different variants directly during the discussion process. Wössner also mentions another option with the Cave: „We can

Research Minister Theresia Bauer tried her hand at virtual urban planning when presenting the Certificate of Funding for the Reality Lab.

Photo: Max Kovalenko

simulate air movements at the touch of a button.“ It goes without saying that discussion of the different variants is always more accurate when they can be better visualized. „Selections are often made when it‘s clear that things work properly,“ says Wössner. Engineering Professor Wilhelm Bauer, Director of both the University of Stuttgart‘s IAT-Institute and the Fraunhofer Institute for Human Factors and Organization (IAO), names two examples to make it clear in terms of efficiency as well that such tools can be very useful in future: „Major transformation processes are coming at us in traffic infrastructures and energy consumption. Our experience with the underground rail hub Stuttgart 21, for example, or with power line routes shows that new forms of participation can result in greater efficiency in both planning and implementation.“ It‘s also important to make efficient use of what‘s already available: „As always, there is a need for more residential areas, but green-field sites are a thing of the past, at least in Stuttgart. That means we have to make efficient use of the inner city,“ says Bauer.

Urban Design Options

The University of Stuttgart‘s Institute of Social Sciences (SOWI) is also part of this project. „We social scientists are interested above all in questions like, „How do people react to changes in their urban surroundings? What are their preferences?“ How can these preferences be fulfilled?“ says Professor Ortwin Renn, emeritus occupant of the Chair of Learning for Technical and Environmental Sociology. The great advantage of the Reality Lab for the sociologist is its ability to combine research knowledge with the contextual knowledge of those on location. Thus the one side sees how traffic flows are organized, and the other sees the actual daily routes of schoolchildren. To Renn it is important to find out how to make the most of virtual and real planning options parallel to each other. „We used to work a lot with building blocks,“ says Renn, the sociologist. „Now, ideally, we show a visualization and people can say, „That‘s how I pictured it!“ But This „participatory modelling“ technique is still somewhat uncharted territory. „A ‚cave‘ like this costs many thousands of Euros,“ says Renn when talking about the 3D-visualisations. „So we try to avoid an endless marathon of digital worlds.“ But he also looks at Resource Efficiency from quite another angle: most people see it in terms of materials and energy. „But time is also a resource, just like trust, and both need to be used efficiently.“ In the final analysis, he sees

Interactive urban planning in the HLRS „Cave" in Stuttgart.

Photo: HLRS

urban planning, with all its resources, as a process of weighing one thing against another: „If there's a chance to save energy and materials by participation, I have to balance that by asking how much time and extra costs are involved. Does the gain in efficiency make up for that? That's a question only the decision-makers can answer." What he means is: the ball is in the politicians' court: „We can't tell the cities what to do," says Renn; „we can only present them with design options – and that may benefit the investors, the residents, or the urban culture. There's no way to have your cake and eat it too. So the decision has to be made either to have or to eat – without entirely eliminating all the other services."

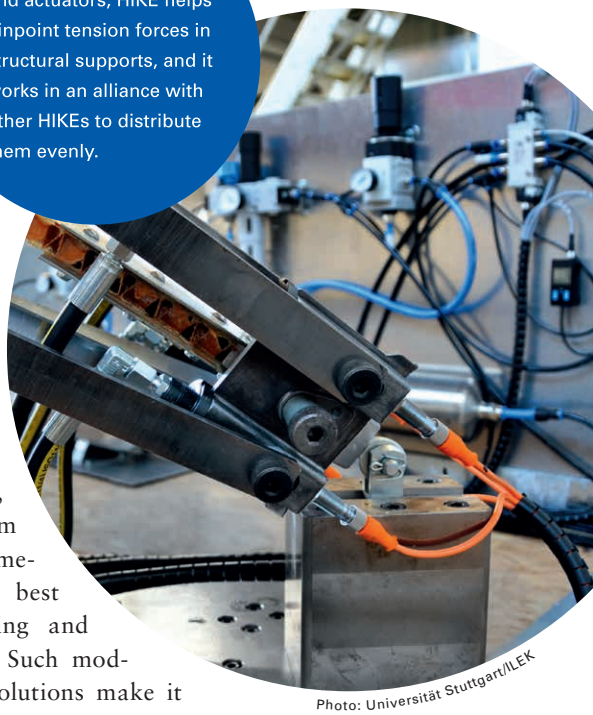
Virtual Reality Stimulates the Imagination.

Now a fourth project partner enters the picture regarding exactly these planning options and variants: the Urban Design Institute (SI), where three team members use ideas from community meetings to develop urban planning concepts. Dr. Martina Baum, who is a professor for Urban Planning and Design at the SI, explains: „Among other things, we use visualization in the Cave to show our results to those behind the project, and then incorporate their feedback. What we want is to lay a solid groundwork for construction planning at the actual site. The cities themselves must procure the building permits." Talking about the work of architects and urban planners in the Reality Lab, Baum says, „We need the complexity of the urban area, and we're used to working with its many interrelationships; we know how a change in one area can trigger massive changes elsewhere, whether structural, social, or just in terms of well-being." The new technologies used here can help to make abstract plans comprehensible. The identity of a city or a district results from experiencing it with all senses. The task now is to find whether and how technology can simulate this experience. „But we have to be careful," says Baum, „not to be too detailed about how something will look in future. The concrete question is: how much detail can go into a simulation without eliminating the imagination of those who see it?" It would be a mistake to think the only purpose is to rubber-stamp a plan. Ideally, the purpose of the Cave is to stimulate the imagination."

When talking about possible gains in efficiency with digitally-aided participatory methods, Baum points out that views of the city are now changing: „In the past, the city was seen only as a Moloch, swallowing land, raw materials, energy, food. But the city, with its unbelievable potential for innovation, is also a resource. It can be the seedbed for innovations." As he points out, it has mostly been urban environments that gave rise to trailblazing ideas, even in the realms of politics and society. Who knows? Maybe one of the next ones will come from this project „Reality Lab and City: Districts 4.0".

Daniel Völpel

Conserving Materials – Intelligently



Working with sensors and actuators, HIKE helps pinpoint tension forces in structural supports, and it works in an alliance with other HIKEs to distribute them evenly.

Photo: Universität Stuttgart/ILEK

Springs, rods, ropes and similar design elements were long seen as reliable means for transferring forces from A to B. In future, intelligent „HIKEs" will be used to detect tension forces. generate forces, and act against overloads in surrounding systems. This in turn will reduce the need to over-size the designs of machines, vehicles, airplane skeletons, and in the construction sector while saving material as well.

„HIKE" stands for „Hybrid Intelligent Construction (i.e. Design) Elements", meaning mechatronic designs containing both mechanical components and integrated sensors, actuators, displays, and control elements which are capable of taking over a wide spectrum of tasks. But „HIKE" is also the name of a research group at the University of Stuttgart encompassing seven institutes from the faculties of Structural Engineering, Aerospace Technology, Design, Production and Vehicular Technology, Textiles, and Process Engineering.
With funding from the German Research Foundation (DFG), the scientists spent six years studying how to create HIKEs out of mechanical design elements. They started by developing the elements and the basic guidelines for a new type of design methodology, including sensors. At first the new HIKEs had only sensors, but actuators were added in the second phase of research, so that the HIKEs are now able to generate forces and movements on their own. With this as a basis, the dynamics and the possibilities that opened up, such as active vibration suppression, were studied.
Insights gained by the various project groups and from different study projects then came together in the „Demonstrator", a gossamer-light support shell that is reminiscent of a tent roof. Among other features, its intelligent design elements make it able to identify different stress situations (from wind, for example). The system also works out and immediately implements the best solutions for distributing and reducing tensile forces. Such modern, adaptive support solutions make it possible to erect buildings with less weight, since the forces working on their support frame – during storms, for example – are countered by forces generated by the HIKE. Initial basic studies of these future-oriented stability concepts in construction engineering have already been carried out.
HIKE has even more areas of application. „We can also see similar approaches in future in mechanical and production engineering and in logistics," says Hansgeorg Binz, a professor and spokesperson for the second funding phase of the HIKE Research team and Head of the University of Stuttgart's Institute of Engineering Design and Industrial Design (IKTD).
The research team also studied how HIKEs organize themselves when put into a quasi-network. Different types of production technology were also used for series production of these new kinds of design elements. Among the results were additional novel elements such as a self-tensioning lifting element.

The Editors

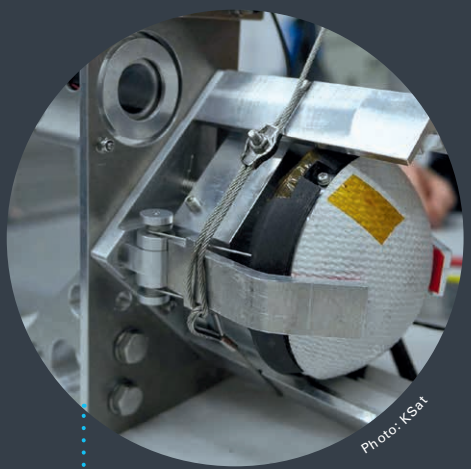


Photo: KSat

A Return Capsule for students

On March 17, 2016, a high-elevation research rocket shot into space from Sweden's city of Kiruna. On board was a micro-return capsule developed by space travel fans studying at the University of Stuttgart. Later, the experiment, entitled „Mikro-Return Capsule 2 REXUS" or just „MIRKA2-RX" for short, will cause a small return capsule to be ejected from the high-altitude research rocket. The purpose of the project is to test a new, more reasonably priced type heat shield under real re-entry conditions.

Moss Versus Fine-Particle Dust

Fine-particle dust has many negative repercussions on the human respiratory tract and cardiovascular system. Moss has been found to offer the possibility of reducing such fine-dust duress. Because of its special structure and extremely large surface, it collects fine-particle dust electrostatically. Ammonium nitrates, which constitute up to 50% of fine-particle dust, are bound by moss plants and converted to plant matter, resulting in elimination of up to 75% of the fine-particle dust. That prompted Stuttgart's Office of the Environment to commission a model study at Neckartor, the street with the highest density of fine-dust in Germany. The project was initiated by the University of Stuttgart's Institute of Building Structures and Structural Design (ITKE), in partnership with the Institute of Combustion and Power Plant Technology (IFK) and the Stuttgart State Museum for Natural History.

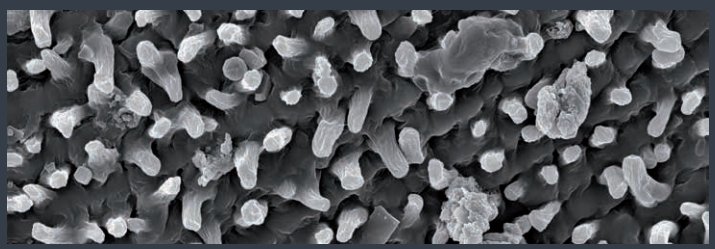


Photo: Martin Nebel

E-Mobility for Special Vehicles

The University of Stuttgart's Institute of Human Factors and Technology Management (IAT) has joined the Stuttgart Airport and the Volk Fahrzeugbau Company in a project designed to aid and accompany small and medium-sized companies (SMEs) which make special vehicles as they cope with the structural revolution brought about by electrification. The IAT is working out guidelines for the project, called „Li-Fleet", to enable SMEs to adapt their existing competence to an the new challenges while developing new areas with potential by mastering innovative forms of technology. The guidelines will first take effect in a pilot project carried out with representative partners under real conditions. The Stuttgart Airport was taken as a test environment inasmuch as special airport tarmac vehicles are already in use there under very rigorous conditions.

Photo: Universität Stuttgart / PI5

A New State of Matter

Working at the University's Center for Integrated Quantum Science and Technology (IQST), Professor Tilman Pfau's team at the University of Stuttgart's 5th Institute of Physics have successfully combined the properties of gases, crystals and superfluids into a single, new state of matter.

Classical views of matter are no longer workable at only a few namometers, far down on the length scale. This is a realm where the building blocks of matter are half wave, half particle, with only a „fuzzy" probability of being found at any given place. Such effects can be observed in ultra-cold, rarified gases. At near-absolute zero temperatures, like -273,15° Celsius, individual atoms become indistinguishable from one another; they combine into a gigantic, collective wave of matter. This curious state of the „Bose-Einstein-Condensate", as it is called, gives the atomic collective astonishing properties: the matter-wave, now a quantum fluid, flows with almost no inner friction and is therefore called a „suprafluid".

Now researchers at the IQST have succeeded in creating such a suprafluid from dysprosium atoms. They call it „quantum-ferrofluid," since the newly discovered material is not only a suprafluid but also has astonishing magnetic properties, much like the ferrofluid familiar in the world of classical physics.

Photo: Universität Stuttgart / ITC

Energy-Efficient Electrochemistry

46 million tons of CO_2-emissions were produced in 2012 alone by the chemical-pharmaceutical industry in Germany. Together with the German National Aeronautics and Space Research Center (DLR) and Plinke Co. in Bad Homburg, the University of Stuttgart's Institute of Technical Chemistry (ITC) wants to convert greenhouse gases into formic acid with the help of renewable energy in a project called „Energy-Efficient Electrochemistry in Micro-Reactor 2.0" (or „EnElMi 2.0" for short). Formic acid is used, for example, for the production of textiles and leather goods. Its production also offers the possibility of storing unused electrical current chemically. As soon as more current is needed, the formic acid can be broken down into hydrogen and CO_2, and the hydrogen can be fed back into a fuel cell. „This project thus makes a small contribution both to the climate and to implementation of the Energy Revolution, which in turn is largely dependent on new types of storage technology," says the project's Coordinator, Professor Elias Klemm of the ITC.

Extremely Miniature

Data storage is the cornerstone of a technologically advanced world. Whereas data are still stored at macroscopic lengths, they will be stored in future in individual molecules. Now the teams of Professors Biprajit Sarkar (Free University of Berlin), Joris van Slageren (University of Stuttgart), and Frank Neese and Mihail Atanasov (Max-Planck Institute of Chemical Energy Conversion in Mühlheim, Germany) have combined for a breakthrough: they discovered the first-ever mononuclear transition metal complex with stable magnetization. This step is of pivotal importance for storing data in molecules and represents a 1000% reduction in size of data compared to today's hard disk drives.

Good Relationships
Dirk Schwede assesses the reuseability of material groups in construction

Successful recycling of building materials depends not only on the individual materials but also on the techniques used to combine them. The Institute for Light-Weight Design and Construction (IEK) is now developing a process that allows planners to assess the reuseability of building materials directly when creating their designs.

According to the German Office of Statistics, nearly three-fourths of all buildings and apartments in Germany were built after 1950, above all in the 1960s and 1970s. Like other things, buildings too have life cycles – from construction to use to demolition. And upon demolition the construction companies have to ask themselves what has value and is reuseable, and what must be disposed of as waste. Official statistics show a recycling quota of more than 90% by weight for the construction sector in Germany. But Dirk Schwede, Junior Professor at the University of Stuttgart's Institute of Lightweight Structures and Conceptual Design (ILEK), has his doubts about the informative value of this figure: „After demolition, heavy building materials like steel or asphalt do in fact remain almost completely in circulation for further construction, but concrete is used only as a filling material or for road-building gravel, and that represent down-cycling, not recycling." Especially now, insulation materials too are being added to the mix. Because of their low weight they barely show up in quantitative statistics based on weight measurement. Nevertheless, they burden the environment: As Schwede points out, „Until recently, polystyrene contained flame inhibitors which make it impossible to re-introduce them for further use. What's more, the mineral wool and rock wool materials used for insulation are of doubtful quality after their recovery at demolition sites, so that there is little interest in recycling them." The result: often only scraps of mineral and rock wool are currently recycled during construction of a building. That's why Schwede sees great potential for the reuse of building materials and is convinced: „It will be more and more important as a social target if we really want sustainable business practices."

Technical Joints?

Whether construction materials can be recycled usually depends not only on how they are selected but also on the way such structural elements and layers are joined together. Experts call this „joining", which can also mean screwing or glueing, for example. From the viewpoint of reuseability, screwing may take more time, but also makes recycling easy; glueing, however, changes the properties of joined building materials to such a degree that they become un-recyclable. Unfortunately, as Schwede points out, „The impact of joining techniques plays no part at all for the assessment of recyclability in today's building design process. It's rare that the individual materials are evaluated in terms of reuseability." As a civil engineer, he and his team want to change that.

They're hoping for help from a software that can be used to assess the recyclability of joined building materials in the construction of buildings. Here Schwede and his team are borrowing a software principle from product design processes in which graphic displays have proven helpful for visualizing the reuseability of structural elements. To demonstrate, they show the evaluation of an outer wall design: a glance suffices to show which materials will be used, whether their surfaces are coated, and the joining technique that is being used. Any waste product created in one building material by another, such as paint, adhesives, mortar or plaster, shows up clearly in the visualization graphic and can be assigned to one of three categories: 1)

Photo: Fotolia

Valuable raw materials and special wastes are often difficult to separate in construction debris.

material which adulterates neighboring materials, 2) materials adulterated by neighboring materials, and 3) pure materials. The idea now is to extend this evaluation technique hierarchically to all element groups in the building and to pattern this according to the elements selected during the planning process.

A Link to Building Data Models

„We have now gathered data for 200 materials and four different types of wall construction and can display them as just described," says Schwede. „So at least we've made a beginning." He and his researchers must determine for every set of paired materials and joining techniques whether separation is possible, whether technical process solutions are appropriate, and what is the most economical way. Online databases, each encompassing thousands of materials, are available for evaluating the properties of construction materials from an environmental point of view, for example. In principle, therefore, Schwede and his team could expand their method to include far more materials. Their focus at present, however, is more on the basic feasibility of this approach and the extent of its practical usefulness as an aid in analyzing structural elements. „For example, we want to put this tool at the disposal of students during seminars so that they themselves can score the recyclability of their building designs," says Schwede. He also sees interesting possibilities for certification processes like those of the German Sustainable Building Council or the U.S. Green Building Council.

„What we're aiming at now is to merge our method with Building Information Modeling," reveals Schwede. That is a building data modeling technique that optimizes the planning, construction and operation of buildings. It is now regarded as indispensable in the construction sector and in facility management. The technique digitally records and networks all relevant building data digital, resulting in a computer model of the building. A merger with the Stuttgart tool would make the reuseability of construction materials immediately visible after demolition of a building.

Michael Vogel

Straw Fiberboards
Esthetic – Functional – Environmentally Sound

They're everywhere: boards pressed from wood chips or fibers are found in varnished furniture or doors, in laminated floors or panels for interior partition walls. But Dr. Hanaa Dahy of the University of Stuttgart's Institute of Building Structures and Structural Design (ITKE) has come up with something new: boards made of straw. In contrast to many conventional wooden chipboards and fiberboards, they emit no toxic substances, can be composted, and are pliable enough for new types of furniture shapes.

Hanaa Dahy has collected as much straw as she could: but not in order to spin gold out of it like Rumpelstilzchen in the famous Grimm story. She came to Stuttgart from her native Egypt six years ago with her husband and 3-year-old child in order to write a doctoral thesis, and now uses straw as an inexpensive alternative to wood in interior design. She knows that wood as a production or heating material can be climatically burdensome when more and more forests are cut down to provide it, and reforestation takes years.

Straw, on the other hand, is an annual waste product: every ton of grain harvested is matched by another 1.5 tons of plant wastes like straw. „All over the world, huge quantities of straw are burned directly on the fields in many countries or, as in Germany, used in waste combustion plants to generate electricity," criticizes Dahy. „That is unfortunate: a more resource-efficient tactic would be to use it industrially. I can always burn it thereafter," says the 35-year-old scientist. But Dahy wouldn't be an architect if she didn't think of future product design when developing her working material. Up to now, architects reach their limit when trying to design free forms like „S"-shaped table legs for furniture out of chipboards or wood fiberboards. „If at all, it can be done today only with work- and cost-intensive methods, such as soaking the boards in water," as Dahy explains.

Wood Fiberboards are Special Wastes

Conventional fiberboards are made of wood chips or fiber wood wastes soaked in wood glue and pressed into boards. After hardening they are usually no longer pliable. „And they cause a lot of problems for the environment," stresses Dahy. Some wood glues contain carcinogenic isocyanate, others occasion concern due to formaldehyde, which they „exhale" into the surrounding air. Waste wooden fiberboards are therefore regarded as special wastes and may not be burned in domestic ovens.

For her part, Dahy uses an environmentally sound, polyvinyl acetate-base adhesive which is similar to white glue, and she employs well-established plastic production methods to produce flexible straw fiberboards. Her method looks like something from a shortbread bakery: a „dough" of straw and melted adhesive is fed through an „extruder" by a worm screw and pressed into a template. Because the adhesive is an elastomer, the boards, which are 80% to 90% straw, remain pliable even after the adhesive has hardened. „For example, we can bend these boards to any desired shape for furniture and partitions and then fix them in place with layers of veneer or use them as non-slip, impact-absorbing yoga mats," says Dahy. Her injection molding method, copied from the plastics industry, could also be used to create sculptures by pressing the straw and adhesive mixture into the desired mold.

In contrast to wooden fiberboards, these straw-based objects could be re-ground at the end of their life cycle, then melted down and converted into new shapes. „What we have here is double recycling: once by using agricultural residues, and a second time by recycling straw fiberboards," says Dahy. And the new boards are compostable too, says the architect

Architect Hanaa Dahy with a flexible straw fiberboard.

Photo: Helmine Braitmaier

enthusiastically. To prove it, she buried sample boards on the university campus; after 15 months, she found that they had been decomposed by organisms in the soil and that roots had grown through them. More recent wood plastic composite materials too are recyclable and can be freely formed with her plastic industry method. A trend has developed since the early 1990s in the form of „WPC“ terrace floorboards, which are normally made of wood powder and plastics like PP, PE or PVC. Dahy criticizes these as „Non-compostable and often dubious from a health and environmental viewpoint because of their halogen-containing flame inhibitors with easily combustable plastics. We, in contrast, can make boards of rice straw, which contains a very high percentage of silicate, giving them a natural flame protection.“ Dahy‘s development work brought her the 2015 Materialica Design + Technology Prize in the „CO_2-Efficiency“ category. Her innovative straw fiberboards are now being patented.

She herself now works at the ITKE as a post-doc scientist. Spread out on a table top she shows visitors different materials, all of them based on straw. Some look like billowing cloths, others can insulate buildings as effectively as conventional polyurethane foam. Some boards look like attractively veneered, curved or straight colored wooden elements. Currently, Dahy is working with industrial partners in a project to develop „green“ room partitions with both heat- and sound-insulating properties. Their heart is a straw-based foam board in which mineral oil-based polyurethane and polystyrols have been replaced by biodegradable plastics. These are contained in a „sandwich“ of two environmentally friendly straw fiberboards. Dahy‘s whole family has been infected with her enthusiasm for straw: when she goes on a walk with her two children, they proudly wear the „doctoral cap“ of straw which Dahy‘s colleagues gave her.

Helmine Braitmaier

A Treasurehouse of Scrap
Efficient recovery of critical raw materials

Neodymium, tantalum, indium – these chemical elements are just as important in modern industry as their names sound exotic to the layman. But the effort of procuring them as raw materials is enormous, so that hopes are to make them available more and more in future through recycling; that would save resources and costs and bolster supplies.

Professor Michael Buchmeiser of the University of Stuttgart's Institute of Polymer Chemistry (IPOC) lays a shining metal cylinder on a table. Not only does it weigh several kilograms, but it could also be an important building block in a technique for recovering the rare metals neodymium and dysprosium. Both metals, important above all for the production of electric devices and electric motors, usually end today on the scrap heap or, as in steel processing, more or less irretrievably in slag. A team composed of researchers from the IPOC, the FEM Research Institute for Precious Metals in Germany's Schwäbisch Gmünd, and the German Institutes of Textile and Fiber Research (DITF) in Denkendorf joined forces in October 2015 in a research project of the Innovation Alliance of Baden-Württemberg to develop an economical recycling technique for neodymium and dysprosium. Buchmeiser has no doubts that it is technically feasible to separate these eagerly-sought metals from electrical scrap; it's just a matter of applied technology: „The scrap is shredded, plastic is separated out, then the metal fraction is dissolved in acid," he explains. That would then make it possible to enrich the dissolved precious metals by means of „selective precipitation, leaving them still somewhat impure. „At the latest, our project enters the picture at this point: „We aim to show the entire chain – from scrap collection to clean separation of recovered elements," says Buchmeiser. His team is working above all on the required sorbents – „Extraction substances with which the precious metals can be selectively bound to special resins, from which they can then be unbound and cleanly separated."

This, however, requires an economically rewarding closed loop process. The basic steps envisioned for this processing flow are technically uncomplicated and have been tested. „The sorbents we are now developing must be inexpensive and producible in large quantities," explains Buchmeiser. At the end, the metals will be „captured" in capsules like the one on Buchmeiser's desk. „At the end we will have salts from which metallurgists can re-create metals."

The heavy metal cylinder held by Prof. Michael Buchmeiser could some day play a key role in the recovery of precious metals.

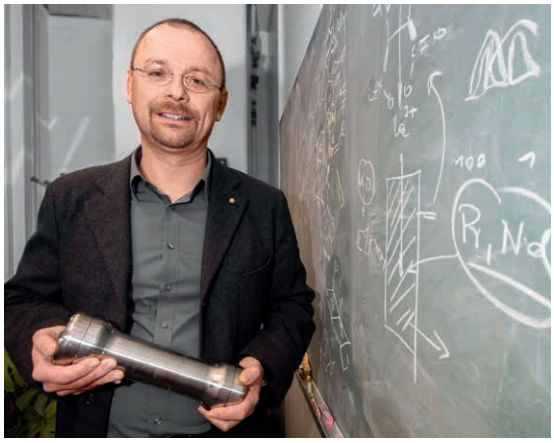
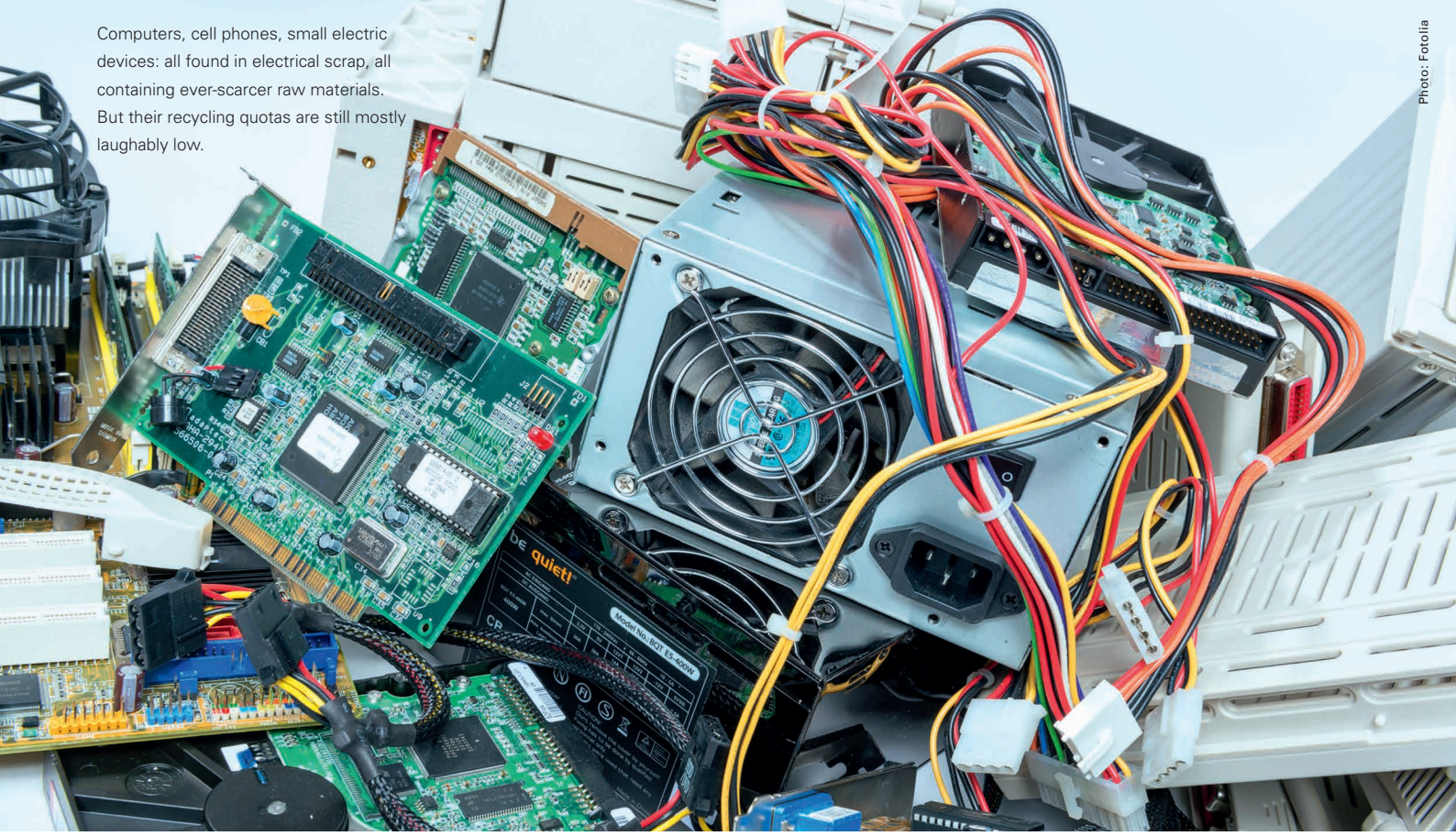


Photo: Jens Eber

At the end of the two-year project it should be clear how large a central processing plant would have to be to separate neodymium and dysprosium economically from electrical scrap. It is estimated that more than 100 tons of these magnetic metals could be recovered from hard disk drives and computers annually. „Ideally, we would set up a



Computers, cell phones, small electric devices: all found in electrical scrap, all containing ever-scarcer raw materials. But their recycling quotas are still mostly laughably low.

Photo: Fotolia

closed loop system with cost-saving benefits and an assured supply of raw materials for industry," says Buchmeiser.

Which Raw Materials are Critical?

Finding an economically feasible industrial method for the recovery of these precious metals would certainly be a milestone; after all, they are among the most critical raw materials in Baden-Württemberg. But not the only ones. Experts at the University of Stuttgart's Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA) set out to find which raw materials are most important and simultaneously the most difficult to procure for industry in Southwest Germany. This kind of analysis is nearly a matter of life and death for this industrial area: companies must not only take price fluctuations for procuring steel, plastics or energy into their calculations but are also threatened by bottlenecks or even politically determined, strategic delays in the supply of critical raw materials. In a project called the Regional Strategy for Resource Efficiency, the ISWA team therefore joined colleagues from other universities to draw up a „Top Ten" list of critical raw materials. In doing so, they took into account not only availability on the market but also the price and the question of how urgently the raw material was needed by industry. Common to nearly all of the raw materials on the list is that they are difficult to derive or limited in supply on the world market. The team also studied possible environmental damage in isolating these raw materials. A large percentage of the precious metals is scraped out of the ground, for example, in gigantic mines in China – with little emphasis up to now on environmental compatibility. Moreover, the Chinese government put a cap on the export of these raw materials during the peak years of the Chinese economic boom. Thus it is no wonder that an intensive search is underway for more independence from raw materials imports.

At ISWA, Detlef Clauß, who heads the Task Area for Closed Loop Systems and Waste Management, says, „The main focus in industry here is on the automotive industry." Correspondingly, the raw materials used for on-board electronics or the innumerable electric motors installed in modern automotive vehicles shot upwards in the final „ranking list". Among the different precious metals, the „Top Ten" of critical raw materials include, for example, tantalum, cobalt, the plati-

Detlef Clauß, Prof. Martin Kranert, and Matthias Rapf (l. to r.) discuss raw materials which are „critical“ and how they can be economically recycled.

Photo: Jens Eber

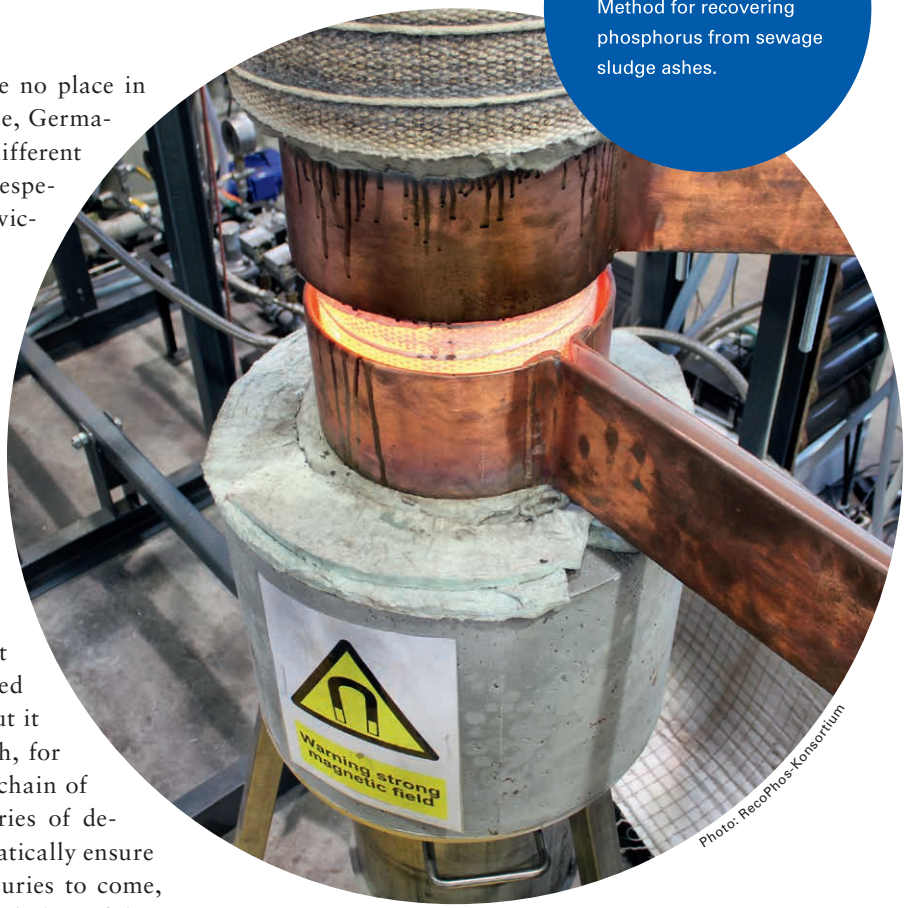
num group, tungsten, and molybdenum. Recycling seems like the logical next step for coping with the threat of scarce supplies. At least theoretically. But actual practice indicates otherwise. „Except for the platinum group, recycling quotas are currently zero,“ is how it‘s explained by Prof. Martin Kranert of the ISWA Chair for Waste Management and Exhaust Air. A needed impulse for such recycling would be industrially feasible processing methods, including functional process flows first and foremost. Kranert believes that many small electric devices languish at the end in scrap bins or are forgotten in dresser drawers. In addition, these devices often contain only a few milligrams of critical raw materials, meaning conversely that relevant amounts of raw materials are spread out extremely thinly throughout society.

For that reason, the research project also includes a resource policy think-tank which has rapidly taken shape since the beginning of the year. Work is also ongoing on development of a disassembly plant and a concept for „the world‘s most efficient raw materials mine“ (as Kranert puts it), where the focus will be on sustainability. Advance trials have also been undertaken at ISWA to recover indium, a metal which is mostly used as a transparent conductor, i.e. indium tin oxide, in flatscreens and touchscreens. Most indium is mined in China, and it is one of the world‘s rarest raw materials. ISWA is working on a means of mechanical processing of discarded devices. „We tried grinding away the coating to recover it as a powder. We found it technically feasible, but efficiently reusing it would require automatization of the individual work steps, that is, removal of the display units and performing the grinding. Sensors are our main problem,“ says Kranert.

Also indispensable would be an initial analysis of how much of this raw material is present in the grinding dust. „At present, production process flows lack detail, and nobody knows exactly which substances and what amounts are contained,“ says Kranert‘s colleague Matthias Rapf.

The ISWA team members are also carrying out similar basic studies of rust and incineration container ash from waste-burning plants. Up to now they have found many compounds, but „only very few of them in large amounts,“ says department head Detlef Clauß. Technically, recovery of these materials from the ashes is possible but inefficient. It would make more sense, the researchers feel, to inform the public better than in the past, for

example, that electric devices have no place in scrap waste containers. „In practice, Germany does a good job of separating different wastes, but the recovery quotas, especially concerning small electric devices, need to climb," adds Kranert.



An InduCarb-Reactor, heart of the RecoPhos-Method for recovering phosphorus from sewage sludge ashes.

Photo: RecoPhos-Konsortium

Orphaned Phosphorus

Phosphorus is completely missing from the „Top Ten" list of critical raw materials because it would unbalance any attempt at statistical calculation. „It is the perfect example of a critical resource," says Prof. Kranert, and Matthias Rapf adds: „The difference between phosphorus and other critical raw materials is that it is irreplaceable." Phosphorus is used mostly as agricultural fertilizer, but it is also important for bone strength, for our DNA, and for the respiratory chain of cells. Even though recent discoveries of deposits in northwest Africa mathematically ensure the supply of phosphorus for centuries to come, producing it is becoming increasingly harmful to the environment. Until now, phosphorus recycling served mostly to recover phosphate for fertilizers. „We and our numerous partners are the only team in the world to develop methods for isolating phosphorus in the form which is indispensable for some branches of industry," says Rapf. An especially large portion of this raw material is found in the ashes left by sewage sludge combustion. A thermochemical process transforms the phosphates in these ashes to phosphorus, which is vaporized and captured. Although phosphorus in its elemental form is much more valuable than fertilizer, it went out of production in Europe some years ago. „Our method could bring the production of white phosphorus back to Europe again," says Rapf.

„Phosphorus recycling absolutely makes sense because it recovers this raw material in its elemental form, says Kranert. That makes it important to develop the technology for doing so today.

Jens Eber

Clean Air and Warm Buildings
Purifying exhaust air with microbes and electrons

The general public has grown critical of what business operations „breathe" into the air, whether it be unhealthy styrene or the odors of a pig farm, and laws have grown stricter. Now the University of Stuttgart's Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA) is working to develop processes for cleaning up exhaust air while saving resources, and is coming ever closer to the goal of reducing both operating costs and energy consumption.

Countless items in everyday life are made of styrol-based plastic; even the gigantic rotor blades of wind power facilities are made of glass fiber-reinforced synthetic resins. Although these plastics are long-lasting and unproblematic in everyday life, they emit styrene when processed and when their initially slow-flowing mass gives off fumes. Lengthy contact with these fumes is dangerous to health.

To counter this, the law requires air purification in areas of a certain size where styrene is industrially processed. „It's technically feasible," says Dr. Daniel Dobslaw, head of the ISWA Biological Waste Air Purification Laboratory. For example, waste air in large production plants is processed thermally, that is, through combustion.

Resource consumption in such processes is high, however – not least because the purified air must be replaced by air from the earth's atmosphere. In winter above all, in turn, a great deal of energy is required to bring this fresh air up to room temperature. As Dobslaw says, „We've long had systems for doing this with water or even metals, but not with air." One reason: air costs nothing. The critical factor is the energy required to exchange and warm the air. For that reason, Dobslaw talks about an idea that ISWA is working on: „To put it simply, we send the air through a filter and then back onto the shop floor." To get to this idea, the team rejected charcoal filters nearly from the beginning. styrene would bind itself in those filters to carbon and then require disposal as a special waste. The same drawback was found in other uncomplicated bio-filters of wood chips or other plant fibers. „So we looked for a sustainable process with a non-reactive basis that could filter volatile organic compounds out of the air, and finally arrived at the „bio-trickling" filter," says Daniel Dobslaw.

Bio-Trickling Filters and Cold Plasma Technology

Clustered beakers and experiments are always throbbing and bubbling at the ISWA laboratory outside Stuttgart's little suburb of Büsnau. There Steffen Helbich and Dobslaw guide visitors to a complex consisting of a thick cylinder, a steel cube, and long tubes and cables. This is the bio-trickling filter, which looks like a stack of rain barrels one on top of the other. Inside it are plastic elements resembling hair curlers. „The bacteria growing on them convert styrene from the air into water, carbon dioxide, and biomass," says Dobslaw.

Moisture is required to ensure that the bacteria feel comfortable and proliferate in the filter housing. On the other hand, they can also be carried off in tiny water drops. For that reason, the Stuttgart researchers looked for a way to kill these organisms and keep them from negating the resource-saving effects of the bio-trickling filter. „And that brought us to our cold-plasma technique," says Dobslaw. It involves an electric field in which electrons emitted in an air flow generate, among other things, oxygen and hydroxide radicals which very efficiently destroy bacterial cell membranes.

The project will finish in the summer of 2016. The research team has been fine-tuning the details since the beginning of the year. Helbich says, „We've greatly increased the cold plasma system's elimi-

nation abilities through better dimensioning of the lead-in water drop separator," meaning that the plasma phase is needed only at certain times. The project also has an industrial partner, and Dobslaw is convinced that this technique can be a commercial success. „Our system's operating costs are highly appealing; we can save a great deal of electricity and heating energy." The process is cheaper by a factor of 10 than thermal treatment of styrol-containing air. „And there's room (or „air") for more!" says Dobslaw with a smile.

Un-Smelly Sewage?

ISWA has just finished a quite similar project together with the PlasmaAir Company in Weil der Stadt, Germany. „Pervasive odors are a problem with many exhaust air emissions," says Dobslaw, and takes sewage sludge drying as an example. Germany's Baden-Württemberg area has legislated that sewage sludge is no longer to be deposited on cultivated fields but must be dried and burned. During the drying process, however, both water and other volatile substances are given off. Dobslaw takes the visitor to Leonberg, where his department operates a pilot fermentation plant for bio-wastes gathered in the region. The fermentation residues are dried there and then used as compost. To remove odors, the exhaust air from the drying process is released into a filter filled with wood chips. The ISWA team diverted some of this air into the pilot plant and again used the cold plasma technique to eliminate odors. The resulting radicals made volatile organic compounds soluble in water, so that they could then be filtered out in a washing phase. It is planned to use a catalytic converter in order to detoxify stable gases like methane or nitrogen.

More than 90% Less Smelly

„Our fermentation system has reached a 90% level of odor removal," reports Dobslaw. They even test-

Dr. Daniel Dobslaw (left) and Steffen Helbich check the bio-trickling filter logbook for recent events.

Photo: Jens Eber

Agar plates after contact with exhaust air from the bio-trickling filter. Left: before the plasma phase, right: after. The rain dispenser was turned on during the contact phase. Increased growth is seen in the marked area on the right, but no growth is seen on the left.

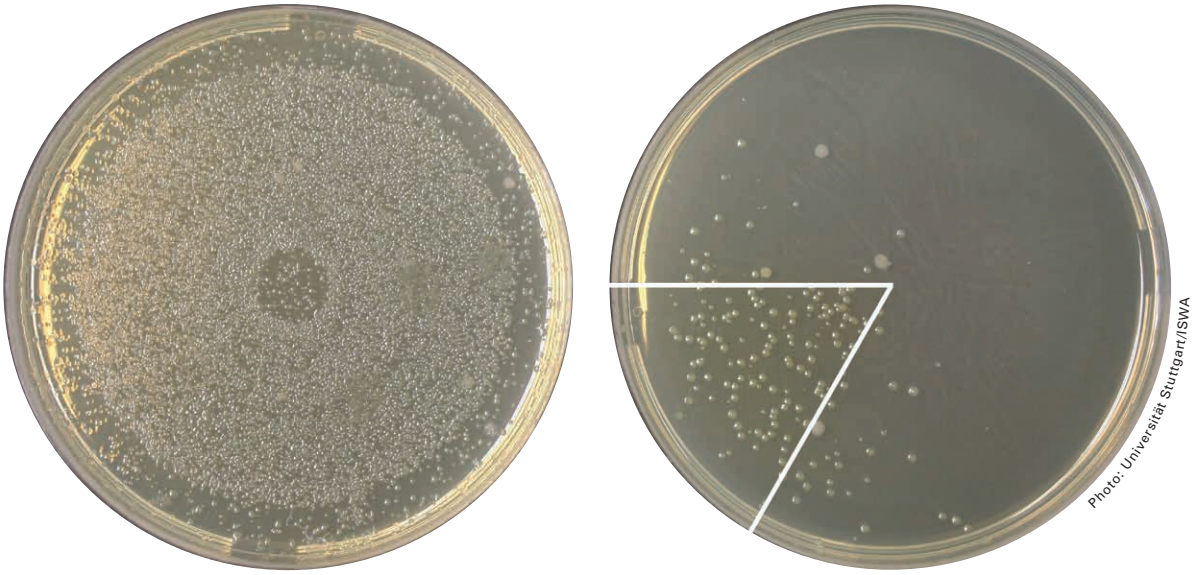


Photo: Universität Stuttgart/ISWA

ed the system successfully in the laboratory with premium gasoline. „The method is highly energy-efficient and also very compact," says Dobslaw. During development, ISWA was thinking foremost of large-scale livestock farming enterprises which would find an easily operated, compact and efficient unit appealing.

Jens Eber

Hybrid Heating

Whereas renewable forms of energy now account for a third of the electricity marketed, heat is still generated mostly by means of natural gas and heating oil. Here is where a linkup of electric current with marketable heating – „sector coupling", as it is called, – offers a chance to compensate for weather-dependent fluctuation of renewable energy and make the most of electricity surpluses when wind and sunshine are plentiful. This is where the University of Stuttgart's Institute of Energy Economics and Rational Use of Energy (IER) comes in: it was commissioned by the German Association of Energy and Water Industries (BDEW) to analyze how the natural gas sector can help merge electricity production with heating needs. The focus in this case was on a rarely-studied consumer sector: trades, retail, and services, including, for example, bakeries, hotels, restaurants, supermarkets, office buildings, and even public institutions like universities and civil authorities. The study showed that the heating market in this segment has a very high potential for flexible electric current and heating management. Moreover, the technology for accessing it is already fully developed and comparatively inexpensive, for example in the form of hybrid heating systems with heating rods; these could easily be provided with suitable control algorithms.

In actual practice, this might be done as follows: when large amounts of cheap current are available, heating needs could be cove w with electrical heating, thus reducing heating fuel consumption. When current is scare and expensive, the heat could be provided with conventional burning of fossil fuels, for example with a gas condensing boiler. Likewise the current needed for electrical heat pumps could be replaced temporarily by using natural gas.

The Editors

Nearly Real

Chemist Svenja Hinderer has made an imitation human heart valve in the laboratory.

„Goodness, how big you've grown!" There are often smiles when children start to shoot up. But for a child with an artificial heart valve, it only means that the next open-heart operation is just around the corner. Dr. Svenja Hinderer's new invention could change that.

The best heart valve is the one we're born with. But various causes can weaken it or render it helpless. That requires a replacement which is not without complications, even for adults. And anyone with an artificial heart valve must take lifelong anticoagulatory medication.

There are no good biological alternatives. Pig heart valves remain functional only for about 15 years, which is why they are used for older persons. And although artificial heart valves last for about thirty years, they cannot grow physically with the bearer. Therefore children must return to the operating theater about every two to three years.

Hope in this situation comes from the laboratory. While doing her doctoral work at the University of Stuttgart's Institute of Interfacial Process Engineering and Plasma Technology (IGVP), Dr. Svenja Hinderer developed an artificial heart valve that's almost human (under the supervision of Prof. Katja Schenke-Layland). Her work, also carried out at the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), brought her the Körber Foundation's German Studies Prize for 2015.

The substrate basis developed and tested by Hinderer over a period of three years consists of numerous molecule chains of proteins and other degradable polymers like polylactic acids. A process of electro-spinning gives them an interwoven, three-dimensional structure. The method involves a syringe, an injection needle, an electric field, and a copper plate as collector. The polymer mixture, dissolved in a solvent, comes out of the syringe.

Like a Paper Napkin

First a droplet forms. Then, whirling in an electrical field, it stretches into a spiraling thread, ever thinner, finer than any spider could make it, while a solvent vaporizes. The result looks like a paper napkin. Fibers of this size are also found in human tissue.

Which is exactly what Hinderer wants. She intends her artificial heart valve to imitate nature as exactly as possible. But she as a chemist had to become part physician to achieve it: „I went to a slaughterhouse, procured pig hearts, and extracted their valves. It was pretty messy!" Also, time and again she examined hospital biopsy tissue specimens. Before long, she understood what polymer structure was required. But the question remained: would it do the job? So she turned to a bioreactor, which can simulate functions of both organs and the body. In the case of artificial tissue, it tests both function and stability by means of circulating fluid in a glass cylinder some 30 centimeters in height in which pressure, carbon dioxide, and temperature can be monitored. Hinderer clamped into it one section of an aorta in which a sac of the heart valve had been replaced with her artificial tissue, and: her textile stood up to the physiologic pressure.

The primary benefit, however, is that the heart valve no longer need be exchanged later. While the artificial fiber tissue itself cannot grow, it is nevertheless taken over by the body and replaced in the long run. The requirements are clear: the material must be completely degradable, and the surface must be so created that cells can grow upon it and replace it bit by bit.

A second bioreactor was used to test possible cell growth. It has a sugar cube-sized chamber along with a pump and a steady circulation of fluid. Here Hinderer's textile was tested with precursor cells, i.e. cells which are still developing their function. Success! the cells settled on the matrix as hoped.

In practice, the artificial heart valve will be posi-

Photo: Fraunhofer IGB

Dr. Svenja Hinderer during a chemical analysis.

Photo: Fotolia

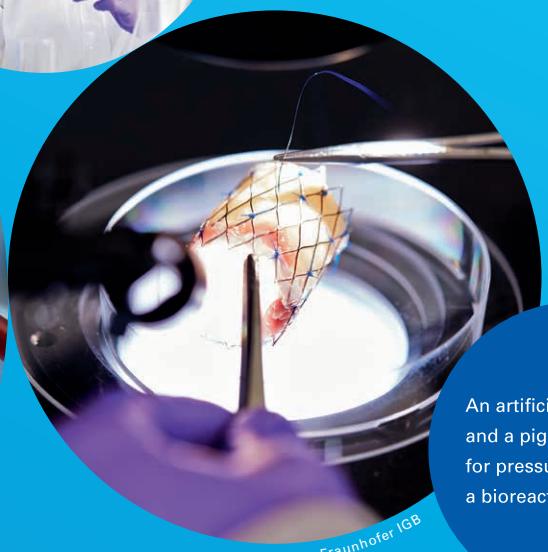


Photo: Fraunhofer IGB

An artificial heart valve and a pig aorta are tested for pressure resistance in a bioreactor.

tioned without cells in the heart, whereupon the body's defence mechanisms will be triggered. Hinderer now believes that her artificial tissue will be absorbed by the body within two to three years.

High Legal and Ethical Hurdles

Because of possible risk to the heart, hinderer is the first to travel this path. Even animal trials have high legal and ethical hurdles. In autumn hinderer will apply for permission to conduct tests with pigs. Then, she hopes, the bioreactors will show that the improved material is even more stable than before. And when will today's process of regular operations on heart valve patients finally end?

„I'll be happy if I live to see it," says the young scientist: It could take more than 15 years. First successful studies have to be awaited, and then trials with human test patients. Then, to obtain approval for a medical product for the heart, she and her team will have to wait until it is certain that no blood clots will form and that the tissue can in fact withstand high blood pressure levels.

An artificial heart valve that is accepted by the body and replaced by cells thus remains a technology for the future.

Ulrich Fries

Plastic Helpers in Climate Protection
New production materials, machines and techniques save resources

Plastics are once more in the public eye – because of garbage in the world's oceans. But Prof. Christian Bonten, head of the University of Stuttgart's Institute of Polymer Technology (IKT), defends plastics as being better than many think. Without them, he says, the climate targets of Paris could never be reached. He and his team are hard at work to improve both the plastic materials used in automobile production and their manifold uses.

Ask Christian Bonten how the IKT's research is helping to save resources, and he counters with another question: „What is the world's scarcest resource?" and immediately provides the answer himself: „Energy! For example, there's no water problem! It just costs a lot of energy to convert seawater into drinking water and pipe it to dry regions. And there's no food problem, because the earth produces enough for all its inhabitants to eat! It's just not properly cooled and distributed!"

Even today, for example, carbon dioxide (CO_2) could be extracted from the air and turned into plastics – but it's just too energy-intensive, meaning: too expensive. That is why the global community largely agrees that greenhouse gases should not be allowed even to enter the atmosphere; rather, energy should be saved and produced from regenerative sources. Doing this is one of the prime factors for retaining and increasing our prosperity, says Bonten. „And the biggest lever in Germany for saving energy consists of its buildings, its traffic, and its production plants." And he's convinced that this cannot be done in all three areas without plastics. Bonten illustrates his conviction by holding up a shiny, silver-colored strip resembling a measuring stick. It is a sample of an extremely hard, fiber-reinforced polyamide. The IKT team has developed a process for producing it. „We need only a few processing steps to produce enormously hard parts which are more light-weight than aluminum but stronger than steel. They are submerged in an injection molding process and then extrusion-coated with hot melted plastic. The automotive industry loves things like this," says Bonten. His colleague Stefan Epple has even managed to combine „pultrusion", which means drawing and simultaneously sprinkling glass fibers with melted plastic, with a chemical reaction. Instead of directly using high-viscosity polyamide, he sprays its source chemical on the fibers. That chemical flows like water and results in a previously impossible depth of infiltration. Shortly thereafter, hard polyamide is synthesized out of this chemical. „We call it ‚reactive processing'", says Bonten.

Only in this way is it possible to make such extremely strong, stiff, endless polyamide profiles. They consist more than 70 per cent of glass fibers enveloped down to their tiniest spaces with polyamide. Polyamide is popular in the automotive industry because substances based on such a combination can be extracted and recycled.

Added to all the other advantages is the fact that these profiles, as light-weight as they are, can be used to reinforce larger plastic parts at strategic points. In this way, complex structural elements of plastic can be used as impact absorbers in millions of automobile doors, thus replacing heavy steel parts. The resulting vehicle is both lighter and consumes less fuel. This breakthrough technique also eliminates numerous work steps and requires much less energy than the production and processing of steel.

Low-Energy Buildings and Households

Central and Northern Europe consume vast amounts of energy for heating buildings, farther south for cooling them. In both cases, heat-insulating plastic makes an important contribution to energy conservation. Studies have shown that foam plastics score best on the ecological balance sheet,

Professor Christian Bonten (l.) and Stefan Epple study a high-strength plastic profile developed at the IKT for light-weight automobiles.

Photo: Uli Regenscheit

whereas products of natural rock wool and cork do worst. Household appliances are becoming more efficient too: refrigerators with good foam insulation need less electricity; dishwashers and clothes washers today are guided by modern sensors; pumps and plastic heat exchangers use less energy and water. Even electricity-saving LED lights would be impossible without plastics.

Here too, says Prof. Bonten, „Plastic production is a low-energy branch, especially in comparison to steel and glass production, both of which require much higher melting temperatures. That's why plastic parts are stealing the show from metal parts. Not because plastic is a less expensive production material: a kilogram of polyamide costs more than a kilogram of construction steel. But the energy savings in series production are so great that a plastic end product is still cheaper." Complex shapes and surfaces for technical parts and designer elements can be manufactured with much less energy and fewer assembly steps than when metals are used.

Efficiency Progress in Production, Traffic and Transportation

The IKT also makes production technology more efficient. For example, the IKT's Tristan Koslowski has found an intelligent way to eliminate two steps in the production process of a fiber-reinforced plastic part: he feeds electric current into carbon fibers so that they heat themselves as a robot advances them into a machine, thus saving separate heating in an oven and a transfer by another robot, meaning less energy. And Oliver Kast, another member of the IT team, is studying heat flows in the heavy extruder and injection molding machines; he wants to use the heat energy of the worm conveyor to dry plastic granulates, thus reducing the overall consumption of energy. Regarding traffic, weight loss means fuel gain, and Bonten offers an impressive statistic: lighten a passenger car by 100 kilograms, and its fuel consumption will drop by 0.15 to 0.4 liters over 100 kilometers (more than 60 miles). During a driving lifetime of 150,000 kilometers (nearly 100,000 miles), that adds up to 60,000 liters. „You always have to think about masses in motion," says Bonten, and points out that energy could be saved any time heavy production materials are replaced by light-weight plastics – like the side-protection profiles mentioned above.

As he points out, this view can also be applied to future power plants. The generation of regenerative energy will be impossible without plastics.

Svenja Göttermann studies foam bio-plastics, whose uses include foodstuff packaging and thermal insulation.

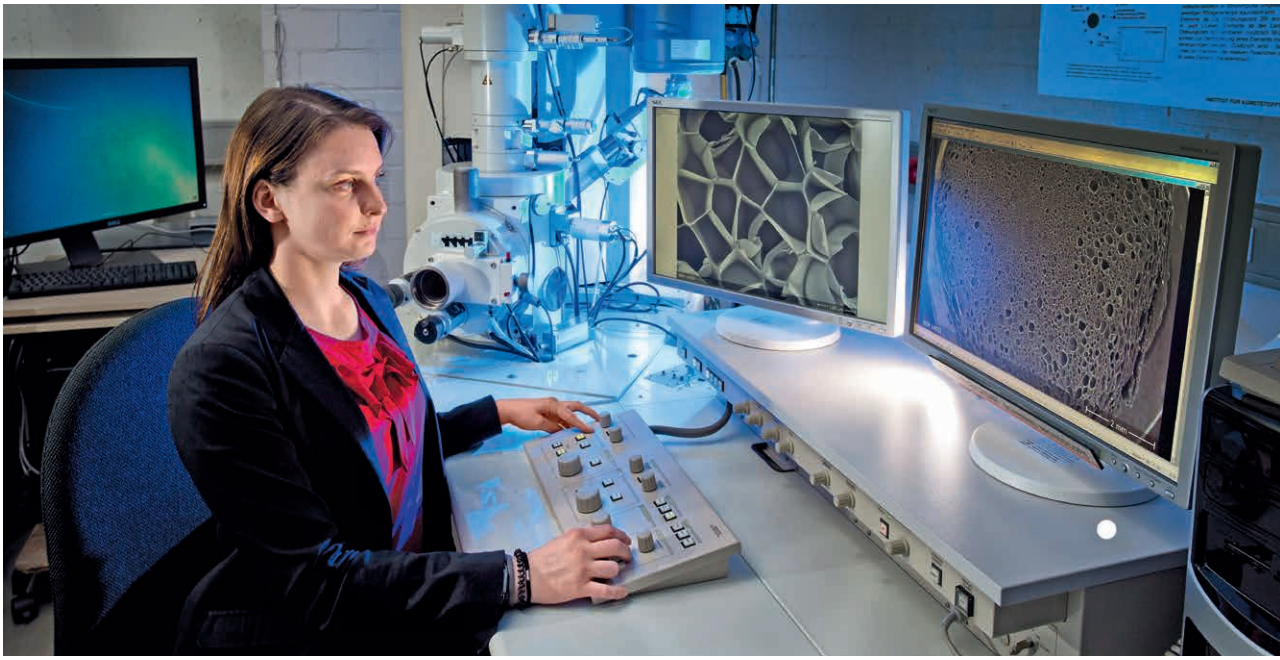


Photo: Uli Regenscheit

„Wind-powered rotor blades will no longer be of metal, which could break." They will have to be light-weight and strong, and therefore will be made of fiber plastic compounds. „And plastics are already being used in new, flexible solar panels and fuel cells," says Bonten.

Replenishable Raw Materials Instead of Petroleum

Research at the IKT is also helping the world to get away from petroleum as the basis for most plastics, thus conserving that natural resource too. As Bonten says, „The world's energy generation currently relies on fossil substances like petroleum, natural gas and coal. For example, only 2.6% of the crude oil consumed in Germany is processed into plastics; soon after its storage, a full 70% is burned as heating oil, diesel, and gasoline fuel. Sad to say, even with plastics made of replenishable raw materials, we will hardly reduce the world's oil consumption. But what we can indeed do is make the plastic industry independent and ready for a future without oil."

Scientists carrying out basic research and filling industrial needs can already point to successes, for example the bio-plastic polylactide (PLA), which is made from lactic acid. „It's quite good for making shopping bags," says Bonten. „True, PLA was previously thought to be non-foamable," but now he mentions the work of chemist Svenja Göttermann, who can alter bio-plastics in such a way that they become foamable and are suitable for foodstuff packaging and thermal insulation. In another research project, engineer Linda Goebel is working with bio-plastics in 3D-printers in order to open up new horizons for developers who work with such 3D-printers. But Bonten warns as well: „Bio-plastics should not lull us into just discard-

ing packaging wastes into the environment; that would be exactly the wrong way.“ In Germany, Austria and Switzerland in particular, he sees no reason for a negative view of the value of plastics: „In those countries, 98.6% cent of plastic items are recovered and re-used.“ Half of them are recycled, the other half, which cannot be cleanly isolated or is too heavily soiled, serves to produce energy and heat. The IKT is therefore also hard at work to increase recycling quotas. One idea is to mingle plastics with carbon fibers and re-use them for injection molding processes. And then there‘s the problem of discarded wastes in the world‘s oceans.

Here Bonten talks about research results he learned about at a UN conference in Africa last year, where he also gave a speech on bio-plastics: the plastic throw-aways found on the coasts of Africa mostly had Asian lettering. „Plastic, after all, is not of itself „the villain“; rather, it‘s us, because we‘re the ones who throw it away,“ says Bonten. „After all: every waste product once had an owner.“ But, he points out sadly, we have a long way to go before all countries see plastic as a valuable resource to be conserved the same way as Germany, Austria, and Switzerland do.

Daniel Völpel

The Search for Potential Energy Savings
Energy Management in Industry

Industry as an end user consumes nearly 30% of the energy consumed in Germany, according to the Federal Ministry for Economic Affairs and Energy. True, this figure has dropped somewhat during the course of time, but still not enough to enable Germany to reach its ambitious energy goals. That has moved the University to look more closely for potential savings and flexibility in specific applications and branches of industry. Here are two examples.

What helps and what is of little use often requires a closer analysis of energy management. That has moved researchers to explore such issues very intently. One such researcher is post-doc candidate Martin Steurer of GREES, the Graduate Research School for Efficient Use of Energy at the University of Stuttgart's Institute for Energy Economics and Rational Use of Energy (IER). When talking about the potential for industrial optimization, Steurer starts with a key problem of many renewable forms of energy: wind power, photo-voltaic systems and water-powered turbines often produce their peak energy when the weather allows, and too little at peak consumption times. „That calls for much better management of energy supply sources than in the past," he says. „And this becomes more urgent as we continue to expand our use of renewable energy." In saying that he has summed up the entire energy system. Or, too look at it a different way: on certain days and at certain times energy is available in much greater supply and at much lower cost than at other times, because the energy companies simply have to get rid of it. „That's where manufacturing companies could get a ‚windfall'," says Steurer, who has a Doctorate in Environmental Technology. And it's how the economic sector views it too: above all, energy-intensive areas like foundries, and plants producing steel, aluminum, glass, cement, or paper eagerly grasp at such financially rewarding straws – „which benefits not only them but in the end the whole system and society as well!" Studies of peak electricity consumption times in Germany, which lie at about 80 gigawatts, have shown that greater flexibility on the part of consumers could provide a leeway of 5 to 15 gigawatts. Experts call it „flexible demand side integration", meaning that industrial plants plan their production activities in such a way as to draw as much inexpensive energy as possible or to take some of their production activities off the electricity network for a while during general peak loads. „Unfortunately, most of these studies to date have found this potential only in the abstract," says Steurer. The only exceptions consist of aluminum, chlorine and steel-producing plants, which are so few in Germany that they can easily be studied in the concrete.

The Most Detailed Study to Date

That prompted Steurer and his colleagues to carry out a detailed analysis of the possibilities for such consumption-"flexibilization" at more than 200 industrial locations in the Federal Republic – including not just technical feasibility but also existing financial and organizational features as well. He also brought on board the public utilities of Aachen, Germany, which have a cooperation agreement with Trianel Company. „Feedback from the parties questioned was very diverse," says Steurer. „For one thing, many companies – in the paper industry, for example – are already far advanced regarding Demand Side Integration. For another, however, issues like energy efficiency and energy management are understood very differently by different individuals." At any rate, the IER study's conclusion was clear-cut: an enormous potential for shifting supply and demand times still remains unused at 70% of Germany's industrial locations.

If energy-intensive areas like the steel industry were to produce more when renewable-source electricity is plentiful on the market, the Energy Revolution would benefit just as much as the balance sheets of those companies.

Photo: Fotolia

The Stuttgart team even regards this estimate as conservative because most of the plant managers queried clearly spoke rather guardedly.

One clear, concrete example of how supply and demand can be steered is found in the industrial production of glass containers. Glass is made from a molten mass heated to far more than 1,000° Celsius. To achieve this, the manufacturer must heat tubs correspondingly. „Companies mostly use oil and gas to provide the necessary energy, because this costs less than electric current," says Steurer. „But because electric heat provides better quality for many of the processing steps, it is used for auxiliary heat." Finding the best balance of energy types thus depends on numerous factors. Companies would eagerly snap up electric current whenever it is inexpensive rather than turning to oil or gas. Another example of Demand Side Integration is found in the paper manufacturing industry, where so-called „scrapers" break wood down into fine fibers – again, an electricity-intensive process. But, says Steurer, „The fibers are interim-stored in silos, and the scrapers don't work around the clock; so these machines could run at times when energy is cheaper" – and that is already being done in the paper industry.

The Technology is Already Available

Steurer goes on to emphasize, „Please remember: we didn't study the potential to be found in future developments, but only what can be done with today's existing forms of technology." Industrial production today already has the good infrastructure it needs as a basis for energy management and also has all the technical equipment it needs for waste processing control. The costs of development would thus be small. It is rather the case that „The real questions concerning an expansion of Demand Side Integration in industry concern commercial and organizational issues," says Steurer. His study indicated that the paper industry has the greatest potential for flexibilization of its energy consumption, followed by cement mills, electrolysis and electric arc processes in the metal-producing industries, and Induction ovens in foundries. Viewed regionally, the German states with the highest number of industrial locations naturally have the greatest potential, meaning North Rhine-Westfalia, Bavaria, and Baden-Württemberg. But low energy prices are presently hampering Demand Side Integration for the time being.

Still, energy management in industrial production is a wide-ranging topic. Demand Side Integration is not the only way to tackle it. For example, the

Renewable forms of energy still cannot meet electricity needs around the clock. However, future surpluses are on the way, which will make intelligent electricity management more important than ever.

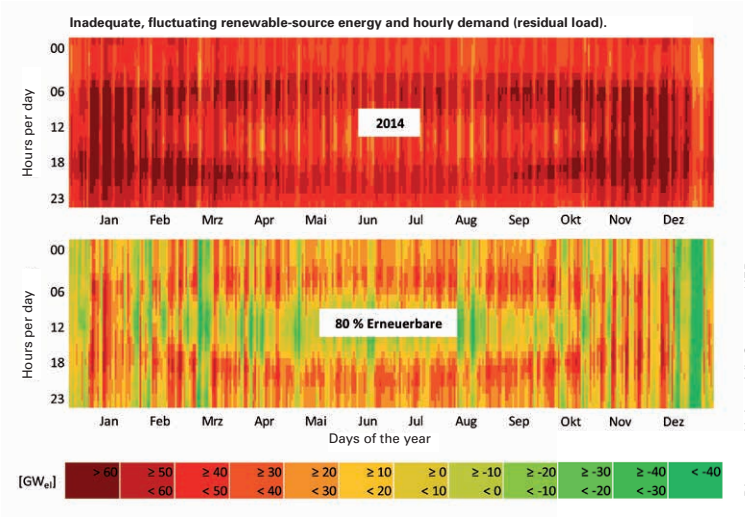


Diagram: Universität Stuttgart / IER

University of Stuttgart and the Darmstadt Technical University joined forces to study how energy consumption and efficiency can be improved by automated manufacturing methods. Their six-year project, called „Ecomation“ and funded by the German Research Foundation, ended in the autumn of 2015. The University of Stuttgart was represented by the Institute for Machine Tools (IFW), the Institute for Control Technology of Machine Tools and Manufacturing Units (ISW), and the Institute of Industrial Manufacturing and Management (IFF). We talked to one of group‘s members, industrial engineer Sylvia Wahren, who said, „Up to now, companies have tried to tackle the issue of energy efficiency with scattered optimization of machines; that is, they don‘t have the whole production picture in view.“ Production is, of course, a complex issue, involving machine tools and their components, peripheral systems for cooling and lubrication, pressurized air facilities, and lighting installations – and on top of that there are the control systems for machines, production, and production plant operations.

Wahren illustrates: „Just a simple example: If a machine tool or its operator were to know that the production planners have scheduled manufacture of the next component for an hour later, then the machine could be put into its energy-saving „sleep mode“ until then. Over the lifetime of machine tools, this could save about 20% of the energy costs. Currently, metal-machining tools like those used for turning or milling can consume up to 150,000 kilowatt hours of energy.

Control systems for individual machines of course already exist and can put the machine automatically into „sleep“ mode during longer downtime phases; however, such control systems that monitor linked facilities for degrees of machine use are still unavailable on the market. That is the type of scenario that calls for Ecomation. As Wahren points out, „The most important criteria in production are naturally an evenly distributed machine capacity, on-time delivery, quality, and covering costs. That makes it clear that energy management must help, not hinder.“

Taking the Whole Production Chain Into Account

The Ecomation Project‘s partners started by recording the energy consumption of components, machines, processes and each company as a whole. In the case of typical machines and components, this was done experimentally depending on different types of use. Then the question was taken up of how to predict energy consumption during fluctuating machine use and to what extent this consumption can be controlled by means of stand-by phases. For this, servoloop feedback systems were used both at the machine and remotely from it. „Just as a test, we used a simulation to study two parallel process flows, each involving several turning and milling machines with their peripheral equipment,“ says industrial engineer Wahren.

Speaking as a researcher, she says Ecomation was basic research, meaning that the results cannot be transferred on a one-to-one basis to actual plant operations. „As far as we know now, for example,

we have isolated a potential for saving up to 15% of energy with production control systems and up to 5% with individual machine control systems. But in an overall automated network these effects could counteract each other, meaning that it's safe to say that the potential for optimization in industrial production on the whole would often be somewhat less than 10%." That doesn't make implementation easier when a company wants to be more energy-efficient but has already exhausted all options with a one-time effect, as for example through good maintenance of its pressurized air systems.

Production processes like those at this machine station are one link in the production chain that was studied by the Ecomation Project.

Photo: Fraunhofer IPA

Hurdles to Savings

The situation is rather reminiscent of the heated debate some years ago about potential savings with electrical devices in standby mode: systematically shutting them down completely with on-off multi-socket connectors would lead to great savings. In sum, a gigantic amount of energy would be saved in Germany or even worldwide every year. But the effect seen by the individual user would remain modest, especially in terms of costs, so that many electric devices continue to doze away in standby mode. This experience gives reason to believe that efforts at energy optimization in industrial production would meet with a similar fate.

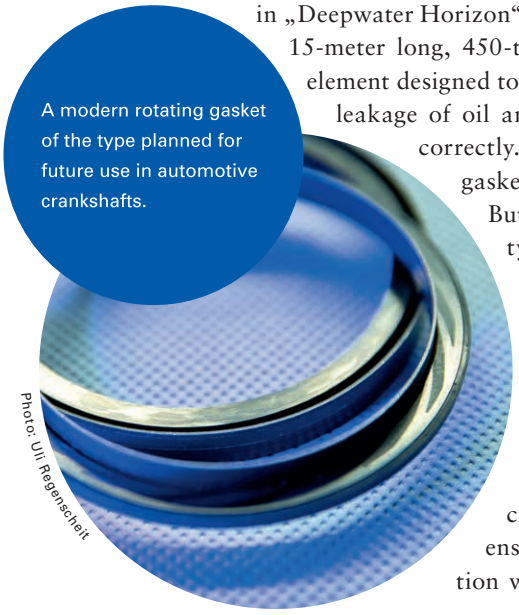
To expand the potential for industrial production savings, the University of Stuttgart's Institute for Energy Efficiency in Production (EEP) now intends to exploit the results of the Ecomation Project and find out on a broader conceptual horizon how to better link the reciprocal aspects of building technology and a flexible energy supply.

Michael Vogel

Undercover Efficiency
Gaskets are more than just rubber

In the world of technology, it's often the little things that determine economic and ecological efficiency. Take rubber gaskets, for example. The University of Stuttgart's Institute of Machine Components (IMA) is already working on the leak-proof technologies of tomorrow.

They're hidden everywhere in components, and often stay unseen: gaskets. Beer bottles, water faucets, cars: if the gasket is intact, the beer tastes fresh when opened, the faucet doesn't drip, and the car doesn't lose oil. „We notice gaskets in daily life only when they perform negatively – sometimes with fatal results," says mechanical engineer Prof. Werner Haas, PhD, and names two prominent examples: the explosion of the US space shuttle „Challenger" in 1986, and the explosion on the „Deepwater Horizon" oil drilling platform in 2010 in the Gulf of Mexico. An O-ring in the Challenger, i.e. a gasket, lost its elasticity during the low temperatures prevailing on liftoff day. And in „Deepwater Horizon" the blowout-preventer, a 15-meter long, 450-ton emergency structural element designed to prevent the uncontrolled leakage of oil and gas, failed to operate correctly. One reason: a damaged gasket.



A modern rotating gasket of the type planned for future use in automotive crankshafts.

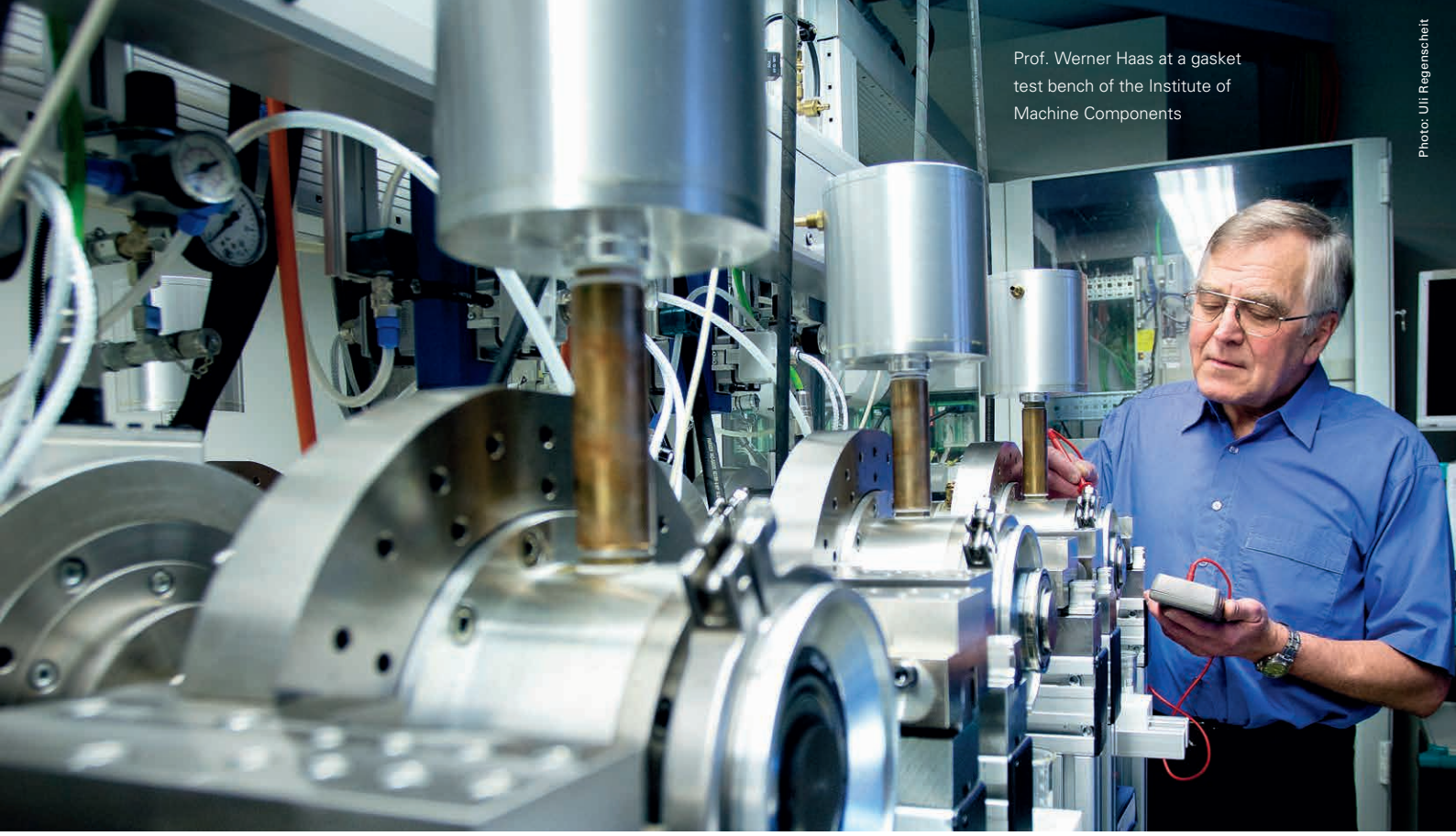
Photo: Uli Regenscheit

But above and beyond safety considerations, gaskets are also important for optimum economic and ecological operation of machines. Haas explains: „Their job in the presence of moving parts is often to retain a lubricant in a specified area to ensure a minimum of friction while preventing oil from escaping and damaging the environment." Gaskets ideally provide only benefits without causing problems. To take the example of an automobile crankshaft, which is typically several centimeters thick and rotates thousands of times a minute: its gasket is in contact with the crankshaft surface, which could be a source of friction. But „science and industry have succeeded in the last 75 years in reducing that friction energy by a factor of 100," says Haas. „And the IMA was intensively involved in the last step, which achieved another improvement by a factor of 12."

Potential Savings of 440,000 Tons of CO_2

These modern gaskets, which will be used for the crankshafts of series-production vehicles in the next two years, basically consist of two rings, one connected to the crankshaft and the other to the crankcase. Grooves which are only a few micrometers deep are cut into the surface of one of the rings. As the crankshaft starts rotating, that ring turns with it, pumps air between the two rings, and prevents it from escaping. The resulting air cushion separates the two rings, minimizing friction, but also keeps lubricant from escaping. One manufacturer of such gas-lubricated, rotating gaskets claims in his advertising that 440,000 tons of CO_2 could be saved annually in Germany if all automobiles had this new type of technology.

„Other types of technological gaskets provide both an excellent seal and a minimum of wear and tear," says Haas. He's thinking of the many applications in which gaskets are almost never replaced or require very little maintenance from their users. That is possible only with gaskets which are contact-free both during movement and when standing still. „Gutter labyrinths" are a good example of this: areas in them where splashing water might enter are cleverly designed to be so tortuous that moisture cannot enter. Sealing systems of this type are use-



Prof. Werner Haas at a gasket test bench of the Institute of Machine Components

Photo: Uli Regenscheit

ful, for example, in the gearboxes of rail vehicles and engines, and require maintenance only at long intervals. Another example: the spindles of machine tools which would otherwise quickly become dirty and heat up due to their rapid rotation. The rotors of modern ocean wind turbines also benefit from this technology, because their gaskets cannot be replaced after they have been set up: the costs, time, and work required would be prohibitive.

One-of-a-kind Research Depth

Headed by Haas, the IMA's 15-person „Gasket Technology" team is delving into all the questions raised by this variegated topic. „Germany has three other academic research institutes in this field, but ours is the only one covering the entire field, including seals for pneumatic, hydraulic, or rotating parts. That makes us pretty much unique in the world." The IMA's equipment includes test benches which can also be used in the service of industry. The IMA team studies not only the compatibility of sealing materials and lubricants but also the reciprocity between seals and their contact surfaces. But often „the devil is in the details", as Haas points out with an example: when a gasket is positioned on a rotating shaft, the rotation can result in slight system differences in pressure between the gasket and the shaft. While that is basically desired, the system naturally must still not allow any lubricant to escape to the outside. „But that is exactly what happens if the shaft surface does not have an optimum contour in terms of roughness," says Haas. That, in turn, can result from the processing methods used to produce such shafts. „Even today, we still do not have a reliable, user-friendly measurement technique for ensuring the necessary quality," says Haas. „But we hope to change that."

Michael Vogel

On the Road in Daily Life- Electrically!
How is electromobility getting on?

The city of Stuttgart has issued fine dust alarms regularly since January 2016, with the recommendation that people use electrically powered cars. But only a tiny percent already own one. To change this, the German government, along with Germany's states and cities, has initiated projects for testing electromobility in daily routine. The University of Stuttgart is participating in some of them and beyond that is studying how to make electrical vehicles more energy-efficient and how to charge their batteries more comfortably.

The will of the German Federal Government is that one million electric automobiles will travel German roads by the year 2020. Still, the Federal Motor Transport Authority has reported that by January 1, 2016 only 25,502 fully electric and 130,365 hybrid passenger cars were in operation in Germany. For every pure „current" car there were 1,767 with combustion engines – presently regarded as the main culprits behind fine-particle dust and nitrogen dioxide. „Stuttgart is one of Germany's leading producers of emissions, and we have to think seriously about that," says Dr. Rüdiger Goldschmidt of ZIRIUS, the cross-faculty Research Center for Interdisciplinary Risk and Innovation Studies at the University of Stuttgart. This is aggravated by the city's location in a bowl-shaped valley, where air pollutants collect around this regional capital. Electric automobiles seem to be an ideal solution here: they have no local emissions and are nearly cat-quiet. For example, a conversion to electric power in taxis, which typically travel many thousands of kilometers a year, could pay big dividends. But can electric taxis compete with combustion-engine taxis? That's what scientists in one of the 34 team projects in Baden-Württemberg's „Window on Electromobility" drive decided to find out. Goldschmidt coordinated the project, in which five Mercedes electric taxis (4x B-Class and one Vito) went through their paces in everyday Stuttgart use. Taxi customers were able to order them from September 2014 to December 2015 under the taxi telephone number.

„E-taxis Have to Pay Their Way"

„Customers were delighted with the electric taxis' acceleration and silence (only the tires could be heard)," says Goldschmidt, who analyzed the acceptance of passengers, drivers, and companies. However, the four taxi companies that used these pre-series production vehicles daily in traffic had to get accustomed to a maximum driving time and range of only 120 kilometers when starting with a full battery and 6 hours to recharge it thereafter. „Company owners with a fleet of vehicles and a team of drivers who think nothing of driving their taxis up to 500 kilometers in a single shift often came up short against the technical limitations," says sociologist Goldschmidt. Other company owners made do with 150 kilometers and only short trips.

„The taxi company owners in the project are aware of the exhaust gas problem in Stuttgart and their own part in it, and are working hard to improve the situation. But business is business," explains Goldschmidt, who as a member of the ZIRIUS team remains convinced nevertheless that „A large percentage of companies will find out how to turn a profit with electric taxis in future." But all of the involved parties must come together at the same table and work out the solutions. That means: the communities, the manufacturers of electric vehicles, the electric supply utilities, and the traffic companies."

But electromobility is not an issue in cities alone. Out in the countryside, where the next supermarket or physician's practice is usually far away and buses pass by only rarely, many people have to rely on a car. For example, a bus usually stops only spo-

Aficionados of E-mobility: Prof. Nejila Parspour and doctoral student Samilo Yavuz.

Photo: Max Kovalenko

radically mornings, afternoons and evenings in the small, 7,000-person city of Boxberg, and often not at all on weekends. In order to close the gaps and reduce countryside emissions at the same time, an alliance of citizens has been providing an honorary „electric travel service“ since April 2014. The initiative was honored as one of 20 winning projects from the state-wide idea competition „“Electromobility in Rural Areas“. It won 1st prize in the category „Man and Environment“ of the „REAL GOOD“ State Honorary Service Competition.

Door-to-Door Service in the Countryside

„A call comes into the Rathaus City Hall through a citizens‘ hotline. A person there records travel requests for the coming day and plans the route to be followed by the electric car, a white Renault Kangoo Type Maxi-ZE,“ says Benedikt Krams. The driver then picks up and delivers his passengers door-to-door Monday to Friday between 8 a.m. and 6 p.m. Under the direction of Prof. Georg Herzwurm and Prof. Ullrich Martin, Krams, who comes from Department VIII of the University of Stuttgart‘s Institute of Business Administration, and David Camacho of the Institute of Railway and Transportation Engineering were available to the city as advisors from the beginning and provided scientific support for the project to the end of 2015. Here even more questions came up:

Does the multi-passenger van which is used have enough battery capacity to guarantee reliable transportation service? And how should daily routes be planned if the manufacturer‘s travel range information is unreliable and the vehicle‘s expected travel range is only a rough estimate, as six of 15 interviewed drivers confirmed? The electric car traveled 75 kilometers a day on the average. „The project showed us the vehicle‘s actual travel,“ says Krams. And battery use was higher in winter and on uphill grades. „Even though I can put part of the braking energy downhill back into the battery, I use up more energy uphill than I recover downhill.“ So it often makes more sense to use detours rather than to drive up hills. Moreover, frequent acceleration on straight stretches used up nearly twice as much energy as a defensive driving style.

„In most cases it was possible to „bundle“ the trips of several passengers, so that the travel range was not much of a problem,“ is how 35-year-old Krams sums it up. In fact, a rapid-charge station would permit continuous service – except for two half-hour charging stops, says Krams. A supermarket could serve as

a location for the rapid-charge station. Drivers must often wait there anyway until their primarily older passengers have finished their purchases. At present, the drivers take a two-hour noon break in the company's courtyard in order to recharge their batteries at conventional charging stations.

Few Offers for Electro-Minibuses

Volunteers in small-area communities with higher resident densities than Boxberg also drive mini-buses in normal transit service according to a fixed time plan. A pilot project is currently underway as part of the „Window on Electromobility" scenario in which scientists from the University of Stuttgart's Institute of Business Administration and the Institute for Railway and Transportation Engineering and other partners are not testing the first battery-powered „People's Bus" in city transit service. „The challenges which the electric vehicle faces are much greater than in the passenger service in Boxberg," says Krams. Because it requires an official permit as a public transit vehicle, the „People's Bus" has the obligation of traveling its route according to a travel schedule. „If passengers on the last route in the evening could no longer be served, it would be a problem," says this economic expert. For that reason it's important that the project's battery-powered minibus have the greatest possible range with a fully charged battery, but not weigh more than a maximum of 3.5 tons so that volunteers with a „B"-Class driver's license can drive them. In addition, the electric „People's Bus" should be handicapped-accessible like those in the urban public transit system. Up to now, however, the Stuttgart researchers have not been able to find such an electric vehicle. Their only choice was to convert a standard minibus to electric power. The new „Electro-People's Bus" will now replace the diesel-engine-powered bus that connects the rural communities of Ebersbach an der Fils, Salach, Uhingen, and Wendlingen am Neckar. The scientific team hopes to find reliable numbers showing whether it makes sense to operate an electric „People's Bus" in a community, depending on uphill climbs, the number of bus stops, and how many passengers are transported, and what amount of public subsidies will be required to purchase the vehicle. As Krams says, „Suburban public traffic is funded by subsidies, but people's buses or passenger cars are a social solution that helps those with restricted movement capabilities and older people to get back into daily life."

The battery-powered „People's Bus" aims to fill gaps in public transportation in rural areas.

Photo: Sabine Ackermann

Unattractive in Private Life

Wolfgang Fischer of the Regional Office for Electromobility and Fuel Cell Technology and coordinator of Baden-Württemberg's „Window on Electromobility" projects, sums it up: „Electric vehicles are ideal for everyday use; the main obstacle at present is their high purchase cost," and it will be a while before electric automobiles are of interest for private persons. However, he sees good opportunities for using electric vehicles in company vehicle fleets, as service and delivery vans, and in the public transportation sector. In those areas, the high cost of electric vehi-

cles is quickly amortized due to their high rate of utilization and relatively low operating costs. „The first step to crank up demand would be to initiate financial incentives like special depreciation options for companies," says Fischer. An additional, positive effect: the electrically powered fleet cars would go

IEW-doctoral students Mike Böttigheimer and Marcel Maier (l. to r.) are shown positioning a charger coil.

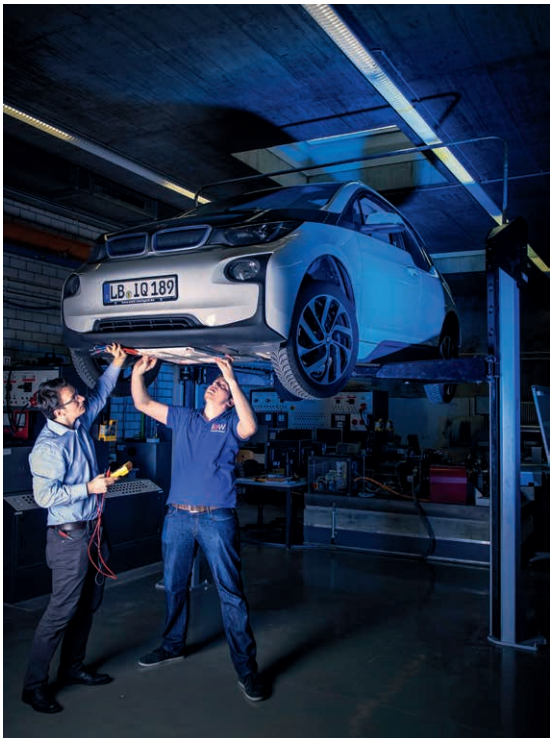


Photo: Max Kovalenko

on the used car market after two to three years and would then be more affordable for private persons. The most expensive component of electric vehicles is still the battery. But Hans-Christian Reuss of the University of Stuttgart's Institute for Internal Combustion Engines and Automotive Engineering (IVK) is convinced that electro-autos will one day cost no more than today's automobiles: the batteries are already growing cheaper all the time, and their energy densities and thus travel ranges are going up. If electric vehicles were to be built in large numbers, that would make them even cheaper, says Reuss. But until that day comes, scientists are working to optimize electrically-powered vehicles so to make them consume less electricity. If they succeed, then electric cars with small, inexpensive batteries could travel farther on a charge. „For example," says Reuss, „we installed automatic range monitors in two electric automobiles so that they accelerate and brake automatically." Just like a careful driver, the car accelerates gradually, takes its „foot off the gas" promptly in case of obstacles, and just as a modern car uses its engine to brake, this car uses downhill stretches to recuperate by putting some of the movement energy back into the battery.

No-Touch Battery Charging

Nejila Parspour is one of the lucky few private individuals now driving around Stuttgart with her own battery-powered automobile. Once a week, she plugs her BMW i3 overnight into a standard electric outlet in her garage at home. With one battery charge and a travel range of about 130 kilometers, she has no trouble getting through the week. Once, however, a 53-kilometer excursion to the city of Heilbronn, which has only three normal charging stations at present, ended „on fumes": „I was there for four hours and could normally have recharged the car at the time, but I couldn't find a charging station," recalls Parspour.

Now she has worked with her team at the University of Stuttgart's Institute of Electrical Energy Conversion (IEW) to develop a non-contact rapid-charging system that inductively transfers 22 kilowatts. That would be enough to recharge Parspour's car with a battery capacity of 21.6 kilowatt hours within an hour. Says engineer Parspour: „The real advantage

Photo: University of Stuttgart / IVK

3D-display of charge coil positions during inductive charging (receiver coil red, charge coil blue).

of cable-free charging is that the driver need do nothing, and could recharge anywhere: on parking lots, at traffic lights, while driving, and could extend the car's range indirectly while doing so." In practical terms, alternating current flows through a primary coil underneath a parking space. The resulting electromagnetic field generates alternating voltage in a secondary coil under the middle of the vehicle's floor. The vehicle's power electronics then convert this into direct current, which in turn charges the battery.

The research team has achieved a high, 94%-degree of efficiency by increasing normal mains voltage with a frequency of 50 Hertz to 85 kilohertz. Parspour assures that this involves no danger to the health of the vehicle's passengers: „We've installed a thin ferrite layer and a copper plate in the car's undersurface that do a wonderful job of shielding against the powerful magnetic field." She and her team chose a 30 centimeter radius for both of these round coils in such a way that the receiver coil is light enough to fit into Daimler's Smart car. In addition, this keeps the stray radiation of the magnetic field small enough to pose no danger to humans who are near the vehicle. One difficulty is that metal objects which by chance come between the coils can heat up, just as kitchen pots are heated by the induced eddies of an induction stove. „We measured this with a heat-sensitive camera on a test bench: coins and keys are relatively harmless, while a steel saw heats up to about 60° Celsius, which could in fact cause skin burns," as doctoral student Mike Böttigheimer explains. In response, he has developed different solutions for detecting metallic foreign bodies on the basis of magnetic flow density. In case of emergency, the charging process would have to be stopped.

Navigators for No-Touch Charging

To transfer electric current with as little loss as possible across the 15 centimeters of air between the charge coil below the parking space to the vehicle's receiver coil, the driver must park the car in such a way that both coils are directly opposite each other as far as possible or are out of alignment by no more than 10 centimeters. To ensure this, doctoral student Dean Martinovic has developed a

parking assistant under the direction of the IVK's Hans-Christian Reuss. As Martinovic drives the modified Smart to within 1.5 meters of an underground coil, a unit resembling a navigation device shows him how far he is from the middle of the coil and the direction in which he needs to drive. This parking assistant, for which a patent has already been applied, allows Martinovic to position the coils within a centimeter directly above one another. Today a driver is still required, but someday the car will park itself completely autonomously. This is possible because of two sensors underneath the car which are used to measure magnetic flow density. A software program calculates the distance from and the angle to the middle of the ground coil. Here Martinovic uses an innovation: a pulsed, low-frequency magnetic field generated by the ground coil. „It's different from dynamically changing, alternating fields; here I avoid interference from eddies induced in the metal undersurface, which formerly caused measurement errors," he says. In contrast, the camera views tested by other scientists for positioning could be obscured by snow or fog. And radio waves from WLAN or GPS units could be reflected from objects and thus make positioning inaccurate.

„Inductive charging is the most customer-friendly solution, and charging cables are probably only an interim stage," says Reuss; „but for large-area installations we will require common standards, for example to ensure an optimum coil geometry." On the whole, Wolfgang Fischer of the Baden-Württemberg Office of Electromobility can certify that Germany is leading the middle of the pack internationally in terms of electromobility: „We haven't yet managed to convert our research findings directly into products; other regions are ahead of us." Where the region scores points, however, is above all in electric motors, charging technology, and power electronics.

Helmine Braitmaier

Efficient Fun
Carina Pötzsch is in charge of water management at the Europa Park

Energy, water, area – recreational parks undeniably have a high rate of consumption. But while it can't be denied, it can indeed be helped. The „Europa Park", Germany's largest leisure amusement park, was awarded a certificate last year as a „Green Amusement Park" for its commitment to sustainability. The Mack family, its owners, have hired, among others, an alumna of the University of Stuttgart to ensure economic use of water.

33.2 liters: that's how much water is needed on the average for each visitor to the Europa Park. And more must be added for the dizzying roller coaster rides over water, fjord rafting, locomotive rides, the tranquil water fountain displays in the more than 500-year-old castle park, or just for trips to the bathroom. Hotel accommodations and swimming pools add even more to the total. 33.2 liters are really not much for an amusement park that is one of Germany's largest providers of water attractions. But with about five million guests annually, this adds up to 166,000 cubic meters – enough to fill 66 olympic swimming pools.

Water is, in fact, in abundant supply in the Rhine plain around the town of Rust, where the Europa Park is located. Carina Pötzsch explains: „We're sitting here on a gigantic table water reservoir which feeds a system of wells deep underground." Pötzsch, an Environmental Technology graduate of the University of Stuttgart, has been head of the Europa Park Water Management Department since September 2015 and is also responsible there for energy management and waste management issues. It's a new position, and the second one created especially in the area of environmental protection – just one indication that the Mack family which owns the park has taken ecologically responsible behavior upon itself as a goal.

Even Small Steps Are Important

It's clear to 28-year-old Pötzsch that every action, big or small, counts: in spite of its seeming abundance, water remains a precious and sensitive resource. „Both the authorities and the communities in the surrounding region take very great care to ensure that the water table does not drop." Preventing such an occurrence is the target of a plethora of large and small initiatives. For example, a centralized system for processing water reduced the consumption of groundwater used to supply artificial lakes and water-based attractions by 50%, and in addition the park's own water works annually supply one million kilowatt hours of environmentally friendly current. Used water is systematically cleaned and returned into the system.

Small steps save water too, however; for example, the park's plants are watered under digital control, and thus to better effect. Taken together, all of these steps have shown results: regular checks and calculations of the underground wells to find whether a so-called „funnel effect" has occurred due to water draw-off has shown that: „The effects are marginal," as Pötzsch says.

In addition to water quantity, water quality also poses a challenge. While not every pool must have bathwater quality, it must nevertheless be visually unobjectionable and hygienically attractive. „Our visitors expect to experience fresh water, not pools green with algae," explains Pötzsch. The likelihood of algae is a challenge, along with the high levels of iron and manganese in the Rhine plain's groundwater, and that requires a filtering system.

A Workplace in the Underworld

As a result, the workplace of Carina Pötzsch is not the glittering world of the Europa Park's 94 hectares, with more than 100 attractions and shows and 4,500 hotel beds. Her „kingdom", one level below ground, is less spectacular. In the technical

Photo: Uli Regenscheit

Minimum consumption, maximum quality: those are Carina Pötzsch's guidelines for water management at the Europa Park.

equipment areas there, man-sized filtering containers filled with sand stand row on row. As the water trickles through the sand it is cleaned biologically and can be returned as clear water to the environment. It is a tried and true technology, but has two drawbacks: the barrel-shaped containers take up much space, and a great deal of water is required to clean out the clotted sand itself.

Therefore Carina Pötzsch has set up a trial facility at one of the hotels to test a so-called „alluvial filter". The technology, still little-known in Germany, comes from the USA and strains used water through perlite, a rock formed from volcanic glass and found in nature. Perlite forms a fine-pored filtering „cake" which is deposited on tubes and subjected to flowing water from swimming pools. This filter technology not only cleans very effectively but also saves up to 70% of water, along with space and electric current.

A Gigantic Water Park

If the technology proves effective, it will be used in a new water park. An „adventure world" will be erected in several stages of construction on an area between the Autobahn and the Europa Park and will offer water slides of all kinds, a swimming pool with artificial waves, a surf simulator, a „Lazy River", and other highlights for „water rats". A wellness area will be added, together with another hotel. The area planned for expansion will be 120 hectares in size and thus twice as large as the Europa Park. Already, 5,000 visitors a day are expected from 2018 on during the first stage of expansion.

The project, expected to cost hundreds of millions, Is not viewed with unmixed enthusiasm among those living in the area, who also advance objections related to water issues. The additional requirement of drinking water alone is presently calculated to be 150,000 cubic meters. Even in the Upper Rhine Rift, where water is abundant, concern has been voiced regarding the groundwater. Others fear that the piping capacities will be inadequate. However, such apprehensions were calmed in a series of people's forums – not least because the Mack family plans to drill its own deep well and to assume the costs for expansion of the infrastructure. Nevertheless, it will remain a challenge to deal conservatively with water and to process used water in such a way that as much of it as possible can be returned, says Carina Pötzsch. The new alluvial filters are viewed as a major contribution in this regard.

Pötzsch's first contact with the new water recycling technology came during her studies in environ-

Carina Pötzsch in one of the Europa Park's technical equipment areas. Behind her: sand-filled filter containers for biological water purification.

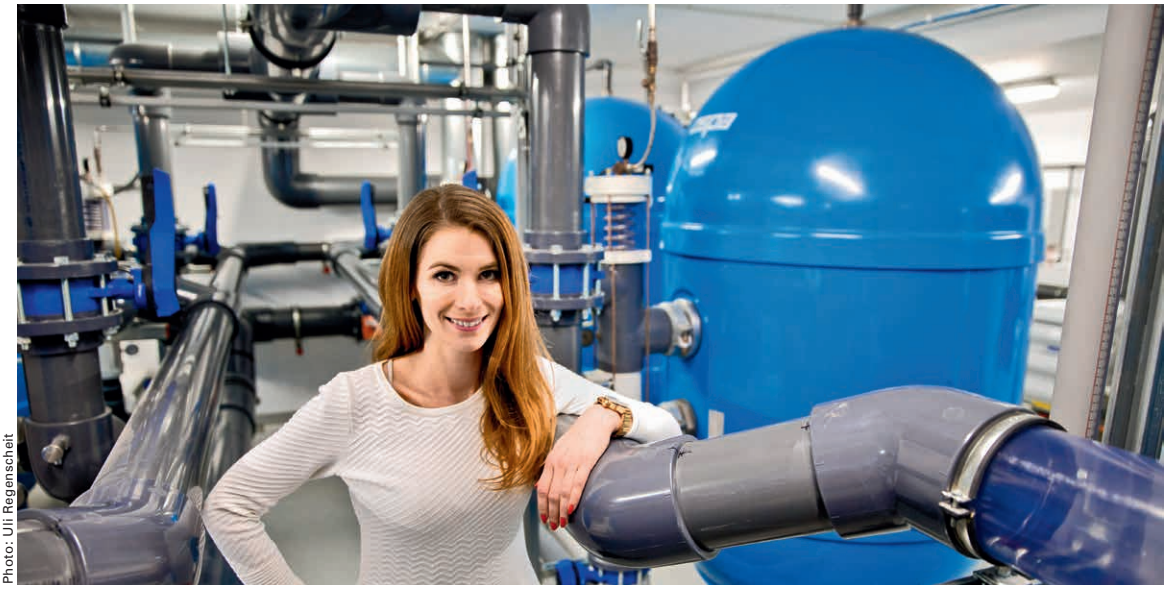


Photo: Uli Regenscheit

mental technology at the University of Stuttgart. „Above all, the main courses were very useful for actual practice; we got a good idea of the available technology and where to get information about it. In my present job, I can apply much of what I learned there one-to-one!"

Why did she, an engineer, choose this field? „Because environmental protection is a future-oriented issue," and also because it covers so many diverse areas. But water intrigued her only gradually and to her own surprise, says Carina Pötzsch with a laugh. But then she became fascinated: „Water resource economy lets me work with entire systems. That's a lot more interesting than working for years to optimize a rubber separator lip."

Andrea Mayer-Grenu

Studying Environmental Technology

Protecting the environment poses major challenges for both industry and for the emerging and developing nations. Many countries of the world are wrestling with urgent problems regarding water, air and soil pollution as well as energy supplies, the infrastructure, and mobility. Solving these difficulties requires cross-disciplinary collaboration involving solutions from both technology and the natural sciences. Self-renewing environmental protection today is mostly replaced by preventive protection: integrated solutions, the creation of closed loops, avoidance of waste, resource protection, and increased energy efficiency are just a few of the issues at the forefront of any commercial effort in this area. With all this in mind, the University of Stuttgart started early back in 1993 by setting up a course of studies for a diploma in Environmental Technology; in 2008 it was converted to the new Bachelor's and Master's Degree system. With great success: study courses are now offered by more than 45 institutes covering almost every discipline relevant to the area of environmental technology. Currently, a total of about 650 students are enrolled in the University of Stuttgart's Environmental Technology Studies Program, and more than 35% of them are women – far more than in other engineering disciplines.

The Editors

Resources for our Future
Science Day 2016

This year's Science Day at the University of Stuttgart took „Resources for our Future" as its motto, and many of the interesting research activities described in this issue of RESEARCH AND LIFE were on hand there „live".

Attention to the conservation of precious resources like water, food sources and raw materials is becoming more important all the time. The University Faculty of Civil and Environmental Engineering's „FOOD Resource Manager" presents complementary study courses to show how we can best reduce CO_2 while saving energy and raw materials when cooking and eating. Will the laser and light resources of the future give us more light with less energy consumption? That was answered in a presentation by Dr. Michael Jetter of the Institute of Semiconductor Optics and Functional Interfaces (IHFG).

And what energy efficiency tricks can we take over from such expert builders as sponges, sea urchins and single-cell organisms? Visitors to the Institute of Biomaterials and Biomolecular Systems (BIO). And specialists in the natural and engineering sciences at the Institute of Interfacial Process Engineering and Plasma Technology (IGVP) are already developing creative research approaches to waste water processing with plasma and energy generation in biogas power plants using algae residues.

The Department of History demonstrated that raw material recycling is not a new invention of our day; even in the Middle Ages, parchment manuscripts were ingeniously cleaned for re-use. And regarding the Here and Now, the institutes of the Faculty of Architecture and Urban Planning joined forces with the International Center for Culture and Technology Research and other case-study laboratories to present the Stuttgart Future City Lab, with a sustainable culture of mobility in Stuttgart, the regional capital.

Julia Alber

Students against a wasteful World

Modern society is quite careless in its use of the world's natural resources like metals and fossil fuels. Still-functional products like mobile phones or TV sets often come to rest at the garbage dump, and valuable raw materials such as phosphorus are found in waste water. Such a predatory exploitation of resources not only eats away at many of the world's resources but also increasingly undermines the environment. A resource-efficient recycling economy in which product components are made reuseable and guided back into economic cycles will spare both resources and the environment.

For that reason, the University of Stuttgart forms international students into experts in the field of waste product management, waste water technology, environmental processing methods and techniques of pure air maintenance with its English-language Master's Degree program WASTE. The degree program's focus is primarily on young persons with a background in mechanical engineering, methods engineering, the environment, construction, and chemical engineering. A recent innovation in collaboration with the Universidade Federal do Paran in Brazil is that the program has now become a double-master's program allowing students to earn a Master's Degree at both universities.

Stuttgart's WASTE students now represent a network of 62 countries. The graduates work for companies, universities, and research institutes in Germany, their home countries, or the entire world. Our world map illustrates where they come from and where they are active today.

hb

Keshav Parajuly (Nepal)
Doctoral student, University of South Denmark: Recycling of Electrical Scrap

Nobuhiro Tanigaki (Japan)
Technical Director, Nippon Steel & Sumikin Engineering / German Subsidiary: Waste Gasification

Oscar Alberto Noreña Trigos (Colombia)
Doctoral student, Interdisciplinary Center for Computer Science (IWR) at the University of Heidelberg: Modelling and Simulation of Spray Combustion

David Castrillón Torres (Colombia)
Project Manager, Yara Germany: Systems for the Reduction of Nitrogen Oxide Emissions

Anna Lelickens (Germany)
Doctoral candidate, Institute for Combustion Technology (ITV) at the University of Stuttgart: Modelling and Simulation of Carbon Combustion

Sukriti Suvedi (Nepal)
Building and Environmental Process Engineer, RP Foundation for Conservation/Nepal: Protection of Historical Monuments and the Environment

Parik Sirumapea (Indonesia)
Environmental Supervisor at Husky-CNOOC Madura Limited/Indonesia, Oil and Gas Company

Gisela Tejada (Mexico)
Methods Engineer at Lafarge-Holcim/Switzerland: Cement Industry

Average percentages of waste management students 2008 - 2016 by home country:

Europe: 19%
Asia and Oceania: 39%
Latin America: 26%
Africa: 11%
North America: 5%

Majid Hassanizadeh From Iran: a Traveler Between Cultures and Disciplines

His career path took him from Iran to the USA and the Netherlands: Majid Hassanizadeh, Hydrogeology Professor of the University of Utrecht, has developed basic methods that can be used by experts to describe the flow behavior of fluids, gases and particles in porous materials like the soil. This has brought him numerous honors, including an Honorary Doctor's title from the University of Stuttgart. Currently he is at work at NUPUS, a graduate college for international training in this field.

Pulling a compact trolley suitcase behind him, Majid Hassanizadeh comes in jeans and a striped blue shirt into the building where the Chair of Learning for Hydromechanics and Hydrosystems Modelling is located. He's well known here, and the colleagues greet him cordially. Hassanizadeh's interests as a hydrogeologist bring him here as much as five times a year to visit Professor Rainer Helmig. In fact, Hassanizadeh already spent 6 months here back in 2010 as a Humboldt research prize winner.

This time he's here for a NUPUS Graduate College Conference on „Non-Linearities and Upscaling in Porous Media" cooperatively sponsored by the University of Stuttgart together with the Dutch universities of Delft, Eindhoven, Utrecht and Wageningen and the Norwegian University of Bergen. Together with Helmig, Hassanizadeh founded the College in 2006 and acts as spokesman for the Dutch participants. Master's Degree students and doctoral candidates have access to advisory services from all participants, along with courses and workshops for budding researchers and a lively exchange of ideas among all participants. „NUPUS brings together different approaches to tackling the many applications of porous media," says Hassanizadeh, who originally graduated in Civil Engineering.

The practical applications couldn't be more diverse: Hassanizadeh's first research interests involved the path taken by groundwater through infinitesimal cracks and pores in the soil and whether it becomes impure when atomic wastes are stored in surrounding layers of rock. Actually, water has always fascinated him: „In Iran, my home country, water is rare and precious, and to us, the sound of running water is one of the most beautiful sounds in existence," says Hassanizadeh. After a while, it hit him that researchers in other disciplines apply the same theories and modelling methods as in groundwater science: all of them deal with fluids, gases and particles and their dissipation into porous materials – an indispensable knowledge for pumping oil out of shale layers buried deep underground, for example.

From Groundwater Research to Diapers and Ink-Jet Printers

While in Holland, his new home, Hassanizadeh, who is now 63 years old, began expanding his field of research. His studies took him next to flow behavior in fuel cells and how to optimize the way they generate energy; then he analyzed the way in which chemotherapeutical agents spread throughout the brain. And now, among other things, he is studying improvements in the way diapers absorb fluids and paper absorbs ink from ink-jet printers. Also, the teams of Hassanizadeh, Helmig, and Bernhard Weigand of the University of Stuttgart's Institute of Aerospace Thermodynamics (ITLR) are analyzing interface applications between air and porous structures in a new cooperative project with the University. They want to find out, for example, whether a thin porous coating can prevent airplane wings from freezing over in winter. „Majid Hassanizadeh has a knack for analyzing questions with different origins in such a way that the parallels between them become clear. That's a gift few people have," says Rainer Helmig. Taking their inspiration from the NUPUS Graduate

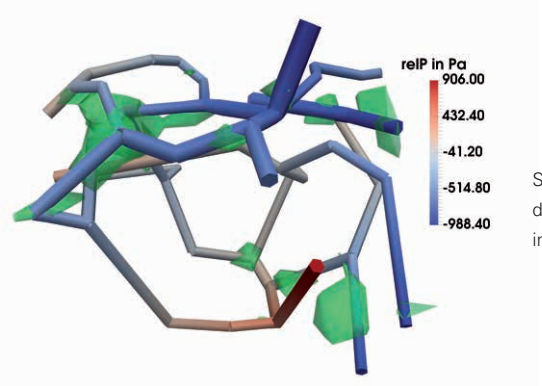
College, the two, who had been science partners for many years, decided to bring all branches of research in the field under one roof, found interested partners, and in the end founded the International Society for Porous Media (InterPore). Hassanizadeh reminisces: „We started, for example, with hydrogeologists, petroleum engineers and materials engineers doing research on the related topics. They held their own conferences, published results in their own scientific journals, and had little contact with each other."

Photo: Helmine Braitmaier

Zooming Into An Infinitesimal Pore

Today, his theoretical work on the derivation of conservation equations for flow and transportation in porous media are the basis for most of the computer simulations with which scientists and engineers simulate the actual underground behavior of water, oil, and air, for example, in virtual reality. The calculations are usually performed by averaging out events governed by physical laws in a single pore over thousands of pores in order to predict how fluids and gases spread throughout the porous soil material.

One starting point for his research was the famous Darcy Law in groundwater science, first formulated in 1865 by the French engineer Henry Darcy to describe permeation in porous media. „However, it fails to take into account that different fluids interact not only with the porous material but also with one another," explains Hassanizadeh. As a hydrologist, he therefore introduced a new variable into the physical equation to account for this interaction and increase the accuracy of calculations by simulation. Hassanizadeh is especially proud of the research laboratory which he was able to establish three years ago in Utrecht with the support of hefty funding from the European Research Council which thus honored him as an established front-rank researcher. „With the microscope there we can zoom into microscopic pores and use cameras to make real-time films of fluids and gases as they permeate into the channels of a porous material and what happens when we change the conditions," says Hassanizadeh. The experiments are indispensable for further improving existing computer models. That is an interface where the teams of Hassanizadeh and Helmig supplement each other: „We supply the expertise in basic theoretical guidelines and experimental studies, and Helmig's team is renowned for its simulations and modelling tools," says Hassanizadeh.



Simulated dispersion of medicinal drugs out of a capillary network into the surrounding tissue.

„Germany is Generous With Research"

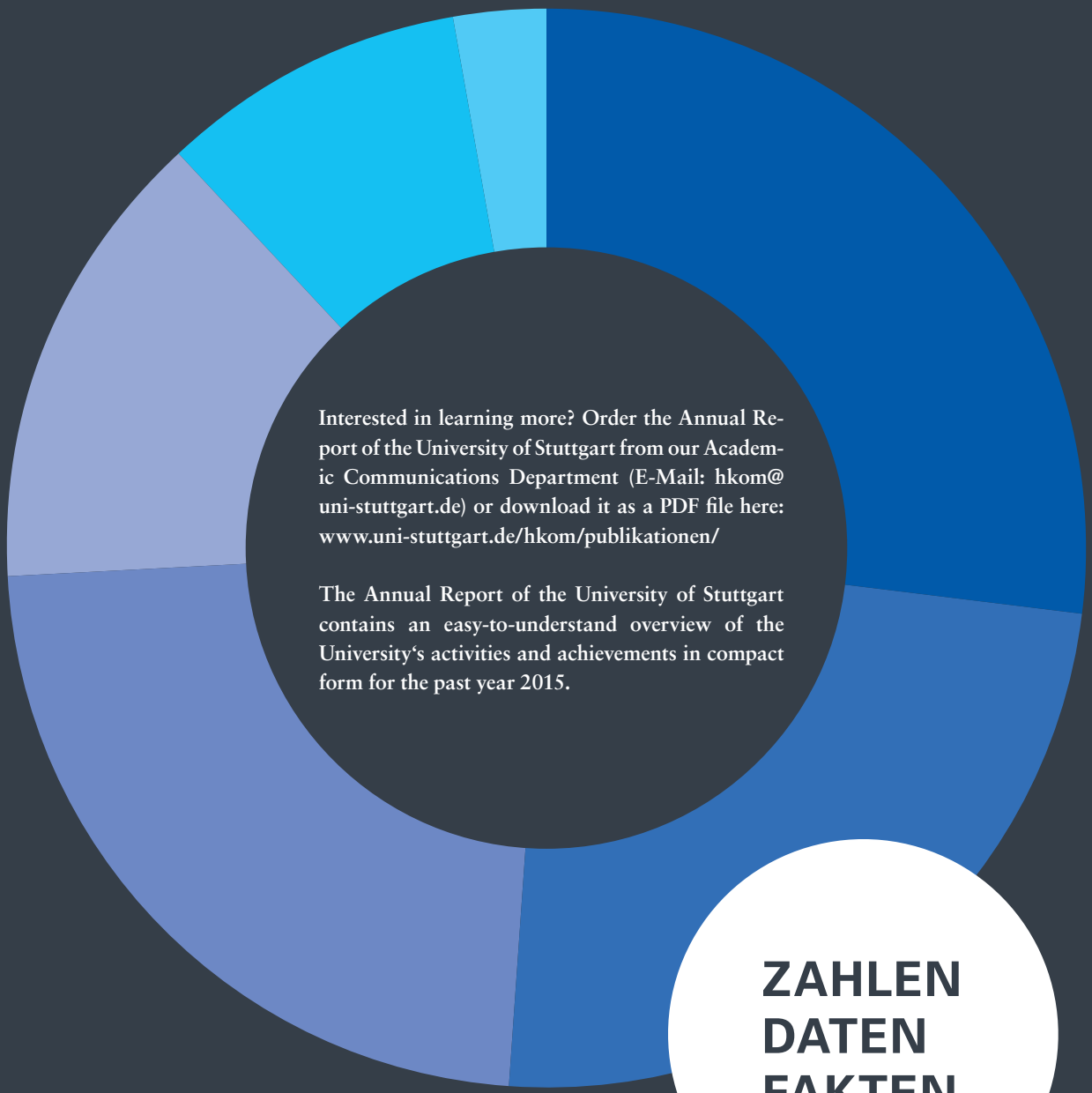
Hassanizadeh has come a long way in his career, which spans more than 40 years. He has been a traveler not only between research disciplines but among cultures as well. Once he had his Engineering Bachelor's degree in the bag, he was drawn as a young man from Iran to Princeton University in the USA, where he began his trailblazing theoretical studies on fluid movement in porous media. Four years later he returned with a Doctor's Degree. But, disappointed by the Iranian revolution, during which the universities were closed, he turned his back shortly thereafter on his homeland. „How is it possible to have a successful academic career here?" was Hassanizadeh's question.

After a year off in the Netherlands for advanced studies, he again got a whiff of research atmosphere in the year thereafter, and: he stayed. „All those years it had always been our plan to return to the homeland," confesses the renowned scientist. „But it's not easy today to carry out top-notch research in Iran: research is not a top priority of the government, and both funding and the necessary infrastructure are lacking," says Hassanizadeh, and praises Germany: „Compared with other countries, including the Netherlands, Germany provides far more funding for research." Then too, there is much competition among the universities in Germany.

At year's end, the NUPUS Graduate College will reach the end of its term, but the close cooperation between the teams of Helmig and Hassanizadeh will continue. That is ensured by a new international research network which will intensify research cooperation and the training of Doctoral students in the field of porous media. Among the participants are not only the present NUPUS partners but also other work groups from the USA, Scotland and Switzerland. The University of Stuttgart will help finance the cooperation in research during the next three years to the tune of 160,000 Euros in all.

Helmine Braitmaier

Annual Report of the University of Stuttgart



Interested in learning more? Order the Annual Report of the University of Stuttgart from our Academic Communications Department (E-Mail: hkom@uni-stuttgart.de) or download it as a PDF file here: www.uni-stuttgart.de/hkom/publikationen/

The Annual Report of the University of Stuttgart contains an easy-to-understand overview of the University's activities and achievements in compact form for the past year 2015.

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Viavi Solutions Deutschland GmbH · Herr Markus Schindler
Arbachtalstraße 5 · 72800 Eningen u. A. · Telefon 07121 86-1207
karriere@viavisolutions.com

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