in2science

The Magazine About People with Ideas

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#9

Magnesium: Solutions in Medicine • The European Water Puzzle • Lateral Thinker with an Adventurous Spirit • Storm Surges & Climate Change • New Ideas for HZG

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

In what way do you contribute to the project in order to help Germany to reach the net zero CO_2 emissions target?

Limiting global warming to 1.5 degrees Celsius compared to pre-industrial levels is possible, but only if CO_2 emissions are reduced quickly and effectively. Within the “Net Zero” project, which belongs to the Helmholtz Climate Initiative (see page 38), scientists at the HZG develop and evaluate target-oriented strategies for avoiding CO_2 emissions.

Institute of Materials Research


©Julia Knop

Prof Thomas Klassen, Institute Director Materials Technology

Net Zero 2050 brings materials and coastal research together. Climate researchers analyse climate change and calculate necessary steps for reduction of greenhouse gas emissions. We develop technical solutions based on hydrogen technology for storage of renewable energy as well as for solar driven reduction of water or CO_2 to obtain hydrogen or carbon-based synthetic fuels. In this way, we would like to (i) support the required change, (ii) provide reliable data, and (iii) open feasible perspectives through new technologies. Based on this, climate researchers can reliably and realistically assess future pathways towards our sustainable future. We can only reach less than +1.5°C if we all work together!


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Dr Martin Dornheim, Department Head Nanotechnology

For Net Zero 2050, we need one hundred percent renewable energy supply by 2050. Fluctuations in wind and solar energy harvesting have to be compensated by sufficiently large energy stores so our future energy demand is covered at any time. Together with my team and our project partners, we aim to provide reliable figures regarding the technical potential and the costs of hydrogen storage. In parallel, we strive to identify new materials for energy storage to continuously update the database.

Institute of Polymer Research


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Prof Volker Abetz, Institute Director

The Institute of Polymer Research is contributing to the HI-CAM Initiative within Cluster 1 “Net Zero 2050” through the “Circular Carbon Approaches” project. The aim is to recycle CO_2 from the air and thus temporarily remove it from the atmosphere. At the same time, new energy sources can be obtained: with the assistance of regeneratively (!) produced hydrogen, the CO_2 can, for example, be converted into synthetic fuels. This conversion requires several gas separation steps, for which our polymer gas separation membranes are suitable. We want to study how the use of membrane processes can be integrated into the procedure.


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Dr Torsten Brinkmann, Department Head Process Engineering

We are working toward this goal in close cooperation with colleagues from KIT, UFZ, HZB and DLR. Using a "direct air capture" process developed by KIT, CO_2 is to be separated from the supply and exhaust air of buildings, then converted to liquid energy sources in a decentralized manner - that is, on site - and also re-used. With the help of process simulation tools, among other things, we are attempting to find the best configuration of membrane process stages that fulfils the necessary requirements in regard to separation quality and needed material flows while also requiring the lowest possible energy input.

Dear Readers,

Have you ever broken a bone that needed to be fixed with an implant? A second surgery is often required following the first procedure in order to remove the metal. This is especially true for children who are still growing. This second operation becomes redundant with magnesium implants, which degrade within the body. The scientists from the Department of Metallic Biomaterials in Geesthacht are therefore researching what are known as “biodegradable implants”. In the Photo Feature, you get a glimpse into their work in the cell culture laboratory, at the bioreactor and into biological characterisation.

Water, sediment and various substances are transported from their sources into the sea - but how do we human beings influence the river-sea system? How do dams, agriculture, industry and shipping activities impact the ecosystem? The international DANUBIUS team studies these issues. We met with the leader of the project and the HZG coordinator in Hamburg. Readers can see the infographic spread in the middle of this issue, where we have compiled the causes, impacts and effects in the rivers and sea.

New alliances are being forged in the field of climate research: the Helmholtz Association launched an interdisciplinary climate initiative in 2019, funding it with twelve million Euros available over two years. In this initiative, climate scientists work closely with colleagues from the fields of materials swcience, polymer research and many other disciplines to develop mitigation strategies and concepts for “Net Zero 2050”.

The new directors address how materials and coastal research can better focus on topics relevant to society: Prof Matthias Rehahn, Scientific-Technical Director, and Silke Simon, Administrative Director, discuss in a joint interview the objectives for HZG staff and what opportunities are available in that respect. In our Portrait sections, readers will learn more about Institute Director Kay-Christian Emeis from Coastal Research and Juliana Clodt from Polymer Research.

The “News” section includes exciting information on various publications, on the “Storm Surge Monitor” and on a project named “Funcoat”, as well as on the new department of “Manufacturing of Light Metal Components”.

We hope you enjoy reading!
Your Editorial Staff

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Gesa Seidel Heidi Hilker

We are pleased to present the ninth issue of in2science

A call for submissions:
Employed at the HZG and have an exciting story or outstanding collaboration you'd like to share? Then please get in touch with our editors. We look forward to your ideas, praise and criticism. Simply write to us at in2science@hzg.de

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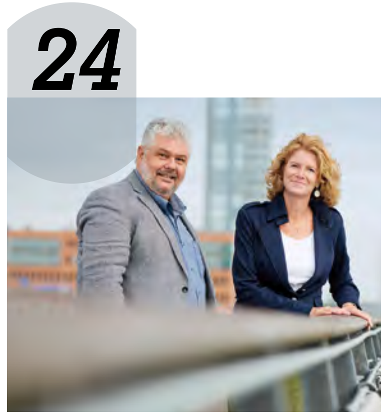
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Magnesium: Solutions in Medicine

Bone screws or other implants made of magnesium possess beneficial properties: the material is elastic in a way that is similar to bone while maintaining its stability during fracture repair. What makes magnesium special is that it dissolves in the body. While other metallic screws or plates made of titanium or surgical stainless steel must often be removed, the need for a second surgery is eliminated when magnesium implants are used. The patient’s overall well-being increases and potential risk of infection is therefore reduced.

In the newly established laboratories at the Geesthacht location, approximately twenty scientists are researching the new materials for the medical needs of tomorrow. The main research challenges are that the implant degradation must be reliably controlled and the bodily reactions must be known.

As soon as the implants are in place, the degradation and the tissue healing processes start. The screws or plates used should initially provide the bones with the necessary stability. The implant should later degrade evenly everywhere without negatively interfering with biological mechanisms. To understand these processes and to systematically control them, the Department of Biological Characterisation in the Institute of Prof Regine Willumeit-Römer is developing innovative series of tests on cells in the laboratory.

Cells in deep sleep

The cells are stored at -210 degrees Celsius in a cryogenic container.
The metabolic processes in the cells are halted at these temperatures. By this the biological materials can be preserved for long time.

Biological technical assistants Nils Holländer and Anke Schuster select the cell stock which will be used for further tests.

Influence of magnesium-based implant materials on the inflammation process

The inflammation processes in response to foreign materials in the body, such as implants, is a complex network of cell reactions and signal molecules. In a series of tests, various reaction phases under normal and inflammatory conditions were simulated.
The study shows that magnesium-based materials influence macrophages as key elements of early immune defence. They promote more rapid organism reaction for improved tissue regeneration.

The Publication:

doi.org/10.1016/j.actbio.2019.10.014

pictures: ©HZG/Christian Schmid

Umbilical cord stem cells

Anke Schuster isolates mesenchymal stem cells from an umbilical cord's blood vessels. These stem cells then differentiate, for example, into bone cells. Mesenchymal stem cells from the umbilical cord can be utilised for various applications: they can be used for stem cell therapy in various diseases or for tissue regeneration. Such cell type can also help eliminate animal experiments, as they are exceptionally well-suited for testing the implant materials for cell compatibility in the laboratory.

The principle cell properties and the ability of umbilical cord stem cells to differentiate into various cell types are under investigation, as they come into contact with the self-degrading bone implant material. Furthermore, the research also clarifies the question as to how cells influence the material degradation behaviour.

pictures: ©HZG/Christian Schmid

Bioreactor as body replacement

In a specially designed bioreactor, the scientists attempt to mimic the biochemical processes that occur in the body as closely as possible. The pink fluid (a synthetic cell culture medium), for example, is to imitate blood - parameters such as the pH value have been adjusted to match the human body. The fluid remains in constant motion through a pump system mimicking the blood circulation.

This is how the researchers aim to understand what precisely happens during implant degradation, whether - as desired - it occurs evenly, and where it begins as well as what accelerates or inhibits it. Doctoral candidate Philipp Globig places the bioreactor into the heating cabinet set at 37 degrees Celsius.

360°

Videos:
We peeked over the shoulders of Anke Schuster, Philipp Globig and René Unbehau while they worked in the lab. You can watch the videos online.
You can also even see the research in 360 degrees: the video provides a complete view of the laboratory. Dr Bérengère Luthringer-Feyerabend, department head of "Biological Characterisation", gives us a tour through the lab at the Institute for Metallic Biomaterials.

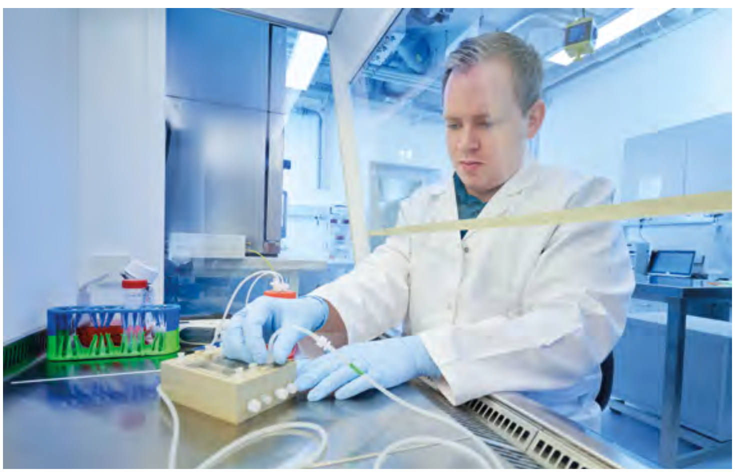
www.hzg.de/magnesium-solutions-in-medicine

Dependent on the composition

The biomaterials researchers work with alloys and add silver, for example, to the magnesium, which acts as an antimicrobial, or add calcium and zinc.

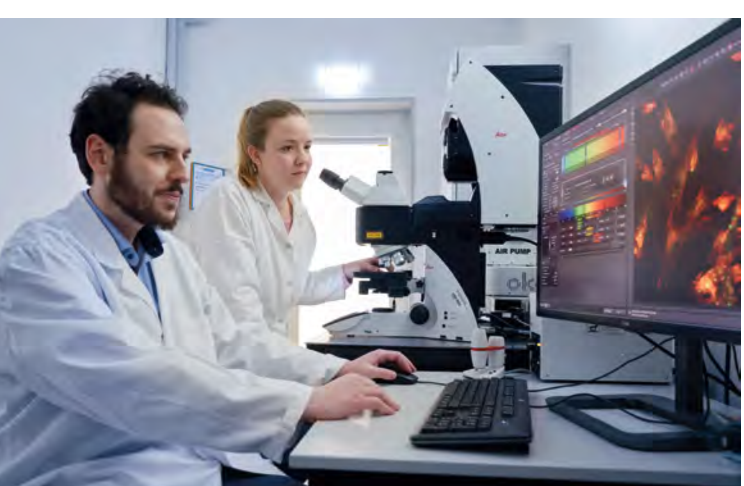
Further photo features can be found in our media library.

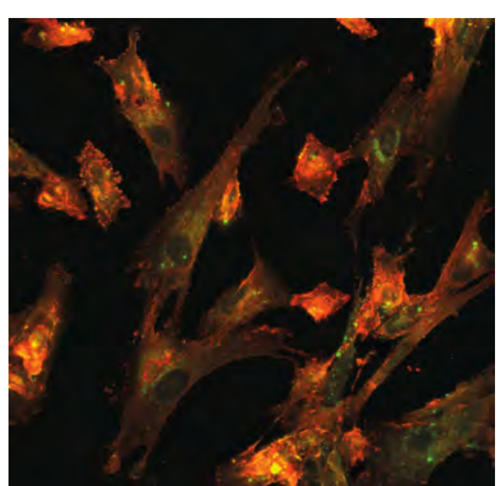
www.hzg.de/media_library



After the cells have grown in the bioreactor, they are prepared further and biochemical and molecular biological tests are performed. The basic assessment of the cell reactions is carried out under microscopic observation.

Doctoral candidate Reneé Unbehau and biological technical assistant Nils Holländer look at the individual cells using the confocal laser microscope. The cell membrane and the intracellular Mg are labeled here in red and green, respectively.





New Ideas for the HZG

2019 was a year of changes at the Helmholtz-Zentrum Geesthacht: With Silke Simon and Matthias Rehahn, the HZG fell under completely new management. In an interview, the two talk about what appeals to them about their new job, what priorities they want to set and what tasks need to be mastered in the future.

You are both relatively new in your positions. What prompted you to choose the Helmholtz-Zentrum Geesthacht?

Rehahn: In my capacities on the Technical Scientific Council as well as a member of the Supervisory Board, I have become thoroughly acquainted with the HZG and its fascinatingly diverse scientific contents and objectives over the span of many years. During this time, I have also seen where I myself would set priorities slightly differently. When I was asked whether I would like to apply for the post of scientific director, I thought to myself: If you already have many new ideas and a great deal of suggestions, you yourself should be prepared to take responsibility to bring them to fruition. Some of these ideas are relatively easy to implement. Others are accompanied by structural changes, which may ultimately lead to a shift in content.

Simon: I've been a part of the Helmholtz Association for eighteen years and the HZG is now the fourth centre where I have worked. Starting out as a professional engineer, I tended to move more and more towards management over the years. The position as HZG's Administrative Director is now the logical conclusion – in a centre that I have known well and for a long time. So we are both new in our positions, but familiar. It's terrific to be accepted by the HZG staff in such a warm and friendly way.

You assumed office at the start of the strategic evaluation within the framework of the Helmholtz Association's two-stage review process by international experts. What are the main results of this process?

Rehahn: We are traditionally very well positioned in the field of materials research. We are a world leader in the development of magnesium or titanium-aluminium alloys. Biomaterials at the Teltow and Geesthacht research sites also performed very well. If selected innovations can be successfully transferred into clinical practice over the next few years, this would be unique worldwide. Polymer research, which includes highly selective membranes for high-performance separation processes, is also regarded as extremely positive. There are numerous promising fields of application of the highest relevance: for example, separation of CO_2 (carbon dioxide) and H_2 (hydrogen) from gas mixtures, or obtaining valuable resources from seawater. Furthermore, the topic of hydrogen will play an increasingly important role in the future, holistically, from generation to storage and utilisation. We will thereby be cooperating closely with a new DLR institute, which will be set up on the Geesthacht premises. Here, as in other fields, the leading position in structural research with photons and neutrons suits us very well. In addition, the HZG is outstanding in coastal research. Additional strengthening could be achieved if the profile was further sharpened, synergies were used more extensively and unique selling points were even more clearly carved out. In addition, it is planned to link coastal research more closely with the Climate Service Center (GERICS). This combination would result in a globally unique position.

What weaknesses did the evaluation reveal? What challenges must be overcome?

Rehahn: One very important point is that we must involve society much more closely in what we do as researchers. This does not merely mean that we must make a more concerted effort to present our research in a more comprehensible manner. It rather means that we should, for example, invite citizens into discourse, where they bring in their own ideas and thoughts. In doing so, we can learn where societal and political priorities lie. What do people expect from science, such as from regenerative medicine? And what are the concerns and fears, for example on the subject of climate change? With GERICS, we have a pioneer who has been engaged in consistent climate communication and shaping the dialogue with society for more than ten years. Materials research, for example, can learn a lot from this. But we also need to become more visible on the political stage, at both state and federal levels. So far, we have only had a medium-level presence in this area.

Rehahn: We must involve society much more closely in what we do as researchers.

ABOUT:

Prof Matthias Rehahn has been scientific director of the HZG since September 2019. Prior to this, he was professor of macromolecular chemistry at TU Darmstadt. He also headed the Deutsche Kunststoff-Institut (German Plastics Institute) and was vice president of the German Federation of Industrial Research Associations (AiF). Rehahn has been associated with the Helmholtz-Zentrum Geesthacht since 2008 – first as chairman of the Technical Scientific Council and then as a member of HZG's Supervisory Board.

ABOUT:

Silke Simon has been HZG's Administrative Director since April 2019. The trained engineer began her career in private construction companies. She then moved to the Helmholtz Association. She initially worked for the German Aerospace Center (DLR) as head of construction and operations. Afterwards she headed the Central Technical Infrastructure department at the Helmholtz-Zentrum München. She then headed the Technical Services and Central Purchasing at the Helmholtz Centre for Ocean Research (GEOMAR) in Kiel.

One central keyword in societal debate is "digitalisation": how well is the HZG equipped?

Simon: Some processes are not yet currently optimised in business administration. They contain too many loops and repetitions. That is why we have now set up a project to restructure and streamline the processes. We are striving to take our staff with us: everyone has the opportunity to help shape the project and get involved. And I see a great willingness to participate in this change.

Rehahn: Digitalisation has fundamental consequences for science. It will ultimately be a so-called game changer. In order to understand materials and substances fundamentally, from their molecular makeup to their behaviour in practice, we need to trace on the digital track what we have done over many years in extensive individual and arrays of experiments. We need to leave the age behind us when someone would go into the laboratory for an exclusively experimental doctoral thesis and says: we'll see what happens. We instead need to completely interconnect experiments and modelling together to develop innovative materials in a more targeted and efficient manner by orders of magnitude and at the same time make reliable predictions about their lifespan or recyclability. Meaningful modelling, however, requires an extremely large amount of high-quality measurement data. We have yet to generate this wealth of data and learn how to handle it intelligently. To do this, we need artificial intelligence, for example. To be successful in this field will help decide whether our society can continue to offer the world competitive products in the future.

Does digitalisation also play an increasingly prominent role in coastal research?

Rehahn: Of course - but coastal research is already much further along. Computer models have been used for a long time. After all, people want reliable forecasts, want to know what impact climate change will have, or know how high to raise the coastal dikes. This can only be done with computer models, so coastal and climate research has long been working with a great deal of computer support. Materials science should be able to benefit from this.

New specialists are needed to meet these challenges. However, as is well known, there is a lack of specialists in Germany. Is HZG affected by this issue?

Simon: In concrete terms, this isn't yet a real a problem. The HZG is still an attractive employer. The shortage of skilled staff, however, is gradually becoming more and more perceptible to us. In some areas, for example, it is hardly worthwhile to advertise a position for a limited period of time. And because the shortage of skilled staff is likely to become more acute in the future, we are in the process of restructuring our Human Resources department and expanding the topics of training and professional development as well as career promotion. As far as the social component is concerned, we have already done quite a bit, for example, by offering more flexible working models. But of course, we want to improve this continuously and provide more opportunities, such as training and development for managers.

Simon: The HZG makes an important contribution to the issue of sustainability.

Rehahn: A particular challenge will be to attract creative professionals who have a sound knowledge of the latest methods of modeling and artificial intelligence. Such specialists are currently in incredible demand. We want to attract them by offering them a special environment: a environment in which they can directly compare the results of their computer models with the results of real experiments and thus develop their models in a targeted and rapid manner. These synergistic interactions between theory and practice are our special strength.

In Germany, there are general complaints that there are too few start-ups and spin-offs. Is this also an issue for the HZG?

Rehahn: In this area I think our centre has a great deal of catching up to do. If you look around, the HZG has an enormous pool of great and practice-relevant ideas. These should actually create a constant flow of start-ups in the coming years. To achieve this, however, we need to create a greater awareness among our scientists that setting up a company can be interesting. This requires significant further development on the administrative side as well.

Simon: We advise potential start-ups on both legal and tax issues and inform them of possible funding support. Unfortunately, we are sometimes involved too late, which makes cooperation a little more difficult. In order to optimise the situation, we are in the process of establishing technology transfer officers in the individual institutes. They will meet regularly, for example to identify interesting ideas for spin-offs and the need for support.

©HZG/Steffen Niemann

Rehahn: Society, the economy and science are currently undergoing a fundamental change.

In short: where do the greatest challenges lie for the HZG and where will there be changes?

Simon: Scientific institutions need to increasingly ask themselves how their resource consumption can be justified and how it can be reduced. With its research priorities, the HZG makes an important contribution to the issue of sustainability – it is personally of central importance to me that the academic world itself is also sustainable, because sustainability is a dimension of quality. In the future, it will become increasingly important in funding decisions for science. We want to prepare ourselves for this.

Rehahn: Society, the economy and science are currently undergoing a fundamental change. In some regions in the world, this process is considerably more advanced than in Germany. This is precisely the great challenge for the HZG as well. We need to completely rearrange the way we work. I predict that the way we work at our centre in ten years will have very little in common with how we work now. We will also need to give up certain research areas and initiate new ones. In order to do this, we need to continually train people here so that they can make their outstanding contribution in a new system with new questions. We should see all this as a great challenge in a positive sense.

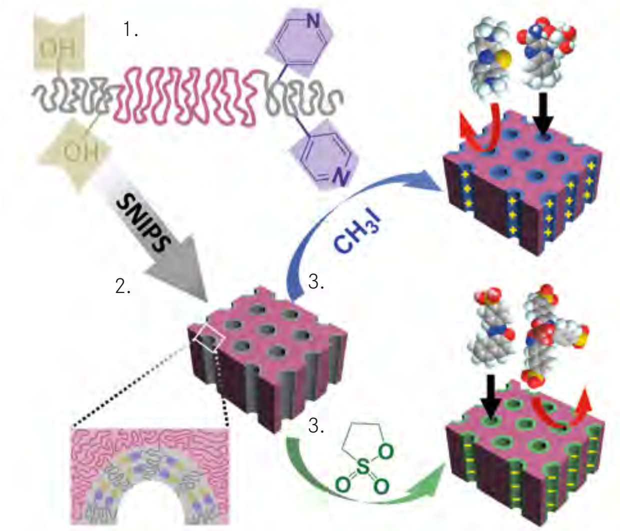
The interview was conducted by Frank Grotelüschen.

News from the Centre

The Charge Is What Counts: Membrane Removes Small Organic Molecules

Many organic molecules, such as textile dyes or drugs, measure no larger than one or two nanometers. This is what makes their extraction and purification on the industrial scale or their filtration from wastewater so demanding. Zhenzhen Zhang from the HZG Institute of Polymer Research has studied this issue and published a new study in the journal *Advanced Materials*. The doctoral student has developed a membrane that not only separates such molecules by size, but also by their charge. Using differently charged but comparably sized organic molecules, she was able to show that her membrane separates very selectively.

Initially, Zhang produced tailor-made polymers with three different blocks, so-called triblock terpolymers. The doctoral student added different functional groups to the blocks located at the ends. Afterwards, the multifunctional nanochannels in the membrane were formed by self-assembly of block copolymers combined with nonsolvent-induced phase separation (SNIPS): the triblock terpolymer dope was cast onto a fleece. As soon as the solvent evaporated and the cast fleece was subsequently sunk into a water bath, small tubes were formed which "grew" vertically downwards from the surface. A subsequent treatment provides the functional groups along the nanochannels with a positive or negative charge.



Scheme of membrane production: 1. Synthesis of tailor-made triblock terpolymers, 2. SNIPS: the functional groups of the triblock terpolymers (-OH, -N) fit exactly into the pores, 3. Subsequent treatment: after treatment with methyl iodide (CH_3I) or propane sultone ($[CH_2]_3SO_3$), the pore tubes are positively or negatively charged and selectively allow the riboflavin or monovalent orange II to pass through. © HZG/Zhenzhen Zhang

Publication:
doi.org/10.1002/adma.201907014

Programmable Biomaterials for Bone Regeneration Introduced

Specifically programmed materials can, under specific conditions, encourage stem cells to transform into bone cells, as revealed by a research team from HZG´s Institute of Biomaterial Science. To do so, the scientists implemented a so-called shape-memory polymer in stem cell research. They used a polymer sheet with an unusual function: it is trained to reversibly morph when exposed to repeated temperature changes.

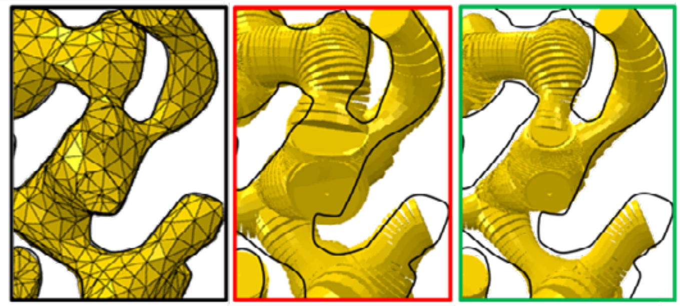
“The programmed polymer sheets could, for example, later be used to treat bones broken so severely that the body can’t repair them by itself,” says Professor Andreas Lendlein, one author of the study, which was published in the renowned journal *Proceedings of the National Academy of Sciences of the USA*.

Publication:
doi.org/10.1073/pnas.1910668117

Nanoporous Metals Precisely Measured

Nanoporous metals are complex, sponge-like materials with many branches of what are known as ligaments (see image). Scientists study how the respective structure - for example, the ligament thickness or the number of branches - effects the mechanical behaviour. How much pressure can such a material withstand? How does the structure deform based on the shape of the individual ligaments?

In order to find out, computer simulations are carried out at the HZG in addition to classical experiments. Researchers from the Materials Mechanics division have tested two known algorithms and a new, specifically developed algorithm using sixteen model structures to facilitate analysis of an important parameter: the thickness of individual ligaments. Subsequent artificial neural network training ultimately led to an even more precise calculation of the actual thickness - this enabled the scientists to close a gap in knowledge.



On the left, a small section from a tomography image is shown. Depending on the evaluation algorithm used, the thickness values assigned to the ligaments are too large (middle) or, in places, too small (right). The original values can be reconstructed with the help of artificial neural networks.

"We are making an important contribution to precisely measure filigree structures at the microscopic level. Imaging methods are getting faster and better, but reliable algorithms for evaluation are still missing. For example, this is essential in medicine to monitor in vivo how metallic biomaterials are broken down," says Claudia Richert. The doctoral candidate works in the Materials Mechanics department and is first author of the study, which has now been published in the scientific journal *Frontiers in Materials*.

Publication:

doi.org/10.3389/fmats.2019.00327

New Method for Converting CO_2

Converting the greenhouse gas carbon dioxide (CO_2) to methane can be considerably improved by using certain metal hydrides. This has now been demonstrated in a study by scientists from the Centro Atómico Bariloche in Argentina and the HZG. These results have been published in the journal *Physical Chemistry Chemical Physics*.

If we wish to limit the climate's warming to 1.5 degrees Celsius, we need to reduce the emissions of the greenhouse gas CO_2. In order to achieve this aim, several approaches have already been studied. One of the most attractive technologies identified converts the CO_2 into other substances.

One example of this is methanation. In this process, carbon dioxide and hydrogen react with each other to form methane and water. Energy can be temporarily stored in methane, which after being distributed via the natural gas network, can be used in both households and industry.

A catalyst is required so that the methanation runs as quickly and precisely as possible. The scientists have focused in this study on magnesium-iron hydride, a complex metal hydride that can be produced cost-effectively and can be easily transported.

"Complex metal hydrides are promising catalysts and suppliers of hydrogen for converting carbon dioxide into methane," says Dr Martin Dornheim, materials scientist at the HZG and co-author of the study. "Using the magnesium-iron hydride, we could completely convert the CO_2 at 400 degrees Celsius within five hours."

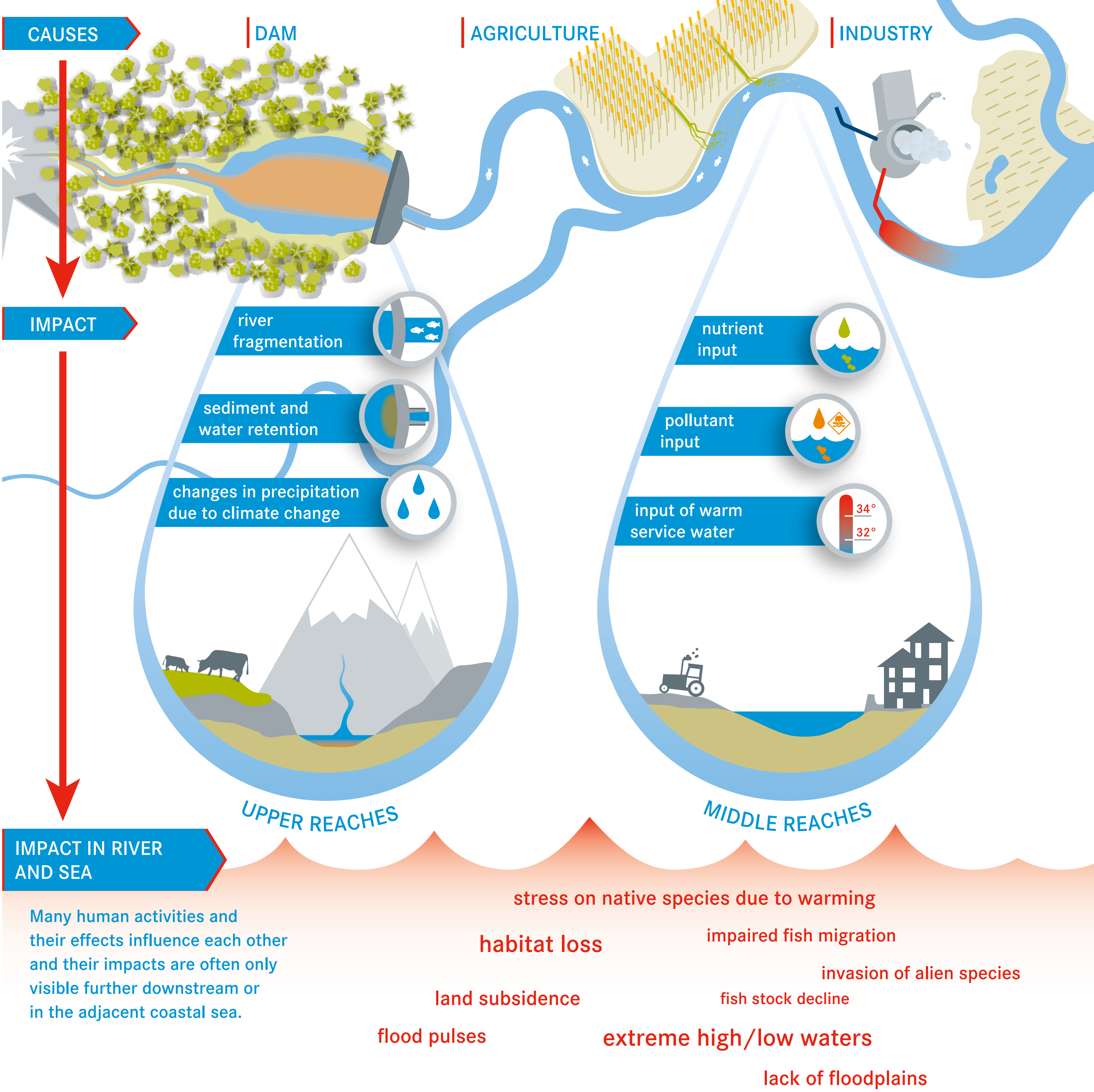
The study was carried out within the framework of the CO_2MPRISE project.

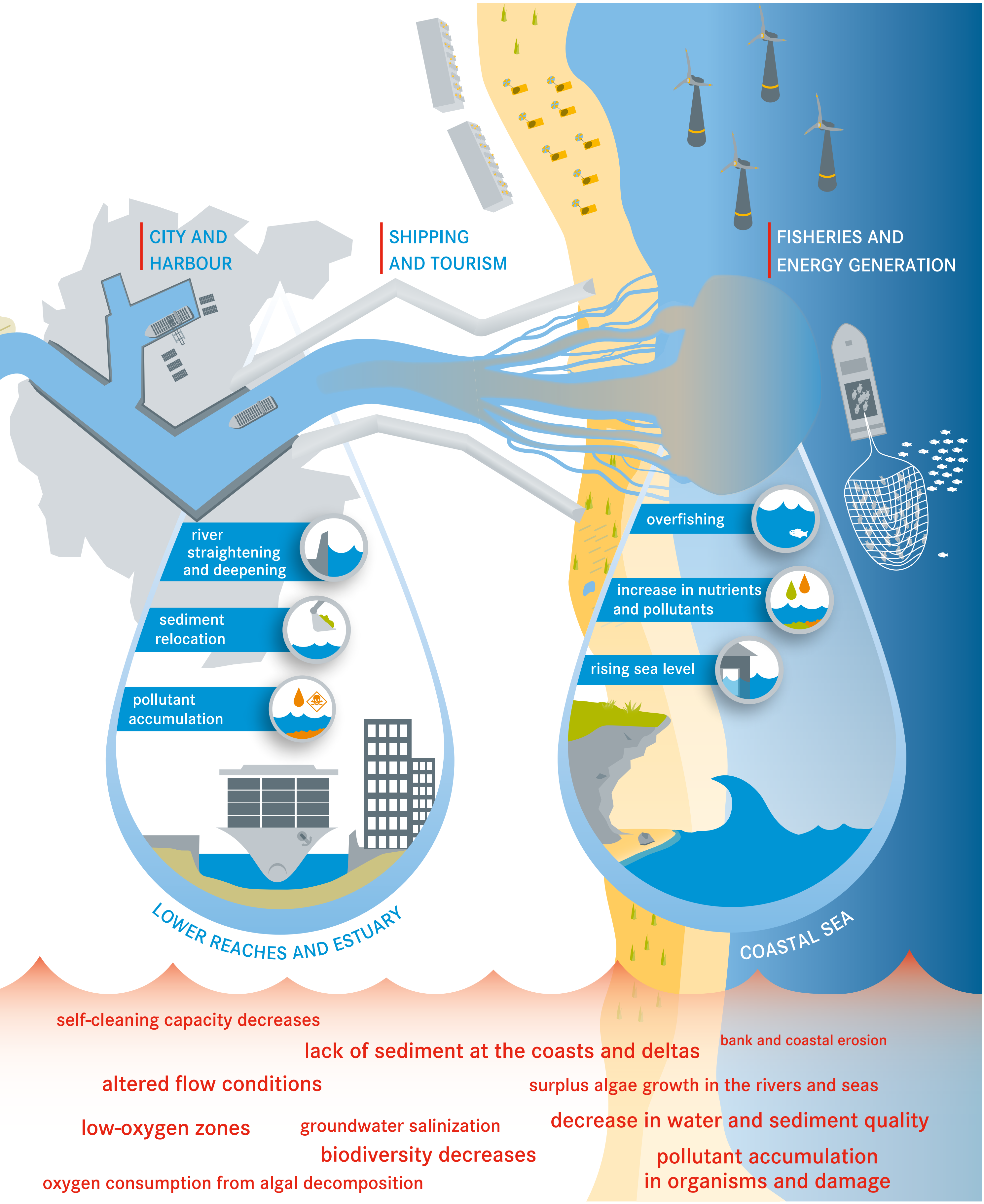
Publication:

doi.org/10.1039/C9CP03826D

From Source to Sea

Rivers transport dissolved substances, sediments, nutrients and artificial substances from land into the sea. Human activities alter habitats on and in the river and sea in a variety of ways - impacting nature and utilisation. In the project DANUBIUS-RI (see p. 24) scientists across Europe explore how river-sea systems change, and they develop solutions for sustainable use and protection of these indispensable ecosystems.




CITY AND HARBOUR
SHIPPING AND TOURISM
FISHERIES AND ENERGY GENERATION
river straightening and deepening
sediment relocation
pollutant accumulation
LOWER REACHES AND ESTUARY
overfishing
increase in nutrients and pollutants
rising sea level
COASTAL SEA
self-cleaning capacity decreases
lack of sediment at the coasts and deltas
bank and coastal erosion
altered flow conditions
surplus algae growth in the rivers and seas
low-oxygen zones
groundwater salinization
decrease in water and sediment quality
biodiversity decreases
pollutant accumulation in organisms and damage
oxygen consumption from algal decomposition

Mission Impossible? The European Water Puzzle

An innovative research infrastructure for advanced studies of rivers and their adjacent coastal seas

Rivers, estuaries, deltas and coastal seas connect more than three quarters of the Earth's land surface with the oceans. Most of the world's population lives close to rivers, lakes, estuaries and deltas, as well as along coasts, where many of the world's megacities are located. Rivers and seas are intrinsically linked through transfers of water, sediment, organisms, nutrients and artificial substances such as pollutants. Everything that happens in the upper part of a river has an impact further downstream and even on the sea into which it flows.

This natural connection between land and ocean is essential for humankind. Humans alter rivers and coastal seas for their benefit, which impacts the environment. However, rivers, estuaries, deltas and coastal seas are still researched and managed largely independently, without consideration of the wider consequences – this is why scientists in Europe no longer want to study rivers and seas separately, but as a continuum, as river-sea systems. An enormous pan-European research infrastructure project bears the name DANUBIUS, in reference to the Latin name Danuvius for the Danube, as that is where the idea germinated.

Ms Friedrich, what are the challenges we are facing in river-sea systems?

Jana Friedrich: Climate change as well as industrialisation and urbanisation, energy generation and shipping, agriculture and fisheries create many problems, which are affecting river-sea systems. For example, dams for hydropower generation and drinking water reservoirs, which humans need, are hindering the natural flow not only of water but also of sediments. These are then missing further downstream, leading, for example, to shrinkage of deltas and coastal erosion. The dams are interrupting the connectivity within the river-sea system, making it difficult for fish to migrate. Another problem is the increase in occurrence and magnitude of extreme events like floods, storm surges and droughts, due to climate change. The challenges are to ensure sufficient flow of water and sediment of good quality for humans and nature from the source to the sea, to promote resilience to extreme events and to deal with the multitude of pressures and their interactions. The biggest challenge, however, is to balance human use and protection of river-sea systems.

It sounded like mission impossible, so I said: "Let's do it". It was and still is a huge challenge but it is an exciting one!

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ABOUT:

Dr Adrian Stanica is coordinating the DANUBIUS-RI project and since 2016 has been Director General of the National Institute of Marine Geology and Geoecology (GeoEcoMar) in Romania. The geologist worked and lived in Italy for several years before joining GeoEcoMar. His main interests lie in research on coastal morphology and sedimentology and in integrated coastal zone management. He possesses considerable experience in research management, including coordinating international projects. He has also worked as a science journalist for the BBC (British Broadcasting Corporation).

Note from the editors:
The current challenges we are facing in river-sea systems are shown in the infographic on pages 22-23.

The biggest challenge, however, is to balance human use and protection of river-sea systems.

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ABOUT:

Dr Jana Friedrich is coordinating the HZG's contribution to DANUBIUS-RI. She studied geochemistry and mineralogy at the TU Bergakademie Freiberg, followed by a PhD at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI). After positions in Switzerland and at GFZ Potsdam, where collaboration with GeoEcoMar began, and as a senior scientist at AWI in Bremerhaven, Jana Friedrich began working at the HZG's Institute of Coastal Research, Biogeochemistry in Coastal Seas. Her research expertise comprises aquatic systems under global change, aquatic nutrient cycles, radiochemistry, in situ observation systems, natural disasters and coordination of international research teams.

Where did the idea for DANUBIUS come from?

Adrian Stanica: The founder of GeoEcoMar, the research institute in Romania, which I am leading now, had the idea of transforming the Danube Delta into a natural laboratory. The Danube Delta has been a biosphere reserve and a World Heritage Site, but managing it was complicated. It was clear that we needed to manage the river, the delta and the sea together as one system. In 2010, Romania declared it as a top priority to develop a research center. Then we started cooperation with other partners such as HZG. In 2013, the idea gained the status of flagship project in the EU strategy.

Jana Friedrich: In 2016, DANUBIUS-RI then was included in the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI). This is like a European quality stamp saying Europe needs such a research infrastructure for the coming decades to be at the forefront of science. It opens the door to funding sources that would otherwise not be available.

DANUBIUS brings together not only earth sciences, life sciences, numerical modellers, and engineers, but also social and ecological sciences – why should these different researchers together study river-sea systems?

Adrian Stanica: Scientists have been working either on rivers or on seas. That is why we don't have a good understanding of river-sea systems from the source to the sea. But whatever you do upstream has an impact further downstream – these activities cannot be separated from one another. Matter, such as sediments and pollutants, is even further transported into the sea. That is why it is important to understand how rivers are affecting the coastal seas. But there are very few research groups around the world connecting freshwater, transitional waters and coastal seas.

Is it difficult to bring all these various sciences together?

Adrian Stanica: From my point of view, one of the most significant weak points in our scientific communities in Europe and globally is that we don't listen to each other. Sometimes we use the same word but we understand different things. That is why communication, which also involves listening, is so important, especially in such an interdisciplinary project.

What does research infrastructure mean?

Adrian Stanica: A research infrastructure (RI) is any type of equipment, facility or lab that will provide services and allow scientists to do scientific work, for example, to do experiments. We are building a research infrastructure, which is distributed across different countries in Europe. It's like a big puzzle – each of these countries has facilities, equipment and expertise needed to observe, analyse, simulate and manage river-sea systems. Some of these facilities are already existing, others have to be built. In the end, we want to put all of these pieces of the puzzle together, which then can be used by interested researchers studying various aspects of river-sea systems. The idea is to establish an infrastructure for future generations to work together.

You defined twelve so-called supersites, which are living labs and where you are looking at specific river-sea systems. Jana Friedrich, you are coordinating the Elbe-North Sea Supersite at HZG. What is so interesting about it?

Jana Friedrich: At the moment, the Elbe-North Sea Supersite encompasses the tidally influenced Elbe estuary, reaching from Geesthacht through Hamburg into the German Bight, as far as the influence of the Elbe goes into the North Sea. On one hand, the Elbe is the lifeline of the region serving the Metropolitan Area of Hamburg, which is economically very important. On the other hand, it is a heavily modified system which makes the Elbe-North Sea Supersite an interesting system to study. For example, continuous dike lines have existed since the 13th century on both banks of the lower river. In addition, the Elbe River is deepened and dredged so that big ships can enter the Port of Hamburg. More than half of the catchment is used for agriculture. The Elbe receives lots of nutrients fuelling algae growth. As a consequence of all this human intervention, the conditions in the river changed completely, leading, for example, to low oxygen and high turbidity in the Hamburg port area and downstream during summer, which has a number of negative implications.

I guess there will be a lot of different data. How can you compare the data?

Adrian Stanica: We will develop and implement the so-called DANUBIUS Commons, a common set of methods and tools, so that data is generated, which can then be compared. This is one of the main challenges between different river-sea systems worldwide.

©HZG/Jana Friedrich

At the source and in the upper part of the river the water is usually still clean and free of pollutants.

Can the results from European river-sea systems be transferred to other systems in the rest of the world?

Adrian Stanica: The supersites are specific areas where we can develop, test and apply our methods and tools to better understand how river-sea systems are functioning, how they are changing and what could be done to improve their state. These methods and tools can then be used also for other river-sea systems.

After the three years of preparatory phase funding, what have you achieved so far?

Adrian Stanica: I think we are a bit more advanced than I hoped we would be when we started in 2016. For example, we developed DANUBIUS-RI's architecture and we started working on the DANUBIUS Commons. HZG and the University of Birmingham led the development of the Science and Innovation Agenda. We also prepared the statutes to apply for status as a legal entity – a European Research Infrastructure Consortium (ERIC). And of course, we started to bring together the community: scientists, stakeholders, representatives of governments.

Jana Friedrich: In addition, HZG applied already for infrastructural funding to build a research platform in Tesperhude at the Elbe, which will represent the first component of the Elbe-North Sea Supersite. We are extremely glad that the state government of Schleswig-Holstein has recognized the importance and granted our request. We will give our best to get the research platform up and running by 2021. This means one piece of the puzzle will be operational then.

Facts and Figures about DANUBIUS

30 partners from 16 countries

Coordination: National Institute of Marine Geology and Geoecology (GeoEcoMar), Bucharest, Romania

www.danubius-ri.eu

2016 – 2019	2020 – 2024	starting 2024
H2020 Preparatory Phase Project (DANUBIUS-PP)	Implementation Phase	Operational Phase (DANUBIUS-RI)

Overarching questions DANUBIUS-RI strives to answer

By posing these questions, DANUBIUS-RI addresses the following research topics regarding river-sea systems: climate change and extreme events, quality and quantity of water and sediments, hydromorphology, biodiversity, ecosystems and their services:

- How are river-sea systems changing due to climate change and human activities?
- How are human activities on land, in the river catchments, affecting rivers and seas?
- How do human activities in one part of the river-sea system influence other areas, both upstream and downstream?
- How do climate change and human activities affect the ecosystems of river-sea systems, their functioning and the services human take from them?
- How can we sustainably manage river-sea systems?

What are the next steps after the preparatory phase?

Adrian Stanica: On the European level, we will apply for status as an ERIC legal entity in early 2020, and we will develop the final concept. Whereas on the national level, we need to prepare, establish and connect the pieces of the puzzle, which together will then form DANUBIUS-RI. Some countries and institutions already have their facilities and equipment in place, like our German colleagues at HZG. Others need to upgrade their existing facilities and equipment. Provided the required funding resources will be in place, DANUBIUS-RI is expected to be operational around 2024. So we have three or four years of warming up and we are really looking forward to that.

Mr Stanica, you are already the director of a research institute in Romania. Additionally, you are coordinating DANUBIUS-RI. What is your personal motivation?

Adrian Stanica: It is part of my life already. I was asked back in 2010 if I am interested. It sounded like mission impossible, so I said: “Let’s do it”. It was and still is a huge challenge but it is an exciting one, bringing people together and trying to find solutions. I like being together with all these great people and experts, who are supporting DANUBIUS-RI. It feels like we are one big family.

Thank you for your time!

The interview was conducted by Gesa Seidel (HZG).

©HZG/Jana Friedrich

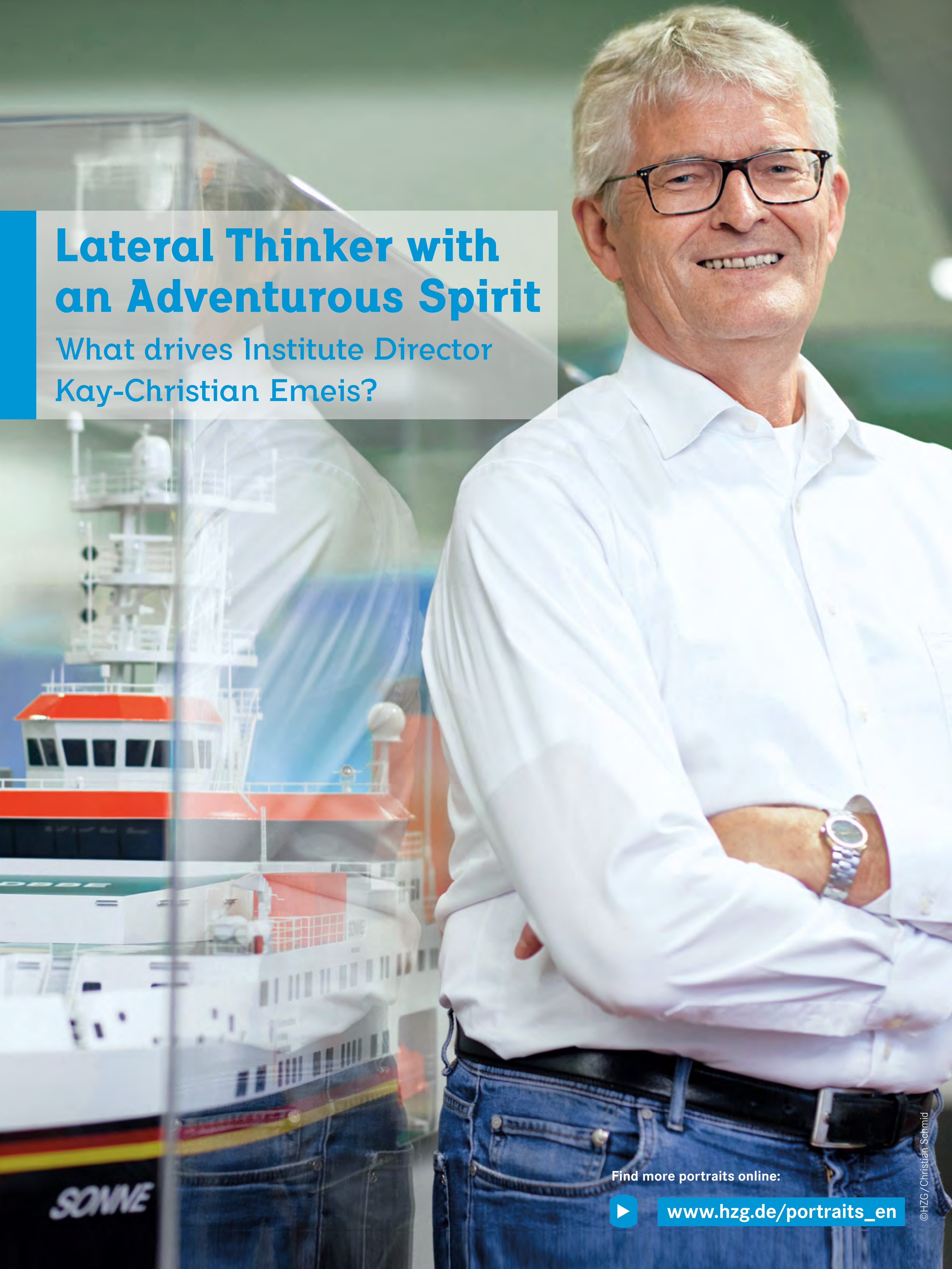
Throughout the entire river-sea system, for example, nutrients from agriculture or pollutants from industry can reach the coastal sea.

Further interviews, which are published in in2science can be found online:

www.hzg.de/interviews_en

Lateral Thinker with an Adventurous Spirit

What drives Institute Director Kay-Christian Emeis?



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Prof Kay-Christian Emeis

leads the division for Biogeochemistry in Coastal Seas at the Institute of Coastal Research

Many a discovery is made by chance. One example is when in fall 2019, the research vessel Sonne sails from Hong Kong to Mauritius. On board is Kay-Christian Emeis, institute director at the Helmholtz-Zentrum Geesthacht. The geologist has been looking forward to this journey for weeks - as it will be the last one for him in his post: the 64-year-old will be retiring in 2021.

Together with colleagues, he slides a measurement instrument into the ocean as dusk begins to settle. The team therefore switches on the deck lights. The light attracts flying fish, which dance on the water. Squids follow and hunt the nimble animals. "Suddenly mahi mahis appeared in the cone of light," says Emeis, as he remembers the large, blue-gold shimmering predators, which have a special predilection for eating squid. "And then sharks thrust into the light and snap for the mahi mahis. Within minutes an entire food chain had formed before our eyes - a spectacle to behold for any researcher."

It is moments like these that Emeis loves so much about his work: as a specialist in biogeochemistry, he wants to explore the complex connections that exist in different marine regions. How does the water's chemical composition affect living organisms and the formation of sediments? Which organisms and processes benefit from the respective substances? And how does this interaction change with the seasons - or over the course of millions of years? Research beyond the frontiers of his field has always fascinated the native of Flensburg: with a great deal of curiosity, he not only travels all the oceans, but soaks up the knowledge from entirely different disciplines, always on the lookout for surprising cross connections. As a student he not only took courses in geology, but was equally interested in palaeontology and mineralogy. His expeditions since the 1980s have led him into the Earth, into unknown cave systems as well as up to the sea, onto the deck of research and drilling vessels. The sensitive ecosystem of tropical coral reefs interests him as much as the absence of large schools of fish off the coast of Namibia; he is interested in the prehistory of the Mediterranean as well as the German mudflats of our time. "What drives me is my curiosity and a certain spirit of adventure," says Emeis. After all, the geology motto, according to which the present is the key to the past, also applies in reverse:

> **From the geological past we learn much about the future developments of our planet.**

In addition to his duties as geology professor at the University of Hamburg, he has also been leading the "Biogeochemistry in Coastal Seas" research division at the HZG for the last nine years. He still has ambitious plans before his retirement in the coming year: he is responsible for the Helmholtz Coastal Data Center (HCDC). This new digital platform is to combine the coastal research data from different institutions and disciplines. "In the next two years we want to become the main data center for the North Sea." There has, however, been a downside for Emeis throughout the years of growing responsibility: the number of his expeditions has dropped. For a long time now he has been sitting more often in conference rooms than in laboratories below deck. He loves life at sea despite the cramped space on board, which can sometimes become a problem for a man of his tall stature. "Ships have always been a part of my life, not only in a professional sense," he stresses. He learned how to sail as a teenager. As to whether he still must undertake some of the physically demanding jobs on board even as head of the institute, he replies: "Of course. That's the fun of it!"

> **Exposed to the wind and weather, even at three in the morning, because it's time for sampling - I like that!**

Which brings us back to discoveries that are sometimes made by chance. Because it was a coincidence that ensured Emeis was responsible for certain measurements on board the Sonne, as a colleague had fallen ill. And now the professor is sitting in front of the data. It comes from the bottom of the Mascarene Plateau in the Indian Ocean. The rocky reef just below the water's surface is the expedition's target and, despite its tropical location, it bears surprisingly few corals. The scientists have never been able to satisfactorily explain this deficiency. The researchers on board the Sonne therefore wanted to take sediment samples. "Taking my water samples, on the other hand, was a purely routine task," says Emeis, "which was to also collect data on this marine region - for example, density, temperature and nutrient content of the water."

Emeis notices how low the oxygen content is at some water depths - those locations possess unfavourable conditions for coral. Emeis sees two explanations: on the one hand, two ocean currents with very different oxygen and CO_2 contents mix at the plateau. On the other, the reef lies directly in the path of the South Equatorial Current in the tropical Indian Ocean. This current flows at high velocity over the plateau. In addition, the tides affect the seafloor in such a way that the water properties there change immensely twice a day, something that makes it difficult for coral to settle.

And so it is curiosity and the merging of different disciplines that added another piece to the marine science puzzle. This approach needs lateral thinkers and those who can tackle problems. Researchers like Kay-Christian Emeis.

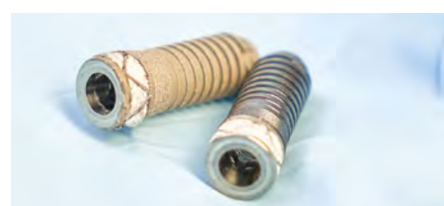
Author: Jenny Niederstadt

Advanced Solutions for Filling the Gaps

The body of a car that automatically repairs small dents. A metal door that makes nitrogen oxides harmless. A ship hull that removes pesticides from the water. And anti-bacterial implants. For now, this all still sounds like pie in the sky, but scientists around the world are investigating and developing new processes to enable the application of such intelligent materials. As a part of two EU projects and one bilateral collaboration with China, scientists from Helmholtz-Zentrum Geesthacht are working on the development of "smart" multifunctional coatings on magnesium and aluminium alloys. These coatings can, for example, be photoactive and use sunlight to transform dangerous chemicals. Or they can provide thermal and/or electrical conductive properties. Simultaneously, the coatings protect the active metallic material against corrosion.

The principle of this surface treatment appears simple: a piece of a metal is immersed in a bath, containing electrolyte, and a current is applied. This causes the oxidation of the metal and a hard, ceramic layer is formed on the surface. With plasma electrolytic oxidation (PEO), the science is in the details. Plasma is using not only components from the bath in order to form a new layer, but it also involves the modification of the metallic surface itself. This leads to a hard, strongly adhesive layer, which can be endowed with multiple properties.

Dr Serdechnova, the HZG scientist from the "Corrosion and Magnesium Surface Technology" department, explains: "PEO layers are characterised by complex microstructures: the plasma oxidises the metallic surface and causes the oxide layer formation, with increased hardness. Since layer formation occurs in an aqueous alkaline solution, without the addition of toxic compounds such as chromium, this makes the process especially eco-friendly." At the same time, PEO allows different nanoparticles such as layered double hydroxides (LDHs) to be introduced into the porosity of ceramic coatings, leading to the formation of coatings with improved functionality, such as photoactive or "smart" anticorrosion coatings. The latter is studied in another EU project, ACTICOAT: the goal of this research project is to fill the PEO pores with anticorrosive compounds to create environmentally friendly protective layers for the light metals, such as magnesium and aluminium. Maria Serdechnova says: "To apply these sensitive particles in the created PEO based microcontainers, very specific changes in the voltage and the process design are required. Many of the



pictures©HZG/Christian Schmid

A bone screw made of a magnesium alloy receives a PEO coating in an electrolyte bath. Clearly visible are the sparking discharges on the screw. The material oxidizes at the sparking points and over the course of time an oxide ceramic layer is formed, which protects the screw from corroding too quickly.

resulting aspects are difficult to predict.” The projects are investigating multistage post-treatment of active metals. For an effective result, some of the particles should be introduced into closed pores, and some into open pores. Releasing the inhibitors when the PEO layer is damaged allows for protection in a variable manner.

Alongside the development of the functionalised materials, a further project goal is the transfer of the technology to key industries such as automotive manufacturing, medical technology, or the chemical industry. A major point of focus is therefore the development of an interdisciplinary partnership between participants from both science and the private sector.

Author: Heidrun Hillen (HZG)

Before the PEO layers can be generated on the material, PhD student Tatsiana Shulha pre-treats the samples.

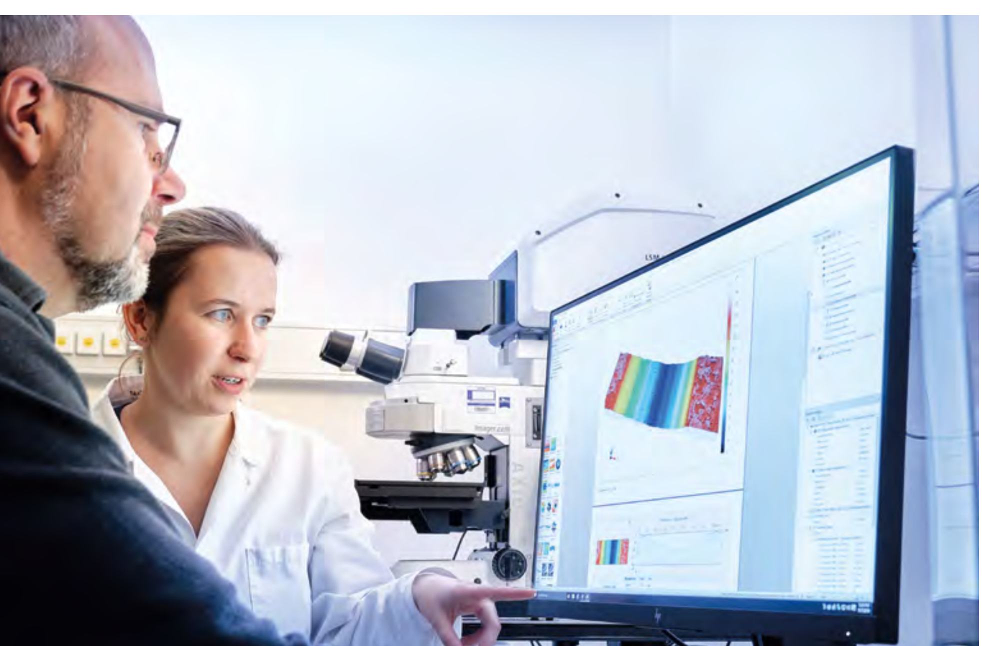
In the **FUNCOAT** project, multifunctional multi-purpose coatings for key industries such as transportation and bio-medicine are manufactured and additionally modified for different functionalities. The main idea of the project is based on optimised "green" PEO processing in order to develop coatings with multifunctional properties on industry-relevant light metal substrates such as magnesium, titanium or aluminum-based alloys. Eight partners from industry and science work together on solutions in the project.

www.hzg.de/ms/funcoat

The EU project **ACTIOCOAT** is dedicated to the development of new, environmentally friendly corrosion protection coating systems for light metal structures (Mg, Al) in automobile and aircraft construction. 4 partners from 3 countries are involved in the project.

www.hzg.de/ms/acticoat

The Joint Sino-German-DFG Research project includes the investigation and development of in situ formation of nanocontainers in the pores of PEO layers on magnesium substrates to achieve active corrosion protection.



Dr Maria Serdechnova checks the results together with her colleague Dr Carsten Blawert.

The focus of the research in Geesthacht is given to the surface treatment of active metals, such as magnesium and aluminium. Unfortunately, they are also highly reactive, and must therefore be specially treated for application in tribological or corrosion-dependent areas of industry.

Storm Surges & Climate Change

Online tool stormsurge-monitor.eu compares current storm surges with long-term developments

During winter, storm surges are a common phenomenon along the northern German coasts. For example, the residents of the "Halligen" tidal islands have adapted to regular inundations, and an almost continuous dike line effectively protects the mainland of the German North Sea coast against storm surge impacts. Over the last century, global mean sea level has been rising by about twenty centimetres and it is expected to further rise in future because of climate change. For strategic planning, long-term monitoring of sea level rise and storm surge climate is therefore essential. The Institute of Coastal Research at HZG has developed a new web tool, stormsurge-monitor.eu, which provides information on the extent to which current storm surges are unusual or still within the range of expected variability.

With the onset of the storm season in autumn, first storm surges are often observed along the German North and Baltic Sea coast. Because of the expected impacts of climate change, researchers are increasingly confronted with questions such as:

- Was the water level during the last storm surge exceptionally high?
- When do storm surges normally occur in winter?
- Is it normal that the water levels remain that high for so long?
- Has climate change already affected storm surges?

Questions like these are important when recent events are analysed and put into context. The new web tool "stormsurge-monitor.eu" continuously monitors storm surges, compares them with previous events, and puts them into a long-term perspective. "With only a few clicks, the user can see and assess whether and to what extent current storm surges and the course of the current storm surge are unusual," explains Dr Insa Meinke, head of the Northern German Coastal and Climate Office. Together with Dr Ralf Weisse, head of HZG's "Coastal Climate" group, and Dr Xin Liu, she has developed the online tool, which is freely accessible. The tool provides, for example, information on the number of storm surges that occurred so far within the current storm seasons and compares them with the number from previous years.

Ralf Weisse explains, "Over the last century, mean sea level along the German North Sea coast has increased by about twenty centimetres. Therefore, the same wind now leads to higher storm surge levels compared to approximately one hundred years ago. Similarly, less wind is needed to raise the water to storm surge levels. This leads to higher storm surge frequencies even if there is no change in storm activity."

The Storm Surge Season: 2019-2020

Initially, the current storm surge season in the North Sea was very calm. However, an extended storm period in February caused up to nine storm surge events depending on tide gauge. Thus, the number of storm surges in February 2020 exceeded the maximum number as observed in the same month in earlier years (1961-1990). Also, in regard to the entire storm surge season, more storm surges occurred compared to the long term mean of the reference period (1961-90). However, the frequency of the current season is still within the range of long term variability of the reference period and is, thus, not unusual.

The period of increased storm activity in early February also caused the highest water levels so far observed within this season. Depending on the location, these water levels are expected approximately every three to eight years. So far, only one storm surge has occurred at the Baltic Sea gauges in Warnemünde and Travemünde, which only reached water levels just above the storm surge level. This roughly corresponds to what we would expect on a long-term average.

©HZG/Michael Fritz

stormsurge-monitor.eu

The storm surge monitor web tool provides such analyses in near-real time. Data and analyses are based on available real time measurements provided by the responsible German authorities via the Pegelonline website. Measurements are automatically analysed daily and put in relation to long-term storm surge statistics. Presently, the analyses are provided for four tide gauges along the German North Sea coast (Husum, Helgoland, Cuxhaven and Norderney) and for two gauges at the Baltic Sea coast (Travemünde and Warnemünde).

The web tool:

www.stormsurge-monitor.eu

What are storm surges?

Storm surges are very high coastal water levels caused by the impact of wind and air pressure on the sea surface. The Federal Maritime and Hydrographic Agency issues a storm surge warning for the German North Sea coast when the expected water level exceeds the mean high tide by more than 1.5 metres. A warning for the Baltic Sea coast is issued when the expected water levels exceed the mean water level by more than one metre. Storm surge statistics may change in the course of anthropogenic climate change due to mean sea level rise and its regional and local characteristics as well as by changing wind conditions. In addition, other effects such as land subsidence or implementation of coastal engineering measures may contribute to changes in storm surge statistics.

Website of the North German Coast and Climate Office
(only available in German language):

www.kuesten-klimabuero.de

The Coating Expert

How to improve air quality through polymer research

Dr Juliana Clodt

scientist from the Process Engineering Department in the Institute of Polymer Research

Juliana Clodt stands in front of a steel frame with various rolls, over which runs a fleece material measuring more than two hundred metres long and up to sixty centimetres wide. A portion of this setup consists of various tubes and a furnace warmed to one hundred degrees. "That's it - our coating machine," says the 37-year-old proudly. She's been learning from her colleague Jan Wind for the last year and a half how to control the system. The engineer is soon retiring. A person must know, just as he does, every little screw on the apparatus - and Clodt is now getting very close. "The large machine instilled a great deal of respect in me at the beginning. I now know, however, very well which screws I need to turn to apply the different layers that give the membranes their desired properties," she says.

"We receive the most varying inquiries from research institutions and from the industrial sector, for example, for flue gas separation." The membranes are basically all structured the same: "We must initially produce the polymer solution that is poured inside the membrane casting machine on a fleece material. This fleece is then immersed in a water bath, whereby the membrane is precipitated and a porous structure is formed. The membrane is then cleaned and coated in three steps," the scientist explains. "The washed membrane roll is clamped in the coating machine and we first apply a silicone-based drainage layer. Then comes the actual active separation layer. For the entire roll we only need seven grams of the polymer, from which this extremely thin layer (measuring fifty to one hundred nanometres in thickness) is produced. Then the topcoat follows, which is used to mechanically stabilise the membrane. The solution compositions and the machine settings during each step are vital for success. After every coating, the membrane rolls once through the furnace to dry and cross-link the polymer coating," says Clodt. Depending on the requirements of the membrane, a different approach can be used to optimise the result. Sometimes it's clear immediately what needs to be changed, but it is often a longer process.

> **I need distance to be creative. The best ideas come to me when I'm doing something entirely different.**

"In 2012 we wanted to develop a membrane in which the pore size could be controlled by temperature as well as by the pH value. The question was how I could dock a molecule that reacts to temperature to a membrane that reacts to the pH value. The idea as to which chemical reaction I needed came to me when painting a balloon for a birthday party" - this resulted in her first scientific publication at the HZG.

As a small child, Juliana Clodt wanted to work in agriculture or as a veterinarian - the desire seemed obvious, as she grew up on a farm near Unna. "But in school, I had already found chemistry fascinating - we undertook a great deal of practical work in the advanced course." Following this path, she studied chemistry at the University of Münster, where she also earned her doctorate.

> **I was especially enthralled by organic chemistry. It was always fun to discover how the molecules would react with each other.**

Clodt always had a special interest in the subject of polymer chemistry. "The postdoc position at the HZG came in 2011, right on cue." Here she learned how to produce block copolymer membranes and she built a protein measurement stand. She has been working in the Process Engineering Department since 2016, where the chemist produces what are known as thin-film composite membranes for gas separation, currently for separating the greenhouse gas carbon dioxide. The mixture of writing and practical work in the membrane casting hall is the perfect fit for her.

During her PhD studies the chemist studied in Amsterdam for six months in 2009 within the framework of a "Graduiertekolleg", an international research graduate programme. By then Clodt had noticed that she belonged in a big city. Today she lives with her family in Hamburg. She and her husband have been together prior to university, and today they have a son and a daughter. Something was clear to the couple: "We take care of the household, children and job on equal footing. We both work about thirty hours a week - the kids benefit from that." It is also clear to the mother that profession and work remain separate. "When I'm off in the evening or on vacation, I'm usually unreachable. It wouldn't work for me any other way." In her free time, she likes to play guitar in her band. And while doing so, who knows what ideas might still come to Juliana Clodt concerning her work in polymer research.

Author: Gesa Seidel (HZG)

“Climate-Relevant Research Must Be Interdisciplinary”

In the Helmholtz Association’s Climate Initiative, mitigation of climate change and adaptation to the consequences of climate change are comprehensively researched.

Extreme events such as droughts, heavy rains and flooding are occurring more frequently today as a result of climate change. Other impacts of climate change are also severe, affecting various sectors, including transportation, agriculture and health. With the Climate Initiative, the Helmholtz Association is addressing one of the greatest societal challenges of our time: climate change. The focus is on the avoidance and reduction of emissions and on the adaptation to climate change impacts.

The scientific community agrees that temperatures will continue to increase unless strong mitigation efforts are implemented. It is up to society to mitigate this change and to adapt to the impacts, which are already noticeable today and will be unavoidable in the future. Within the framework of the 2015 United Nations Climate Change Conference in Paris, it was agreed that the planet’s warming should be limited to well below 2 degrees Celsius, or 1.5 degrees Celsius, compared to pre-industrial levels. This target can only be achieved if greenhouse gases, mainly carbon dioxide (CO_2), are clearly reduced.

Climate-relevant research, however, is conducted not only in the areas of climate, coastal and marine studies. Scientific innovation from materials sciences and polymer research is also necessary, which becomes clear in this new interdisciplinary project, initiated by the Helmholtz Association. The Climate Initiative, launched in July 2019, has received twelve million Euros from the Helmholtz Association president’s Initiative and Networking Fund. Fourteen Helmholtz centres are participating. This is so far the largest cross-centre initiative for the entire association.

The Climate Initiative focuses on three areas: “Avoiding Emissions”, “Adaptation to Climate Consequences” and “Communication”. In all these areas, researchers are cooperating and conducting holistic research on climate change – as climate change affects many areas (of life).

Avoiding Emissions: “Net Zero 2050”

The “Net Zero 2050” cluster, the area of “Avoiding Emissions”, is led by Prof Daniela Jacob. It connects associated research within the Helmholtz Association to support reaching the target of “net zero CO_2 emissions by 2050” in Germany. Of course, other research activities – outside Helmholtz –are necessary in addition to political dialogues, governmental frameworks and sustainable business practices.

“Within the scope of ‘net zero 2050’, we want to scientifically investigate strategies and new methods for removing CO_2 from the atmosphere supporting, the German framework require-

HELMHOLTZ KLIMA INITIATIVE

Participating Helmholtz Centres:

German Aerospace Center (DLR) • German Cancer Research Center (DKFZ) • German Center for Neurodegenerative Diseases (DZNE) • Karlsruhe Institute of Technology (KIT) • Forschungszentrum Jülich (FZJ) • Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) • GEOMAR Helmholtz Centre for Ocean Research Kiel • Helmholtz-Zentrum Berlin (HZB) • Helmholtz-Zentrum Dresden-Rossendorf (HZDR) • Helmholtz-Zentrum Potsdam, German Research Centre for Geosciences (GFZ) • Helmholtz Centre for Infection Research (HZI) • Helmholtz-Zentrum Geesthacht, Centre for Materials and Coastal Research (HZG) • Helmholtz-Zentrum München, German Research Center for Environmental Health (HMGU) • Helmholtz Centre for Environmental Research (UFZ) • Max Delbrück Center for Molecular Medicine in the Helmholtz Association (MDC) ments," says Daniela Jacob, head of the Climate Service Center Germany (GERICS), a scientific organizational entity of HZG. "We will identify and present key topics and examine previously proposed methods and ideas. In this manner, we want to advance promising technologies relevant to the development of a national net zero strategy, but we also want to gauge their associated effects to provide a basis for balanced decisions." Two case studies are planned. One will provide a strategy for a climate neutral city and the second will examine how the Helmholtz Association as a whole can become climate neutral. "Climate-relevant research must be interdisciplinary," says Jacob. This is why HZG experts from GERICS, the Institute of Coastal Research, the Institute of Materials Research and the Institute of Polymer Research are contributing to "Net Zero 2050". Furthermore, nine additional Helmholtz centres are collaborating closely in the four projects of "Net Zero 2050".

Project 1: Roadmap and Scenarios. This project, led by GERICS, will scientifically evaluate the measures investigated in the other "Net Zero 2050" projects for the reduction, extraction, storage and use of CO_2 and bring them together in a web atlas. Models and methods will be developed for integrated scenario analyses on net zero emission pathways. Aspects of marketing design, regulatory framework conditions and the resulting investment incentives are also incorporated as well as user perspectives on key social aspects.

Project 2: Approaches Towards Carbon Recycling. Two methods for extracting CO_2 from the atmosphere are studied in this project. The CO_2 is then to be converted into chemical energy sources with a high energy density using renewable energies. The HZG's Institute of Polymer Research participates here by researching, among other areas, CO_2 separation through the use of membranes.

What does "net zero" mean?

• In order to achieve the targets set forth by the Paris Agreement by the year 2050, net emissions of the greenhouse gases (CO_2, methane and others) must be reduced to zero.

• Net zero means that all further unavoidable greenhouse gas emissions are to be removed from the atmosphere, thus making the Earth's climate balance net zero (after deduction of natural and artificial sinks).

• By using technology, CO_2 can be extracted from the atmosphere and stored. These stored emissions are called "negative emissions".

• The later net zero is achieved, the more negative emissions are required.

Project 3: Potential and Integration of Subsurface Storage Solutions. With the shift from fossil fuels to renewable energies, energy storage becomes increasingly vital. The salt caverns in which gas and heat have so far been stored are only available to a limited extent. An alternative would be the porous groundwater layers that exist in many parts of Germany. How that would be technically and economically feasible, however, will be studied in Project 3, to which HZG's Institute of Materials Research is contributing.

Project 4: Storage Solutions in Nature. In cooperation with GERICS, the potential of natural terrestrial and marine systems to reduce CO_2 emissions and to store carbon is assessed. This analysis will also include the impact of measures for achieving the net zero targets in Germany.

Adaptation to Climate Change

In this area, adaptation options and strategies will be developed for various aspects of life such as health, agriculture, energy supply or transport. This field of activity is led by Prof Georg Teutsch from the Helmholtz Centre for Environmental Research (UFZ).

In collaboration with scientists from other Helmholtz centres, researchers from the Institute of Coastal Research and GERICS will actively contribute to these activities. GERICS will provide the necessary regional climate change information. The Institute of Coastal Research will develop a "storm monitor" – an online tool to help assess wind and storms on a scientific basis. Users will be able to see here whether a current storm can be considered an extreme event in relation to the past and whether or not it can therefore be regarded as a consequence of climate change.

Communication

The aim of the Climate Initiative's third area is to establish Helmholtz as a source of expertise and information and as a communicator on important issues of climate research and climate change.

Becoming More Climate Friendly, Step by Step

Light metal components made in Geesthacht

A new group in HZG's Institute of Materials Research is involved in the manufacturing of light metal components. Their leader is Prof Noomane Ben Khalifa, mechanical engineer and professor of manufacturing technology at Leuphana University in Lüneburg. One of his group's main research areas is to find customised manufacturing methods and process routes for the materials developed at the institute, which should also conserve resources.

The modern metal industry consumes a great deal of resources and produces large quantities of CO_2. For producing just one ton of crude steel, 1.7 tons of CO_2 emissions are generated. This contrasts with the fact that by 2030, industry must reduce its greenhouse gas emissions by approximately half compared to 1990. This, at least, is what the German government's climate protection plan stipulates for the industrial sector. This sector is therefore searching for ways in which to become more sustainable and climate friendly. This can, on the one hand, be done using skilful alloy development, but on the other, by adapting the processing steps, whereby the manufacturing technology is tailored to the materials.

From Antiquity into the Future

Metallurgy in itself is nothing new. Humanity began to utilise metals some ten thousand years ago, working the material through forging, hammering and rolling. Even as early as the Copper, Bronze and Iron Ages, humans had figured out that the properties of their sword or plough could be altered through the respective fabrication process. The tools became harder by heating them several times, or sharper if they used additives such as ash.

The experiential knowledge from forging ultimately led to material innovations. Even today such innovations often arise through new or improved materials and from the associated processes and machining work. Noomane Ben Khalifa explains, "One example of innovative materials are lithium-ion batteries used in electric cars and smartphones. Today's batteries can be charged more quickly and have a longer lifespan than those of a few years ago. The speed of innovation has increased enormously. Products wind up on the shelves much faster than thirty years ago. Modern industries must keep up with this tempo." Ben Khalifa also sees potential for production engineers in small and medium-sized metal industry businesses, where the trend is turning away from mass production towards flexibility and indi-

ABOUT:

Prof Noomane Ben Khalifa

After completing his mechanical engineering studies at the TU Dortmund in 2005, Noomane Ben Khalifa worked as a researcher at the the Institut für Umformtechnik und Leichtbau at TU Dortmund. There he finished his doctorate in 2012. Since 2018 he has been professor at Leuphana University in Lüneburg and is head of a working group at the Helmholtz-Zentrum Geesthacht.

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Noomane Ben Khalifa (second from the left) in conversation with scientist Merle Braatz (left) and doctoral students Jonas Isakovic and Danai-Glykeria Giannopoulou (right).

vidualisation. The components or products manufactured in small quantities should be affordable and also be produced in a manner that conserves resources.

New Technologies for New Materials

Due to climate change, lightweight materials are in demand in automotive engineering. For example, reducing the weight of a car by just three hundred kilograms will lower its fuel consumption by approximately one litre per one hundred kilometres and the CO_2 emissions by two kilograms. Lightweight engineering, however, has its challenges. Structural components of a car body, for example, can be made lighter by using new materials, but they must also be strong enough to protect occupants in an accident. Noomane Ben Khalifa says, “Our colleagues in the institute develop new, lightweight materials, and we analyse the further process chains, asking ourselves which screws we can adjust.” This is because the new materials, due to their formability and mechanical strength, are often more difficult to process. This sometimes requires entirely new forming technologies so that the sheet metal for the car bodies can actually be produced from the light metal alloy.

The researchers combine the varying manufacturing technologies together to produce components with the best

Using various methods, the research group develops and tests multi-material components for combining different material properties.

properties. "In principle, the blacksmiths from earlier times would have done the same thing," explains the scientist. "Nevertheless, we use the most modern analysis methods and model simulations, such as finite element simulations, machine learning or artificial intelligence." Thanks to these digital tools, materials science is even more innovative, whether it is incremental forming, deep drawing or even extrusion. The scientists closely examine the different methods to find the optimal process for the specific application. In doing so, they check which technology consumes the least energy and how materials can be optimally recycled. Ben Khalifa names one application: "We are thinking about new concepts for wind turbines made of light metals, such as aluminium and magnesium. These materials are, in comparison to reinforced plastic components, considerably more climate friendly, both in terms of production and in recycling after use."

In order to develop such customized materials, the scientists must acquire basic knowledge on composition, synthesis, and modelling as well as on manufacturing and processing technologies. Through targeted temperature control or by changing different parameters in the process, for example, the material properties can be improved.

From Computer Modelling to the Finished Component

Complex simulations provide the scientists with initial insights into which materials are suitable. Only after this step are experiments carried out and the material is processed further. The advantage at the HZG is that the entire chain - that is, from the simulation to the production to the processing and detailed description - is covered at the institute.

What challenges does manufacturing technology face today? "One challenge is certainly the short innovation cycles that characterise the economy today. From an economic point of view, however, the greatest challenge is the low CO_2 production of lightweight components," adds Ben Khalifa

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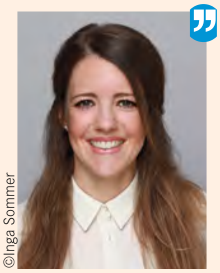
One processing technique used at the HZG for research is extrusion. In this method, the metal is heated and then pressed through a die using the extrusion press. Each material has its individual properties and requirements in terms of the manufacturing process. What these are exactly, the HZG wants to find out.

In what way do you contribute to the project in order to help Germany to reach the net zero CO_2 emissions target?

Limiting global warming to 1.5 degrees Celsius compared to pre-industrial levels is possible, but only if CO_2 emissions are reduced quickly and effectively. Within the "Net Zero" project, which belongs to the Helmholtz Climate Initiative (see page 38), scientists at the HZG develop and evaluate target-oriented strategies for avoiding CO_2 emissions.

Climate Service Center Germany (GERICS)

www.net-zero-2050.org



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Bettina Steuri, Scientist

Net Zero 2050 is a pretty grand and complex plan – approximately sixty people from ten Helmholtz centres are working on four projects and two case studies. As scientific coordinator, I am at the moment heavily involved in the many diverse facets of communication. Internally, this means networking the interdisciplinary projects in the best possible manner and establishing transparent communication structures. For external communication, we are, for example, creating a website on the topic of "Climate Neutrality 2050" and a web atlas with which the project results are to be made available to the interested public.

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Dr Markus Groth, Scientist

As a staff member of the Department of Climate Impacts and Economy at GERICS, I am responsible for carrying out a case study on climate neutral cities in Karlsruhe. Karlsruhe is one of the pioneering German cities in climate neutrality, and the collaboration in this case study is central for the exchange between science and practice. For this purpose, mainly two workshops are planned in which members from the political, administrative, economic and public sectors in Karlsruhe as well as scientists from the Helmholtz Climate Initiative are participating. In addition to working on solutions to achieve climate neutrality, they will discuss both the state of research and demands for science.

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Knut Görl, Scientist

Since October 2019, I have been collating key parameters of the national climate protection roadmaps from around the world that have so far been submitted to the United Nations Framework Convention on Climate Change (UNFCCC). In accordance with the Paris Climate Agreement, all signatory states have committed themselves to creating their own road maps by the end of 2020 to achieve climate neutrality by 2050. Within the framework of the Helmholtz Climate Initiative, central actors and knowledge gaps are identified and system boundaries of national roadmaps are defined, for example, by using workshops. We are also examining to what extent these roadmaps already contain important elements for the development of a "National Net Zero Atlas" for Germany.

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