The structure is growing, bar by bar. Modern art? Not at all! This is research. The multi-armed construct is an eddy covariance station that measures the exchange of water and trace gases between the atmosphere and the soil on a field near Jülich. Prof. Nicolas Brüggemann and his colleagues are expanding the station by a new component: an isotope analyser. This will allow them to find out where the greenhouse gas, carbon dioxide, and the water molecules that the station detects come from. This is revealed by certain types of atoms in the substances, so-called stable isotopes. The proportions of these vary according to their origin.
Cultivating for the climate

Winter sowing instead of fallows: this would allow us to reduce more CO₂.

1.5 degree target concerns us all!

An interview with the climate expert Prof. Astrid Kiendler-Scharr

Solid ‘n’ speedy

New concept shortens charging time of solid-state batteries.

A matter of taste

The psychologist examines how other senses can influence taste and what happens in the brain.

Microwaves instead of ovens

Saving energy in materials processing: electric and magnetic fields make it possible.

An open race

Scientists around the world are working on various concepts for quantum computers – including at the EU’s new research flagship.

Brain research with artificial intelligence

Self-learning software determines information from brain scans about personality traits and mental illness.

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2.2 plus

Research in a tweet
Leaps, big and small

A new mobile phone, a financial reform or a diagnostic method – in everyday life, game-changing innovations are often called quantum leaps. This definition can even be found in the prescriptive German language dictionary, the Duden. However, a quantum leap is originally anything but big. The term was introduced about one hundred years ago to describe a process in the world of atoms: the tiny leap or – physically more precisely – the transition of an electron in an atom from one energy state to another. No wonder quantum leap as a metaphor for great progress causes raised eyebrows in many physicists. Hopefully this will not happen to you when, in our cover story, Prof. Q*bit gives you a glimpse of his everyday life in the quantum world and you read up on the current status of the race for the first quantum computer.

From there, it is just a small leap to the next pages: right into the correlation of brain scans and personality traits as well as diseases, the influence of smelling and seeing on our taste, and the question of whether the climate target of 1.5 degrees is achievable at all.

We hope you enjoy reading!

Your effzett editorial team
Ozone hotspot China

China has the highest ozone levels in the world: whereas the concentration of ground-level ozone in Europe and the USA is declining, it has been increasing in the Middle Kingdom for years – Chinese cities are now experiencing similarly high peak values as in the USA in 1980. These are the findings of Chinese, American and Jülich researchers. At the Jülich Supercomputing Centre, they compared current Chinese measurement data with values from the worldwide ozone database TOAR.

ARTIFICIAL INTELLIGENCE

Improved brain tumour diagnostics

In order to detect brain tumours, doctors use various imaging procedures such as magnetic resonance imaging (MRI) or positron emission tomography (PET). Researchers from Jülich, Cologne and Aachen have now used artificial intelligence to obtain valuable additional information from MRI and PET images that would otherwise remain hidden from doctors. In this way, they receive information about the genetics of the tumour that would otherwise only be accessible by means of tissue samples. This information is also decisive for the type of treatment. The results must now be confirmed in further studies before physicians can possibly use them in everyday clinical practice.
**Light-driven antibiotics**

Several fluorescent protein molecules from the flavin-binding protein family have an antibiotic effect when irradiated with blue light. Researchers from Jülich and Düsseldorf have discovered this together with Spanish and Argentinian scientists. These newly detected properties make the “luminous” proteins interesting for new biomedical applications and therapeutic approaches.

**CLIMATE RESEARCH**

Ivy filters particulate matter

Poor air quality and so-called heat islands are a problem in many cities. Green façades could help against this, as scientists from Cologne and Jülich have proven. Ivy covers have a heat-insulating effect on the façades in winter and a cooling effect in summer. They also absorb harmful nitrogen oxides and filter particulate matter. That was the result of temperature comparisons of green and bare façades in Bonn and of experiments in the Jülich nitrogen oxide measurement laboratory.

- INSTITUTE OF ENERGY AND CLIMATE RESEARCH -
The Excellence Commission has selected 57 Clusters of Excellence of the 88 applications for funding for 2019. For four clusters, Forschungszentrum Jülich is the strong partner at the side of the respective university. The scientists focus on sustainable energy systems, plant sciences and quantum technology.

SUCCESSFUL

Large storage capacity, short charging times and high safety: the goal of the “FestBatt” cluster, which is being funded with around € 16 million, is to bring the next generation of solid-state batteries into use. Taking part in the three-year project next to Forschungszentrum Jülich are 13 scientific facilities.

DATA STORAGE

Skyrmions – not the only ones of their kind

Jülich scientists have provided experimental evidence of a new class of tiny magnetic objects for storing data. The flat, three-dimensional structures appear on the surface of special alloys. They are only a few millionths of a millimetre in size, and the researchers call them “chiral magnetic bobbers”. The bobbers could complement the already known skyrmions – tiny magnetic vortices – and with these, become future storage units that save space and energy.

- PETER GRÜNBERG INSTITUTE -

EFFICIENT

He has had a key influence on battery research in Germany: Prof. Martin Winter, founding director of the Helmholtz-Institute Münster, a branch of Forschungszentrum Jülich. The chemist recently received the Federal Cross of Merit, First Class for his outstanding achievements.

- INSTITUTE OF BIO- AND GEOSCIENCES -

HONOURABLE

... biomass is supplied by the energy plant Sida hermaphrodita when it grows on fermentation residues from biogas plants, as plant researchers from Jülich and Lüneburg report. In the beginning, the young plants avoided the fertiliser depot – the roots grew in other directions. After a short time, however, they developed a dense network of roots in the fermentation residue fertiliser depot and grew extraordinarily well. The researchers explain the starting difficulties with the large amount of ammonium in the fermentation residues: soil bacteria must first convert this into nitrate. The depot-fertilised shrub could help make nutrient-poor soils, such as in Mecklenburg-West Pomerania, sustainably useful.
In 1938, Konrad Zuse completed the Z1 – a mechanical calculator which for the first time worked with binary numbers and not with the decimal system. Three years later, with the Z3, he produced a calculating machine that operated via electromagnetic switches, so-called relays. The Z3 was the world's first universal computer. These are computers which were not built for a special purpose, but which could solve different tasks by mathematical calculations.
An open race

Computers that calculate according to the rules of quantum physics could possibly solve special tasks faster than today’s supercomputers. However, universal machines of this kind still only exist as laboratory experiments.

The race has long begun: who will build the first quantum computer, far superior to today’s supercomputers? Companies such as Intel, IBM, Google and Microsoft are taking part in the race. The USA, Canada, China and Japan are investing considerable sums in the development of these exotic calculating machines. The US government, for example, supports research into quantum technologies with around € 170 million per year. In the science metropolis of Hefei, Beijing has a quantum laboratory built for almost € 9 billion. The EU has just launched a € 1 billion funding programme for quantum technologies; an important part of this flagship programme is dedicated to quantum computers.

“The developments in this area are being driven forward with great enthusiasm,” says physics professor David DiVincenzo of the Peter Grünberg Institute (PGI-2), a pioneer in the field of quantum information science. The exotic computers raise high expectations. Many experts are certain that such a machine will solve certain mathematical problems much faster than all computers of today combined. For example, quantum computers could, in a matter of seconds, search through huge databases, deal with complex logistics problems and calculate the properties of molecules for chemistry and materials research. They would also be able to cancel out the standard procedures currently used to encrypt data on the Internet. Today’s computers are too slow to cope with the many calculation steps to decrypt the data in a reasonable amount of time. With the computing power of a quantum computer, this would be easily possible.

Yet: what has been achieved so far falls short of expectations. This is no surprise to David DiVincenzo: “The participants in this race don’t run very fast. It’s as if they were all dragging around a 100-pound backpack. These are virtually the enormous technical challenges that still need to be mastered. So no race like at the Olympic Games,” explains the Jülich researcher, smiling. More than 20 years ago, the physicist had already formulated five basic criteria that a universal quantum computer must theoretically fulfil. Every newly developed model must be measured against these in the laboratory.

FROM BIT TO QUBIT

In order to better understand the challenges and pitfalls, one has to realise that quantum computers do not work like conventional computers. The world of the latter consists of bits, zeros and ones. A bit is the smallest possible unit of information. In order to be able to use a component as a carrier of information, it must above all possess one property: it must be able to assume two different states corresponding to zero and one. Conventional computer chips calculate with billions of microscopically small semiconductor transistors that function like tiny flip switches for the electrical current. A control voltage can switch them between “on” and “off”, between zero and one.

Quantum computers, on the other hand, calculate with quantum bits, so-called qubits. They can assume not only the states of zero or one, but at the same time also any value in between. This is due to the information carriers that are used. These are the smallest objects we know, such as atoms, ions, electrons or photons. Completely different rules apply for them than for classical microelectronics – they are subject to the often bizarre rules of the quantum world (see also p. 14). One of these rules is the possible superposition of states. The experts call it superposition. It allows quantum objects to assume several states simultaneously. Furthermore,
the individual particles can be entangled in an arrangement of qubits. They are then connected to each other as if by magic. Because of these two phenomena, quantum computers are capable of performing many operations simultaneously with each switching operation. David DiVincenzo sums it up: “With this parallel processing, they should be able to beat conventional computers, which execute the commands one after the other, in certain tasks.”

At least that’s the theory. In practice, however, a phenomenon called decoherence thwarts the experts’ quantum computation plans. Behind this lies the fact that quantum bits react sensitively to external influences such as heat or radiation. These interference factors cause the entangled states to decay again after a few microseconds. Therefore, the lifetime of a piece of quantum information also depends on how well the researchers manage to shield the computer from the environment.

CAGES, CHAINS AND DEFECTS

The research groups involved in the global race for the quantum computer have chosen various ways to achieve this goal. The ideas for the heart of such computers, the physical storage cells, are manifold: some experts rely on defects, which they specifically incorporate into thin diamond layers, or on exotic materials, which are actually insulators but conduct electricity on their surface. Other researchers hold a chain of ions in suspension in a vacuum between two electrodes. David DiVincenzo is concerned with quantum dots. These are semiconductor cages into which individual electrons are locked. Their angular momentum – the direction of their own rotation, so to speak – can store the value of the qubit. “The advantage is that there is already a lot of know-how about the manufacturing of these semiconductor structures: conventional chip production is also based on semiconductors.”

Companies like IBM and Google favour superconducting circuits. In their conductor loops, the current can circle...
In certain tasks, quantum computers should be able to beat conventional computers, which execute the commands one after the other.”

David DiVincenzo
rely on the qubits finding the solution to the calculation problem themselves by jumping back and forth until the system reaches its minimum energy level,” says the expert. “You start by setting the parameters and then let the system evolve until you get an answer.” However, this is at the expense of flexibility: Only certain tasks can be solved in this way: optimisation problems, for example for the calculation of traffic flows, but also deep learning problems and quantum simulation problems.

The annealers can find the fastest way from A to B for hundreds of motorists in the urban canyons of big cities, but they will never be able to break encryptions on the Internet.

The physicist hopes to be able to establish a focus on quantum computing at the Jülich Supercomputing Centre in the course of the EU flagship programme, which would not only be open to experts from Forschungszentrum Jülich: “I imagine this as a platform on which different types of quantum computers will be available. We would then have a user infrastructure that offers user support and access to different experimental device types with different levels of technological maturity, complemented by our simulations. We might have remote access to quantum computers from commercial providers. And we would operate a European quantum computer and a quantum annealer. This would allow users to choose from a wider range the system that is best suited to their problem.” The signs in the race for the quantum computer would then be pointing to cooperation and not to competition – because together, things may just work out best.

ARNDT REUNING

“You rely on the qubits finding the solution to the calculation problem themselves by jumping back and forth until the system reaches its minimum energy level.”

KRISTEL MICHIELSEN

FOURTH COMPUTER GENERATION (UNTIL ABOUT 1975)

With transistors and integrated circuits

In 1958, Texas Instruments developed the integrated circuit. Its advantage: several transistors could be mounted on the same electronic circuit without using electrical cables. Due to the miniaturisation of switching processes, computers became not only smaller, but also cheaper – prerequisites for the later triumphal march of personal computers and home computers.
It was launched in mid-2017: the third research flagship of the European Commission. With €1 billion in funding for ten years, it is intended to promote the development of quantum technologies in Europe. In addition, the Federal Government is funding the development of quantum technologies in Germany with €650 million until 2021. “In the EU, we have a high level of scientific excellence in quantum technology. The flagship is designed to help us translate this potential into commercial products together with the industry. We would otherwise run the risk that findings that have been initiated in Europe will be developed into marketable applications outside the continent,” explains physicist Tommaso Calarco, who came from Ulm University to Jülich’s Peter Grünberg Institute (PGI-8) in September 2018. He is one of the spiritual fathers of the Quantum Manifesto – a twenty-page thesis paper that initiated the new flagship.

The programme aims to advance technologies that manipulate individual atoms, electrons or photons. In the first round, 20 projects have been funded since October 2018. The construction of a quantum computer is the “Holy Grail” of this research, explains Calarco: “But I also see other missions of great social relevance, such as securing European communications networks through quantum cryptography.” Behind this lies the tap-proof exchange of messages, in which the secret key is transmitted in the form of quantum information. Eavesdroppers would disturb the quantum properties, thus betraying themselves. In addition, high-precision navigation devices and sensitive sensors for medical diagnostics are to be developed. Jülich is involved in three of the 20 projects. Among other things, as part of the OpenSuperQ project, a quantum computer based on superconducting circuits is to be built there – the first of its kind in Europe. What’s special here: both hardware and software architecture will be disclosed and accessible so that the entire research community can participate in its development and use the computer. Forschungszentrum Jülich plays a key role in this, says Calarco. The diversity of expertise along the quantum technology development chain is convincing: “Not only are new theories and ideas born here. The approaches can also be tested experimentally due to the extensive infrastructure.”

Take-off for the quantum flagship!

In 1971, Intel presented a new component, a so-called single-chip microprocessor. On the chip, entire rows of transistors are accommodated on a single piece of silicon to save space. Microprocessors are still the heart of every modern computer today. They have made computers even smaller, more powerful and cheaper.

FIFTH COMPUTER GENERATION (CURRENT)

With microprocessors and highly integrated circuits

In 1971, Intel presented a new component, a so-called single-chip microprocessor. On the chip, entire rows of transistors are accommodated on a single piece of silicon to save space. Microprocessors are still the heart of every modern computer today. They have made computers even smaller, more powerful and cheaper.

In the new quantum technology flagship, research rests on four pillars. Tommaso Calarco explains what these are in an interview in our web magazine: effzett.fz-juelich.de/en
As an inhabitant of the quantum world, it is not easy for me to report on my everyday life. Things are so different around here. They follow their own rules, the rules of quantum physics, dominated by a certain fuzziness. For example, if my assistant asks me where I will be at three o'clock sharp this afternoon, I answer: "In the office and in the lab." Of course he wants to know: "But where? Where exactly?" And I reply: "Well, in both places!" For humans and other non-quants, this might be hard to imagine. But I can assure you: for me, this has often proven to be extremely useful.

In the quantum world, we are also bothering with questions of identity. It's always the same: you would like me to tell you whether I am a particle or a wave. I shrug my shoulders, sigh briefly and say: "What do you think? I'm both. This is called the wave-particle duality."
We know no moods in the quantum world. We’re in states, and we jump back and forth between them. These are veritable quantum leaps. For example, when I dance and whirl in a circle, my spin—this is my own angular momentum—obeys the rules of quantum physics. I can then turn around my axis only to the left or to the right. I jump back and forth between the two directions. But since I also possess the properties of a wave, my states can overlap. That’s what we call **SUPERPOSITION**, a mixture of the two spins. I turn to the left—and at the same time to the right. It’s unimaginable, actually, but that’s how it works with us quanta.

Relationships in the quantum world are very special. And that’s because of the phenomenon of **ENTANGLEMENT**. Proximity and distance are therefore not mutually exclusive with us. My wife and I, for example, we have entangled. We are connected to each other as with an invisible bond, no matter how far away we are from each other. And when we change our properties, we don’t do it alone, we change them both at the same time. That’s the way it is with us quanta. However, I have been told that even in the human world, intimate relationships exist over great distances—without any entanglement.
Our brain is highly complex. In everything we do, different brain regions work together in so-called functional networks. Prof. Simon Eickhoff, Director at the Institute of Neurosciences and Medicine (INM-7), deals with these networks and their activity patterns. The neuroscientist has a big goal: he wants to assess the extent to which these patterns have changed in people suffering from depression, schizophrenia or Parkinson's disease. He hopes that, based on this information, the further progression of a disease can be predicted individually.

Eickhoff and his team have investigated how artificial intelligence can be used to obtain information from brain scans. For this purpose, the researchers trained a self-learning software to predict the personality traits of people on the basis of their brain scans. The programme delivered promising forecasts for three out of five features: openness, agreeableness and emotional stability. Using the software, the researchers also found that certain functional networks in the brains of people suffering from schizophrenia or Parkinson's are disturbed.

effzett has spoken with Mr. Eickhoff.
To what extent could people with mental or neurological diseases benefit from your research in the future?

Let’s take depression: up to 30 per cent of all people who have recovered from severe depression fall ill again later. For many patients, it is very important to know if indeed this will happen to them. However, no doctor can give them a reliable prediction at present. We think that our methods have the potential to give an individual prognosis, that is, provide the individual probability of a relapse.

Another example is Parkinson’s disease. For example, many patients want to know whether they will develop dementia in the foreseeable future – a question that is of great interest to relatives as well. I see a very important field of application for prognostic methods here as well.

How is that going to work?

The idea can be explained with the help of two patients whose current state of disease appears to be the same, but for whom our algorithms indicate differences based on brain scans. They suggest that the condition of one patient should actually be better, while the condition of the other patient should be worse. This means that the algorithms may indicate different courses of the disease even before the symptoms can be recognised by the doctor. Such differences in the functional networks could be made visible from MRI images by new methods of machine learning. In the best case, doctors could deduce the further course of the disease from this and treat patients accordingly.

I would like to emphasise that we are still a long way from the clinical application of our methods. However, especially the approaches taken for network characterisation and individual prediction are already progressing very promisingly.

But there will certainly be people with depression or Parkinson’s who don’t want to know their future ...

Yes, and I am an advocate of the right not to know. On the other hand, however, as a doctor, I have learned that the question as to what comes next is the most important and urgent question for most patients and their relatives. The reason for that is that many psychiatric and neurological disorders progress in phases, such as schizophrenia, or they progress slowly, such as dementia.

Could your results also change the treatment of mental and neurological illnesses in the future?

I very much hope so. Another problem is that not every medication helps every patient. Not every depressive person benefits from every antidepressant, for example. The situation is similar with schizophrenia. In the case of unsuccessful treatment, something new has to be tried out, which is very
unsatisfactory. Our goal would be to find signatures in the brain that tell us that we should best treat these patients with drug A and not with drug B. However, we are still at the beginning in this.

You use machine learning methods for your approach. There is criticism and concern about the use of artificial intelligence and the possible misuse of patient data. What is your opinion?

In any case, these fears must be taken seriously. US insurance companies, for example, are currently considering evaluating brain scan data. They want to calculate the risk of illness for individual people and I fear that they want to exclude risk cases with foresight. Or think of the “Social Credit System”, which is already being tested in China: the state evaluates the behaviour of citizens with the help of artificial intelligence. However, the consequence cannot be that we in Germany stop research on these topics. Here in Jülich, we have the opportunity to shape developments in the healthcare sector and to make the possibilities and limits of these technologies transparent. The research centres of the Helmholtz Association are committed to society: We do not do research to maximise profits, but to find answers to major societal challenges. We should seize this opportunity.

INTERVIEW: FRANK FRICK

From brain scan to prognosis

### 1 Identifying functional networks

**What is it?**
Functional networks consist of different brain regions that work together when we perform complex tasks. For example, when we recognise faces or memorise something. From the individual characteristics of such networks, conclusions can be drawn about mental illnesses as well as cognitive performance or personality traits of a person.

**What have the Jülich researchers done?**
They evaluated several thousands of studies from all over the world in which the brain activities of test subjects were examined using functional magnetic resonance imaging. This enabled the Jülich researchers to precisely identify functional networks in the brain – the basis for determining future connection patterns of these networks individually and using them to predict personality traits or diseases such as Parkinson’s and schizophrenia.

### 2 Brain scans with the help of functional MRI

**What is it?**
Functional magnetic resonance imaging (fMRI) produces special images of the brain. These make brain regions visible that are active at the moment of exposure. Different regions are active depending on what we do – whether we are moving an arm or simply lying still.

**What have the Jülich researchers done?**
They evaluated fMRI images of hundreds of subjects who gave free rein to their thoughts during the scans. The researchers determined the brain activities and interactions in the previously identified functional networks.

### 3 Self-learning software calculates prognoses

**What is it?**
Self-learning software is not programmed to solve a problem, but is trained with the help of data – to recognise patterns in fMRI data, for example.

**What have the Jülich researchers done?**
They used such a software to assign certain personality traits to activity patterns in the functional networks. These characteristics were derived from personality tests that the test persons had previously completed. The researchers trained the software on data sets in which personality traits or diagnoses were known. The software then adapted its mathematical model and was finally able to predict these characteristics in new people.

In another study, it was possible to determine from fMRI images whether a person suffered from schizophrenia or Parkinson’s disease or whether he or she was mentally healthy.
What are you researching right now, Mr Gonzalez-Julian?

Jun.-Prof. Jesus Gonzalez-Julian, Institute of Energy and Climate Research, Materials Synthesis and Processing (IEK-1)

“Some hot stuff: together with my team, I am developing new materials which are particularly heat-resistant, for example for turbines in power plants and aircraft or for solar power plants. These so-called MAX phases combine the positive properties of ceramics and metals. Ceramic can withstand high temperatures, but is brittle, while metal is very stable, but deforms in the heat. The MAX phases are heat-resistant and not brittle. We are also the first in the world to combine MAX phases with silicon carbide fibres. This is to further improve the mechanical properties.”
Materials scientist Olivier Guillon sees great potential in materials processing with electric and magnetic fields.

**Microwaves instead of ovens**

Achieving more with less energy – this is an important goal of the energy transition. New procedures could reduce consumption in the case of particularly energy-intensive processes in the industry – with the help of electric and magnetic fields.
very child knows it: the microwave. It can be found in almost every modern kitchen. A cup of milk can be heated quickly and easily with this device. Nothing gets hot on the outside and the microwave oven stays cold on the inside as well. The trick behind it: electromagnetic fields cause the water molecules in the milk to oscillate. The friction of the water molecules against each other creates heat, the milk heats up.

Prof. Olivier Guillou, Director at the Institute of Energy and Climate Research (IEK-1), wants to use this principle to save energy – not in the kitchen, but in production processes in industry. “Electric and magnetic fields could help to drastically reduce energy consumption, especially in the processing of metals and high-performance ceramics – we believe by more than 50 per cent in some cases,” says the materials expert. High-performance ceramics are not exotic materials. We use them in household appliances, in vehicles or in communication. They are regarded as key materials for the conversion and storage of energy. However, processing them consumes a lot of energy. About 7 per cent of the primary energy demand in Germany is used for industrial heat treatment.

This is mainly due to the high melting points of ceramics. High temperatures must be generated to process the materials as it is only at high temperatures that they can be compressed and deformed as desired. Today, this is usually done in accordance with the “oven principle”: as when baking a cake, an oven is preheated. It gets hot both inside and out and will be warm long afterwards. “This involves a great deal of energy, only a fraction of which flows into the actual processing of the workpiece,” explains Guillou.

This is exactly what can be avoided with the help of electromagnetic fields. As with the milk in the microwave, the heat is generated solely in the component part. “This makes more efficient use of the energy supplied. It also accelerates the manufacturing process, because the component part reaches its desired working temperature much faster with this method than by heating it according to the oven principle,” says the scientist. Jülich researchers have already tested a possible field of application for the method: they have manufactured ceramic components for solid-state batteries using this principle.

The new manufacturing processes could help Germany achieve its ambitious goals for the energy transition: in addition to switching to renewable energies, energy consumption is to be reduced by 20 per cent by 2020 compared with 2008, and even halved by 2050. The International Energy Agency (IEA) as well has defined energy efficiency as one of four key measures to limit global warming to a maximum of two degrees by 2100.

“However, materials processing with electric and magnetic fields opens up even more possibilities,” says Olivier Guillou, who has been in charge of the Priority Programme of the German Research Foundation (DFG) on this topic since 2016. Together with colleagues from the programme, he recently summarised the state of research in a study. For example, scientists are working on improving the properties of certain materials by means of electric and magnetic fields that activate the movement of atoms. This allows materials to be compressed and formed better or the atomic structure to be systematically influenced.

Raw materials can also be saved, for example with permanent magnets. Nowadays, these are installed in almost every electronic device: in refrigerators, mobile phones or even in the generators of wind turbines. Powerful magnets in particular often contain valuable raw materials, such as the rare earth metals neodymium and dysprosium, which are extracted almost exclusively in China under precarious environmental conditions.

THE WORLD’S STRONGEST MAGNETS

Neodymium can be used to build the currently strongest magnets in the world, while dysprosium makes the magnets heat-stable. The quantities used are considerable: one 3-megawatt wind turbine alone contains 1.8 tons of neodymium iron boron magnets. Colleagues from the DFG Priority Programme use external electromagnetic fields to direct atoms in the magnets’ microstructure: “The properties of the magnet are thus improved and less rare earth metals used,” says Guillou.

However, such procedures will probably only be ready for practical use in about 10 to 15 years’ time. The basics still need to be researched. For example, more needs to be found out about the interactions between electric or magnetic fields and the material. “The processes take place on different time scales and in different orders of magnitude: from nanoseconds to hours, from the atom to the macroscopic part,” explains the Jülich scientist. “The DFG Priority Programme is an important step forward here: It brings together the research groups, which have so far independently investigated the different phenomena.” There is no doubt: This is efficient research to advance energy efficiency and, thus, the energy transition.

Katja Lüers

How does a microwave work?
Read more in our web magazine:
effzett.fz-juelich.de/en
1.5 degree target concerns us all!

In early October, the Intergovernmental Panel on Climate Change (IPCC) published its special report on the 1.5 degree climate target. The bottom line: it’s urgent! In order to keep global warming well below two degrees Celsius, everyone is called upon: governments, the economy and the citizens. Climate expert Prof. Astrid Kiendler-Scharr was involved as an expert in the report. We asked her for her assessment.

In the Paris Climate Agreement, the international community of states agreed to limit global warming to well below two degrees, preferably to 1.5 degrees. Is that still possible at all?

The report shows that it is difficult, but indeed possible. We need a strong shift in energy technology towards renewable energy sources to achieve this ambitious goal. The fact that coal and other fossil fuels are not conducive to the climate is – at least in Germany and the majority of other nations – completely undisputed. Nevertheless, the urgency with which measures for climate protection would have to be taken is not yet clear to politicians and the wider public, or the necessary steps have not yet been implemented.

What steps would that be?

All processes that cause greenhouse gases to rise should be minimised as far as possible. This includes, for example, industrial production, agriculture or livestock farming. Also important: we need a new awareness of our lifestyle, based on knowledge and conscience. It is not enough to plant a tree once in your life. We must feel good when we act sustainably in all areas. Politically, a viable path is usually via subsidies or tax breaks: cycle paths, local public transport, storage facilities for renewable energies – these are projects in which politicians can take action, thus making climate protection more attractive for everyone.

Has the special report increased the pressure on politicians?

First of all, it should be noted that the report was requested by politicians. Science has presented the facts and revealed the consequences. However, it is not the task of research to conduct politics. And that’s a good thing. It is not science, but politics that must now decide how appropriate solutions can be brought about. In any case, the report has brought the issue of climate change to the fore again.

Do you already see consequences in politics?

This will have to be seen in the next few months. The decision of the EU ministers of the environment to lower the limit values for carbon dioxide emissions of new cars by 35 per cent, not leaving them at 30 per cent, could be an indication. However, numerous measures are needed to achieve ambitious climate targets, as the report points out. All current calculations show, for example, that we have to actively remove CO₂ from the atmosphere in order to avoid a temperature increase of more than 1.5 degrees.

Why that?

CO₂ is one of the long-lived greenhouse gases. It takes over a hundred years for it to dissolve. The combustion of fossil raw materials since the beginning of industrialisation, however, has released far more CO₂ into the atmosphere than
What if ...?
Worldwide increase in temperature and its consequences in 2100

+5°C
Sea levels rise by up to 2 metres locally. Large areas near the coast are flooded, megacities such as Miami in the USA or Guangzhou in China are on the verge of at least partial evacuation. All ice sheets are melting. A further massive increase in sea levels begins.

+4°C
The global distribution of water is changing drastically. Already dry regions are becoming even drier, southern Africa, the south-west of the USA and the Mediterranean region being especially prone to droughts. The frequency of extreme floods is increasing on half the earth’s surface. Sea levels rise by up to 1 metre.

+2°C
Weather extremes are even more frequent. The Arctic is ice-free in summer. Sea levels rise by up to 90 centimetres. Researchers fear a tipping point. This leads to the melting of the ice sheets of Greenland and of West Antarctica. This would cause the sea level to rise by several metres over the course of the following centuries.

+1.5°C
Extreme weather such as heavy rain, flooding, heat waves, droughts and the intensity of storms are increasing. Sea levels rise by up to 80 centimetres.

Sources: IPCC reports, 4-degree World Bank report, articles in journals such as Nature and PNAS et al.

The Paris Climate Agreement

In the 2015 Paris Climate Agreement, 196 countries decided to limit the rise in the global average temperature to “well below 2 degrees” by 2100, but if possible even to 1.5 degrees Celsius above the pre-industrial level. This is to significantly reduce the risks and impacts of climate change. The UN commissioned the Intergovernmental Panel on Climate Change (IPCC) to conduct a study on whether and how this goal can be achieved. This special report on the 1.5 degree target has been available since 8 October 2018.

The earth could have absorbed again in the same period. Even if CO₂ emissions were reduced to zero today, natural sinks such as forests and oceans would be far from sufficient to significantly reduce the proportion of CO₂ within a few decades. This could only be achieved if it were actively removed from the atmosphere. The situation is different with short-lived trace gases and air pollutants.

What role do these short-lived substances play in climate change?

Short-lived climate drivers are, for example, atmospheric ozone, methane or aerosols, that is, airborne particles. The time they stay in the atmosphere is clearly limited. If we want to achieve the 1.5 or 2 degree target, we have to turn seriously to these short-lived fabrics. Ground-level ozone, for example, is formed by anthropogenic air pollutants. It is not only harmful to humans and the environment, but also a powerful greenhouse gas. Here, therefore, measures to improve air quality have a direct effect on the climate.

Are aerosols not considered cooling for the climate?

Yes and no. The situation with aerosols is complicated. The net total of all aerosols leads to a cooling, but some aerosol types like soot can also have a warming effect. At the same time, they act as cloud nuclei. Clouds, on the other hand, have a cooling or warming effect depending on composition, time of day and altitude. If we better understand these complex interrelationships, there is a chance of achieving success in climate change in the near future. This knowledge could be of use in the transition phase until the reduction of CO₂ is further advanced.

Adherence to the CO₂ reduction targets has not seemed to work properly so far. Is the 1.5 degree target better suited to achieving effective climate protection?

In any case, setting a temperature target is a paradigm shift that was first agreed in the Paris climate agreement. Previously, the climate issue had been discussed from the emissions point of view: which concentrations of which greenhouse gases may still be emitted until a certain limit is exceeded? However, these climate targets and their implementation were obviously not a success story. By 2020, for example, emissions...
in Germany should fall by 40 per cent compared with 1990 levels. Now, in 2018, this will be difficult to achieve. It remains to be seen whether the temperature target will actually lead to mandatory measures being taken or whether it will be used as an excuse not to have to commit to unpopular concrete emission targets.

And how does the paradigm shift affect research?

There is a clear increase in expectations towards science. It must now make clear statements as to which atmospheric composition, greenhouse gas and air pollutant concentrations are associated with which temperature increase. This means that more attention is paid to details such as the effects of long-lived greenhouse gases and short-lived climate drivers. There is therefore not only a lot of work to be done in politics, but also in science.

INTERVIEW: BRIGITTE STAHL-BUSSE

Greenhouse gases ...

Proportions of the 909 million tonnes of total emissions 2016 in Germany in CO₂ equivalents*

* CO₂ equivalent describes the warming potential of a gas compared to the corresponding amount of CO₂.

** Hydrogen-containing chlorofluorocarbons, perfluorocarbons, sulfur hexafluoride.

Sources: German Environment Agency

... and how effective they are

Comparison of effectiveness and lifetime

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Solid ‘n’ speedy

Great hopes are currently associated with solid-state batteries. They do not contain any liquid parts that could leak or catch fire. They are therefore considered to be safer, more reliable and more durable than conventional lithium-ion batteries. So far, however, they take a very long time to charge and discharge. Researchers at the Institute of Energy and Climate Research (IEK-9) have now solved this problem – by cleverly selecting materials.

The new solid-state battery

The anode, cathode and electrolyte are made of very similar materials. They all contain various lithium phosphate compounds. This eliminates a weak point of previous solid-state batteries: the interfaces between the solid electrodes and the solid electrolyte. This interface is not without gaps. This impedes the ion migration through the battery and consequently the charging and discharging current and thus also the charging duration. If the contact resistance between the electrodes and the electrolyte is reduced by means of similar materials, the possible current flow increases.

Improved

- Compared to previous solid-state batteries
  - **Energy density increased** by about 30%
  - **Charging time shortened** 1 hour instead of 12 hours

Still to be done

- **Improving capacity**
  - Currently 84 per cent after 500 charge/discharge cycles. Losses of less than 1 per cent after 500 cycles are theoretically possible.
- **Enlarging the battery**
  - The Jülich solid-state battery currently has the size of a button cell.

Wide variety of benefits

Possible applications for solid-state batteries

- Electric cars
- Smart phones
- Mobile computers
- Medical technology
- Smart homes
A matter of taste

Gingerbread, cinnamon biscuits, speculaas: these biscuits are much tastier around Christmas than on a mild October afternoon or in the first spring sun. But why is that? Kathrin Ohla can answer this question. She investigates taste – how it is influenced by other sensory impressions and what happens in the brain when tasting.

A plate full of Christmas cookies at a photo shoot in early autumn? That's not everybody's cup of tea. Kathrin Ohla, psychologist at the Institute of Neuroscience and Medicine (INM-3), is also torn. An outside temperature of 20 degrees Celsius and a neutral office do not immediately evoke a Christmassy mood. The other senses are simply not yet attuned to Christmas – but it is exactly these that are important for tasting. “The sense of taste alone would give us little pleasure,” says Kathrin Ohla. “Putting it simply, it only knows sweet, sour, bitter, salty and umami, which comes from Japanese and can best be translated as savoury.” It is therefore not possible to recognise a particular foodstuff solely by its taste. For example: beer. The taste recognises only “bitter” – a vapid impression. It is only the combination of senses that make beer what it is. Our eyes see the white, foaming beer head, our nose smells the hops, our mouth feels the tingling of the sparkling fluid. And it is precisely these other senses that make Christmas cookies taste better by candlelight and the scent of cinnamon, with mulled wine and the Christmas tree than at the barbecue party at the quarry pond.

Ohla and her team have investigated the interplay of different senses in a series of studies. They all confirm: above all, seeing and smelling influence the taste. For example, in pink-coloured, slightly sugared natural yoghurt, many people taste aromas of strawberry or wild berries although it does not contain any at all. Via their scent, aromas such as banana or vanilla, for example, can enhance the sweet taste. The link between smell and taste is particularly strong, because during chewing, molecules are released from the food which we inhale retronasally through the nose – that is, directly from the mouth into the nose. This is why, in everyday life, we often confuse smelling and tasting.

Even newborns have preferences regarding taste: “If you give a drop of sugared water onto their lips, they react positively, while with a bitter substance or lemon juice, they make the familiar lemon face,” Kathrin Ohla says enthusiastically. This innate preference or dislike is vital. “This is how we distinguish nutritious from harmful food,” according to the researcher. “Bitter”, for example, is a potential indication that a thing might be poisonous – after all, most poisons taste bitter. A sweet taste, on the other hand, signals that a food contains carbohydrates and thus quickly available energy. Umami indicates protein-rich food and thus a good source of energy, and it is also preferred from birth. A sour taste, in contrast, has an ambivalent function: on the one hand, it indicates that valuable vitamin C could be contained, while on the other hand, it warns against spoiled food such as sour milk. The situation is similar with salty foods. Although salty taste indicates important electrolytes, too much salt is harmful and is therefore rejected. It is the dose that is crucial.

NUTRITIOUS OR UNPALATABLE?

So taste is often about the question: nutritious or unpalatable? Keep eating or spit it out? But how soon do we know? How quickly does our brain process information regarding taste and then return it to our tongue? In order to answer this question, Kathrin Ohla and her colleagues carried out a number of studies using electroencephalography (EEG) to measure the brain waves of volunteers. The test persons tried different samples during the studies and worked on several tasks at the same time: for example, they indicated when they tasted something, what they tasted and how pleasant and intense the taste was. The evaluation of the data was then carried out with the help of machine learning algorithms trained to allocate taste sensations to brain-wide response patterns. The researchers correlated the time required to detect and to differentiate between tastes with the time that participants needed to make the same decisions. The brain data enabled them to recognise when taste processing in the brain begins and how it is linked to perception.

The most important insight: taste is processed much faster by the brain than had previously been assumed. “The first measurable signal is the trigger for our behaviour with
respect to taste, so whether something is tasty or perhaps not so good," says Ohla. This means that no downstream processing steps are necessary in the brain. It takes about 175 milliseconds for the test persons to notice that they taste something. “Prior to our measurements, researchers assumed that this would take about three times as long,” reports Ohla. For comparison: we have a first visual impression after about 100 milliseconds, hearing takes about 80 milliseconds. “However, the taste molecules do not directly encounter receptors the way that, for example, light does on the retina during vision,” said Ohla. “They must first dissolve in the saliva on the tongue until they reach the taste buds and the receptors in them. That alone takes roughly 50 milliseconds.”

The researchers also showed that there are differences in how quickly we perceive certain tastes. We taste sour and salty faster than sweet and bitter – and the brain also decodes the tastes with a corresponding time delay. We can distinguish bitter and sweet the moment we taste them. It is different with sour and salty: although the study participants noticed a little faster that they tasted something, it then took them longer to find out what it was – and they often confused the two tastes. “Evolutionarily, it makes sense that we can immediately and reliably distinguish bitter – that is, potentially toxic – from sweet, that is nutritious,” says Kathrin Ohla. “However, it is still unclear why more time passes between perceiving and distinguishing salty and sour tastes. We will have to look into that more closely.”

So we can realise very quickly that the salad dressing does not taste good. But it is not always certain to judge whether there is too much vinegar or salt. Too much bitter almond aroma in the cookie dough, on the other hand, is clear. And even if her findings do not play a direct role in baking cookies, Kathrin Ohla has a tip for this case: bitterness can be “masked” with a little sugar. Then it’s just a matter of the right mood to ensure tastiness.

JANINE VAN ACKEREN

Kathrin Ohla wants to use a new test to find out where in the brain information about taste is processed. Read more in our web magazine: effzett.fz-juelich.de/en
Cultivating for the climate

The harvest has been brought in, the winter grains are already slumbering in the ground. But in the time between harvest and new sowing, many fields lay fallow for months, some even remain uncultivated until spring. That could change in the future – for the sake of the climate. The cultivation of catch crops could help to reduce CO₂.

“We notice that grain fields, for example, are harvested earlier and earlier in summer. The autumn or spring sowing also shifts forward, but not as significantly. Thus, fields lie fallow for longer periods of time. This means that the period in which arable plants convert CO₂ using photosynthesis becomes shorter,” says Dr. Alexander Graf from the Institute of Bio- and Geosciences (IBG-3), who is investigating the CO₂ exchange between soils, plants and the atmosphere.

After the harvest, some farmers cultivate catch crops which are not harvested but ploughed under later, such as mustard and oil radish. This prevents nitrate leaching into groundwater, saves fertiliser and improves soil quality. Catch crop sowing could apparently also help to slow down the increase in CO₂ concentrations in the atmosphere and thus mitigate climate change.

Graf and his team have found that a field with repeated catch crop cultivation absorbed about 60 per cent more CO₂ than a field that had been left fallow more often and for longer periods. They had collected data from two arable fields for four years. “The next step is to find out under which conditions plants and soils store and release which quantities of CO₂,” he emphasises.

Not only the respective soil properties play a role here, but also the increasing amount of CO₂ in the atmosphere, which acts as additional fertiliser for some plants, or global warming, which causes organisms in the soil to release more CO₂ into the air. “When we understand these exchange processes better, we can pinpoint concretely whether and how which catch crops can be used specifically for climate protection,” says Graf.

CHRISTIAN HOHLFELD

MIT WINTERSAAT MEHR CO₂ ABBAUEN

A field that is repeatedly tilled with catch crops between the sowing times of plants such as sugar beet and wheat absorbs 60 per cent more CO₂ than...

8 days longer than 50 years ago, fields lie fallow

... a field that lies fallow until the next sowing. During fallow, a field emits about half of the CO₂ it absorbed before.
Why there?

The chemist Florian Speck works at the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (HI ERN), which was founded in 2013 as a branch of Forschungszentrum Jülich.

Why is Erlangen a good research location for you?
A lot of competence centring around our focus, hydrogen research, is concentrated here. We cooperate with the university, with Siemens and with the Bavarian Centre for Applied Energy Research, for example.

What are you researching specifically?
We focus on fuel cells. They make it possible to drive vehicles with hydrogen instead of petrol. An important component of fuel cells is the catalyst. It presently contains platinum, which we intend to replace with less expensive metals to the largest possible extent.

How do you do that?
Prof. Karl Mayrhofer, Director at HI ERN, has developed a unique method with which we can characterise the corrosion behaviour of different catalysts accurately and quickly. This improves our basic understanding of long-life catalysts.

Local geography

City cycling ...

is a Climate-Alliance campaign. The city of Erlangen, in which the cycle traffic volume is higher than anywhere else in Bavaria, took part again in 2018. There were 16 HI ERN employees who covered as many kilometres as possible by bike instead of taking the car for three weeks – thus saving 685 kg of CO₂.

The “Bergkirchweih” ...

has taken place since 1755 and is thus the oldest funfair in Germany. The “5th season” in Erlangen always begins on the Thursday before Whitsun and lasts twelve days.

Religious refugees ...

from France – the Huguenots – prompted Margrave Christian Ernst von Brandenburg-Bayreuth to build a new, baroque “ideal city” next to the old Erlangen with wide, straight streets and many squares in the 17th century. Later, the two parts of the city grew together.
THUMBS UP

SINGING IN THE CLEAN ROOM

Team initiative for the Science Year

“Who sings at the craziest place?” asked the “Science Year” initiative as they looked for vocal talents in summer 2018. The staff of Forschungszentrum Jülich did not tarry long and took part in the campaign “Sounds like teamwork” with the song “Unser Stammbaum” (Our family tree) by the band Bläck Fööss. The fact that three institutes opened their hallowed halls of research for the music video was well received not only by the viewers. Not even the protagonists from Forschungszentrum Jülich get a regular chance to be in a true clean room laboratory.


WORLD LITERATURE ON YOUTUBE

Classics in a nutshell

Goethe’s “Faust” in 9 minutes or Kafka’s “The Metamorphosis” in 11 minutes? Dramaturge Michael Sommer offers the hefty, several-hundred-page tomes of world literature short, crisp and “to go”. On his YouTube channel “Sommers Weltliteratur to go”, he stages the classics everybody knows from their German classes back at school with the help of Playmobil in such a way that literature amateurs will be able to have their say and that even die-hard connoisseurs get their money’s worth.

– HTTP://SOMMERS-WELTLITERATUR.DE/ –

TWEETS FROM ANTARCTICA

Homemade frozen foods

Eggs for breakfast, plus a slice of bread with honey or chocolate spread? What is standard procedure for Central Europeans is a great challenge for the crew of the Concordia Research Station in Antarctica – at least if they want to eat in the open. At temperatures around -70 degrees Celsius, every meal turns into frozen food within seconds. Station manager Cyprien Verseux shows what this looks like on his Twitter page in an impressive fashion, providing insight into life in the freezing cold.

– HTTPS://TWITTER.COM/CYPRIENVERSEUX –
Fit as a fiddle after three vodkas? Clear-headed despite lack of sleep? Both have apparently the same biochemical cause in the brain. #Sleep #Alcohol

Dr. David Elmenhorst and his colleagues from Cologne and Jülich have proven these correlations. They investigated how test persons reacted to sleep deprivation or the influence of alcohol. The researchers assume that there is a common biochemical mechanism in the brain. Their findings could help prevent accidents caused by fatigue. [http://fz-juelich.de/sleepdeprivation](http://fz-juelich.de/sleepdeprivation)