



The stuff of the future

Hydrogen is a beacon of hope for the energy transition

FROM THE AIR

Drones help to optimise manioc cultivation in Africa

IN THE DEEP

How soils can better provide for plants

ACROSS BORDERS

Jülich builds bridge of knowledge to Palestine



Unusual flying object

Floating and gathering: for several weeks in May and June 2020, the Zeppelin NT could be marvelled at over the Rhineland. The airship flew in the service of atmospheric research and collected measurement data on nitrogen oxides, trace gases and fine dust in the air. This is how Jülich troposphere researchers wanted to find out how the pandemic affects air quality lockdown in the corona.



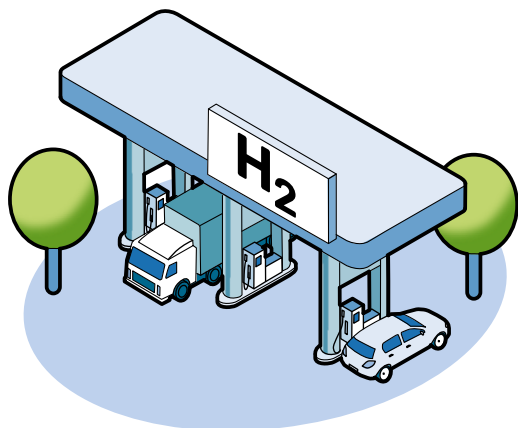
Climate researcher Astrid Kiendler-Scharr says more on the topic in the video (in German): fz-juelich.de/covid-luftqualitaet

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Hydrogen is to help implement the energy transition. Technology from Jülich can make an important contribution to this.

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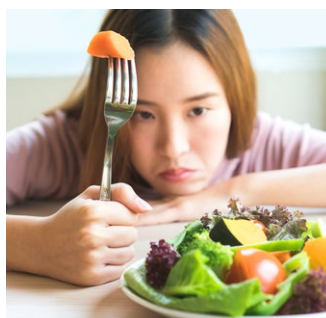
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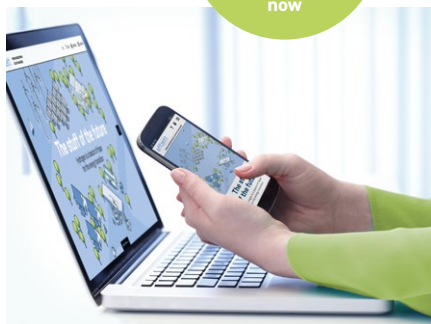
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The number one

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Even Jules Verne already predicted a brilliant future for hydrogen: “Tomorrow’s energy is water broken down by electricity. The elements of water broken down in this way, hydrogen and oxygen, will secure the Earth’s energy supply for the foreseeable future,” he wrote in his novel “The Mysterious Island”, published in 1874. Almost 150 years later, the German Federal Government adopts the National Hydrogen Strategy. The fiction of Jules Verne becomes the declared goal: according to Federal Minister of Education and Research Anja Karliczek, green hydrogen is the energy source of the future, and Federal Minister for Economic Affairs and Energy Peter Altmaier wants to make Germany the world’s number one in hydrogen technologies.

There is still a lot to be done to fulfil the hopes that rest on the gaseous lightweight. However, Jülich researchers are confident that it can succeed. They have been working for years in various fields to pave the way for hydrogen. Our cover story shows what already works and what is still missing.

You can also read how Jülich builds a knowledge bridge to Palestine, how the “soil pantry” always stays well stocked and that debates about research results are part of the knowledge process.

We hope you enjoy this issue!

Your *effzett* editorial team

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Conception and editorial work: Annette Stettien, Dr. Barbara Schunk, Christian Hohlfeld, Dr. Anne Rother (responsible under German Press Law)

Authors: Marcel Bülow, Hannah Faber, Dr. Frank Frick, Christian Hohlfeld, Jannis Lindner, Katja Lüers, Christian Meier, Dr. Regine Panknin, Martha Peters, Tobias Schloßer, Dr. Barbara Schunk, Brigitte Stahl-Busse, Angela Wenzik, Dr. Janine van Ackeren, Erhard Zeiss

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Contact: Corporate Communications, tel: +49 2461 61- 4661, fax: +49 2461 61- 4666, email: info@fz-juelich.de

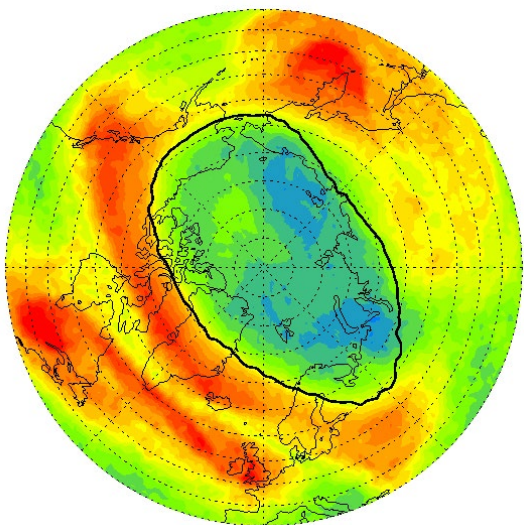
GEOSCIENCES

Cautious, heavy rain

Heavy rain swamps roads, floods underground garages and can trigger mudslides. It often causes considerable damage and endangers people. Researchers from Jülich and Hanover have developed methods which can assess in detail the threat that heavy rain poses to municipalities. They created a digital information system including corresponding maps for the federal state of Hesse.

Municipalities, ministries and also private individuals can use it to take efficient precautions.

- INSTITUTE OF BIO- AND GEO-
SCIENCES -



CLIMATE RESEARCH

Ozone loss over the Arctic

This winter, ozone losses in the stratosphere over the Arctic have been greater than in previous years. As calculations by Jülich climate researchers have shown, this was mainly due to the particularly low temperatures in the stratosphere. In addition, the Arctic polar vortex was stable for an exceptionally long phase this year, so that ozone depletion took place over a longer period of time.

- INSTITUTE OF ENERGY AND CLIMATE RESEARCH -



A detailed interview can be accessed online:
fz-juelich.de/quantum-reality

INQUIRED

Quantum strategy systematically

The Helmholtz Association published a quantum strategy in March 2020. The Jülich Chairman Prof. Wolfgang Marquardt coordinates the Helmholtz Research Field Key Technologies.

Mr Marquardt, what is the strategy about?

Helmholtz addresses many aspects of quantum technologies. With this strategy, we are bundling our competencies and setting ourselves clear objectives that we want to achieve within seven years. Reviewers highly praised the concept, especially for its systemic approach.

What are these objectives?

We not only want to clarify fundamental questions, but also, together with our partners, develop concrete technologies such as a quantum computer and components for quantum communication. Science and industry must work together in new formats to achieve this. It is precisely these objectives that are also contained in the Federal Government's "future package" – an important signal.

What can Jülich contribute to this?

Jülich is broadly positioned, especially in quantum computing. We are working on various types of qubits, the memory elements of a quantum computer, but we are also developing entire systems – such as a quantum computer together with German and European partners.

CHRISTIAN HOHLFELD ASKED THE QUESTIONS.

INFORMATION TECHNOLOGY

Artificial synapses made to measure

Scientists around the world are working on energy-efficient computers that are based on the way the human brain functions. They rely on components that are capable of learning – similar to the synapses of human nervous systems. Researchers from the Jülich Aachen Research Alliance (JARA) and the Heraeus technology group have now discovered how the switching properties of these so-called memristive elements can be specifically influenced: what is decisive are material differences so small that they have so far been overlooked by experts.

- PETER GRÜNBERG INSTITUTE -



185,000

battery storage units

in German private households were storing surplus electricity from photovoltaic systems at the end of 2019. This means an increase of 48 per cent compared to 2018. The total capacity of the storage units has increased by 53 per cent to 1,420 megawatt hours, as shown in an analysis by researchers from Jülich and Aachen. This corresponds to the average annual electricity consumption of 350 four-person households. There was also a significant increase in the capacity of stationary large battery storage systems, which are primarily used to stabilise the power grids.

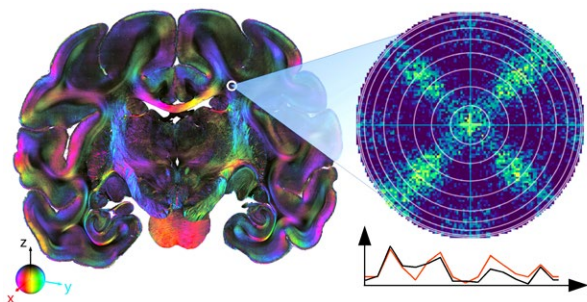
- INSTITUTE OF ENERGY AND CLIMATE RESEARCH -

Better view of nerve fibers

A new method makes the courses of nerve fibres in the brain visible with micrometre precision and in detail, even where the fibres cross. This helps to better understand the structure and functioning of the brain.

The method involves the use of a light microscope to shine through brain slices and analyse the scattering of light. Complex simulations on supercomputers helped the researchers from Jülich, Groningen and Florence in developing the method.

- INSTITUTE OF NEUROSCIENCE AND MEDICINE -



ELECTRON MICROSCOPY

Prize winner: Prof. Knut Urban

Prof. Knut Urban, Senior Professor of the Jülich Aachen Research Alliance (JARA), received the Kavli Prize for Nanoscience, along with Prof. Harald Rose, Prof. Maximilian Haider and Prof. Ondrej Krivanek, for further developing electron microscopy. The researchers' work formed the basis for a new generation of high-precision devices that make it possible to image and study materials at atomic resolution. The Kavli Prize is endowed with \$ 1 million.

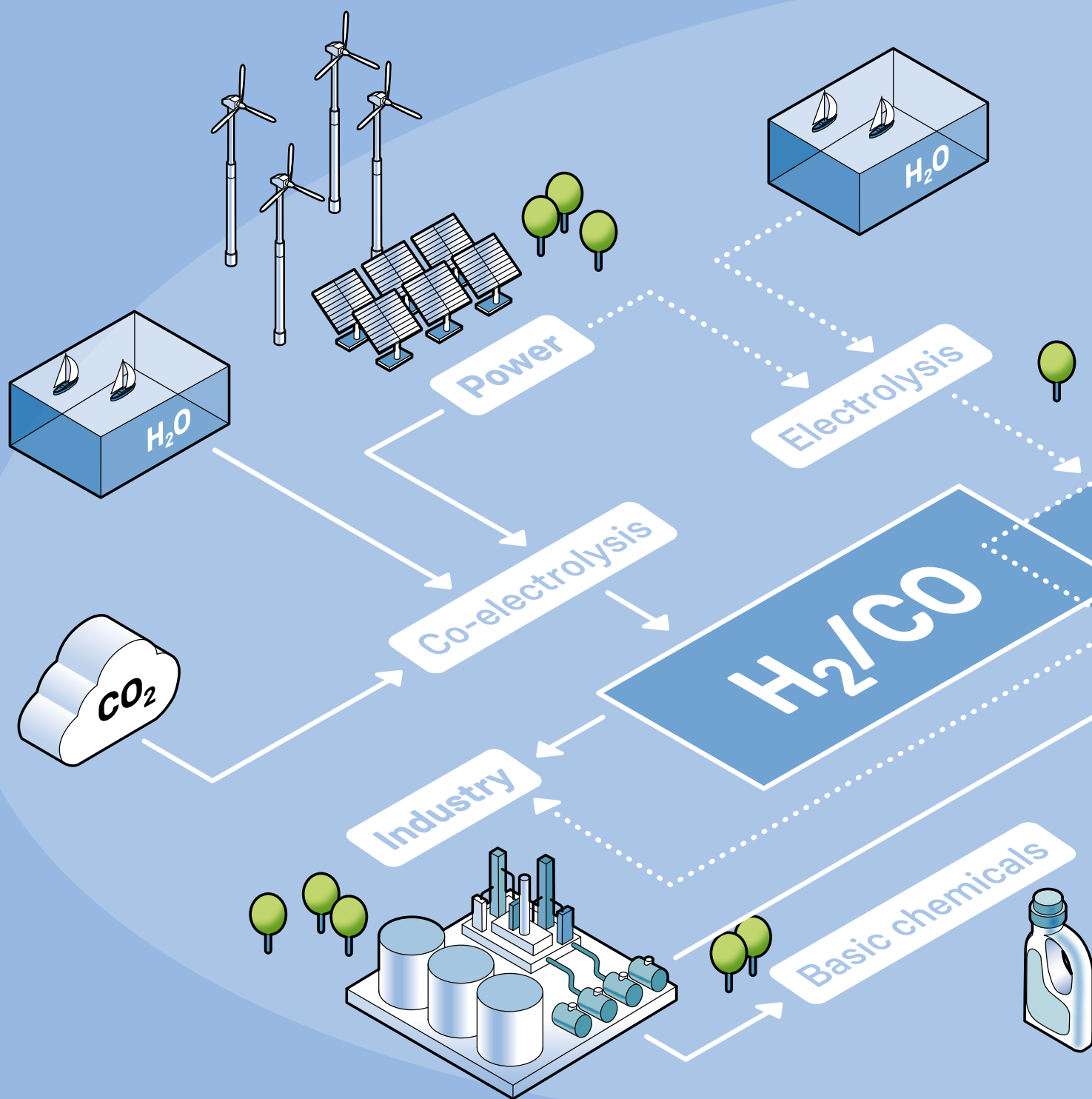
- ERNST RUSKA-CENTER FOR MICROSCOPY AND SPECTROSCOPY WITH ELECTRONS -

Errors improve storage

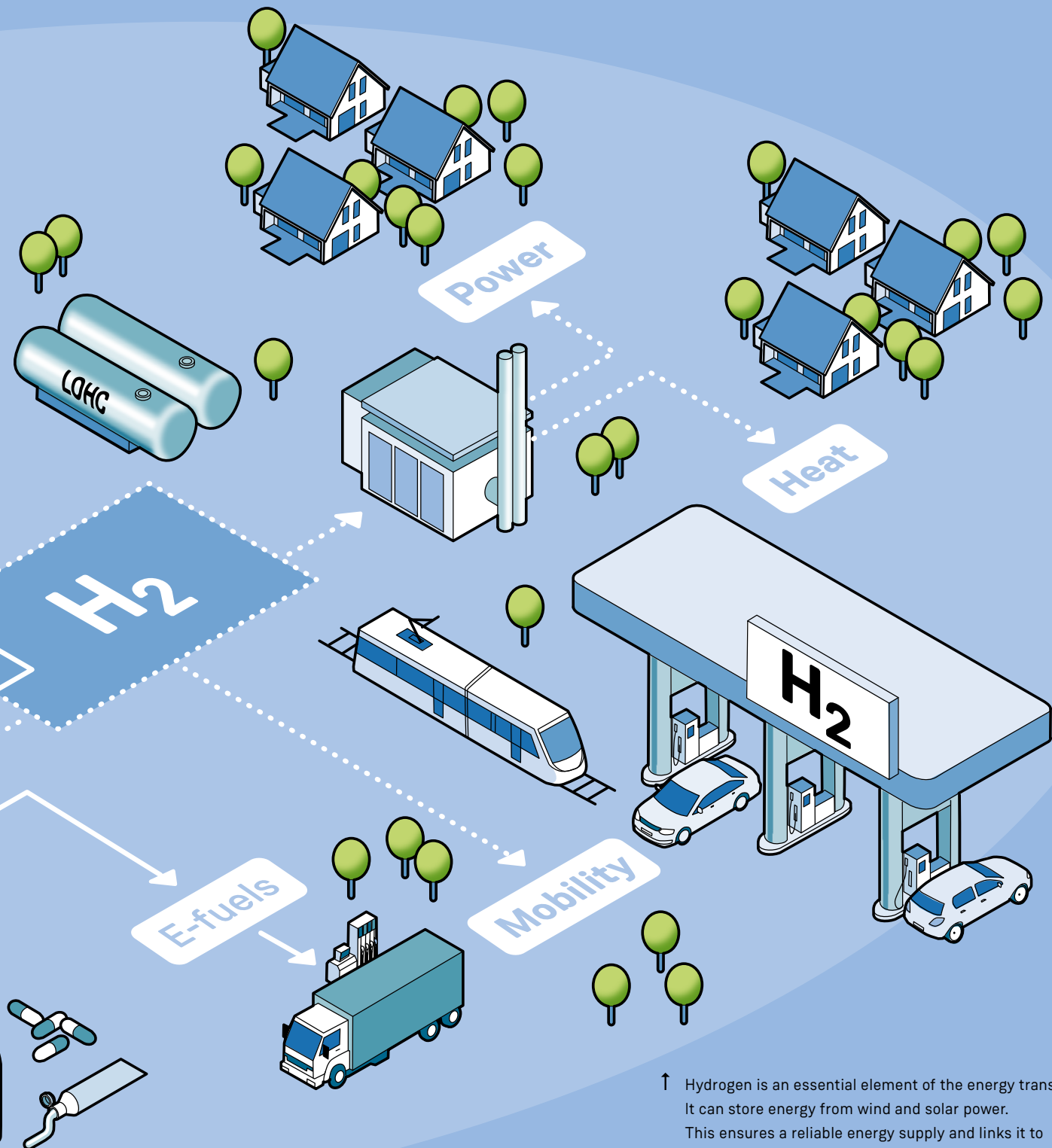
In the future, data could be stored in the form of tiny magnetic vortices – so-called skyrmions. Correspondingly powerful and energy-saving chips still only exist as a concept. Computer simulations from Jülich physicists have now shown an unusual, but useful effect: material defects improve the performance of a specific type of these data storage devices. Defects are normally undesirable in nanoelectronic components.

- PETER GRÜNBERG INSTITUTE/INSTITUTE FOR ADVANCED SIMULATION -

The driving power



Hydrogen stimulates great expectations. It is expected to ensure the energy transition. At the same time, hydrogen technologies are intended to become a new export hit for Germany. The potential is there, according to Jülich researchers. They are addressing all aspects regarding this beacon of hope.

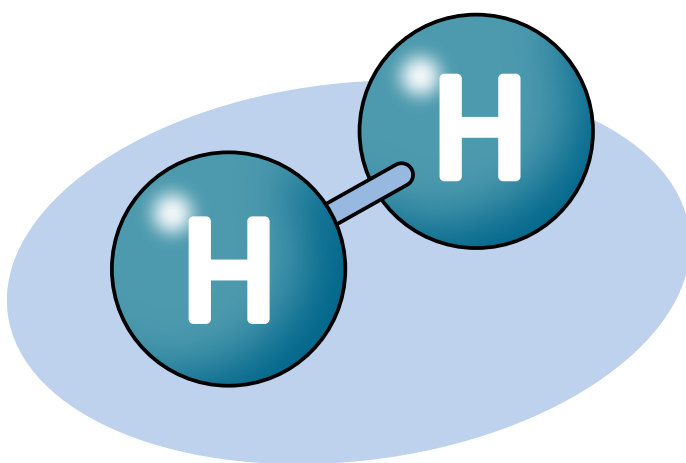


↑ Hydrogen is an essential element of the energy transition. It can store energy from wind and solar power. This ensures a reliable energy supply and links it to transport, heat generation and industrial production.

#1

Beacon of hope

Hydrogen is the smallest and lightest chemical molecule. Still, it plays an important role in the restructuring of the energy system.



Germany is to become a global pioneer in hydrogen. This is the intention of the Federal Government's National Hydrogen Strategy. Hydrogen is not only considered a central element for Germany to achieve its climate targets by 2050; it is also regarded as the urgently needed building block for networking and optimising electricity, transport, industry and the heating supply. Germany is to secure a leading international position in hydrogen technologies, thus opening up new sales markets for the German economy. Following the example of space travel, Federal Minister of Education and Research Anja Karliczek even speaks of establishing a "Cape Canaveral of hydrogen" in Germany.

Hydrogen is attractive because it can be used to store electricity from renewable energy sources, as green electricity is generated very discontinuously: sometimes the wind blows forcefully, sometimes not at all. The sun does not always shine with the same intensity, either. Surplus electricity that is not immediately needed in the grid could be used to produce hydrogen. "This can be stored over long periods of time and then be used when there is no wind, for example," says Prof. Olivier Guillon from Jülich's Institute of Energy and Climate Research (IEK-1).

However, it is not only this storage function that makes hydrogen essential for the energy transition. It also offers a way out of a dilemma: after all, it is not foreseeable that all aircraft, ships and trucks can ever be powered electrically by batteries. "Even so, in the transport sector we have to abandon the classic supply of diesel or petrol if we want to emit only the same amount of greenhouse gases into the atmosphere in Germany in 2050 as we take from it," says Prof. Detlef Stolten, who works on energy systems at IEK-3. The solution could be fuel cells – climate-friendly drives that use "green" hydrogen (see box).

But that's not all: hydrogen can also help the chemical industry through a difficult transition, as it is dependent on carbon sources to produce medicines and plastics, for instance. As long as it relies on mineral oil or natural gas for this purpose, the result will be a poor climate balance. "Using so-called Power-to-X technologies, hydrogen and, if CO₂ is added, carbonaceous gases can be produced from green electricity. These could replace mineral oil and natural gas to produce basic chemicals for the industry and liquid fuels, such as for aviation. In this way, hydrogen links the sectors of electricity, industry and transport," emphasises Prof. Rüdiger Eichel, electrochemistry expert at IEK-9

Colourful hydrogen

Hydrogen (H₂) is a colourless gas. Depending on the type of production, however, it is assigned a colour.

Green: H₂ is extracted through electrolysis in a climate-neutral way with electricity from renewable sources.

Grey: H₂ is produced from fossil raw materials such as natural gas. This generates around 10 tons of CO₂, the greenhouse gas, per ton of H₂.

Blue: H₂ is produced from fossil fuels, but the CO₂ produced is separated and stored so that it does not enter the atmosphere.

Turquoise: H₂ is produced by splitting natural gas at high temperatures. Solid carbon is produced in the process. If the process runs on heat from renewable energy sources, no CO₂ is produced.

However, there are still some obstacles to overcome: a lot of energy is lost in the production, storage and use of hydrogen. This drives up costs. The infrastructure for transporting and refuelling hydrogen safely is also expensive. In addition, there is hardly any operating experience with some of the hydrogen technologies so far.

Jülich energy researchers are working on paving the way for hydrogen. “We have comprehensive, holistic expertise in this: it ranges from basic research to application – starting with the materials and electrochemistry and leading on into the key technologies and understanding of systems, which allows us to make technical, societal and economic assessments,” says Olivier Guillon. According to the materials scientist, this is unique in Germany. So, these are the best prerequisites for hydrogen to really fulfil its role as a beacon of hope.



↑ Prof. Detlef Stolten, Director of the Institute of Energy and Climate Research (IEK-3)

#2

The producers

Electrolysis systems produce the hydrogen, Jülich researchers improve them.

The windmills are turning fast. Production of green electricity is running at full speed. Electricity, not needed by the computers in offices, households and industry at the given moment, can be used to split water in electrolysis systems. In this way, hydrogen is produced and the electrical energy is converted into chemical energy. This allows excess electricity to be stored.

“We are working on the optimisation of three different electrolysis processes,” says Dr. Martin Müller, process engineering specialist at the Institute of Energy and Climate Research (IEK-14). “Each process has its strengths and weaknesses. It is still open which one will win the race, and it also depends on whether the electrolysis system is installed directly at a wind farm, a home solar power system or in a chemical network, for example.”

“Germany can be a frontrunner”

Detlef Stolten researches the energy supply and use of tomorrow. He has been concentrating on the transformation of the energy system from a technical-economic standpoint since 2010.

Prof. Stolten, do hydrogen technologies open up new opportunities for Germany’s economy?

Yes. While the market for battery technology is largely dominated by Asian suppliers, the race is still open regarding electrolysis and fuel cell technology. Germany and Europe have a good chance of playing in the lead here. However, action must be taken quickly.

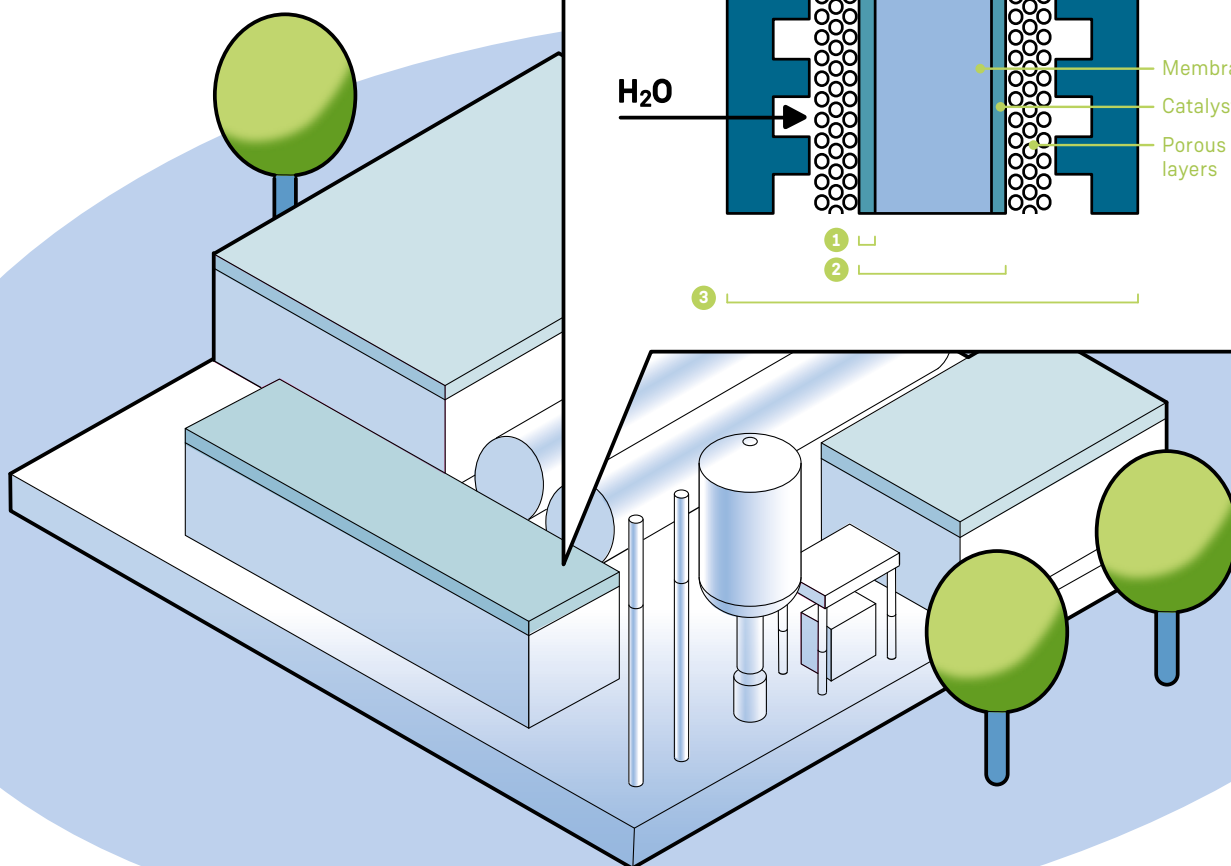
What’s the rush?

If we hesitate too long, others will win the race. In order to be successful in global competition, we need a domestic market for hydrogen technologies, that is, a corresponding infrastructure with pipelines, storage facilities and filling stations. It takes a long time to establish this, so we have to start now.

Germany will not be able to produce all the hydrogen it needs itself. How much will we have to import?

We were able to show in a study that, for a climate-neutral Germany in 2050, it would be cost-optimal if about half of the hydrogen needed were imported and the other half were produced in Germany. A prerequisite for this, however, is the further expansion of renewable energies.

Electrolysis system



Type 1: The classical one

Plants where the central component, the electrolyte, is an alkaline liquid can be bought off the shelf, so to speak. Alkaline electrolysis plants make do with inexpensive materials. A major disadvantage is their low power density: they produce comparatively little hydrogen per square centimetre of surface area. Large space requirement and high material consumption are the result. "Alkaline electrolyzers are generally considered to be technically mature, but we are pursuing new approaches to increase their power density," says Müller. One of these approaches is based on new partitions which are installed in the liquid electrolyte to electrically isolate the negative pole (cathode) and the positive pole (anode) from each other.

Type 2: The promising one

Higher power densities than alkaline electrolyzers are achieved in systems in which the electrolyte does not consist of a liquid but of an extremely thin layer, a so-called polymer electrolyte membrane (PEM). However, the high costs of PEM plants stand in the way of wider dissemination. "Jülich researchers have their sights set on various parts of the facility to change this," says Dr. Marcelo Carmo, electrochemist at IEK-14.

Where Jülich researchers improve the cell

1 PEM systems require expensive and rare noble metals such as platinum and iridium. Yet, Jülich researchers have recently developed an anode (positive pole) which needs no more than a touch of iridium oxide to achieve excellent results. With such electrodes, PEM systems could be realised that only require about 10 per cent of the iridium quantity used so far.

2 Jülich scientists have produced the unit, which consists of a coated membrane and electrodes, using a process that is suitable for mass production and yet flexible: the substances for the individual layers are each finely distributed in liquids and the resulting dispersions are applied step by step with a slotted nozzle.

3 A new design of PEM electrolysis systems with very thin membranes makes it possible to supply the water in a different way than conventionally. According to calculations, this results in a 15 per cent reduction in investment costs.

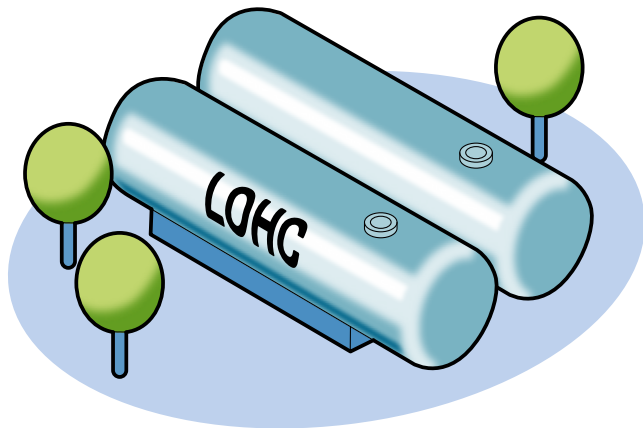
Type 3: The hot one

While alkaline and PEM electrolysis systems are usually operated at around 80 °C, the third electrolysis process requires more than 650 °C. In these so-called SOE systems (Solid Oxide Electrolysis), the high operating temperature must be maintained even when no current is available. This is because starting and stopping the system would cost even more energy – and this would also tire out the material more quickly. The technology is economically interesting nevertheless: “The SOE systems are very well suited to use the heat generated by many industrial processes. Then, they convert the electricity very efficiently into the chemical energy of hydrogen,” explains Prof. Ludger Blum of IEK-14. In recent years, Jülich researchers have made SOE electrolyzers more reliable and durable through various improvements.

#3

The liquid carrier

A process developed by the Helmholtz Institute Erlangen-Nürnberg makes it possible to store and transport hydrogen safely and easily. By 2022, it will be tested in everyday operation at Jülich.



Hydrogen leaving the electrolyser is a colourless and odourless gas, lighter than air. But what to do with it? It must be stored and transported before it can be used at a later date or in another place. Lest it take up too much space, it is usually compressed and stored in pressure vessels, underground in salt caverns or cooled to below minus 240 °C so that the hydrogen becomes liquid. There is an alternative, however: the so-called LOHC technology. In a chemical reactor, hydrogen is bound to a diesel-like and flame-retardant organic carrier liquid, the Liquid Organic Hydrogen Carrier, or LOHC for short.

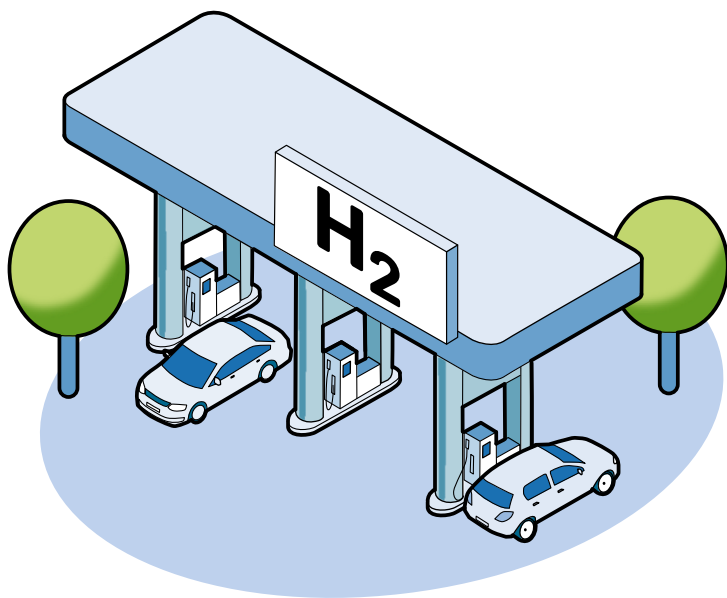
In the same reactor, the hydrogen can be split off again as soon as it is later needed for power generation or for fuelling fuel cell vehicles. Bonded to the LOHC, the hydrogen can not only be safely stored at atmospheric conditions in classic steel tanks, but can also be transported in classic tank trucks, tank wagons or tank ships. The technology is based on research work carried out by a team led by Prof. Peter Wasserscheid at the Helmholtz Institute Erlangen-Nürnberg, a part of Forschungszentrum Jülich.

At the Jülich research site, an LOHC facility that is unique in the world will be tested in daily operation by 2022. It will become part of the “Living Lab Energy Campus”, a real laboratory for future energy systems at the Jülich research campus. The LOHC facility will be coupled to a combined heat and power plant and use the waste heat generated there to release the hydrogen from the carrier liquid. The hydrogen storage process, in turn, releases heat which flows into Forschungszentrum Jülich’s local heating network.

#4

The sources of power

Thanks to Jülich research, fuel cells are becoming more cost-effective and more efficient.



The hydrogen flows through pipelines to combined heat and power plants and filling stations. LOHC trucks supply small places that are not connected to the pipeline systems. Fuel cells are used to release the maximum of the stored energy. They generate electricity from the hydrogen. For this purpose, they additionally require oxygen; the only exhaust produced

is water. In the combined heat and power plants, the fuel cells generate electricity for housing estates, also using the heat produced in the process. This increases efficiency. In vehicles, fuel cells drive engines.

So-called SOFC fuel cells are particularly well suited for combined heat and power plants (CHP). SOFC stands for Solid Oxide Fuel Cell. This type is extremely efficient in converting hydrogen into electricity. Since SOFC fuel cells in CHPs can run continuously, there is no need to frequently start up the system to the required operating temperature of around 700 °C, which would cost energy and put a strain on materials. For fuel cells to be operated economically, they must last as long as possible. With a SOFC fuel cell they developed themselves, Jülich researchers have proven that cells of this type function perfectly for more than ten years in continuous operation. “At the beginning, hardly anyone would have thought so because of the high operating temperature and the resulting material requirements,” says Prof. Ludger Blum from IEK-14.

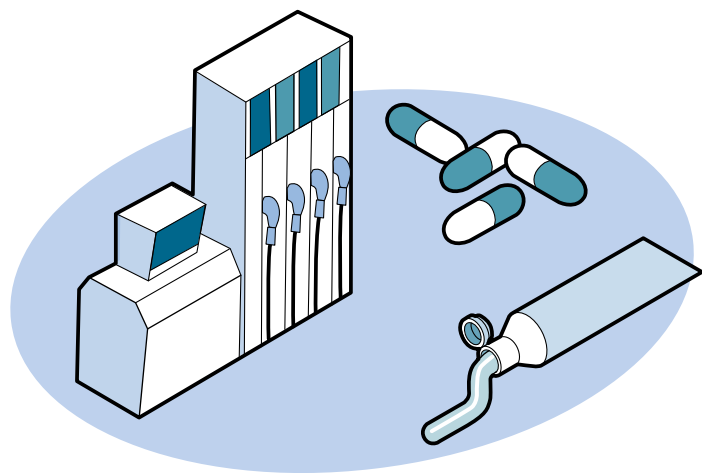
In addition, Jülich researchers have developed a solid oxide system on a laboratory scale that they can switch back and forth within ten minutes: between an electrolysis mode, in which it produces hydrogen with electricity, and a fuel cell mode, in which it generates electricity from hydrogen. “If a plant can be operated as an electrolyser or as a fuel cell, depending on requirements, then instead of two plants only one plant is needed to store electricity in the form of hydrogen on site and convert it back into electricity at a later date. This helps to save considerable costs,” explains Blum. Besides, such reversible cells are suitable for use in remote stations on islands or mountains. The performance of the reversible cell still decreases quite rapidly with increasing operating time, especially in electrolysis mode, but the researchers are working to change that. They are also in the process of transferring their findings from the laboratory scale to larger plants.

Another Jülich team, together with researchers from TU Wien (Vienna), has increased the power density of so-called metal-supported SOFCs by more than 200 per cent within a few years. “The decisive factor was that we systematically optimised the structure of the electrochemical functional layers and the cell architecture,” says Dr. Martin Bram of IEK-1. Car manufacturers are interested in metal-supported SOFCs, which they would like to use in electric cars as range extenders in order to continuously charge the vehicle battery. Metal-supported SOFCs are particularly suitable for this purpose because they can withstand shocks and vibrations on the vehicle floor better than the usual full ceramic fuel cells.

#5

The value adders

Jülich researchers are working on sustainable processes to produce basic chemicals and liquid fuels using green hydrogen.



Production is rolling: synthetic materials, varnishes, adhesives, medicines and fuels are produced in the factories of the chemical park. The elementary components of these products – hydrogen, oxygen and carbon – have so far mostly come from crude oil and natural gas. “Power-to-X technologies can change that. Here, power stands for sustainable electricity, X for added value,” explains Jülich energy researcher Prof. Rüdiger Eichel. The elements are then supplied by water and carbon dioxide (CO₂), which is separated from industrial waste gases or the atmosphere. Electricity from wind and sun provides the energy needed to rearrange the elements, so to speak, and to turn them into fuels or basic chemicals. Thus, the production process does not generate any climate-damaging gases.

Eichel coordinates the “Kopernikus project P2X” in which 49 partners from industry, science and civil society are jointly researching and developing Power-to-X technologies. The researchers were particularly successful regarding the starting point of the process chain: the so-called co-electrolysis units. These not only use electricity to split water, but also convert CO₂, producing a mixture of carbon monoxide and hydrogen. Experts call it syngas because it can be used for synthesis, i.e. for the production of various chemicals.

As a special feature, the electrolysis system developed by Jülich researchers in the P2X project can produce syngas in which the mixing ratio of hydrogen and carbon monoxide can be set as desired. “This is crucial to ensure that the syngas has the right composition for the desired fuel or required basic chemical,” says Eichel. The P2X researchers are also developing the facilities with which the syngas can then be processed into fuels such as synthetic diesel or kerosene. “In this way, the supply of liquid fuel for high-performance vehicles such as aircraft, ships and trucks is to be made renewable in the future,” says Prof. Ralf Peters of IEK-14. He coordinates the fuel synthesis activities in the C3-Mobility research association in which 30 partners from science and industry – including many car manufacturers – research climate-neutral fuels for the traffic of the future.

“Together with our partners from science and industry, we want to bring the technologies that we develop in the various projects into widespread application as quickly as possible. The structural change in the Rhineland’s lignite mining area offers great opportunities in this respect,” says Eichel. This is the aim of the iNEW project (Inkubator für Nachhaltige Elektrochemische Wertschöpfung; incubator for sustainable electrochemical added value), which the German government is funding with over € 20 million as part of its immediate action programme for structural change. “Previously, energy-intensive industries have always been located in regions where coal, gas or oil was extracted. Now we have the opportunity to put this alliance of energy and added value on a sustainable track,” says project manager Eichel.

FRANK FRICK



More about Jülich’s
hydrogen research at:
fz-juelich.de/hydrogen

More about hydrogen research
in the Helmholtz Association:
[helmholtz.de/en/current-topics/
hydrogen-technologies](https://helmholtz.de/en/current-topics/hydrogen-technologies)

Sowing knowledge, harvesting food

Cassava has the potential to sustainably secure food supplies in Africa. However, the yields are too low. An international team of researchers wants to change this – with improved plants and drone flights.

SUPER TUBER

Cassava conquers the menus of trendy restaurants. Prepared like chips, the carbohydrate-rich tuber is a welcome alternative to potatoes. Things are different in Africa: cassava is an important staple food for the people there. The plant is very well adapted to the tropical climate: in the rainy season, the plant stores so many nutrients in its roots, which are as thick as arms, that it can survive the five-month dry period. After the end of the dry season, as soon as the soil is no longer hard and the plant has replenished its underground storage, the up to three-metre-high plant is harvested – with all its valuable carbohydrates. This is what makes the plant so popular as a food.



LOW YIELD

With almost 50 million tons per year, Nigeria is the largest producer of cassava, but the harvest yield is not very efficient. “If you look at the situation here, in agricultural practice, farmers create 70 to 80 per cent of the maximum possible yield. With Nigerian cassava, it is only about 20 per cent,” explains Prof. Dr. Uwe Rascher from the Jülich Institute of Bio- and Geosciences (IBG-2). More water, more arable land or the use of expensive technology to increase yields are difficult to achieve. However, if the plant were more robust and higher in yield, cassava could contribute to food security in precisely those areas where this has been lacking.

THE CASS PROJECT

An international team of scientists is working on a variety of the cassava plant that is even better adapted to West African conditions and delivers higher yields. In the Cassava Source-Sink (CASS) project, Jülich scientists are conducting research in collaboration with colleagues from Friedrich-Alexander-Universität (FAU) Erlangen, who are coordinating the project, ETH Zurich and the International Institute of Tropical Agriculture, among others, in Ibadan in southwest Nigeria. CASS is financed by the Bill & Melinda Gates Foundation.



AIRBORNE RESEARCH

In the field trial in Nigeria, the CASS team is testing various cassava varieties. The researchers have access to around 500 varieties, which were created in crossbreeding experiments involving the four most frequently used varieties. During the tests, Jülich experts observe the aerial part of the plant. “We want to measure, in the course of the seasons, how and where the plant grows and how well it photosynthesises,” explains Uwe Rascher. A drone developed at Jülich is used to document the growth of more than 9,000 plants: it photographs the plants from the air. A specially modified software analyses these images and creates 3D models from them. Using these, the researchers can observe exactly how certain cassava types grow. This is a method that can also be used to study the growth of other food plants such as yam or millet.



TECHNOLOGY AS A SEED

Dr. Anna van Doorn is at the heart of these activities. The former employee of Uwe Rascher now works at the cassava experimental station in Nigeria. “Only when we understand how the plant grows under the local conditions can we try to improve it in a targeted way,” she explains. Anna von Doorn will be accompanying on-site research over the next three years and flying the camera drone, for which she played a major role in the development of hardware and software at Jülich. She also hopes to soon be able to involve Nigerian students in her work. This is an important step for Uwe Rascher: “We want to do research with local partners and only introduce technologies and processes that our partners in Africa can use sustainably. If the new processes can then be routinely carried out in the producing regions, we were successful as a research institution.”



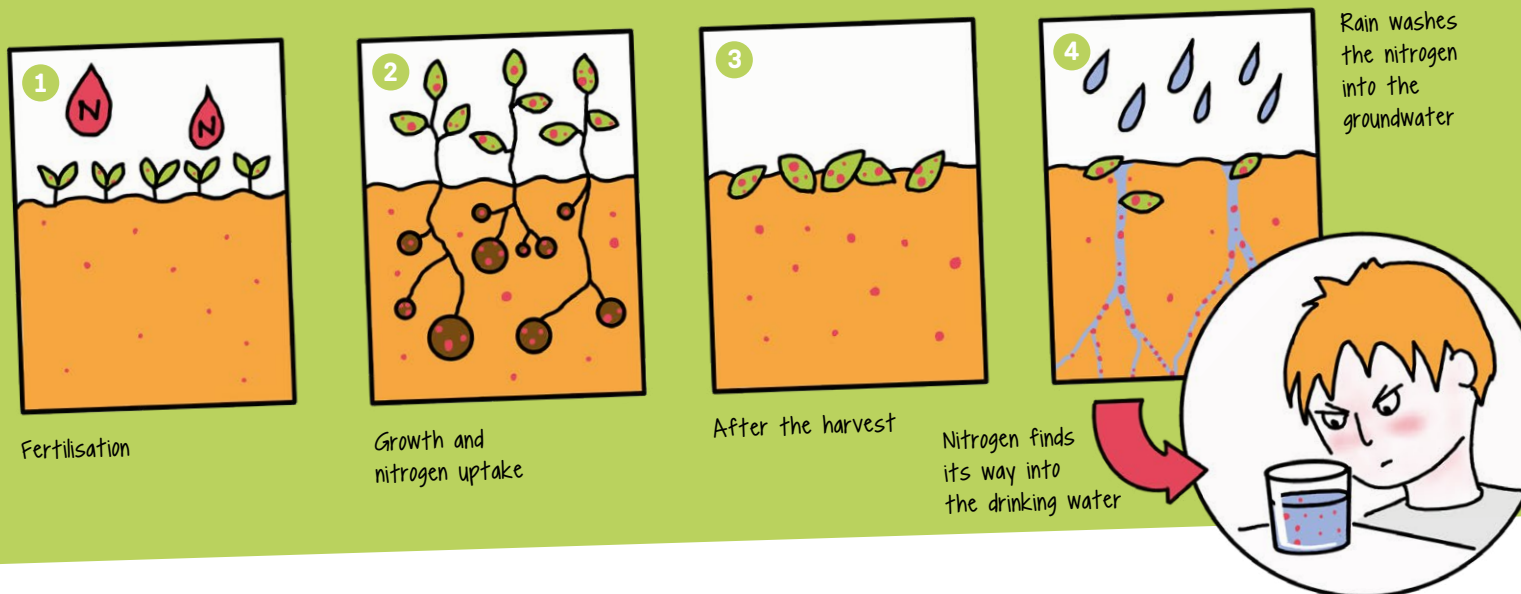
More about the work of Anna van Doorn in the online edition: effzett.fz-juelich.de/en

The soil as a pantry

Field crops need nutrients and water to grow. They get both from the soil, but soils across the world are producing increasingly lower yields. Researchers at Jülich are investigating how soils can better provide for plants and be used more sustainably.

Soils are the plants' pantry: they provide them with nutrients, above all with nitrogen, phosphorus, potassium, magnesium, calcium and sulphur. However, soil erosion, pollutants, climate change, overfertilisation and the like threaten this valuable resource. The United Nations warn that soil erosion alone could halve the crop yield. So it is high time to use the soil more sustainably. The necessary knowledge is being developed by scientists from the Institute of

Bio- and Geosciences (IBG-3) and their partners in the projects of the BonaRes funding initiative: how can important nutrients such as nitrogen and phosphorus be provided and used sustainably? How do plants get access to nutrients in the soil pantry which until now have been too deep? Does growing down into the subsoil protect against dry summers?



Keeping the nitrogen in the soil

1 2 If grains, potatoes and vegetables are to thrive and provide a rich harvest, they need nitrogen in the first place. This is why farmers apply nitrogen fertilisers to the fields – the required amount can be adjusted specifically by measuring the soil and observing the plants.

3 After harvesting, the leaves of the plants remain on the fields, for example in the case of rapeseed and potatoes. The leaves rot over time and release the nitrogen stored in them back into the soil as autumn progresses. There, bacteria convert it into nitrate.

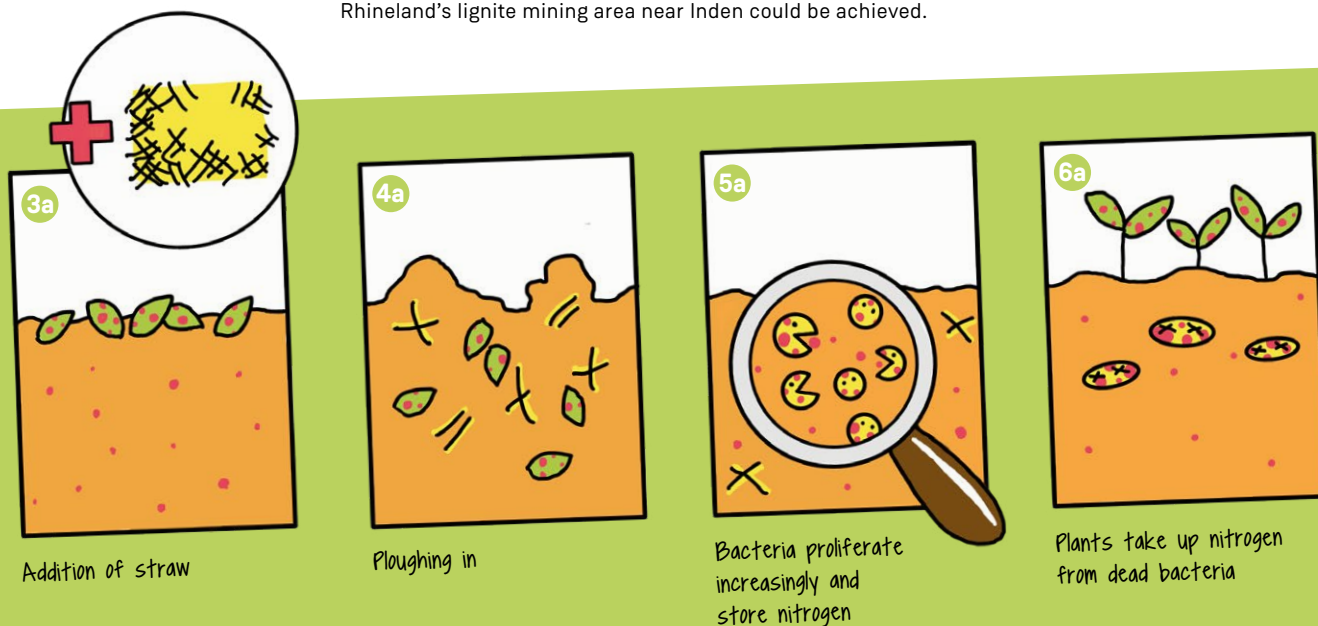
4 Rain washes the nitrate into the ground water and indeed to a considerable extent: in this way, up to 100 kilograms of nitrogen per hectare can find their way into the drinking water per year.



BonaRes

BonaRes is short for “Boden als nachhaltige Ressource für die Bioökonomie” (soil as a sustainable resource for the bioeconomy). The aim of this funding initiative of the Federal Ministry of Education and Research: to better understand the soil ecosystem and to develop new strategies for the sustainable use of this resource. Jülich’s Institute of Bio- and Geosciences (IBG-3) is involved in three BonaRes projects.

↑ In the context of BonaRes, Nicolas Brüggemann is also investigating how the recultivation of the former opencast mining sites in the Rhineland’s lignite mining area near Inden could be achieved.



BACTERIA STORE THE NUTRIENT

How can drinking water be protected from nitrate, and how can the nitrogen be saved over autumn and winter into spring and summer so that it is then available again for the growing plants?

3a 4a Together with partners, IBG-3 researchers have found possible solutions in the Inplamint project. “After the harvest, we put biomaterials such as wheat straw or sawdust on the fields,” says project leader Prof. Nicolas Brüggemann from IBG-3.

5a The biomaterials release carbon, which serves as food for bacteria and fungi. Due to the good feed supply, the bacteria and fungi – in short, microorganisms – proliferate. The trick: besides carbon, they also absorb nitrogen from the soil.

6a What sounds simple has a great effect: with four to five tons of wheat straw per hectare, between 40 and 70 kilograms of nitrogen can be stored in the microbial biomass per hectare. Over the months, the carbon release of the wheat straw declines, the bacteria die, the nitrogen is released and is available to the plants again.



↑ Recycled fertiliser you can touch: Nina Siebers shows the form in which the phosphorus could reach plants.

Phosphorus from animal bones

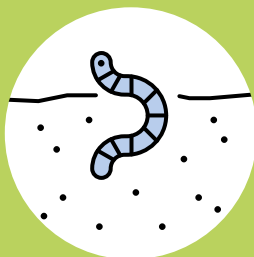
Nitrogen alone is not enough for the plants to grow: no plant can thrive if phosphorus is missing. Fertilisers can be used to enrich the soil with phosphorus – but plants only take up between 10 and 30 per cent of the phosphorus from the fertiliser!

This is because roots only take up phosphorus in dissolved form via the soil water. However, a large part of the phosphorus binds so firmly to soil minerals that plants cannot use it. What's more, the reserves of easily degradable rock phosphate on earth are running out and some of it is mined under questionable conditions. In the InnoSoilPhos project, researchers are therefore testing an alternative: phosphorus fertiliser from charred animal bones. "They contain phospho-

rus, because phosphorus is an important building block for bones and teeth, and animal bones are available as slaughterhouse waste," explains Jülich expert Dr. Nina Siebers. But does the recycled fertiliser provide enough phosphorus for the plants? In order to investigate this, Siebers' team produces the main component of the bone char fertiliser, the mineral hydroxyapatite, in the laboratory.

"We label the phosphorus in the hydroxyapatite with the radioactive phosphorus isotope ^{33}P – in this way, we can observe how quickly the plants take up phosphorus from the fertiliser and how much of it," summarises Nina Siebers. The first results speak in favour of the bone char fertiliser.

Multi-talented soil



Habitat

Soils are home to animals, plants and microorganisms. In turn, earthworms, bacteria and the like help the soil to remain fertile.



Sponge

Soils absorb large quantities of rainwater and filter it. Part of it is stored in the soil – plants can help themselves to it. The rest drains away and replenishes the groundwater reserves.

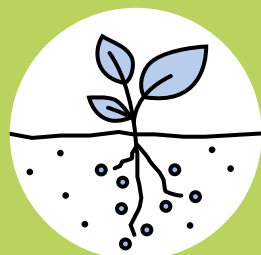
Recycling yard

Microorganisms and other organisms in the soil decompose dead organic matter such as leaves and crop residues, thus making nutrients available.



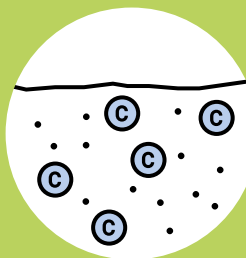
Pollutant filter

Toxic and environmentally harmful substances are also filtered, neutralised and bound in soils. This means that these do not find their way into the drinking water or, if they do, only in small quantities.



Pantry

Plants can absorb, in particular, phosphorus, iron, calcium or nitrogen from the soil via their roots – important nutrients for plant growth.



Climate protector

Soils store carbon: about five times as much as trees and other above-ground biomass. In this way, they help to limit the greenhouse effect.

“We are creating a kind of guarantee that allows the plants to get enough water and nutrients in the dry summers.”

PROF. WULF AMELUNG,
INSTITUTE OF BIO- AND GEOSCIENCES (IBG-3)



Ploughing to depth

If you see farmers with their ploughs in the fields, they usually only work the top 30 centimetres of the soil. However, about two thirds of the water resources and more than half of the nutrients are found in the subsoil below. The subsoil is usually so compacted that the plant can hardly extend its roots there. Special



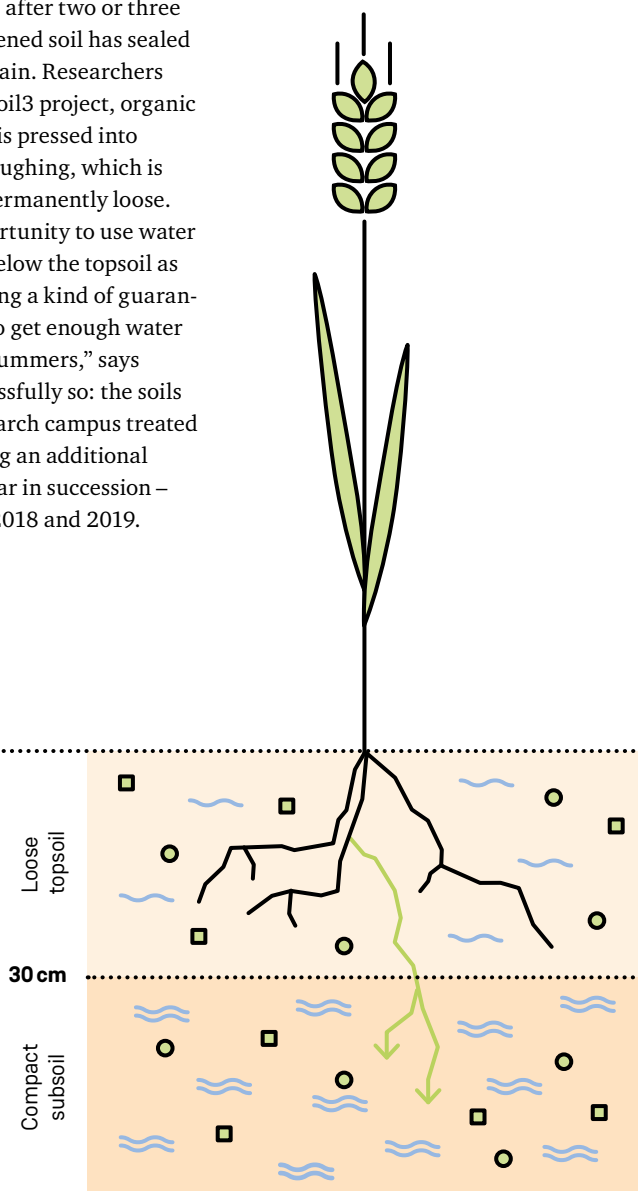
↑ On the Klein-Altendorf research campus near Bonn, in pits about two metres deep, researchers observe how roots make their way through the soil.

methods of ploughing and loosening the subsoil are hardly economical: after two or three years at the latest, the loosened soil has sealed itself off and compacted again. Researchers want to avoid this. In the Soil3 project, organic materials such as compost is pressed into the subsoil during deep ploughing, which is intended to keep the soil permanently loose. The plant is given the opportunity to use water and nutrients from areas below the topsoil as required. “So we are creating a kind of guarantee that allows the plants to get enough water and nutrients even in dry summers,” says Prof. Wulf Amelung. Successfully so: the soils of the Klein-Altendorf research campus treated in this way are now yielding an additional 20 per cent for the third year in succession – even in the drought years 2018 and 2019.

TEXTS: JANINE VAN ACKEREN

The subsoil stores large quantities of water and nutrients. However, plants often use the top 30 centimetres of the soil, the topsoil. The subsoil is too firm for the plants' roots. In order to change this, Jülich researchers are working on methods to loosen the subsoil lastingly. Moreover, they use simulations to investigate how each individual root interacts with different soils. In this way, they can observe how changes in the soil affect roots and thus the rest of the plant.

— Water ● Nutrients ■ Fertilisers



The loss of taste

A worldwide online survey confirms that an infection with the new coronavirus can impair the senses of taste and smell in a characteristic way.

People who cannot smell or taste anything suffer considerably. “Olfactory and gustatory disorders influence eating behaviour, diminish the ability to enjoy food and have an effect on social life: for example, those affected fear that they will not perceive their own body odour or not be able to recognise dangers such as smoke emission in time,” says psychologist Dr. Kathrin Ohla from the Institute of Neuroscience and Medicine (INM-3).

Impairment of the senses of smell and taste is considered a symptom of COVID-19. To find out more about this, the Global Consortium for Chemosensory Research (GCCR) – where Ohla is a member of the steering committee – launched a worldwide online survey already at the beginning of April. All adults who suffer, or have suffered in the last two weeks, from a respiratory disease such as COVID-19, flu or cold are eligible to participate. Even the first analyses of the current survey provide valuable insights.

Firstly, they confirm that infection with the SARS-CoV-2 virus can lead to a complete loss of the sense of smell and also the sense of taste. “These olfactory and gustatory disorders, however, are different from those that occur with colds or flu,” says Ohla. For example, COVID-19 impairments are hardly associated with a blocked nose – unlike in



↑ Tasting is an important part of the quality of life. Kathrin Ohla examines what happens in the brain during this process and, currently, how COVID-19 affects the sense of taste.

The study on the web



gchemosensr.org/surveys/en

cases of cold or influenza. In addition, respondents infected with SARS-CoV-2 only rarely report phenomena such as smelling things that are not there or smells being more unpleasant than before the illness. Finally, there is evidence that the impairment of smell and taste in COVID-19 already occurs at the very beginning of the disease, whereas in influenza and colds they often do so when the other symptoms are already on the wane. However, the study does not show how frequently the symptoms occur. The researcher suspects that patients with olfactory and gustatory disorders are more likely to participate in the survey than those without such symptoms because of their personal involvement.

The first results are based on the statements of several thousand participants. By now, the researchers are already working on further analyses based on tens of thousands of participants and on a test for use at home, with which those affected can continuously test their senses of smell and taste. “In this way, we want to find out how long the olfactory and gustatory disorders last and how often permanent impairment occurs,” says Ohla. According to the head of the Cognitive Neurophysiology research group, such information is necessary in order to be able to properly advise and treat those affected.

FRANK FRICK



What are you researching right now, Mr Pütz?

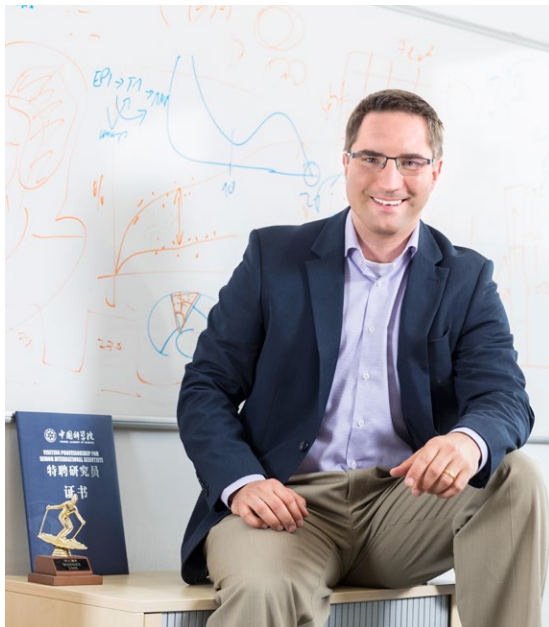
Dr. Thomas Pütz, Institute of Bio- and Geosciences, IBG-3: Agrosphere

“At our institute, we are investigating the effects of climate change on the water and matter fluxes in the soil. For this purpose, I regularly go underground to check our lysimeter systems. Lysimeters are 1.5-metre-high stainless steel cylinders sunk into the ground, open at the top and filled with naturally grown soil. A very sensitive scale and various sensors in the lysimeter record precipitation, evaporation, dew, temperature and water content, as examples. Via a service manhole in the centre of six lysimeters, I can check the metrology.”

Science is not black and white

Data are an important basis for gaining insights and testing theses. However, data analysis and its interpretation also have their pitfalls – this is also evident in the research on COVID-19.

The starting point: one data set and 70 research groups from all over the world who independently evaluate it to the best of their knowledge using established scientific methods. The task: check nine predefined hypotheses and answer with yes or no. The result: in six of the nine hypotheses, the results of the groups differed from each other – sometimes significantly. “This shows that despite identical initial data, the type of analysis can have a strong influence on the result,” explains Prof. Simon Eickhoff, director of the Jülich Institute of Neuroscience and Medicine (INM-7), who participated in the study with his team.



↑ Simon Eickhoff investigates the organisation and function of the brain using imaging techniques and artificial intelligence. For this purpose, he and his team often interpret large amounts of data.

In the evaluation of the various data analyses, it turned out that the interim results were in part very similar, but that different analysis steps subsequently led to a different weighting of data. “So, different results can occur particularly with yes-or-no decisions. This is no different in the neurosciences than in virology or epidemiology,” emphasises Simon Eickhoff. It is important to him to raise awareness of the fact that there is often not one “right” approach in science. “Science simply is not black and white. This is why open data and transparency are very important aspects in such analytical decisions,” says the neuroscientist. “In addition, however, we also need better communication that not only announces the results, but also puts them in context.”

This is also evident in the corona pandemic, in which scientists have to research the new virus from scratch and constantly adapt the state of knowledge to new findings. Yet: “In this case, science does not take place in a ‘black box’ from which – after long internal discussions – an irrefutable truth emerges,” says Prof. Hans Peter Peters, expert for science communication at INM-8 (see also interview next page). The public is witnessing “science in the making”, so to speak.

While uncertainties and different interpretations of data are part of the scientific community, they sometimes cause irritation among politicians and the public. “Moreover, in a crisis situation such as the corona pandemic in particular, it is out of our hands when an internal debate within the scientific community becomes public. It is the responsibility of the journalists to draw well-founded conclusions and put the facts in context,” emphasises Hans Peter Peters.

BRIGITTE STAHL-BUSSE



← The social scientist Hans Peter Peters explores the interface between science and media and how journalistic coverage is received by the public.

“Crisis as an opportunity”

In times of corona, scientists are in demand as interview and discussion partners. Even unwieldy topics from virology and statistics are popular. Jülich expert Prof. Hans Peter Peters explains why. He focuses on public opinion on science and technology.

Prof. Peters, why is science currently so popular?

In acute crises, people have a very high motivation to learn something because the knowledge is directly relevant to them. Nor do they shy away from unwieldy explanations, as the quotas of partly arid scientific contributions confirm. Information is actively retrieved and requested because it helps to understand, evaluate and assess the situation and also the measures prescribed.

Has science now reached the core of society as a result of corona?

We have been living in a scientified society for decades, but as a rule we simply do not notice it. Modern medicine, technology and political consulting based on scientific findings are part of everyday life. In the corona crisis, science is now increasingly moving into the public consciousness. Current surveys, especially on corona, show that the population is currently particularly positive about research. I think this is mainly due to the fact that science is currently associated with the promotion of the key social value of “health”.

Knowledge-based decisions seem to go down well in the pandemic. Will this also affect the debate on climate change?

The special nature of the current situation is that it is acute. Climate change, on the other hand, is a slow process. The difference lies not in a difference in communication or action by scientists, but in the situation: one value – life and health – is prioritised and everything else is temporarily ignored. In the course of the past few weeks, we have already seen a shift in these priorities: towards educational justice, the economy and civil rights and liberties. Such aspects are also relevant to climate change, and although climate change is very well communicated and widely accepted as a fact in Germany, the implementation of the necessary, far-reaching measures is lacking in reality. Apparently, we are good at tolerating contradictions between insight and behaviour. In addition, facts are often suppressed despite better knowledge if the consequences are just too inconvenient. However, perhaps the current crisis is also an opportunity for change on a broad scale, since supposedly self-evident assumptions are being fundamentally questioned.

INTERVIEW CONDUCTED BY BRIGITTE STAHL-BUSSE.



Builder of bridges

Ghaleb Natour came to Germany in 1979. Born as a Palestinian in Israel, he saw no future for himself in his home country. 41 years later, in Jülich, he has established the largest German-Palestinian research cooperation in Germany.

The huge photo on the wall draws a viewer's attention: a gnarled olive tree adorns the picture. Firmly rooted, grown over centuries. The motif radiates strength, confidence and calm – similar to the man who photographed it: Ghaleb Natour, Director of the Central Institute of Engineering, Electronics and Analytics and professor at RWTH Aachen University, who was born in 1960 as a Palestinian in Israel. "The fruit, the odours – I identify with the land, no matter what it's called!" His Palestinian compatriots often blankly shake their heads when the 60-year-old emphasises that he

is Israeli and Palestinian: "Many people are like this when it comes to religion: you are either Muslim or Christian. For them, there is nothing in between," says Natour. He has succeeded in this balancing act, however: with a German wife, Catholic parents-in-law, Muslim parents and two children who are open to both religions. The physicist is a bridge builder between Palestine, Germany and Israel, without wagging a finger and with a lot of patience, strength and confidence.

“We want to give the students a future as scientists in Palestine.”

GHALEB NATOUR

He came to Germany in 1979 because he saw no future for himself in Israel: the discrimination Natour experienced as a young Arab Palestinian in Israel was too strong. The 19-year-old ended up in Heidelberg, learned German, studied physics – and stayed. He has never regretted this decision. However, the deep attachment to his native country has remained. So even as a young man he had in mind to one day use his experience for innovation projects in the Middle East.

SINGULAR COOPERATION

Initially, there were only minor activities such as lectures for scientists in Palestine. However, the idea of an exchange increasingly took shape until Natour finally successfully applied for the Palestinian-German Science Bridge at the Federal Ministry of Education and Research (BMBF): the kickoff took place in 2016. Today, in 2020, Forschungszentrum Jülich can look back on a collaboration between the two countries that is unique in Germany. Over the years, about 50 Palestinians have taken advantage of the offer to conduct research at Jülich. The proportion of women is at a good 50 per cent. Meanwhile, the number of applicants clearly exceeds the available placements. “These are excellent applicants who, as young scientists, are an asset to Forschungszentrum Jülich,” emphasises Caitlin Morgan from Corporate Development, who is responsible for the organisational part of the Science Bridge.

Promoting excellence is not the only issue, however. “We want to establish a sustainable infrastructure for experiments and scientific measurements so that, in addition to pure teaching, Palestinian universities can develop a research practice that will offer students a future in science,” explains Ghaleb Natour.

What a lot of people don’t know: at Palestinian universities, learning and teaching takes place, but research is rarely conducted. There are hardly any laboratories or large-scale equipment. “If, for example, a lathe were sent to Palestine so that machine engineers could learn how to operate such a machine, it would not even pass through Israeli customs – on the grounds that the Palestinians could build weapons with it,” explains Natour.

But the 60-year-old will not be discouraged. Instead, in persuasive efforts for the benefit of research, he has



Rawan Mlih, age 38,
doctoral researcher at the
Institute of Bio- and Geosciences

I was already at Jülich in 2015 for my master’s thesis. In 2018, I came back to do my doctorate. Jülich is a high-tech location and offers students many opportunities for research. Moreover, in Germany, women, too, have the opportunity to pursue a career in science. In Palestine, women also opt for a scientific branch – not to become researchers, however, but teachers. Or they end up in unemployment. I also like the fact that people in Germany are free to express their opinion.

repeated talks with the presidents of the Palestinian universities, or he talks with young faculty members who understand and support his approaches. “With them and with the graduates from Jülich, we are building the research infrastructure brick by brick,” Natour says confidently. Among them are Rawan Mlih, Hasan Sbaihah and Falastine Abusaif, who are doing their doctorate at Jülich and want to help shape Palestine’s scientific future. Time

“We started the cooperation with one institute director in Jülich, and today, 22 are involved!”

GHALEB NATOUR



Falastine Abusaif, age 32,
doctoral researcher at the
Nuclear Physics Institute

Thanks to the Science Bridge, I was able to realise my dream of a doctorate as a nuclear physicist at Jülich – and truly under the working conditions required for high-precision physics experiments. Surprisingly, it is mainly men who study mathematics and physics in Germany, which is different in my home country. However, I have to honestly admit: I miss my home a lot, my neighbours, the social fabric and the Islamic call to prayer in the mosque – especially during Ramadan.

and again, the heads of the Jülich institutes also confirm how ambitious, motivated and disciplined the guests from the Middle East are. “We started the cooperation with one institute director in Jülich, and today, 22 are involved,” says Natour happily.

While the first years of cooperation were unilateral in character, with young Palestinians coming to Jülich, a mutual exchange is increasingly taking place: German scientists give seminars, workshops and lectures in Ramallah and the Palestinian Universities throughout the year. Apart from the motivation to gather new impressions, there is another aspect that makes Jülich scientists’ stays in Palestine appealing: the pleasant climate. Sun and heat, for example, allow the algae researchers to carry out some experiments better in the land of olive groves than at Jülich. The photovoltaic industry also benefits from the sunny location. At the same time, the visiting German scientists promote understanding of the importance of outstanding research – which, however, requires measuring instruments and laboratories.

FURTHER FINANCING SECURED

When the Palestinians come to Jülich, they bring new approaches with them, for example cell lines or a new algorithm that they want to optimise. Or they use computer simulations to compare the different behaviour of female and male pedestrians in Germany and Palestine – this has already resulted in joint publications in journals.

Once a year, all those involved meet for a major conference, sometimes in Jülich, sometimes in Palestine. “Of course there are geopolitical problems with the Gaza Strip, which is hermetically sealed. If the workshop is held in Ramallah in the West Bank, for example, the scientists from the Gaza Strip can only be connected via video conference. It is not at all possible to participate personally,” explains Natour. It makes him all the more hopeful that two women from the Gaza Strip are currently doing their doctorates at Jülich.

In 2021, funding for the Science Bridge would actually have ended. Ahead of schedule, however, due to the high demand and good cooperation, the BMBF has extended the project to 2024 and increased the funding. “We want to open the programme further, involve universities of applied sciences and take vocational training into account in order to strengthen the mid-level faculty in Palestine,” explains Natour. His scientific commitment has long since developed into a matter close to his heart in order to give Palestine a future in science and technology – precisely the future that Ghaleb Natour was denied in his home country.

KATJA LÜERS

Two science bridges, one success story

Ghaleb Natour developed the initial ideas for cooperation with Palestine in talks with the Federal Ministry of Education and Research (BMBF) in 2010. In December 2016, the starting signal was given for the “Palestinian-German Science Bridge” (PGSB), and in March 2020, the BMBF approved its extension to September 2024. The total budget is around € 5.8 million. More than 20 young women and men are doing their doctorates at Jülich, 16 master students and ten bachelor graduates have completed their theses. The funding programme contributes to the long-term and sustainable establishment and development of the research and technology infrastructure at Palestinian universities.

There are also long-standing ties with Georgia: the Georgian-German Science Bridge (GGSB), which was founded in 2004, resulted from a contact between scientists from Tbilisi State University and Forschungszentrum Jülich in the early 1990s. An integral part of the cooperation are workshops, three jointly operated SMART|Labs in Georgia, guest lectures and research visits of Georgian scientists to Forschungszentrum Jülich.



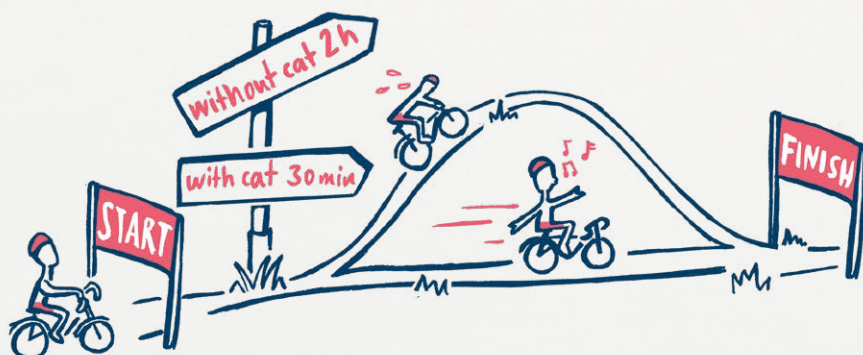
**Hasan Mohammad Hasan Sbaihah,
age 28, doctoral researcher at the
Jülich Institute of Neuroscience
and Medicine and at
RWTH Aachen University**

There are big differences between Germany and Palestine – practically on all levels. The biggest difference in research is the lack of scientific equipment in my home country, but it is precisely this equipment that is at the heart of research and helps scientists to make progress. Plus: unlike Germany, Palestine provides only marginal financial support for research. During my two-year stay at Jülich so far, I have already been to Palestine twice, supported by the Science Bridge, and have given courses at universities dealing with how new, modern imaging techniques help to diagnose diseases in the brain. By passing on my newly acquired knowledge, I contribute to building a new generation of researchers in Palestine.



CATALYST

Catalysts are solid, liquid or gaseous substances that accelerate chemical reactions. They are not consumed in the process and do not alter the final product.



CAUTION, SHORTCUT!

A Catalyst provides an alternative to the usual reaction pathway, a kind of shortcut. This requires less energy — thus leading faster to the finish line.

WHERE DO YOU FIND CATALYSTS?



NATURE

Functions and processes in all living organisms are controlled by catalysts, mostly by so-called enzymes. They also help to produce alcohol, vitamins and hormones.



INDUSTRY

Chemical or biocatalysts can be used to produce plastics, fertilisers, medicines and fuels — over 80% of all chemical industry processes use catalysts, often reducing costs in doing so.



ENERGY PRODUCTION

Catalysts are important for the energy transition. They help to store and release excess electricity from solar or wind power plants as hydrogen.

ENVIRONMENTALLY FRIENDLY

Using less energy means protecting the environment. Catalysts also help purify car and industrial exhaust gases and wastewater and reduce undesirable by-products.



WHAT IS JÜLICH DOING?

Jülich researchers are developing and testing catalysts, such as for the hydrogen economy, as well as the separation of CO₂ and biocatalysts for various industrial processes.



THUMBS UP

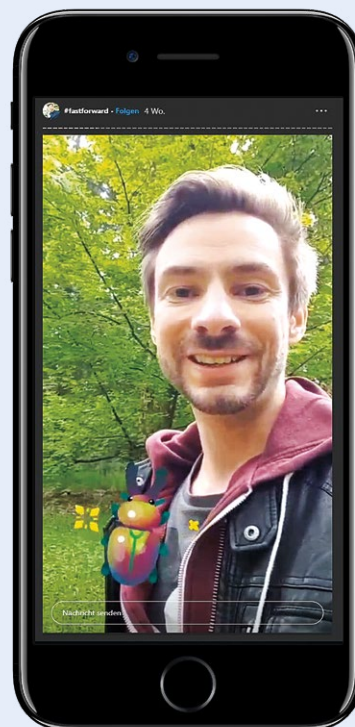
DONATING COMPUTING TIME

Project Folding@home

Helping from home to find a drug for coronavirus? Folding@home wants to make this possible. In the project of Washington University in St. Louis, USA, volunteers donate unused computing time from their notebooks and PCs to science. Using special software, small subtasks of large protein simulations are transmitted to private computers and solved there.

The aim is to use joint computing power to better research diseases such as COVID-19 or cancer and possibly develop drugs.

- FOLDINGATHOME.ORG -



INSTAGRAM VIDEO

Into the forest to the bark beetle

Who doesn't know bark beetles?

Many forests are threatened by the vermin, especially since its population has increased significantly in some places thanks to favourable conditions.

But what actually is it that makes the bark beetle dangerous for trees? This is exactly what Tobias Brüggemann explains on Instagram: On his channel "tobiology.de", he has made the critters from the family of the weevils the protagonist of a contribution. Successfully so: with his excursion into the forest, he took first place in the "Super Fast – 24h Instagram Challenge". 18 instagrammers had participated in the video competition of Fast Forward Science.

- FZ-JUELICH.DE/FASTFORWARDSCIENCE -

TWITCH CHANNEL "FORSCHUNGSSTROM"

Watch and join in

Science communication the alternative way: about once a month, the format "Forschungsstrom" (research current) goes online on the video portal Twitch. The relaxed forum, in which topics from science and research are presented and discussed, can be seen live on the Internet via the platform.

What makes this special: on Twitch, viewers sitting at home in front of their screens can ask questions and make contributions via a chat.

All programmes can also be watched on YouTube afterwards – at this point of course without live chat.

- FORSCHUNGSSTROM.TV -

RESEARCH IN A TWEET

Together for the super battery: the European initiative @2030Battery develops #energystorage for a climate-neutral society.



Clear concept

Tomorrow's energy storage systems are to combine outstanding performance, sustainability, safety and profitability. In order to join forces in Europe, institutes from nine countries have joined forces in the "BATTERY 2030+" initiative, including the Helmholtz Institute Münster of Forschungszentrum Jülich and the Münster battery research center MEET. In 2020, the initiative presented its concept for the battery of the future.

battery2030.eu