Resolving the lull

The expansion of wind power is collapsing. New momentum is needed for the energy transition to succeed.

EXPRESS COMPUTER
Tommaso Calarco explains the quantum computer breakthrough

CRISIS AIDE
With molecules and models against coronavirus

HIGH FLYER
Michael Saliba researches solar modules of the future
A colourful, deep-sea jellyfish? No, what you see here is the cross section of a vine. What is important here are the dots of various sizes. These are the plant's water conduits: vessels through which water flows from the roots to the leaves. Some 15 per cent more water is transported through the narrowest vessels than had previously been calculated on the basis of conduit diameter alone. This is what comparisons of model calculations and in-vivo measurements by plant researchers from the Institute of Bio- and Geosciences (IBG-2) and their colleagues from the USA revealed. The reason is that all vessels are interlinked in a complex network. This greatly affects the distribution of flow in the stem. According to the researchers, models need to take this into account.
Galactic support
Cosmic radiation helps to determine the water content of soils and plants.

High flyer
A new class of materials for solar modules brings momentum to photovoltaic research.

Climate research at the end of the world
A measurement campaign in Tierra del Fuego provides data on the atmosphere of the southern hemisphere.

Fresh breeze into the lull
The expansion of wind power has gone flat. Jülich experts explain why this has to change and how this may come about.

Pioneer flight of quantum computing
Tommaso Calarco explains why solving useless tasks is a success.

Quantum news
In search of the super qubit | A new candidate

Together against the crisis
Stopping the corona pandemic: Researchers are working on active substances and prediction models transnationally – also at Jülich.
Standstill and action

Nobody had expected this – especially not in December 2019, when work on this issue of effzett began: the corona pandemic has dominated life in recent months and will continue to do so. The crisis affects everyone.

Scientists are also facing great challenges. Knowledge about the virus and therapies are expected to be available after a few months instead of years, as would usually be the case. This can only be achieved through open exchange, collaboration and close networking – a cooperation that will also be a benefit in post-corona times.

Jülich scientists, too, are working on strategies against the virus in transnational alliances (see pages 16-17 and www.fz-juelich.de/coronavirus). They also continue to research major issues that are likewise changing our lives, even if these issues are currently receiving less attention – such as the necessary restructuring of the energy system to make Germany almost climate-neutral by 2050 at low cost. Wind power plays a decisive role here. However, there is more of a standstill than action in terms of expansion. You can also read about the state of the silicon solar cell competition, the progress being made in quantum computing and how galactic radiation helps soil researchers.

We hope you enjoy this issue and above all: stay well!

Your effzett editorial team
Bringing light into the dark: More than half of the earth’s internal heat is most likely the result of radioactive decay processes deep in the lower mantle. This is the result of measurement data from the Borexino detector (picture), which detects neutrinos 1,400 metres below the earth’s surface in the Gran Sasso massif near Rome.

“The hypothesis that there is no more radioactivity in the depths of the earth’s mantle can now be ruled out with 99 per cent certainty. Instead, decay processes provide part of the energy that drives volcanoes, earthquakes and the earth’s magnetic field,” says Jülich researcher and Borexino physics coordinator, Prof. Livia Ludhova.

- NUCLEAR PHYSICS INSTITUTE -

Extremely resilient

New synthetic fibres hold 4 million times their own weight. The unique combination of maximum tensile and tear strength opens up applications in wind turbines, aerospace, sports equipment and lightweight construction. An international team of researchers with Jülich participation has developed the fibres from a commercially available plastic material using a new spinning and processing method.

- JÜLICH CENTRE FOR NEUTRON SCIENCE -
Scientists and doctors have frequently tried to classify the manifold symptoms of schizophrenia. The signs of the disease – such as social withdrawal, memory disorders or hallucinations – differ considerably among those affected. Jülich brain researchers have now used artificial intelligence (AI) to divide the symptoms into categories. In the future, the findings could enable treatment that is better tailored to the individual patient.

**AI classifies symptoms**

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**25 million euros ...**

is the amount provided by the Federal Government for the BioökonomieREVIER project. Participants from science, business, politics and civil society jointly develop concepts for the structural change of an entire region: The Rhenish lignite mining area is to become a model for resource-efficient and sustainable management. Scientific coordinator of the project is the Jülich bioeconomy expert Prof. Ulrich Schurr.

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**Robust battery**

Materials researchers from Jülich and China have developed a solid-state sodium battery that still has over 90 per cent of its initial capacity after 100 charging cycles. In contrast, previous batteries of this type could no longer be used after less than 20 cycles. Solid state batteries cannot leak and are considered safe and resistant.
Surprising differences

Findings about the tiny contacts between nerve cells, the synapses, have so far mostly been obtained from animal experiments. Jülich brain researchers have now created 3D computer models of human synapses based on samples of human tissue. They found marked differences between humans and animals, but also between men and women. According to the researchers, the differences show that findings from animal models cannot readily be transferred to humans.

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BIOTECHNOLOGY

The menu of the TBC pathogen

Special white blood cells, the macrophages, are part of the body’s own “health police” and eat up adverse bacteria. Tuberculosis (TBC) bacteria, however, can survive inside the macrophages. Together with English colleagues, Jülich researchers have determined that the imbibed pathogens feed on various amino acids of the macrophages, among other things. However, the bacteria must themselves produce one amino acid that is essential for survival: serine. This could be a starting point for new medicines.

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PHYSICS

Magical nanostructures

Jülich physicists Prof. Rafal Dunin-Borkowski and Prof. Stefan Blügel, along with two researchers from Mainz and the Netherlands, want to detect nanoscale magnetic 3D structures in solids that have particle-like properties. The European Research Council supports the project in the form of an “ERC Synergy Grant” with € 11.8 million. The existence of magical 3D structures, including so-called Hopfions, has so far only been theoretically predicted in outline. Hopfions are expected to make it possible to build highly energy-efficient computers modelled on the human brain. Jülich and Mainz researchers led by Stefan Blügel have already discovered a new magnetic interaction in magnesium germanide crystals that could possibly be used to generate Hopfions.

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Fresh breeze into the lull

Germany is to become greenhouse gas neutral by 2050. This requires a restructuring of the energy system, with onshore wind power playing a central role. However, its expansion in Germany reached a historic low last year. Jülich researchers warn that the climate targets are running into danger.
Some 70 metres above the ground: a small group is cramming into the engine room of the visitor wind turbine, “Windfang” (wind collector). Everyone is looking up at Horst Kluttig, who leads the tour. The physicist is sitting on the highest rung of the top ladder in the engine room, his legs dangling while a fresh breeze swirls around him. He looks out of the roof hatch, which he normally only opens to get to the anemometers on the drop-shaped nacelle. “But on days like today, when I bring guests up here, then of course we also want to enjoy the view,” he says and lets his gaze wander: over the hilly landscape of the German-Dutch border, the meadows and bare wintry fields as far as the rooftops of Aachen. It is hard to count how many wind turbines there are all around: it might well be some 100 to 150 plants. “A great deal has been done here in the past three decades,” explains the wind power pioneer from Aachen, who, as a wind farm planner, has followed the ups and downs of wind power in Germany from the very beginning.

Meanwhile, the industry is in a lull period, and expansion in Germany has practically come to a standstill. In 2019, no more than 325 onshore turbines with a total capacity of 1,078 megawatts were built in Germany – around 80 per cent less than just two years previously. This has been the lowest level of gross new construction since the introduction of state subsidies in 2000.

ENERGY TRANSITION AT RISK

There is almost no drive behind the expansion of wind power. “If Germany doesn’t readjust quickly, the energy transition will not be possible,” warns Jülich industrial engineer Dr.-Ing. Martin Robinius. At the Institute for Energy and Climate Research (IEK-3), the scientist keeps an eye on the entire German energy system.

Using computer models, he and his colleagues at IEK-3 designed a cost-optimised roadmap for the energy transition. According to this, renewable energies must be comprehensively expanded, buffered by huge underground hydrogen storage facilities, by 2050. In the future, biomass and biogas are supposed to cover a quarter of Germany’s energy demand. Buildings must be efficiently insulated; they will be heated mainly by heat pumps. The most important prerequisite for the conversion of the energy system, however, are the onshore wind turbines, says the Jülich expert: “Wind power is the fundamental pillar, the backbone of the energy transition. Without it, we will not be able to meet the climate targets we have set ourselves.”

Germany has set itself the goal of becoming largely greenhouse gas neutral by 2050. This means reducing emissions of CO2 and other climate-relevant gases accordingly. The researchers had calculated separate scenarios for the current political targets of 80 to 95 per cent reduction compared to 1990. Yet, whether the reduction was set at 95 or only 80 per cent had no influence on the role of wind power as the central component in the restructuring of the German energy system. Martin Robinius explains: “The only difference is the capacity of the wind energy performance that we will have installed in 2050. In the 95 per cent scenario, we would have to build an average capacity of 6.6 gigawatts annually. The value for the 80 per cent target would be 3.8 gigawatts. However, reality looks different at present: we had only 2.5 gigawatts in 2018 and just under 1 gigawatt last year.”
There are diverse reasons for the stagnation. For example, the political framework has changed, especially with regard to the allocation of subsidies, but a lack of social acceptance is also part of the problem. In the middle of last year, more than 300 wind turbines became the subject of lawsuits in Germany.

Back in the visitor wind turbine on Vetschauer Berg near Aachen. Horst Kluttig and his guests have meanwhile left the nacelle and are climbing down a narrow ladder to the viewing platform one level below. The hatches and steel walls are reminiscent of a cramped submarine. All visitors wear helmets and climbing harnesses for safety.

The viewing platform clings to the tower below the nacelle; a ring-shaped gallery, protected from wind and weather. The huge rotor blades whiz past the windows every second. More than 10,000 visitors have already come up here to learn about the technology of wind turbines and their contribution to the electricity supply – but also about the controversy surrounding the turbines. “Phalanxes of wind turbines ruin the landscape, yes, you hear that again and again,” says Horst Kluttig. But it had not always been like that. There were no protests from the local residents against the first projects around Aachen. These only came up ten years later, when more and more turbines were built.

\[\text{Expansion hitting rock bottom}\]

Annual gross construction of onshore wind turbines in Germany (in megawatts)

Sources: Internationales Wirtschaftsforum Regenerative Energien (IWR), Deutsche WindGuard GmbH
Dr. Hawal Shamon knows the arguments for and against wind power. At the Jülich Institute of Energy and Climate Research (IEK-STE), he works on acceptance research: how easy is it for people to get into a new technology? And what are the reasons for acceptance or rejection? “By no means was an interference of landscape through the huge turbines classified as the strongest argument against wind power,” explains the social scientist. For an online study, he and his colleagues asked more than 1,000 people, mostly with a strong educational background, how convincing they found a range of pros and cons regarding certain technologies for generating electricity – from conventional coal-fired power plants to photovoltaic parks. In the case of wind power, the first concern was the negative impact on bird life.

**FACTS CHANGE LITTLE**

It is difficult to say how many birds actually perish due to the wind turbines. Counting the animals that died in accidents is in itself already a challenge, because some carcasses may fall into a neighbouring cornfield or be eaten by a fox. All these birds will not be included in the statistics. The figures for Germany range between 10,000 and 100,000 fatal collisions per year, depending on the research project. However, would concrete figures or studies really influence or even change the minds of convinced opponents or supporters of wind power? Hawal Shamon also investigated this in his online survey. Did the participants change their attitude towards the different techniques of power generation after they had informed themselves about the pro and con arguments? The result: most of them stuck to their original opinion. In only 22 per cent of those surveyed could arguments contribute to them at least partially revising their attitudes. However: “In another 16 per cent of the participants, we could see a polarisation. In their case, the preconceived opinion had only been reinforced by addressing the arguments,” explains the researcher.

Dr. Wilhelm Kuckshinrichs, who is an economist at the Institute of Energy and Climate Research (IEK-STE) and was also involved in the study, points out a crucial problem: “Politicians long believed that people automatically accept a new technology if only they were given enough factual arguments. But it isn’t that simple. In this case, new paths will have to be paved that go beyond purely factual arguments.”
At the bottom of the wind turbine: a spiral staircase waits behind the green door. Inside the tower, its 300 steps lead to the visitor platform. The neighbouring wind turbines can only be climbed via a ladder in the tower.

In the meantime, the group of visitors has started to descend within the wind turbine on Vetschauer Berg – not on a narrow ladder, as would be usual for turbines of this size. In Aachen, a spiral staircase inside the steel tube makes climbing easier. The guests’ steps resound on its steps. It is hardly noticeable that the construction swings back and forth.

“The tower is of course a big resonance box,” explains Horst Kluttig. “You can hear all the noises very clearly here – especially what is happening upstairs in the nacelle: the humming of the generator; a quiet mechanical noise of the shaft. When the wind picks up, it’ll get louder in here in the tower.”

However, when it comes to noise pollution from wind turbines, it is not usually these noises that are meant. Complaints from residents usually concern the aerodynamic noise of the plants: the rotor blades cut through the air, briefly compressing and depressurising the air masses. Sufficient distance from residential areas helps to attenuate the sound, but the distance which is perceived as sufficient is also the subject of lively debate.

Last year, for instance, politicians argued over standardising the different regulations of the federal states and introducing a blanket distance rule at federal level. A minimum distance of

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Acceptance of power generation technologies

Online survey with 2,400 participants

4 = strongly in favour
2.90 Rooftop photovoltaics
2.35 Open-space photovoltaics
2.34 Offshore wind power stations
1.98 Onshore wind power stations
1.47 Biomass power plants
0.19 Gas-fired power plants

-1.55 Coal-fired power plants
-2.08 Nuclear power plants (fission reactors)

-4 = strongly against

Source: Experimental Online Survey on Energy (ENSURE) 2018 (IEK-STE); quota sample (age, education and gender)
Horst Kluttig and his guests have meanwhile reached the bottom of the visitor wind turbine at Vetschauer Berg. A few more steps on the outside stairs, then everyone has solid ground under their feet again. The enormous rotor rotates continuously far above their heads.

Looking up at the tower, the physicist explains: “Some of the turbines here at the wind farm have reached their expected lifespan of 20 years.” He therefore advocates for the distance between residential areas and wind turbines be decided on a case-by-case basis at municipal or regional level, based on local conditions. The experts at IEK-3 are currently developing an open source software which can be used to show which areas in Germany are available for wind power – under certain conditions. Martin Robinius: “Community representatives can enter any minimum distance on a graphical user interface and then see how the usable areas change. This would be an important decision-making aid for the municipalities to weigh for themselves whether and where a plant should be built. In the northern federal states, for example, many municipalities are passionate about wind power. They see it as a promising area of business, and a 1,000-metre rule would only interfere with this. In southern Germany, on the other hand, the municipalities fear for their landscape.”

By no means did respondents classify an interference of landscape through the huge turbines as the strongest argument against wind power.”

DR. HAWAL SHAMON

1,000 metres to settlements consisting of five or more residential buildings was under discussion. In the future, however, this will only be a benchmark; each federal state will be in a position to continue to decide for itself.

“The 1,000-metre distance would definitely harm the whole system,” believes Martin Robinius. “Depending on from which size of settlement such a regulation should take effect, this could mean the end for wind power in Germany.” He therefore advocates for the distance between residential areas and wind turbines be decided on a case-by-case basis at municipal or regional level, based on local conditions. The experts at IEK-3 are currently developing an open source software which can be used to show which areas in Germany are available for wind power – under certain conditions. Martin Robinius: “Community representatives can enter any minimum distance on a graphical user interface and then see how the usable areas change. This would be an important decision-making aid for the municipalities to weigh for themselves whether and where a plant should be built. In the northern federal states, for example, many municipalities are passionate about wind power. They see it as a promising area of business, and a 1,000-metre rule would only interfere with this. In southern Germany, on the other hand, the municipalities fear for their landscape.”

OFF TO COURT FOR SPECIES PROTECTION

A strict distance regulation would have hardly any influence on the acceptance of wind power at the locations anyway, emphasises Wilhelm Kuckshirichs. This is the result of a sector survey conducted by Fachagentur Windenergie an Land, a non-profit association promoting the environmentally friendly expansion of onshore wind power throughout Germany: the majority of lawsuits currently pending against the approval of wind turbines – 72 per cent of the total of 325 turbines – relate to the protection of species. About almost a quarter of the complaints against plants were filed due to concerns of compromised health and well-being. If acceptance of the technology is to be increased, citizens in the communities must be actively involved in the projects: “Involve them as early as possible in the plans and decisions, respond to their wishes, suggestions, but also their concerns. Monetary arguments can also play an important role here.”

A wind citizen’s compensation, that is, a direct payment to affected residents as discussed last autumn, is only one possible model among many. Reduced electricity tariffs or the participation of the municipalities in the profits of the wind farm are also conceivable. A joint project in the form of a cooperative could also lead to acceptance through participation: “In our experience, the feeling of being involved in a plant, even being co-owners of such a plant, has a very positive effect on the local people. Other experts also confirmed this with various practical examples, which they presented at a workshop of the European Economic and Social Committee at Jülich in late 2019.”

Looking up at the tower, the physicist explains: “Some of the turbines here at the wind farm have reached their expected lifespan of 20 years.” He nods towards a windmill that is standing still. “The plant over there shows clear signs of weakness, it has technical problems from time to time. This means that the older turbines are due for repowering.”

They are to be replaced by more powerful wind turbines. However, since these will also be sitting on higher towers and have a larger rotor, the total number of turbines at Vetschauer Berg is expected to be reduced from nine to three or four. Horst Kluttig still hopes for a smooth transition.
and fewer players are participating. “There are certain risks involved for the providers: they have to invest in the planning of a new wind farm in advance, but they cannot be sure that they will be successful in the tender competition, which would give them the chance to refinance their investments. Of course, this is particularly difficult for companies in which the money comes largely from the participation of citizens.”

GROWTH IS CAPPED

His colleague Martin Robinius agrees: “The bidding process no longer works in this form. Citizen-owned wind farms are not given sufficient consideration there. But this is exactly what would be important for acceptance: that a community builds a wind farm and recovers part of the profits itself.”

What is more, the tendering model sets an upper limit to the growth of wind turbines. This is because a maximum of only 2.8 gigawatts is auctioned off each year – which is significantly less than the 6.6 gigawatts that, according to the researcher’s calculations, are needed to achieve the climate targets at the lowest possible cost. This cap was intended to ensure that the expansion of the distribution networks for the electricity generated could keep pace with the expansion of wind power. However, according to Kuckshinrichs, the expansion of the above-ground electricity networks is also encountering major problems of acceptance.

Admittedly, the electricity does not necessarily need to be transported via power lines. “One could go along with the enormous dynamics of renewables and think about using the electricity to produce hydrogen or other energy carriers,” says Prof. Detlef Stolten from IEK-3, who is concerned with the construction and costs of an appropriate infrastructure. For example, excess electricity generated during windy periods could be used to break down water into its elementary components. Hydrogen would then serve as a chemical energy storage to overcome wind and solar lulls. In addition, the gas can be bound to organic carrier liquids and thus transported safely in tank trucks over long distances – without the need for an overland pipeline. “Even if there is no ideal solution, the energy transition is definitely feasible. We don’t have to change anything fundamentally, but we do have to make adjustments in many areas – whether in tendering procedures, distance regulations, approval procedures and public participation – and we have to do so quickly,” says Wilhelm Kuckshinrichs. “Then the wind power industry will gain momentum again,” adds Martin Robinius.

ARNDT REUNING

Wilhelm Kuckshinrichs argues that the amendment of the Renewable Energy Sources Act (EEG) in 2017 represents a hurdle for the rapid expansion of wind power. Prior to this, every operator of a wind farm had received a pre-determined price per kilowatt hour of electricity – for 20 years. “For the companies, this naturally entailed a strong investment security. And this meant that smaller players were also on board, such as citizen wind farms, which have less money up their sleeves,” says the Jülich energy expert.

However, the feed-in compensation has now been replaced by a tendering model. Anyone who wants to build wind turbines must apply for funding at auctions. The companies offer consignments of wind power. Whoever can deliver at the lowest price is awarded the contract. The thought behind this: the competition is intended to ensure that the providers with the most efficient technology and the best locations will prevail. According to Wilhelm Kuckshinrichs, however, the procedure has contributed to the stagnation of the market because fewer

“Politicians long believed that people automatically accept a new technology if they are given enough factual arguments. But it isn’t that simple.”

DR. WILHELM KUCKSHINRICHES
Wind energy you can touch: Horst Kluttig and his daughter Elanor demonstrate on a mini wind turbine that even a gentle blow to the rotor blade makes an LED light up.

Energy mix today and tomorrow

Gross electricity generation in Germany by energy source in billion kilowatt hours (kWh)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>2019</th>
<th>2050*</th>
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<tr>
<td>Wind (onshore)</td>
<td>101</td>
<td>154</td>
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<tr>
<td>Wind (offshore)</td>
<td>45</td>
<td>193</td>
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<tr>
<td>Lignite</td>
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<tr>
<td>Other</td>
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<td>75</td>
</tr>
<tr>
<td>Electricity imports</td>
<td>0</td>
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</tr>
</tbody>
</table>

Amount of electricity and share of renewable energies

- 2019: 604 billion kWh, 40%
- 2050: 999 billion kWh, 99%

*scenario

Sources: Bundesverband der Energie- und Wasserwirtschaft (BDEW, as of 11.02.2020), Forschungszentrum Jülich/Institute of Energy and Climate Research (IEK-3)
New active ingredients against the virus

Active substances against viruses are aimed at stopping their reproduction. There are various approaches. Jülich researchers led by Prof. Dieter Willbold from the Institute of Biological Information Processing are working on three of these. Together with experts from the Charité hospital in Berlin, they are developing a molecule that will prevent the coronavirus SARS-CoV-2 from entering the human cell. Only there can it continue to reproduce. The scientists prevent this step by blocking the virus’ entranceway, the binding of the viral spike protein to the so-called ACE2 receptor.

In two other projects, the Jülich structural biochemists are investigating how two components of the virus can be inhibited: the protein ORF8 and the enzyme 3C-like protease. Both are essential for the reproduction of the virus in the cell.
Testing drugs with supercomputers

It is also possible that existing drugs may help fight the virus. The difficulty is to identify promising candidates quickly and reliably. For this purpose, the EU project EXSCALATE4CORONAVIRUS uses the computing power of the largest supercomputing centres in Europe, including the Jülich Supercomputing Centre (JSC). The computers will search for drugs against those proteins that are essential for the coronavirus to survive. “With the help of such virtual screenings, or systematic tests, in combination with biochemical and phenotypic high-throughput screening, billions of molecules can be evaluated against selected targets within a few weeks,” explain Jun. Prof. Giulia Rossetti and Prof. Paolo Carloni from Jülich’s Institute of Neuroscience and Medicine (INM-9). The INM-9 is carrying out part of the screening alongside the JSC and partners from science and industry.

Simulating a pandemic and its course

In addition to the search for effective treatment methods, the aim is to predict the course and extent of the infectious disease, but also the effects of countermeasures. Experts around by Prof. Thomas Lippert from the Jülich Supercomputing Centre, along with researchers from Heidelberg University and the Frankfurt Institute for Advanced Studies, are making forecasts for this with the aid of mathematical models and current data from the Robert Koch Institute. First results and science-based recommendations were presented to policy makers and the public shortly after Easter. The forecasts are constantly updated, and researchers are also working at full stretch on regionally differentiated models.

Keep an eye on smell and taste

The loss of the senses of smell and taste may indicate a COVID-19 infection. An online survey and an online smell and taste test will help to differentiate between the symptoms of this infection and those of other respiratory diseases. Over 500 experts from 50 countries are involved in the project, including the Jülich researcher Dr. Kathrin Ohla from the Institute of Neuroscience and Medicine (INM-3).

The study and the tests: gcchemosensr.org

In its ad hoc recommendation at the end of March, the Ethics Council pointed out that there is also an ethical conflict involved in the pandemic. Which conflict is this?

A permanently high-quality, efficient health care system must be ensured, and at the same time, the measures must avert or mitigate serious side effects for the population and society. The situation calls for a careful balancing of the various interests, and the basic principles of solidarity and responsibility must not be allowed to go astray.

What does the Ethics Council recommend?

At present, the chief aim is to significantly slow down the spread of coronavirus. The appropriateness and effects of the measures must be constantly reassessed.

What role does science play in the pandemic?

Scientific findings are of central importance for the evaluation. For example, models are needed that allow for accurate prediction regarding the course of the pandemic and the impact of individual measures, thus supporting political decision-making.

TEXTS: CHRISTIAN HÖHLFELD
It's stunning: eternities ago, many millions of light years away, stars died, and today, their explosion helps to determine the moisture of the earth on our planet. More precisely, the cosmic rays generated by stellar explosions help (1). When these hit the earth's atmosphere, neutrons are produced (2). A part of them hurtles to the surface at high speed and penetrates to a depth of almost one metre. The neutrons bounce off heavy atoms in the ground, such as silicon (3). When they hit water molecules, however, they give off part of their energy to the hydrogen's light atomic nuclei. This slows down the neutrons (4). The more often they collide with hydrogen atoms, the slower they become. For many of them, the energy is at some point no longer sufficient to leave the ground (5). “This is why there are far fewer so-called fast neutrons travelling over moist soils than over dry ones,” explains Jannis Jakobi from the Jülich Institute of Bio- and Geosciences (IBG-3). This difference can be detected with a special method called Cosmic Ray Neutron Sensing: “We use neutron detectors in meadows and fields as well as a mobile measuring device in a van (6). In passing, so to say, we use the device to count the fast neutrons (7) near the ground, thus determining the soil moisture relatively easily and over a large area,” explains Jakobi.

In the future, the researchers want to measure the water content of plants in the same way, since their hydrogen atoms also slow down the neutrons. “For this purpose we use another detector (8) to measure so-called slow neutrons (9) above the ground. These have had eight to twelve collisions with hydrogen atoms,” says Jakobi. “From the ratio of slow to fast neutrons, we want to draw conclusions about the water content and biomass of trees and field plants.” Such information might help farmers to optimise irrigation, for example.

Janosch Deeg
What are you researching right now, Mr Krause?

Dr. Dorian Krause, Head of the High-Performance Computing Systems division at the Jülich Supercomputing Centre (JSC)

“I help to develop next-generation supercomputers. These will be even more powerful, but also more energy-efficient and therefore significantly quieter. Noise protection headphones will then be rendered superfluous. Aside from that, I am working on ways to combine supercomputing with web and cloud technologies. For example, researchers around the world will, in the future, be able to use the huge amounts of data that are collected at Jülich in the creation of an extremely detailed 3D model of the human brain.”
Pioneer flight of quantum computing

With Jülich support, a quantum computer of Google has solved a task that currently no classical computer can handle. Jülich expert Prof. Tommaso Calarco from the Peter Grünberg Institute (PGI-8) explains why this quantum supremacy could become as important as the first motorised flight of the Wright brothers.

I am a layperson: can you explain to me what problem the Google quantum computer has solved?

Actually, no. It’s an abstruse mathematical problem with no practical use, in which one throws the dice many times with the quantum computer, so to speak, and calculates the random distribution of the results. Understanding the problem isn’t easy, even for experts. The Google team chose it because it’s suited like no other to demonstrate the supremacy of the quantum computer over the classic computer. In other words: the relatively few functional qubits that can be generated so far are sufficient for it. Qubits are the quantum counterparts of bits. The Google quantum computer solved the task with 53 qubits in less than five minutes – according to Google, it would take the world’s fastest supercomputer several thousand years.

The physicist Tommaso Calarco is considered one of the leading experts in quantum computing. He is one of the initiators of the Quantum Flagship of the European Commission and Chairman of the Quantum Community Network, a network of high-profile members of the quantum technology community.
This is another reason for my enthusiasm: a few years ago, I would never have dreamed that quantum supremacy could be demonstrated before my retirement.

How old are you, then?

I just turned 50.

So quantum computer development is about 15 years ahead of your expectations. Google has surged ahead. Can others still catch up with the company now?

Yes. Scalability is considered a major challenge which even Google has not mastered yet: you need thousands of qubits that are as perfect as possible in order to perform really useful calculations. It’s still completely open who will be ahead in the end. Perhaps the IBM corporation will overtake Google in this respect. We in Jülich are also building a quantum computer with funding from the European flagship initiative, involving components from all over Europe. It’s not so important whether we reach the next milestones before or after these corporations. The crucial thing is that we do not want to be dependent on American or Chinese companies. After all, export stops may occur: we would then suddenly no longer be able to buy quantum computers from Google, for example.

A calculation without any practical value – isn’t this rather sensationalism than a scientific breakthrough?

This impression is completely wrong. It’s a great scientific achievement. I’m particularly enthusiastic precisely because it’s a result of basic research. Anyone who only asks about the direct benefit of a result – as is often the case – will at best get the innovation of tomorrow, for example a car with a few per cent less fuel consumption. But if you hold back a little on the question of benefit, you might get the innovation of the day after tomorrow.

According to a computer scientist from the US, the current computing success of the quantum computer is reminiscent of the Wright brothers’ first flight, as this flight did not solve any urgent problem at first. Is it an apt comparison?

Yes, I find the comparison very fitting. The Wright brothers’ first motorised flight in 1903 was a twelve-second short hop, which initially created no new means of transport and had no practical use. Today, it’s no longer necessary to explain to anyone that air transport has changed our world enormously.

Had you expected that the supremacy of the quantum computer would be successfully proven?

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Let’s just fly: Orville Wright in November 1904, barely a year after the maiden flight. Initially, the Wright brothers did not solve an urgent problem with their flying machines at the beginning of the 20th century – and yet they changed the world.
Google’s quantum computer is based on superconducting circuits. Does this mean that other technologies with which quantum computers could basically be built are out of the picture?

Again, no. It’s still completely uncertain which technology may provide thousands or even millions of qubits that are as faultless as possible. Therein lies a great opportunity for Europe as well: for example, we also research and develop quantum computers based on ion traps or optical traps. We Europeans have access to laboratories, infrastructure and skills that have been greatly expanded in recent years. Google or other companies, on the other hand, would have to start from scratch if they wanted to switch to these technologies.

Jülich operates conventional supercomputers of the highest performance class. Doesn’t this compete with the prominent role of Jülich in the European quantum computer initiative?

On the contrary. Until we have millions of perfect qubits, we must ensure that the precious qubits only do what they are unbeatable at doing. No quantum computer resources should be wasted on anything a classical computer can do. This includes the entire preparation of the actual calculation. For the foreseeable future, it’s imperative that supercomputers and quantum computers work together.

When will there be a quantum computer that can be used in practice?

In the European Quantum Flagship, we have agreed on the following answer: it will take at least 10 to 20 years. It worries me when some companies give the impression that quantum computers will soon be able to solve all problems. This exaggeration almost inevitably leads to disappointment – thus harming our field of research and society. Fortunately, the European Commission and the German government have meanwhile realised that staying power is essential for success in the development of quantum computers.

The interview was conducted by Frank Frick.

Support from Jülich

“Quantum supremacy” means the point in time at which a quantum computer is, for the first time, superior to a conventional computer in a particular task. Proving this was considered a great challenge. In September 2019, Google announced that it had achieved this quantum supremacy. Researchers from the Jülich Supercomputing Centre (JSC) headed by Prof. Kristel Michielsen were also involved in the scientific publication on the evidence. By means of simulations on the Jülich supercomputer JUWELS, they helped to verify the results and determine the performance of the quantum processor.
The Helmholtz Association's central infrastructure for quantum computing is being established at Forschungszentrum Jülich as a national priority: the Helmholtz Quantum Center (HQC). Research covers the entire spectrum of quantum computing – from research into quantum materials to the development of prototypes and their application. HQC is closely linked to the Jülich Supercomputing Centre. The Helmholtz Association is funding the project with almost € 50 million.

In particular, the HQC will investigate different types of qubits – the quantum computer equivalent of classical computer bits. “Each type has its own advantages and disadvantages. It is still completely open which concept will eventually prevail,” explains Prof. Stefan Tautz from the Peter Grünberg Institute (PGI-3), who is representing the scientists during the launch phase of the HQC.

The HQC will work closely with the Quantum Flagship of the EU, in which various Jülich experts are involved. In the flagship project OpenSuperQ, for example, Jülich scientists and collaborating European partners are investigating superconducting qubits. A new Jülich research team headed by Prof. Pavel Bushev is already testing small prototypes of superconducting quantum computer chips developed by Swedish partners in the OpenSuperQ project. An alternative platform – atomic qubits in optical traps – is being developed by Jülich scientists and their partners in the flagship project PASQuanS.

In search of the super qubit

“A new candidate

Qubits, which consist of superconducting circuits, need bitter cold: about -273 degrees Celsius, which is about almost 0 degrees Kelvin. Complex and expensive cooling systems are necessary to reach such temperatures. Researchers from Jülich, Münster and Moscow found out that superconducting qubits could possibly be produced not only from the usual low-temperature superconductors, but also from high-temperature superconductors. In experiments with nanowires made of the high-temperature superconductor yttrium barium copper oxide, quantum effects already occurred at 12 to 13 degrees Kelvin. A much smaller and cheaper cooling technology is sufficient to achieve such temperatures of -260 to -261 degrees Celsius. The researchers led by Prof. Rafał Dunin-Borkowski from Jülich’s Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons assume that high-temperature superconductors could even increase the number of qubits on a chip and the computing speed.

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3.8 per cent – the efficiency that Japanese researchers achieved with their solar cell in 2009 did not knock anybody’s socks off. This value indicates how effectively solar energy is converted into solar power. Conventional solar cells made of crystalline silicon achieved up to 26 per cent in the laboratory at that time.

Even so, it made experts around the world perk up: the Japanese solar cell consisted of a material that had been known for 40 years and that researchers had not credited with any special properties for photovoltaics until then. Its crystal structure is characteristic for the organometallic material (see illustration). It belongs to the perovskites, named after a naturally occurring mineral. “It came as a surprise to many that this perovskite material can be a semiconductor, making it suitable for solar cells,” says Saliba. He had already started researching these materials in early 2011 as a young doctoral researcher in Oxford. Perovskites have decisive advantages over silicon crystals: they can be produced simply, cost-effectively and in an energy-saving manner.

It soon became apparent that the efficiency of perovskite solar cells could be improved enormously. A kind of gold rush broke out among materials researchers worldwide: there were already about 50 scientific publications on semiconducting perovskites in 2013 and over 3,800 in 2019. “By now, the efficiency record of perovskite solar cells is at an astonishing 25.2 per cent, which is very close to the record value of 26.7 per cent for silicon cells optimized over decades. Originally it seemed ambitious to expect that perovskites would achieve an efficiency beyond 20 per cent within just ten years. The development is unprecedented in solar cell materials research,” says Saliba.

The 37-year-old physicist is one of the stars of the research field: in 2020, he received the Heinz Maier-Leibnitz Prize of the German Research Foundation, which is one of the most important awards for young scientists in Germany. The magazine “Capital” voted him among the “Young Elite - the Top 40 under 40” in the Science and Society category twice; the magazine “MIT Technology Review” included him in the list of the world’s leading innovators under 35 in 2017; and the Institute for Scientific Information counts him among the most frequently cited scientists in his field. After stays in the USA, the UK and Switzerland, he is now the director of the Institute for Photovoltaics at the University of Stuttgart and also head of the Helmholtz Young Investigators Group FRONTRUNNER at the Jülich Institute of Energy and Climate Research (IEK-5).

NOT YET STABLE ENOUGH
Saliba is always on the hunt for higher efficiency and a deeper understanding. In 2016, for example, working together with researchers from Switzerland, he showed that by inserting rubidium atoms into the perovskite structure, solar cells can be produced with an efficiency of 21.6 per cent. He is also concerned with probably the biggest hurdle on the way to a marketable perovskite solar cell: the lack of long-term stability. “If perovskite solar cells are to replace the established silicon technology, they must function for a comparable period of time,” says the physicist. This is a high requirement, since silicon modules age quite slowly: they lose very little of their performance even after more than 20 years of practical use. What is more, the service life of newly developed modules can be reliably predicted using standardised methods. “However, these tests cannot simply be transferred to perovskite solar cells. Unlike silicon, perovskites react to strain such as temperature fluctuations, moisture, hail, light and preload,” Saliba explains. He is working with colleagues from all over the world to develop...
comparable tests for perovskite solar cells and to understand the ageing process in detail. His research team has also produced a perovskite solar cell with an efficiency of more than 20 per cent that loses power less quickly in the laboratory than previous perovskite cells. To this end, Saliba and his colleagues replaced previously used, temperature-sensitive methylammonium ions with a mixture of rubidium, cesium and formamidinium ions.

Saliba is convinced that science has so far only been digging at the edge of the perovskites “gold mine”: he has calculated that over 6,000 different perovskites would be possible by simply combining the components used so far. This number rises to over 14,000 if only one additional component were added. If it is then also taken into account that the quantity ratios of the components can be chosen almost arbitrarily, a nearly infinite variety of perovskites is the result. “I’m pretty sure that there are perovskites among them that are even better suited for solar cells, LEDs or sensors than the ones known so far,” says Saliba.

In Jülich, he wants to use automated processes to produce many of these semiconducting perovskites as micrometre-sized particles in a liquid, so-called colloids, in a short time. Pre-tests – which are also automated – will then provide initial indications of particularly promising candidates. The Jülich Young Investigators Group is also looking for perovskites that can be applied on top of silicon cells. Since perovskites and silicon absorb different spectral ranges of sunlight, they could be used in tandem to exploit a broader spectrum of light for power generation. “In this way, the competitors silicon and perovskite could become a dream team,” says Saliba with a chuckle.

FRANK FRICK
Climate research at the end of the world

Icy lakes, rugged rocks, vast steppes and harsh weather – Tierra del Fuego is known for its breathtaking nature. However, it was not the latter that attracted scientists to the southernmost tip of America, but the previously hardly-explored atmosphere of the southern hemisphere. The researchers collected data at altitudes of up to 90 kilometres to optimise models and better understand climate change.

The Tierra del Fuego archipelago is the wind-blown southernmost tip of Argentina and Chile, about 1,000 kilometres from Antarctica. In September and November 2019, several atmospheric researchers and engineers moved their laboratories to this inhospitable area – or, to be more precise, into a draughty aircraft hangar in the city of Rio Grande on the main island of Tierra del Fuego and on board the research aircraft HALO. The aircraft was stationed there for the “SouthTRAC” measurement campaign and equipped with a globally unparalleled instrumentation.

The goal of the campaign: to obtain new data on the composition and exchange of atmospheric layers in the southern hemisphere. “Above all, we need reliable data on the composition and transport of trace gases, particularly at altitudes where the troposphere and stratosphere meet – that is, at about 8 to 15 kilometres. This region is crucial for also understanding climate change in the southern hemisphere and improving existing climate models,” explains Dr. Peter Preusse, physicist at the Jülich Institute of Energy and Climate Research (IEK-7). The researchers also want to close some of the gaps that still exist, for example with regard to air pollutants, ozone depletion and gravity waves.
Meticulously planned over two years, the campaign ran like clockwork on site. Surprising weather phenomena did not change this, nor did computer and car breakdowns, which were mastered professionally and sometimes unconventionally. Read more on the following two pages.

40 scientists and technicians are in the field.

3 million euros is the budget of the campaign.

Being aboard during SouthTRAC

The SouthTRAC measurement campaign flights were coordinated by Jülich experts together with colleagues from the German Aerospace Center (DLR), the Karlsruhe Institute of Technology (KIT) and the universities of Mainz and Frankfurt. Other partners were the University of Wuppertal and Heidelberg University. A total of 13 instruments were accommodated on board the HALO research aircraft, including three precision instruments that are unique worldwide and were developed and built with Jülich participation: the GLORIA infrared spectrometer for measuring temperature, trace substances and aerosols; the FISH hygrometer for determining air humidity; and AMICA for measuring other trace gases.

Personal impressions of the campaign in our Jülich blog:
blogs.fz-juelich.de/climateresearch/tag/southtrac
Gravity waves and ozone depletion

They show up as billows and stripes in clouds: gravity waves – atmospheric disturbances that influence winds, temperatures and the chemical composition of the earth’s middle and upper atmosphere. These air oscillations occur, for example, when strong winds hit high mountains, such as the Andes or the mountain ranges of the Antarctic Peninsula. The waves are powerful: for example, they can weaken the polar vortex over the Antarctic. At an altitude of up to 80 kilometres, the vortex races at over 200 kilometres per hour and influences the climate all over the world. If it is disturbed or collapses prematurely – as was the case in the winter of 2019 – then, among other effects, the ozone depletion in the stratosphere is lower and the ozone hole is therefore much smaller than in normal weather conditions.

The researchers characterise the three-dimensional expansion and the structures of such gravity waves with the aid of the GLORIA spectrometer and the novel ALIMA laser, which radiates spectacularly from the roof of HALO up to a height of 90 kilometres. The campaign also focused on so-called planetary waves with wavelengths spanning half the earth. The data are also expected to clarify the extent to which these waves contribute to the exchange of air between the troposphere and stratosphere. This is because the exchange of air changes the distribution of trace gases such as water vapour and ozone in the upper troposphere and lower stratosphere. This distribution in turn influences how heat is absorbed by the atmosphere and dissipated into space or reflected back to the ground. These processes are thus key elements in understanding climate change.

Hurdles, big and small

Not everything always runs smoothly. Even before the campaign really gets underway, the sea container is stuck in port, packed with special equipment to every nook and cranny. 50 metres of Internet cable are missing. There is a thick fog on the day HALO arrives. A computer with the data of three irretrievable measuring days refuses to cooperate. There are additionally the small dramas like mud and extreme wind that ruin rental cars and bring hikers to their knees. Then, however, the customs authorities come to an understanding after all; a local electrical dealer solders the missing cables together; the fog lifts; and the data can later be salvaged at Jülich. A farmer drags the rental car out of the mire, and all researchers return unharmed from their hiking tours to find answers on how to meet global climate targets.
Air pollutants

A dark lining stretches over the horizon. It bears witness to the devastating forest fires in South America and Australia. During the transfer flights of the research aircraft HALO between Germany and Argentina, the measuring instruments on board occasionally recorded “such high concentrations of air pollutants like carbon monoxide, for example, as the colleagues had never seen before in their entire careers,” reports Jülich expert Dr. Jörn Ungermann. Degradation products of the various air pollutants are very long-lasting and, over time, even penetrate the stratosphere. According to the researchers, the effects of the large-scale fires on the climate are not yet foreseeable.

TEXTS: BRIGITTE STAHL-BUSSE

Research flights over the South Pole

During the polar night, the atmosphere above the poles cools down considerably. As a result, the polar vortex is formed, with winds of over 100 m/s at its edge. Gravity waves originate north of it over the Andes and south over the Antarctic Peninsula and then spread out into the polar vortex. To explore this, the research aircraft HALO flew into the polar vortex. By combining the GLORIA and ALIMA measuring instruments, the spread of the waves from the troposphere to the mesosphere could be tracked. A second goal was to study exchange processes between the troposphere and stratosphere. These can be quantified on the basis of concentrations of typical trace gases such as water vapour, carbon monoxide, CFCs and ozone.
**BIOECONOMY**

Bioeconomy means operating sustainably — if possible, without fossil raw materials and without producing waste, modelled on cycles in nature.

**BIOBASED**

Plants, animals, microorganisms and their products provide resources for food and materials such as medicines, bioplastics or even fuels.

**CYCLES**

Renewable resources, but also plastics or rare metals, are to be efficiently recycled. Tailor-made biocatalysts, for example, can help here.

**ADDED VALUE**

Biobased products do not simply replace conventional products, but sometimes have additional properties. For instance, aircraft wings made of artificial spider silk would be lighter and would save fuel.

**THE VISION**

- Enough food and healthy food for all
- Securing sustainable energy and raw material supplies
- Protecting the climate and the environment

**WHAT IS JÜLICH DOING?**

Jülich is concentrating on the fundamentals of resource, product, and material cycles:

- Cultivating bacteria
- Improving the use of plants
- Improving soil productivity
- Contributing to the transformation of the Rhineland lignite region into a bioeconomy region, the BioEkonomicRenew

**2020**

is the Science Year of bioeconomy. For 20 years, the Science Years have been bringing research and society together throughout Germany. They are intended to stimulate debate, present ideas and make science more transparent.
EXPLANATORY FILMS

Max Planck relies on YouTube

In its new explanatory film series “Wissen Was” (Knowing What), the Max Planck Society relies on two well-known YouTubers: MrWissen2go and Doktor Whatson deal with topics from the Max Planck spectrum in approximately ten-minute short films: in interviews with researchers, the YouTubers trace Europe’s beginnings or investigate how best to encourage the general public to donate organs.

– WWW.YOUTUBE.COM –
– KEYWORD: MAXPLANCKSOCIETY –

EXPLORING PROFESSIONS THROUGH PLAY

Serena Supergreen

Serena is a perfectly normal teenager who goes on vacation with her friends. Before and during the journey, the protagonist of the computer game “Serena Supergreen” has to solve tricky puzzles and learns – almost incidentally – all kinds of exciting things about renewable energies. The so-called serious game for computers and smartphones is intended to impart knowledge and arouse interest in technical professions among young people.

– WWW.SERENASUPERGREEN.DE –

FROM PODCAST TO THE STAGE

Methodically incorrect

Every two weeks for well over seven years, Nicolas Wöhrl and Reinhard Remfort have been talking shop about science. The recordings of their easygoing conversations, which last up to four hours, can be downloaded as a podcast under the keyword “Methodisch inkorrekt” (methodically incorrect). Those who prefer watching rather than listening can watch the experiment of the week on their YouTube channel, which recently won the Youlius Award. But that’s not all. The two physicists have been taking to the stage since the end of 2018: as “rock stars of science”, they present banging experiments or test the quality of the latest “Chinese gadgets” in live shows.

– WWW.MINKORREKT.DE –
Efficiency record for organic solar cells. The flexible photovoltaic modules (OPV) now achieve an efficiency of 12.6 per cent.

#Solarcells

The new solar module

is a joint development of the Helmholtz Institute Erlangen-Nuremberg for Renewable Energy (HI ERN), a Jülich branch office, and its German partners. OPV modules made of lightweight flexible materials open up new applications, for example in mobile devices or clothing. Compared to silicon solar cells with an efficiency of over 25 per cent, they are much easier to manufacture, but not yet as efficient.

https://t1p.de/o2he