

FACTS AND FIGURES



SHAPING CHANGE

Almost 6,800 people are working hand in hand on this mission at Forschungszentrum Jülich, including 672 visiting scientists from 62 countries. We are one of the major interdisciplinary research institutions in Europe and, as a member of the Helmholtz Association, contribute to solving the major social challenges of our time.

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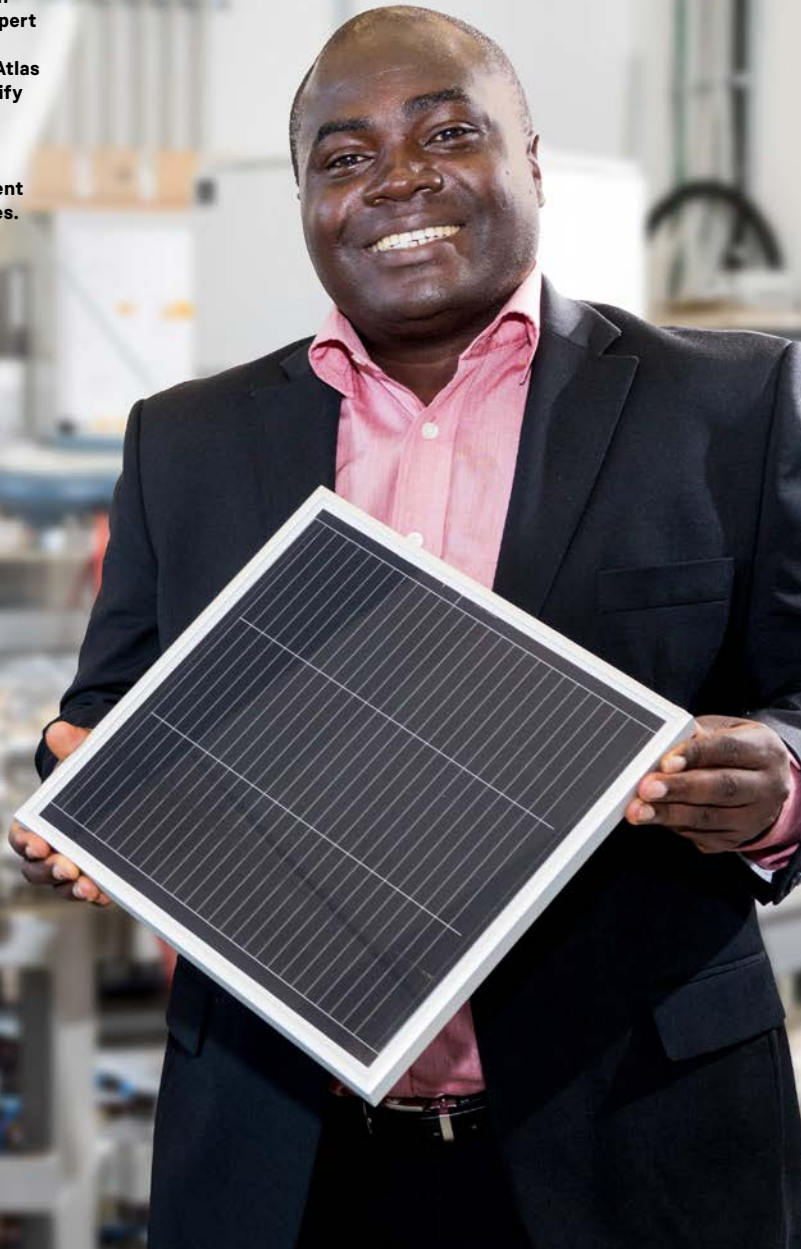
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Jülich physicist Solomon Nwabueze Agbo is an expert on “green” hydrogen. He coordinates the “H2Atlas Africa” in order to identify the potential for the sustainable production of hydrogen in the west and south of the continent using renewable energies.





RES EAR CH

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Shaping change: this is what motivates us at Forschungszentrum Jülich. We explore options for a digitalized society, a climate-friendly energy system and resource-conserving economic activity. We combine natural life and technical sciences from the information, energy and bioeconomics fields with our expertise in high-performance computing, and we use one-of-a-kind scientific infrastructures.

JÜLICH RESEARCH AT A GLANCE

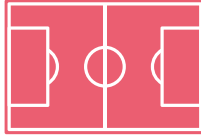
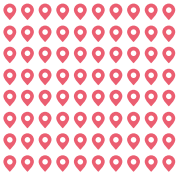
10

Institutes



80

Institute sections



238

football fields

would fit into the 1.7 square kilometre campus of Forschungszentrum Jülich.



812

million euros

of revenue for Forschungszentrum Jülich in 2020



900 MHz NMR spectrometer

Institute of Biological Information Processing



Supercomputer JUWELS

Jülich Supercomputing Centre



Atmospheric simulation chamber SAPHIR

Institute of Energy and Climate Research

SELECTED RESEARCH INFRASTRUCTURES ON THE JÜLICH CAMPUS

3

Research focus areas



Information



Energy



Bioeconomy



68

New patent applications

in 2020



2,473

Publications

in 2020



EMPHASIS

Institute of Bio- and Geosciences



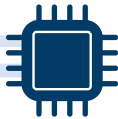
Electron microscope PICO

Ernst Ruska-Centre



Particle accelerator COSY

Nuclear Physics Institute



Nanotechnology

Helmholtz Nano Facility



Quantum computer

Helmholtz Quantum Center (in the planning stage)



FOCUS INFORMATION

The focus on information allows Jülich research to bring together three areas: the simulation and data sciences of **high-performance computing** (HPC), **brain research** and the research on bio-based and nanoelectronic-based information technologies of the future. Many research results are based on large amounts of data. For Jülich researchers, big data has long been part of everyday life. They are working to find answers to complex questions using the flood of data, for example in climate research, neuroscience and materials research. Using JUWELS for this purpose, which is currently Europe's fastest supercomputer, they are developing modular hardware architectures for exa-scale computing. Another focus at Jülich is quantum technology – from the basics to application. In the “Quantum Flagship”, the largest **quantum computing** initiative in Europe, the first freely programmable European quantum computer is being built at Jülich.

Technology-based information processing is closely interlinked with research on biological systems. Learning from the brain – the basis for innovative computing concepts such as neuromorphic computing. The vision of the EU-funded Human Brain Project is to understand the human brain through simulation. **Artificial intelligence** helps in developing a high-resolution atlas of the brain. Through the EBRAINS platform, experts all over the world can access data and tools for brain research and translation into clinical and technical applications. This opens up new possibilities for diagnosis and therapy, for example in Alzheimer's disease, and in the development of innovative neurotechnologies.



Water cooling in the JUWELS supercomputer

High-performance computing

SUPER FAST, SUPER ECONOMICAL – JUWELS

Towards the end of 2020, the Jülich supercomputer JUWELS was ready: with its new booster module, it can perform 85 quadrillion computing operations per second (85 petaflops). That is equivalent to the computing power of more than 300,000 modern PCs. This massively expands simulation boundaries. JUWELS is also Europe's strongest platform for the use of artificial intelligence (AI). By the time JUWELS was completed, it was not only the fastest supercomputer in Europe, but it was also the most energy-efficient system within the highest performance class.

The computer, developed by Forschungszentrum Jülich, the French-German company Atos and the Munich-based supercomputing

specialist company ParTec together with the US manufacturer NVIDIA, is a powerful tool that Jülich scientists, along with partners from science and industry, use to answer complex research questions. A current example from the Covid-19 crisis is computer-supported drug development. The computing power of the booster makes it possible to simulate the processes taking place before, during and after the meeting of a potential active substance with a receptor or protein in a sufficiently realistic way (see p. 26).

Brain research

OPTIMIZING THE DIAGNOSIS OF DEMENTIA

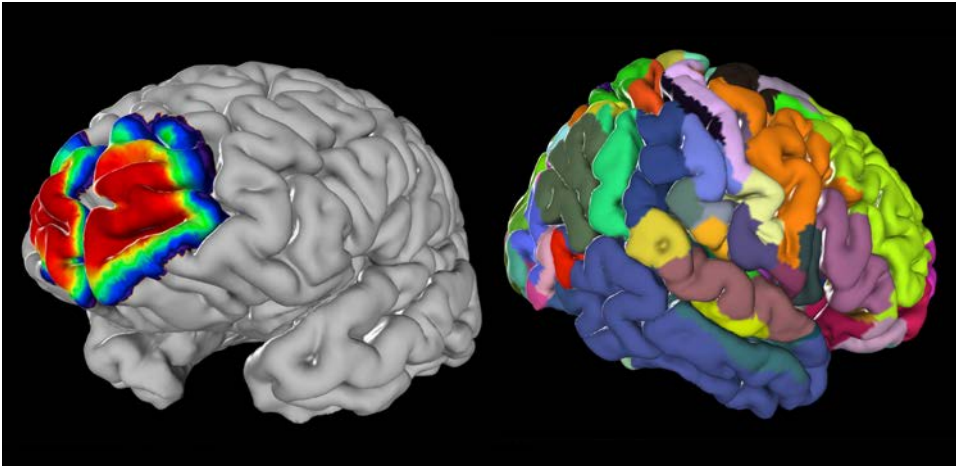
In order to diagnose a neurodegenerative disease such as Alzheimer's dementia, several test procedures are combined. Positron emission tomography (PET) can provide valuable information. Various biomarkers are available for this. For example, amyloid PET makes pathological amyloid deposits in the brain visible; ^{18}F -fluorodeoxyglucose, or (^{18}F -FDG)-PET, clears the way for evaluations of glucose metabolism and, thus, brain activity. Both methods complement each other.

However, there has been uncertainty about the optimal time to use these procedures as well as in what combination and order the PET biomarkers should be used. A panel of inter-

national experts from various disciplines, including Forschungszentrum Jülich and the University Hospital Cologne, has now turned to the available evidence and clinical expertise and developed an algorithm, which the experts present in the journal "Lancet Neurology". They propose three main diagnostic pathways in which the biomarkers amyloid PET and ^{18}F -DFG PET are applied at different positions in the sequence of diagnostic procedures, depending on the clinical presentation. In doing so, they also hope to stimulate further research on optimal diagnostic strategies.



The risk of developing Alzheimer's dementia increases with age. Jülich researchers optimize diagnostics.



Areas of different brains can be very different. Therefore, Julich-Brain displays the position and shape of individual regions as probability maps. Different colours indicate how often a certain area is found at the respective location.

Brain research

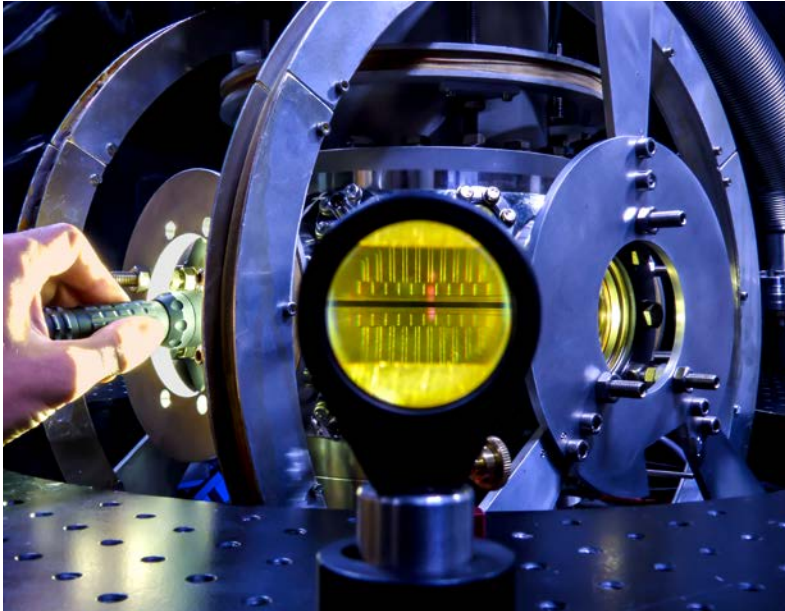
“GOOGLE EARTH” OF THE BRAIN

A three-dimensional map of the brain that depicts the variability of brain structure with microscopic resolution – that is the Julich-Brain Atlas. A team of researchers from the Institute of Neuroscience and Medicine and from Heinrich Heine University Düsseldorf, led by Prof. Katrin Amunts, presented the atlas in the renowned journal “Science” in 2020. The atlas shows the different brain regions, which differ in the distribution and density of the total some-odd 86 billion nerve cells and in their function. So it is like a kind of “Google Earth” of the brain.

More than 24,000 wafer-thin brain slices from 23 brains in all were digitized, assembled on the computer in 3D and mapped by experts.

Since no two brains are exactly alike, the Julich-Brain Atlas shows the size and location of the areas as probability maps.

Created in around 25 years of work, this is the most comprehensive digital map of the cellular brain architecture so far: it covers around 70 per cent of the cerebral cortex and deeper core regions. It is available to researchers worldwide through the new EBRAINS infrastructure (p. 46) as part of the European Human Brain Project. The atlas serves as an “interface” to connect information about the brain in a spatially precise way and thus to better understand the functioning of the brain and the mechanisms in diseases.



The University of Innsbruck's ion trap

Quantum computing

FIND THE ERROR

In the future, quantum computers could solve special tasks much faster and more efficiently than conventional supercomputers. Quantum information is fragile, however. This is why quantum computers must also be able to correct errors, such as when entire qubits – the carriers of quantum information – are lost.

Qubits are prone to errors induced by undesired environmental interactions. These errors accumulate during a quantum calculation and thus correcting them becomes a key requirement for reliable use of quantum computers. In the scientific journal “Nature”, a group of researchers from Jülich’s Peter

Grünberg Institute and RWTH Aachen University, together with colleagues from the Universities of Innsbruck and Bologna, presented a method that enables quantum computers to continue computing even if they lose some qubits. For one thing, it enables an ion trap quantum computer to detect such errors and for another, to adapt to the loss of qubits in real time, all while maintaining the protection of fragile quantum information. The building blocks developed can also be used for other quantum computer architectures, the researchers emphasize.

Artificial intelligence

ROBOT LEARNS NANOLEGO

Scientists from the Peter Grünberg Institute, together with colleagues from TU Berlin, have developed an artificial intelligence that can independently learn to grasp and move individual molecules.

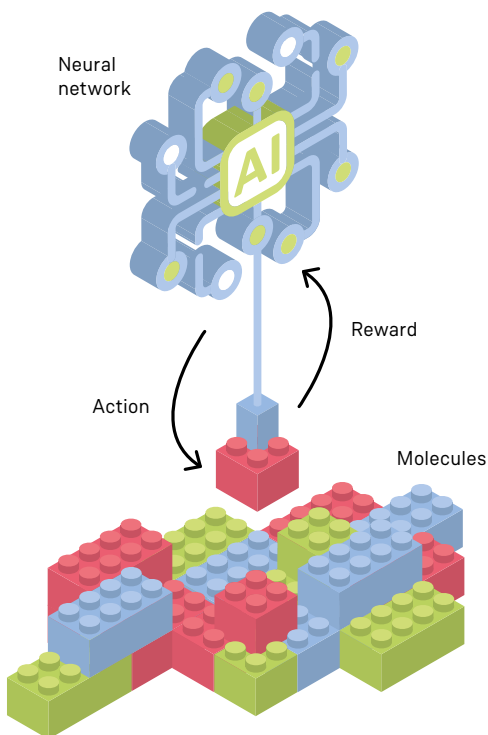
Most materials consist of different molecules – similar to a Lego model composed of different building blocks. With a scanning electron microscope, atoms and molecules can be moved. However, the molecular building blocks of the nanoworld behave completely differently from macroscopic objects, each needing its own “instruction manual”. Targeted movement of molecules with the tip of the scanning electron microscope was previously only possible by hand, through trial and error.

With the help of a self-learning autonomous software control system, it has been possible to automate this process. In reinforcement learning, the software agent is not given a solution path, but success is rewarded and failure punished. This way, after completely random actions at the beginning, it learns

rules over time about which movement is most promising in which situation, and gets better with each run.

This is the first time that artificial intelligence and nanotechnology have been successfully brought together. The method, published in the journal “Science Advances”, could pave the way for robotic, automated design of functional structures, such as quantum devices or innovative materials.

Artificial intelligence controlling a scanning tunnelling microscope: initially, the movements involved in grabbing and setting down molecules are random. After each run, AI learns from the experience, thus operating better and better.





FOCUS ENERGY

The EU wants to be climate neutral by 2050. By 2030, CO₂ emissions are to be reduced by 55 per cent compared to 1990. At the same time, it is essential to secure the power supply, keep industry competitive and improve air quality. Jülich scientists **are modelling scenarios** to find out how these goals can be achieved. They make recommendations for a future energy system that is based on renewable energies and develop technologies for it.

Hydrogen plays a key role in this: it is intended to replace fossil fuels, store energy, enable mobility and serve as a basic material for the chemical industry – efficiently and cost-effectively. In addition, it should also be “green”, that is, produced with the help of renewable energies. Jülich research on this topic is diverse, ranging from material development for electrolysis plants, fuel cells and solar modules to the investigation of electrochemical processes and the transport, storage and use of hydrogen. **Batteries** are indispensable as energy storage devices. Jülich researchers optimize established systems and develop new battery types. Forschungszentrum Jülich is also pursuing a value chain for the research into technologies for storing excess electricity in high-energy chemicals, for example for use as fuel.



Batteries for electric cars – their performance could be improved in the future through additives to the electrolyte.

Battery research

“VITAMINS” FOR LITHIUM BATTERIES

Lithium metal batteries and lithium ion batteries continue to be considered the most promising energy storage devices for electric vehicles and portable devices. In the journal “Solid State Electrochemistry”, a team from the Institute of Energy and Climate Research/ Helmholtz Institute Münster and the MEET Battery Research Center at the University of Münster described how the performance of these batteries can be improved by means of additives to the electrolyte.

While not fundamentally changing the nature of the battery, the additives can enhance performance when added in small quantities – similar to vitamins in the living organism. This

is how the scientists describe this research approach. They studied the effect of two such additives, each individually or in combination, on different lithium-based high-voltage batteries and found that there is no one-size-fits-all solution for all battery types examined. In some cases, one additive brought more advantages, in some cases the other, and with still other batteries, a mix of both “battery vitamins” was the most successful. The systematic approach serves to more precisely understand synergy effects and the interaction of the additives with the components of the battery – such as the electrode surfaces – and to use them to improve performance.

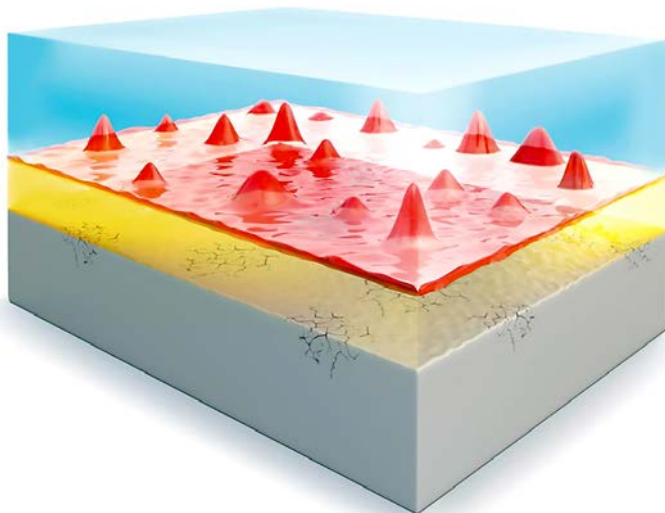
Battery research

UNDERSTANDING DEFECTS

Lithium ion batteries that store nine times as much energy as they do today would allow electric cars to travel much further than before without having to stop to charge. Smartphones would also be operable for longer. This would be possible with the same battery weight and size if an electrode made of silicon were used instead of the usual graphite anode. Speaking against this: silicon anodes can only withstand a few charge-discharge cycles. After that, cracks form in the silicon anode or parts of the material even turn into powder.

An international team of scientists from the Jülich Institute of Energy and Climate Research has now observed how the defects

form in the anode and reported on them in the scientific journal “Nature Communications”. The researchers describe in detail how, during the charging process, two layers are formed at the boundary between the liquid electrolyte and the surface of the silicon crystal: one of inorganic, the other of organic lithium compounds. Lithium ions migrate into the silicon crystal; an inhomogeneous, non-crystalline lithium-silicon alloy is formed. Cracks and other defects appear at the boundary between amorphous alloy and crystal already during the first charging process – the anode deforms. The researchers conclude that in order to increase stability, the inhomogeneity of the boundary layer would have to be reduced.



Inhomogeneities in the outer boundary layer (red) lead to different lithium contents in the silicon anode (yellow/grey) during charging, resulting in cracks and other defects.



A study looked at 12 different synchronous areas, such as the city of Lisbon, to understand frequency changes in power grids.

Modelling scenarios

LEARNING FROM OLD NETWORKS

The conversion to renewable energy sources brings with it new demands on power grids. To meet them, energy research can learn from existing systems. With an international team of researchers, scientists from the Jülich Institute of Energy and Climate Research studied various electricity systems on three continents. Their aim was to understand the frequency changes that result from the relationship between energy supply and demand. The study covered 12 different synchronous areas. These are regions with different power plants and consumers that are interconnected and operate at the same frequency.

Depending on feed-in and consumption, the frequency tends to fluctuate around its reference value. Simultaneous measurements at different locations in the continental European synchronous area showed significant differences between the frequencies in Lisbon, Karlsruhe and Istanbul, for example, for a time scale of seconds. The fluctuations say a lot about how a synchronous area is operated, such as how large the grid is, how often control measures are taken and much more. The results were published in the scientific journal “Nature Communications” and are expected to help design and test new energy concepts worldwide.

Hydrogen

HYDROGEN FROM A STRATEGIC POINT OF VIEW

Scientists from the Jülich Institute for Techno-Economic Systems Analysis issued a statement in which they generally welcome the Federal Government's hydrogen strategy of June 2020. Hydrogen is one important option for achieving the goal of reducing greenhouse gases by 95 per cent by 2050. The Federal Government's initiative points in the right direction.

Hydrogen pipeline infrastructure

in 2050



For example, the strategy provides for a doubling of today's hydrogen demand to about 90 to 110 terawatt hours by 2030. Jülich calculations show that, for a greenhouse gas reduction of 95 per cent, the demand for hydrogen will increase to almost 400 terawatt hours between 2030 and 2050: a future hydrogen infrastructure should be oriented around this demand, which can be expected in the long term. The goal of the national strategy is to establish a domestic electrolysis capacity of 5 gigawatts by 2030. This corresponds to about 14 terawatt hours of green hydrogen. Hence, the national hydrogen strategy relies mainly on hydrogen imports. Significantly higher domestic production is possible, however, and can be competitive, analyses by Forschungszentrum Jülich show. This requires an accelerated expansion of wind power and photovoltaics. Hydrogen also plays an important role in the long-term storage of energy. According to the Jülich researchers, this is only insufficiently addressed in the hydrogen strategy.

Transmission pipelines

- 90-500
- 501-800
- 801-1,150
- 1,151-1,500
- 1,501-1,850
- Distribution pipelines
- Port
- Electrolyzer



Together they launched the project for “green” hydrogen made in Africa: Prof. Harry Vereecken, Dr. Solomon Nwabueze Agbo (project coordinator), Dr. Heidi Heinrichs, Parliamentary State Secretary Thomas Rachel, Prof. Wolfgang Marquardt, Prof. Detlef Stolten, Dr. Wilhelm Kuckshinrichs and Prof. Uwe Rau (from left).

Hydrogen

HYDROGEN FROM AFRICA

Africa as a producer and exporter of sustainably produced hydrogen – that is the idea behind the project “H2Atlas-Africa”. The continent with a rapidly growing population, whose energy needs are increasing, also has great potential for renewable energies. This would allow hydrogen to be produced sustainably and used for a climate-neutral energy supply in Africa and Europe. The project is funded with around €5.7 million by the Federal Ministry of Education and Research and coordinated by Dr. Solomon Nwabueze Agbo from Forschungszentrum Jülich.

Partners are the centres for climate research in Ghana (West African Service Centre on Climate Change and Adapted Land Use) and in Namibia (Southern Africa Science Centre for

Climate Change and Adaptive Land Management). Together with researchers, engineers and technicians on site, the aim is to identify potential locations for plants that can extract renewable energy – for example from photovoltaics – and use it to produce hydrogen in electrolyzers. Scientific, technological and economic aspects are taken into account in this, and so are environmental protection, climate change and social components. For instance, agricultural land and water resources that are essential for the supply of people must not be used.



FUTURE FIELD BIOECONOMY

The sustainable bioeconomy is a **bio-based circular economy** that manages without fossil raw materials, instead relying on renewable raw materials. Scientists at Forschungszentrum Jülich are developing, for example, new value creation processes. They use customized microorganisms and biological catalysts to produce valuable materials for medicines, bioplastics or even fuels from renewable raw materials or waste such as plant residues. In **biotechnology**, automation, miniaturization and digitization play an important role in shortening development times and making them more predictable.

Agriculture and plant research are also part of the bioeconomy. Researchers use **experimental data** from trial fields and simulations of soil-plant interactions to help optimize yields, reduce fertilizer and address changes caused by climate change. Digital monitoring supports tailored irrigation and can indicate stress in plants at an early stage.

It is to be demonstrated in the Rhineland region, which serves as a model region, how a changeover to a fossil-free economy can succeed after the phasing out of coal-fired power generation. One building block for this is the “Bioökonomie-REVIER”. This is being coordinated by Forschungszentrum Jülich, and it networks the local players. For ten years now, scientific expertise and modern infrastructures in key bioeconomy topics have been pooled in the Bioeconomy Science Center, which is the competence centre of Forschungszentrum Jülich and the University of Bonn, Heinrich Heine University Düsseldorf and RWTH Aachen University.



Prof. Jan Marienhagen,
head of the research
group “Synthetic Cell
Factories” at the
Institute of Bio-
and Geosciences

Biotechnology

PREVENTING FALSE REPORTS

Microorganisms such as the bacterium *Corynebacterium glutamicum* make themselves useful in the production of a variety of substances such as chemicals, medicinal agents or food supplements – from simple basic materials and with little energy input. High hopes are therefore being set on this “white biotechnology”. However, it is not so easy to select the most suitable bacteria from a large number of variants. While biosensors can make the cells that produce the desired product – such as a certain amino acid – glow, they often make mistakes and also indicate those cells that only contain substances more or less similar to these.

A team of Jülich scientists has now, along with other colleagues, found a way to prevent such false reports. In the scientific journal “Nature Communications”, they describe how they improved the validity of the previous method. The specificity of a biosensor that previously indicated both the amino acid histidine and the amino acid lysine was successfully changed: after modification, it can no longer detect lysine. Such customized biosensors are considered an important step on the path to efficient cell factories for a sustainable, bio-based economy.

Agriculture

CARBON INTO THE SOIL

The amount of carbon in the atmosphere increases by more than four billion tonnes every year due to man-made CO₂. In the journal “Nature Communications”, an international team of scientists, in which Forschungszentrum Jülich is involved, has advocated for the sequestering of a large part of this carbon in the soil. Such a strategy could, at the same time, slow down climate change and help to ensure food security. The amount of carbon in the soil would increase by a mere 0.4 per cent if it were possible to store the entire four billion tonnes of carbon in the soil. Prof. Wulf Amelung from Jülich’s Institute of Bio- and Geosciences considers about a third of this amount to be realistic. He is leading the initiative together with his French colleague Prof. Dr. Abad Chabbi.

In order to increase the amount of carbon in the soil, plant growth in particular would have to be increased: by liming acidic soils, by fertilizing according to need, by clever irrigation – adapted to local conditions in each case. Many measures are most promising for soils that have been partially degraded by overuse and have lost a lot of carbon. However, knowledge about the condition of soils is very fragmentary. The scientists therefore recommend the establishment of databases that record the condition of land worldwide on a small scale, as well as the modelling of possible crop yields and of required fertilizer use.



Increasing the input of carbon into the soil could slow down climate change and increase crop yields at the same time.



Drones at work in the fields

Experimental data

DATA FOR PLANT PROTECTION

Artificial intelligence is to help overcome the major challenges that climate change poses for agriculture, such as increasing drought or newly emerging pests. To this end, Forschungszentrum Jülich and the Helmholtz Centre for Environmental Research agreed in 2020 to collaborate with the Volcani Institute of the Israeli Agricultural Research Organization. This collaboration between Jülich and the Volcani Institute focuses on the sustainable use of soil and water resources, on improving the properties of crops, on plant protection and on phenotyping amidst dynamic environmental changes.

Forschungszentrum Jülich has special test facilities available for this purpose that are nor-

mally used in medicine: a magnetic resonance tomograph (MRT) and a positron emission tomograph (PET). These allow soil columns to be examined and root growth to be observed; the PET can even be used to track the transport of carbon in the roots. Artificial intelligence is used to analyze the data obtained in this way – a central topic in the German-Israeli collaboration. The data reveal, for example, how to properly water to promote ideal root growth or how certain pests affect the plants. In the future, swarms of drones could search fields for pests and soil robots could perform targeted treatments.

Bio-based economy

GREAT TUBER, EVEN GREATER

Cassava is one of the most important staples of West Africa. With almost 50 million tonnes per year, Nigeria is the world's largest producer of the carbohydrate-rich tubers. However, the yield is lower than it could be: it is only about 20 per cent of the possible maximum. In the Cassava Source-Sink (CASS) project, scientists from the Jülich Institute of Bio- and Geosciences are working together with colleagues from Friedrich-Alexander Universität Erlangen-Nürnberg, ETH Zurich and the International Institute of Tropical Agriculture in Ibadan, Nigeria, to find a more robust and higher-yielding variant of the plant. CASS is financed by the Bill & Melinda Gates Foundation.

In the field trial in Nigeria, the researchers are testing around 500 cassava varieties created through cross-breeding experiments. The Jülich experts observe the above-ground part of the plant to see how well it grows and performs photosynthesis. The development of more than 9,000 plants is documented with a drone developed at Jülich. A special software analyzes the aerial images and creates 3D models from them. In this way, the growth of cassava can be understood under the real conditions of the country – a prerequisite for systematically improving the plant. The aim is for Nigerian farmers to be able to use the technologies and processes sustainably and without support from abroad in the future.



Dr. Anna van Doorn played a key role in developing the hardware and software for the camera drone at Jülich. She now works at the cassava experimental station in Nigeria.



View from above into a *Sida* perennial: the green stems lignify in autumn and winter and can then be harvested.

Bio-based economy

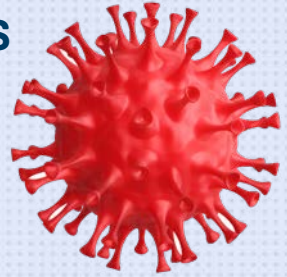
SIDA BURNS

It grows four metres high, thrives even on poor soils and develops up to a third more biomass than maize – the perennial *Sida hermaphrodita*. The plant is frost-tolerant and provides biomass for more than 20 years, totalling up to 25 tonnes at dry weight. It thus has great potential as a biomass supplier in a future bio-based economy. Together with the Fraunhofer Institute UMSICHT, Jülich scientists investigated how *Sida* can be cultivated in the most economically sensible way and used as a sustainable heating material. They presented their results in the journal “Global Change Biology – Bioenergy”.

The cost-benefit analysis showed: two plants per square metre are optimal. With denser cultivation, the costs increase more than the yield. For the investigation of *Sida*'s burn behaviour, the biomass was processed into chips, pellets and briquettes. The material burnt best in pellet form, and pellets also proved to be the most ecologically sensible option in terms of processing, storability and fresh water consumption. Currently, the Bioeconomy Science Center is investigating further possible uses for *Sida*, for example for insulation materials, in the paper industry or as a raw material supplier for platform chemicals.

MASTERING THE COVID-19 CRISIS

The Covid-19 pandemic has posed extraordinary challenges to society. Scientists at Forschungszentrum Jülich, like many other researchers in the Helmholtz Association and worldwide, are contributing their expertise to overcoming the crisis.



PREDICTIVE MODELS OF THE OCCURRENCE OF INFECTION

Daily forecasts of the R-value

How fast is Covid-19 spreading in Germany? On the website [rtlive.de](https://www.rtlive.de) (in German), the Jülich Institute of Bio- and Geosciences provides daily forecasts of the R-value for the federal states. This value indicates how many people an infected person infects with the virus on average in a certain unit of time. The value must be below 1 in order for the spread to be contained. The infection data collected on the coronavirus regarding the major European countries also converge and are evaluated at Jülich. These predictions are accessible at [rtlive.de/global.html](https://www.rtlive.de/global.html).

County-specific predictions of new infections

How many new coronavirus infections are there? Data specialists from Forschungszentrum Jülich, together with neuroinformatics scientists from Osnabrück University, have been providing the latest model results on a daily basis. On high-performance computers at the Jülich Supercomputing Centre, data from the Robert Koch Institute is being statistically analyzed with a probability-weighted

new Osnabrück model. The daily estimates of reported new infections as well as a five-day forecast are available for each German district at [covid19-bayesian.fz-juelich.de](https://www.covid19-bayesian.fz-juelich.de) (in German).

Simulations on contact restrictions

What good does it do if people reduce their contacts? Calculations by Forschungszentrum Jülich and the Frankfurt Institute for Advanced Studies (FIAS) show: less is more. Based on the situation in Germany in autumn 2020, the researchers assumed a phase with mild, generally implemented contact restrictions, after which stricter contact restrictions would be imposed. The simulations indicated: if 90 per cent of the population reduced social contact by 75 per cent, the incidence could drop from 150 to less than 50 within five weeks. This does not yet include the occurrence of new virus mutations.



TASTE AND SMELL DISORDERS RELATED TO COVID-19

How can you tell it could be Covid-19? Infection with the SARS-CoV-2 coronavirus can impair the sense of smell and taste, even leading to complete loss. This was confirmed in 2020 by a worldwide online survey conducted by the Global Consortium for Chemosensory Research (GCCR). Psychologist Dr. Kathrin Ohla is a member of the GCCR's steering group. She headed a research group at the Jülich Institute of Neuroscience and Medicine until 2021. First results of the non-representative online survey were published in the journal "Chemical Senses". According to these published results, on a scale between 0 and 100, the olfactory ability of participants suffering from Covid-19 decreased by an average of about 80 points. A newly developed "smell check" ([riech-check.de](https://www.riech-check.de), site in German) could serve as an early warning system in the future.



Dr. Kathrin Ohla



OPTIMAL VACCINE PACKAGING

What is the best way to deliver an mRNA vaccine into human cells? BioNTech, the Mainz-based biotechnology company that, together with the US pharmaceutical company Pfizer, developed the first Covid-19 vaccine approved in the EU, is collaborating with the Jülich Centre for Neutron Science (JCNS) to answer this question. Usually, mRNA is packaged in nanoparticles to be introduced into cells. There, it serves as a blueprint for the production of certain virus molecules, which then train the immune system to defend itself against the viruses. With the help of small angle neutron

scattering experiments at the Heinz Maier-Leibnitz Zentrum in Garching, different approaches for the packaging and delivery of mRNA were investigated. This showed that, for the structuring of these nanoparticles, it comes down to the right combination of materials. In 2020 in the journal "Cells", the researchers report that nanoparticles containing both lipids and polymers work best for delivering their cargo into cells.



SEARCH FOR ACTIVE SUBSTANCES AGAINST CORONAVIRUS

How could we prevent the SARS-CoV-2 coronavirus from entering and multiplying in human cells?

Blocking entry and multiplication

Viruses enter the cell via specific receptor proteins to which they dock (lock-and-key principle). If they are prevented from entering by, in a manner of speaking, gluing or bending the key of SARS-CoV-2 so that it no longer fits into the lock, this could inhibit infection. Researchers at the Jülich Institute of Biological Information Processing (IBI-7) are developing molecules that specifically bind to the key of the SARS-CoV-2 coronavirus and render it useless. In another project, the search is on for molecules that inhibit a viral enzyme – the so-called main protease – which is fundamen-

tal for the reproduction of the virus. For this purpose, an additional computer-based screening was carried out at the Jülich Supercomputing Centre. More than one million substances – including active pharmaceutical ingredients, natural substances and organic molecules – have been studied with some promising candidates identified, as a team led by chemist Birgit Strodel reports in the journal “Bioorganic Chemistry”.

Search with concentrated computing power

A team of researchers led by Prof. Giulia Rossetti from the Jülich Institute for Advanced Simulation describes in the journal “ACS Pharmacology and Translational Science” how it is possible to predict more precisely which molecules inhibit the main protease of SARS-CoV-2. Researchers from the European joint project EXSCALATE4CORONAVIRUS (E4C), the Human Brain Project and other European research institutions were involved. They used the computing power of Europe’s largest supercomputer centres for this, including the Jülich Supercomputing Centre. One problem: the shape of the enzyme is extremely flexible. The scientists calculated the numerous formations that the active centre can adopt and what molecules would have to look like in order to block it. With this knowledge, they have already found two suitable inhibitors.



Birgit Strodel



Prof. Astrid Kiendler-Scharr



CORONA AND AIR QUALITY

More solar power due to the lockdown

When it comes to photovoltaic systems, clear air leads to yield increases. Scientists from the Helmholtz Institute Erlangen-Nürnberg for Renewable Energies, from MIT and from the solar company Cleantech describe this side effect of the corona lockdown in the journal “Joule”. In the Indian metropolis of Delhi – one of the world’s most polluted cities – the decrease in particulate matter pollution led to more sunlight reaching photovoltaic systems, which produced more electricity. Their yield in late March 2020 was 8.3 per cent above the levels of the past three years.

Effects of the lockdown in the Rhineland

How do pandemic-related restrictions, for example in traffic and industrial production, affect air quality in the Rhineland? This is what climate researcher Prof. Astrid Kiendler-Scharr from the Jülich Institute of Energy and Climate Research, Troposphere, is investigating with a measurement campaign that started in May 2020. Trace gases and particulate matter were measured with a Zeppelin NT on several flights.

INSTITUTES AND SECTIONS

1 Ernst Ruska-Center for Microscopy and Spectroscopy with Electrons

- Physics of Nanoscale Systems
- Materials Science and Technology
- Structural Biology
- Coordination and technical infrastructure

2 Institute for Advanced Simulation

- Jülich Supercomputing Centre
- Quantum Theory of Materials
- Theoretical Soft Matter and Biophysics
- Theoretical Nanoelectronics
- Theory of the strong interactions
- Computational Biomedicine
- Theoretical Neuroscience
- Civil Safety Research
- Data Analytics and Machine Learning
- Materials Data Science and Informatics

3 Institute of Bio- and Geosciences

- Biotechnology
- Plant Sciences
- Agrosphere
- Bioinformatics

4 Institute of Biological Information Processing

- Molecular and Cellular Physiology
- Mechanobiology
- Bioelectronics

- Biomacromolecular Systems and Processes
- Theoretical Physics of Living Matter
- Cellular Structural Biology
- Structural Biochemistry
- Neutron Scattering and Biological Matter
- Technical Services and Administration

5 Institute of Energy and Climate Research

- Materials Synthesis and Processing
- Microstructure and Properties
- Techno-Economic Systems Analysis
- Plasma Physics
- Photovoltaics
- Nuclear Waste Management and Reactor Safety
- Stratosphere
- Troposphere
- Fundamental Electrochemistry
- Energy Systems Engineering
- Systems Analysis and Technology Evaluation
- Helmholtz-Institute Erlangen-Nürnberg for Renewable Energy
- Helmholtz Institute Münster
- Theory and Computation of Energy Materials
- Electrochemical Process Engineering

6 Nuclear Physics Institute

- Experimental Hadron Structure
- Experimental Hadron Dynamics
- Theory of the strong interactions
- Large Scale Nuclear Physics Equipment

7 Institute of Neuroscience and Medicine

- Structural and Functional Organisation of the Brain
- Molecular Organization of the Brain
- Cognitive Neuroscience
- Medical Imaging Physics
- Nuclear Chemistry
- Computational and Systems Neuroscience
- Brain and Behaviour
- Ethics in the Neurosciences
- Computational Biomedicine
- JARA-Institute Brain structure-function relationships
- JARA-Institute Molecular neuroscience and neuroimaging

8 Jülich Centre for Neutron Science

- Neutron Scattering and Biological Matter
- Quantum Materials and Collective Phenomena
- Neutron Analytics for Energy Research
- Neutron Methods
- Technical Services and Administration

9 Peter Grünberg Institute

- Quantum Theory of Materials
- Theoretical Nanoelectronics
- Quantum Nanoscience
- Quantum Materials and Collective Phenomena
- Microstructure Research
- Electronic Properties
- Electronic Materials
- Quantum Control
- Semiconductor Nanoelectronics
- JARA-Institute Green IT
- JARA-Institute Quantum Information
- Technical Services and Administration
- Quantum Computing Analytics
- Functional Quantum Systems
- Neuromorphic Compute Nodes
- Neuromorphic Software Ecosystem

10 Central Institute of Engineering, Electronics and Analytics

- Engineering and Technology
- Electronic Systems
- Analytics

SHAPING CHANGE WITH RESEARCH

The Rhineland region is a region in transition – away from the climate-damaging use of lignite and towards sustainable value chains. Structural change is one of the central social challenges, not only for the Rhineland lignite region, but for the whole of North Rhine-Westphalia. Forschungszentrum Jülich is actively helping to shape this process. With scientific excellence, it contributes to developing innovations and products, attracting new cooperation partners to the region and

maintaining high-quality jobs as well as generating new jobs. The Rhineland region is to become a model for new economic activity in this way. Funded by an immediate action programme of the Federal Government and together with regional partners from business, science and civil society, projects in information technology, energy technology and the bioeconomy are being developed and implemented.

Shaping Change

NEUROTEC – INTERIM GOALS ACHIEVED

The project “Neuro-inspired artificial intelligence technologies for the electronics of the future” (NEUROTEC) is about making computers more energy-efficient. Artificial intelligence, in particular, consumes a lot of energy for machine learning, far more than our brain does. Neuromorphic or brain-inspired computer hardware aims to reduce energy demand.

In 2020, many interim goals were achieved: for example, a facility was

built for the production of so-called memristors, which are key components of the new type of hardware. Computer simulations provided models for the behaviour of the memristive elements. These can now be used for circuit design. A first such circuit has been given to the industry as a production order. The Rhineland region is thus gaining in its image as a location for neuromorphic technologies.

BIOÖKONOMIEREVIER – NEW STUDY REVEALS POTENTIALS

The development of regional bioeconomies is a key prerequisite for the transformation towards a bio-based economy (see p. 20 “Future Field Bioeconomy”). This is how it was formulated in November 2020 at the third “Global Bioeconomy Summit”. The concept was developed in the model region BioökonomieREVIER Rheinland.

On behalf of the Jülich BioökonomieREVIER coordination office, Prognos AG has investigated the importance of the agricultural and food in-

dustry for the bioeconomy in the Rhineland region. The study found, among other things: every job in the agriculture and food sector provides 0.6 additional jobs. The biomass potential – from organic waste and straw to beet slices – amounts to about 1.17 million tonnes per year. In combination with the region’s excellent research infrastructure, this could make important contributions to sustainable value chain systems, for example with biorefinery processes.

Structural change will profoundly alter the Rhineland region. Dr. Leonie Göbel and Niklas Hielscher from the Institute of Bio- and Geosciences at the Hambach open-cast mine.





Prof. Rüdiger Eichel from the Institute of Energy and Climate Research is coordinator of the Copernicus project Power-to-X and head of the structural change project iNEW.

iNEW – MODEL REGION FOR CO₂ USE

The Rhineland region is to become a demonstration region for sustainable industrial production processes that use climate-damaging carbon dioxide as a raw material. In February 2020, at a fireside chat with mayors and district councillors from the municipalities affected by the lignite phase-out, Prof. Rüdiger Eichel explained how this can be achieved. He coordinates the project “Incubator for Sustainable Electrochemical Value Chains” (iNEW 2.0) at Forschungszentrum Jülich.

In new material conversion processes, hydrogen, basic chemicals and fuels – for the energy and chemical sectors as well as for transport and traffic – could be produced from CO₂ using sustainably generated electricity. The open information platform iNEW 2.0 brings together developers and users as part of the overarching project “Accelerator Sustainable Power-to-X Value Chains” (ANABEL) in order for the new technologies to contribute to the success of structural change as soon as possible.

MORE IDEAS FOR STRUCTURAL CHANGE

Forschungszentrum Jülich is currently developing a concept for a new Helmholtz Cluster in close cooperation with the federal and state governments: the aim is to make the Rhineland region an innovation and demonstration region for a sustainable hydrogen economy that is compatible with the infrastructure. In addition, state-of-the-art methods from, for example, artificial intelligence and cognitive data analysis could be made available to regional partners from business and science.

The infrastructure platform “ER-C 2.0”, for instance, is intended to help companies push forward new technologies for the development of innovative materials. Establishing an innovation centre for applied quantum technologies could bring science and business together in this research and development area. A new transfer and conference centre could become a place of dialogue for all players of structural change.

In the iNEW project, Lucy Dittrich and her colleagues are investigating how the greenhouse gas carbon dioxide (CO₂) can become a sustainable raw material with the help of new technologies.



RESEARCH INFRASTRUCTURES

Scientists at Forschungszentrum Jülich have access to extensive, highly specialized research infrastructures. Facilities such as the Helmholtz Nano Facility (HNF), the Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C) or the Jülich Centre for Neutron Science (JCNS) complement each other and, as world-class infrastructures, are also available to external researchers.

Methods and instruments are developed, set up and operated as user facilities in close cooperation with partners from science and industry.

ESFRI (European Strategy Forum on Research Infrastructures) identifies research infra-

structure measures that are important for Europe in terms of strategy and research policy. EBRAINS, the new digital research infrastructure of the Human Brain Project (HBP), has been included in the Roadmap 2021. Jülich also coordinates the ESFRI project EMPHASIS for plant phenotyping as well as the projects PRACE for the pan-European supercomputing infrastructure and IAGOS for research into the Earth's atmosphere, both of which have already been implemented. The Ernst Ruska-Centre 2.0 and the German contribution of the European Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS-D) were included in the National Roadmap in 2019.

RESEARCH INSTRUMENTS AND FACILITIES

HELMHOLTZ NANO FACILITY (HNF)

Unique throughout Europe, the Helmholtz Nano Facility (HNF) is a research infrastructure for researching, producing and charac-

terizing nanostructures and atomic structures for information technology. To this end, it provides scientists a source for tools and knowledge. Work at the HNF focuses on quantum computing, the components of which are based on the laws of quantum mechanics and use qubits for computing.

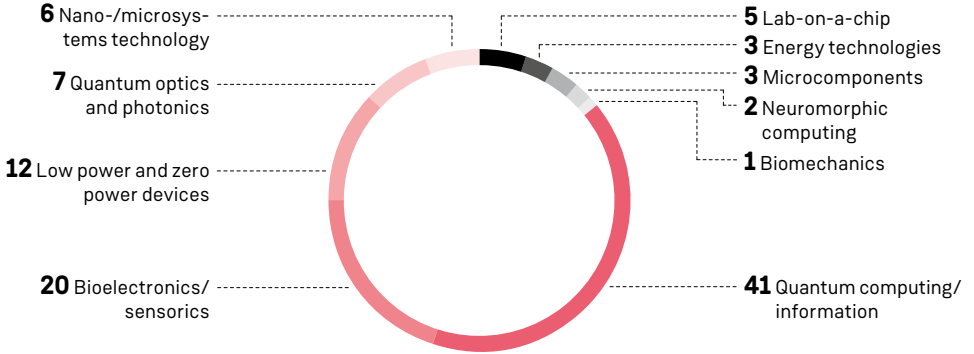
1,000

**square metres
clean room space DIN ISO 1-3
is provided by the HNF.**

As a state-of-the-art clean room facility with 1,000 m² clean room DIN ISO 1-3, the HNF offers resources in production, synthesis, characterization and the integration of structures, devices and circuits.

Usage according to research area¹⁾

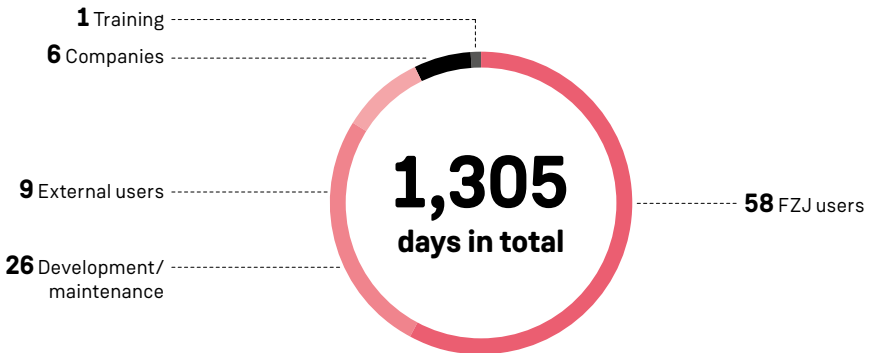
2020, in per cent



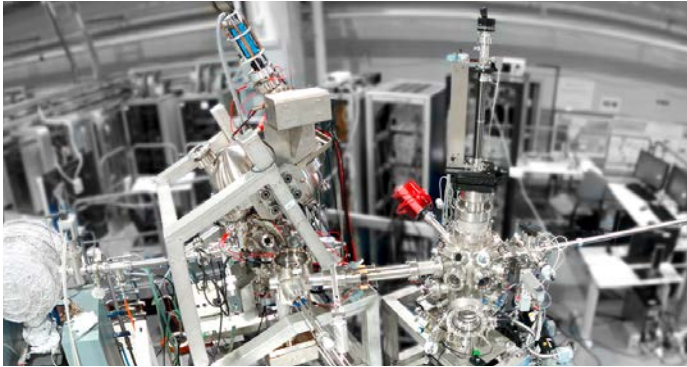
1) **Nano-/microsystems technology:** integration of mechanical, optical and electronic components into one system | **Quantum optics:** systems for the interaction between light and matter | **Photonics:** optical processes and technologies for the transmission, storage and processing of information | **Low power devices:** electronic components with low energy requirements for the processing or storage of information | **Bioelectronics:** the combination of biological and electronic systems | **Quantum computing:** circuits based on the laws of quantum mechanics | **Biomechanics:** influence of mechanics on cells | **Microcomponents:** production of nanotechnological and microtechnological components | **Energy technology:** energy generation systems | **Lab-on-a-chip:** microfluid system for analysis

Allocated usage time²⁾

2020, in per cent



2) The proportion of Jülich users was higher than usual in 2020, partly because access by external users was restricted due to corona regulations.



Experimental setup at the NanoESCA beamline at the Elettra synchrotron radiation source in Trieste (Italy)

JÜLICH SYNCHROTRON RADIATION LABORATORY (JSRL)

Research within the Jülich Synchrotron Radiation Laboratory (JSRL) ranges from basic research to materials science and the development of device technology. The JSRL offers photons in a wide energy range, from a few eV up to 10 keV. The JSRL thus complements the instruments operated by the JCNS at various neutron sources and the electron microscopes of the ER-C.

At the synchrotron sources DESY (Hamburg), ELETTRA-Synchrotron (Trieste, Italy) and BESSY (Berlin), the Peter Grünberg Institute

(PGI) operates state-of-the-art photoemission spectrometers and photoemission electron microscopes.

The JSRL facilities provide a platform for basic research in nanoelectronics, technological developments and innovative device concepts. In application-oriented research, ideas for technological innovations are realized, such as the quantum revolution in information technology. Research focuses on quantum materials (spintronics) and energy.

Users

2020

Instrumentation	Internal users	External users
DESY (Hamburg) ¹⁾	80%	20%
Elettra (Trieste, Italy) ²⁾	33%	67%
BESSY (Berlin)	100%	-

1) Award according to proposal principle, 2) award via application

EUROPEAN INFRASTRUCTURE FOR MULTI-SCALE PLANT PHENOMICS AND SIMULATION FOR FOOD SECURITY IN A CHANGING CLIMATE (EMPHASIS)

The European Infrastructure for Multi-Scale Plant Phenomics and Simulation for Food Security in a Changing Climate (EMPHASIS) is a plant phenotyping infrastructure distributed across Europe. Here, the external appearance of plants, the phenotype, is analyzed and measured; for example the architecture of roots or the number of leaves. The development of the European infrastructure is being coordinated at the Jülich Institute of Bio- and Geosciences as part of the EU-funded EMPHASIS-PREP project. EMPHASIS supports scientists in studying plants in different environments to enable more efficient crop production in a changing climate, to ensure future food security and to trigger a sustainable European agricultural economy. Information systems for data collection and a platform with mathematical models are linked by EMPHASIS at the European level. Knowledge and new technologies are shared and scientific education is supported. Thus, researchers from Europe are given access, for instance, to the facilities of the Jülich Plant Phenotyping Centre (JPPC).

EMPHASIS builds on the EU research infrastructure projects EPPN/EPPN2020 and will expand the portfolio of phenotyping infrastructures, integrate national infrastructures and ensure sustainable and long-term use of the infrastructures.

197

**Facilities throughout Europe
for plant phenotyping in the
EMPHASIS database**

24

**European countries are
members of the EMPHASIS
Support Group**

150

**Transnational research projects
in EPPN2020 with scientists
from 34 countries**

JÜLICH SUPERCOMPUTING CENTRE (JSC)

The Jülich Supercomputing Centre (JSC) provides scientists at Forschungszentrum Jülich, at universities and research institutions in Germany and Europe as well as in the industry with computing capacity of the highest performance class, supporting them in their research projects. It responds at short notice to new user requirements such as the use of cloud services or artificial intelligence (AI), interactive supercomputing or the development of concepts and services for long-term data curation.¹⁾

Since the introduction of the Top 500 list of the world's fastest supercomputers, the systems operated at the JSC have always been

1,500

Users

350

Projects

Users according to region

Computing time projects peer-reviewed by an independent panel of experts

Germany	1,200
Europe (without Germany)	220
Countries outside Europe	80

among the top 20. Currently, along with the JURECA system, the most powerful system in Europe is available in the form of JUWELS. It was supplemented by a GPU-based booster module in 2020, thus providing a computing power of 85 quadrillion computing operations per second (85 petaflops²⁾ (see p. 9, "Super fast, super economical – JUWELS").

Energy efficiency (flops per watt) plays an increasingly important role in the operation of high-performance and supercomputers. With the JUWELS booster, the most energy-efficient system among the 100 most powerful computers in the world is available at Jülich. It is used for a wide range of applications, from basic research to climate and materials research to life sciences and engineering sciences. In addition, more than 1,000 scientists used the HPC systems in smaller collab-

1) Activities required to maintain research data over the long term so that it remains available for reuse and retention.

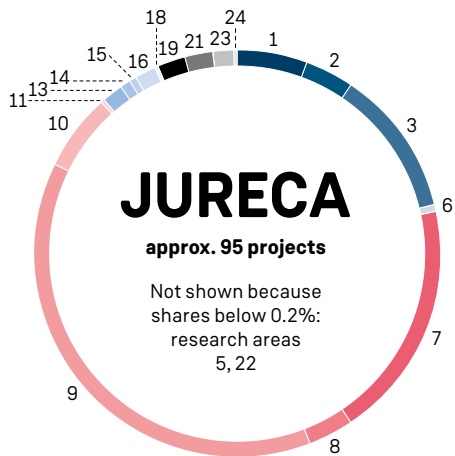
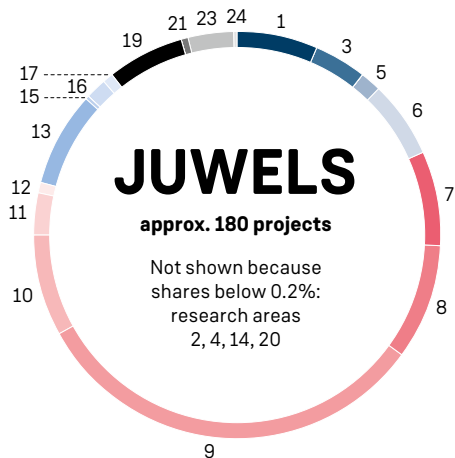
2) The computing power of computer systems is expressed in floating point operations per second (FLOPS). This value indicates how many floating point number operations (additions or multiplications) can be performed by a system in one second.

orative projects with the JSC without formal peer review in 2020. About 10 per cent of the users consume about 90 per cent of the re-

sources, since Jülich, as a national supercomputing centre, is primarily intended to support large-scale projects.

Usage according to research area

pro rata, as of November 2020



Research areas

- 1 Fundamentals of biology and medicine
- 2 Medicine
- 3 Neuroscience
- 4 Agricultural sciences (JUWELS only)
- 5 Chemical solid state and surface research
- 6 Physical and theoretical chemistry
- 7 Condensed matter physics
- 8 Optics, quantum optics and physics of atoms, molecules and plasmas
- 9 Particles, nuclei and fields
- 10 Statistical physics, soft matter, biological physics, nonlinear dynamics
- 11 Astrophysics and astronomy
- 12 Mathematics (JUWELS only)
- 13 Atmospheric, marine and climate research
- 14 Geophysics and geodesy
- 15 Mineralogy, petrology and geochemistry
- 16 Water research
- 17 Mechanics and constructive mechanical engineering (JUWELS only)
- 18 Process engineering, technical chemistry (JURECA only)
- 19 Fluid mechanics, technical thermodynamics and thermal energy technology
- 20 Materials technology (JUWELS only)
- 21 Materials data science
- 22 Electrical engineering and information technology (JURECA only)
- 23 Informatics
- 24 Construction and architecture



Small angle scattering instrument KWS-1 of Forschungszentrum Jülich at Heinz Maier-Leibnitz Zentrum in Garching (at the left)

JÜLICH CENTRE FOR NEUTRON SCIENCE (JCNS)

The Jülich Centre for Neutron Science (JCNS) operates neutron scattering instruments at top sources in Germany, Europe and globally, offering them to a large user community.

Experiment duration at Heinz Maier-Leibnitz Zentrum, Garching

2020, in days

1-3 days	54%
4-7 days	35%
8-15 days	11%

Neutrons serve as microscopic probes to conduct research in the fields of soft and condensed matter, biosciences and energy materials. Neutron research provides important contributions to meeting the major challenges that society is facing, for example with research into modern high-performance materials for energy storage or in environmental analysis.

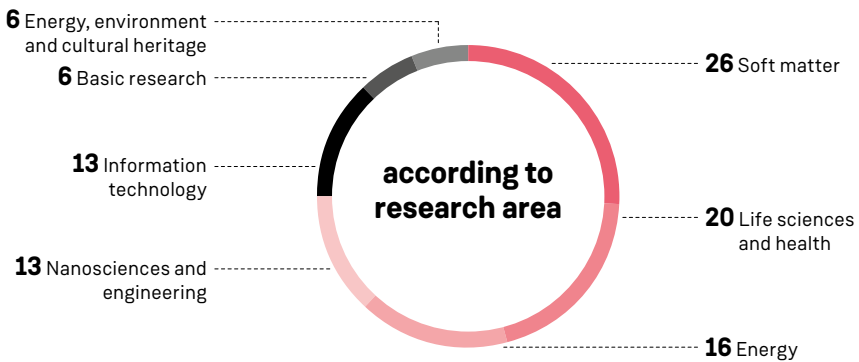
Together with its partners, the JCNS designs, builds and installs new instruments at neutron sources, such as for the European Spallation Neutron Source ESS in Lund, Sweden, or for a future high brilliance accelerator-based

neutron source (HBS). An important milestone was reached in 2020 with the publication of the “Conceptual Design Report”, which describes the construction and functioning of such a plant. 2020 also saw the launch of the

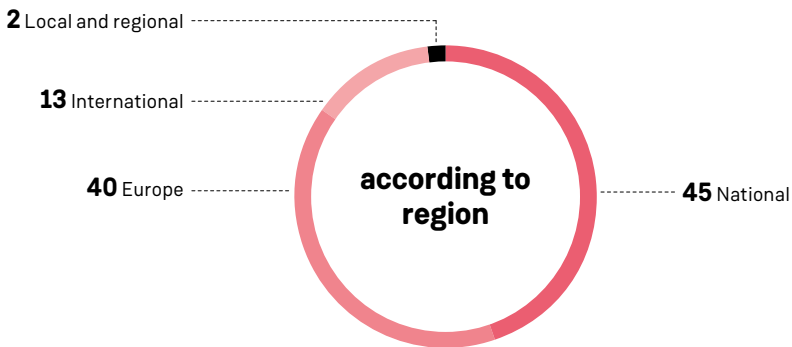
Helmholtz project “AI for Neutron and X-ray scattering”. The aim is to apply artificial intelligence methods and algorithms to experiments with neutrons and their evaluation.

Usage of the neutron source of Heinz Maier-Leibnitz Zentrum, Garching

2020, in per cent¹⁾



2020, in per cent²⁾



1) Due to the Covid-19 pandemic, the reactor at MLZ 2020 was only in operation from mid-January to mid-March 2020.
 2) Distribution of users present on site

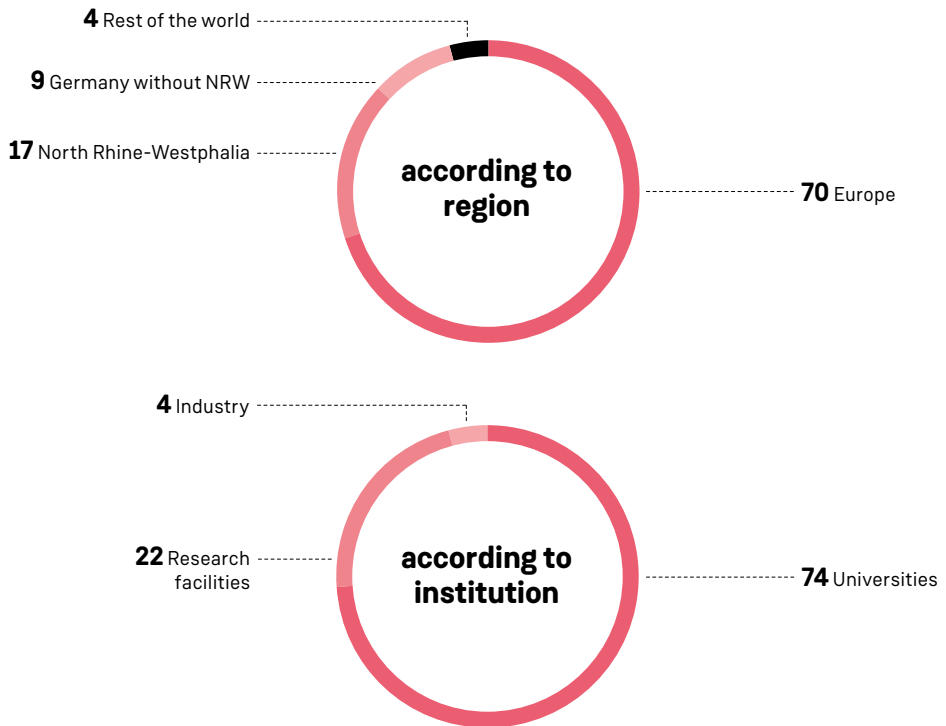
ERNST RUSKA-CENTRE (ER-C)

The Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C) is the national research infrastructure for ultra-high resolution electron microscopy. It is jointly operated by Forschungszentrum Jülich and RWTH Aachen University. The electron optical instruments provided and further devel-

oped by the ER-C can be used to investigate and describe structures at the atomic and molecular level. With PICO, the ER-C has one of only two electron microscopes in the world available for this purpose that, in addition to spherical aberration, can correct yet another lens error: chromatic aberration. The knowl-

External users

2020, in per cent



edge gained from PICO helps, among other things, to develop innovative materials.

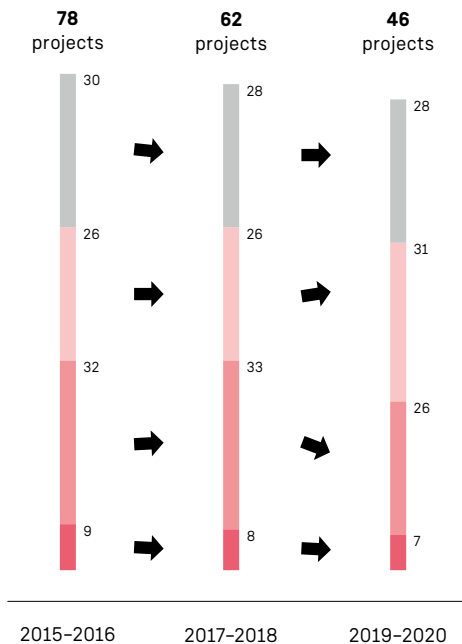
The ER-C thus creates incentives for companies dealing with novel materials and technologies to settle in the Rhineland region and contribute to the development of a competence region for innovative materials technologies and, ultimately, to the success of structural change.



The PICO electron microscope can measure atomic distances and displacements to within one picometre.

Usage according to research area

2020, in per cent



Energy research

- Catalytic nanoparticles
- Fuel cells and batteries
- Gas separation membranes
- Photovoltaic materials
- Thermoelectric materials

Fundamental solid state research

- Complex and novel materials
- Heterogeneous interfaces
- Lattice defects

Information technology

- Ferroelectric materials
- Magnetic nanoparticles
- Semiconductor nanostructures

Principles of electron optics

- Novel measurement techniques and analytical methods

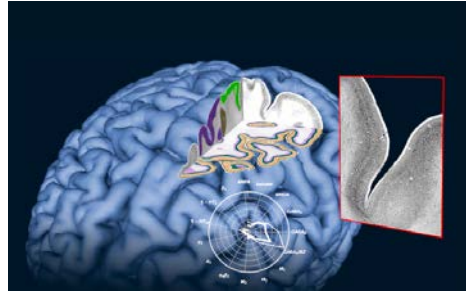
EBRAINS

EBRAINS is a new digital research infrastructure created as part of the EU-funded Human Brain Project (HBP). The aim is to promote brain research and the translation of scientific findings in this field into brain-inspired innovations in computing, medicine and industry. To this end, multidisciplinary neuroscience works closely with the developers of state-of-the-art information technologies and uses powerful computers to assemble the ever-growing knowledge about the brain from different research fields. With EBRAINS, the HBP is establishing the hub for this cooperation in Europe.

EBRAINS in numbers

as of February 2021

- More than **500** scientists at over **130** European partner institutions from **19** countries are involved in the development of EBRAINS.
- EBRAINS contains more than **1,000** data sets, **90** models and **150** analysis programmes from **1,110** scientists.
- EBRAINS “Medical Informatics Platform” is installed in **30** European hospitals. It offers data protection compliant access to **20,000** data sets of patients with e.g. dementia, epilepsy or traumatic injuries.
- **412** institutions in Europe and around the world use EBRAINS.



The digital brain atlas links the knowledge of brain research, such as information on the localization of brain areas, receptor densities and cell distributions.

Being the first research infrastructure of its kind in the world, EBRAINS provides a web portal that offers access to the most comprehensive database on the human brain to date as well as to powerful digital tools, for example for simulation or AI-based analytical methods. The “EBRAINS Computing Services” coordinated by the Jülich Supercomputing Centre form the computationally powerful basis of EBRAINS and make it possible to integrate platforms and solutions from the various EBRAINS services into complex workflows. The offer also includes the extremely high-resolution 3D atlas of the human brain created by the Jülich Institute of Neuroscience and Medicine (see p. 11, “‘Google Earth’ of the Brain”), supercomputing methods specially developed for neuroscientists and “neuromorphic” computers inspired by the brain.

OTHER RESEARCH INSTRUMENTS AND FACILITIES

ESS Competence Centre

Coordinates the Jülich contributions to the European Spallation Source ESS (the world's most powerful neutron source)

Imaging Core Facility (ICF)

Pools the imaging methods of neurosciences and medicine

Jülich Centre for Structural Biology (JuStruct)

Combines infrastructure and expertise on atomic-resolution structural biology methods

Cooler Synchrotron COSY

Particle accelerator and storage ring (for generating proton and deuteron beams)

SAPHIR and SAPHIR-PLUS

For researching processes in the atmosphere

Biomolecular NMR Center

With ultra high-field spectroscopy for structural biology

Membrane Centre

For developing membrane systems for new energy-efficient technologies

Helmholtz Energy Materials

Characterization Platform (HEMCP)

For materials research in energy technologies

ENVRI-FAIR

Makes data from all European Earth system research freely accessible worldwide via the European Open Science Cloud (EOSC)

Helmholtz Quantum Center (HQC)

Technology laboratory on the research spectrum of quantum computing, from quantum materials to quantum computer systems (see p. 83, "A Centre for Quantum Research")



The Jülich atmospheric chamber SAPHIR

No plant can thrive if phosphorus is missing. In the InnoSoilPhos project, Nina Siebers tests the forms in which phosphorus could reach the plants, for example in the form of fertilizer made from charred animal bones. The former Helmholtz young researcher works at the Institute of Bio- and Geosciences.





PEOPLE

Page
50 – 69

We want to get young people excited about science and support them in the best possible way. They are the explorers, idea generators and designers of tomorrow's society. Our aim is to attract the best minds in international competition. Open, responsible, with vision – our campus is a good place for inspiring exchange between people from all over the world. Diversity enables progress and creativity and opens up new perspectives.

PEOPLE AT JÜLICH AT A GLANCE

6,796

Employees



2,669

Scientists
(education included)

1,565

Technical staff

1,380

Project management organizations

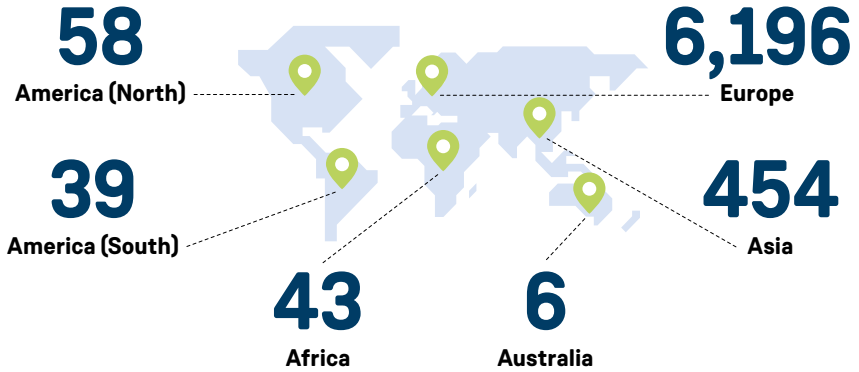
315

Trainees, placement students

867

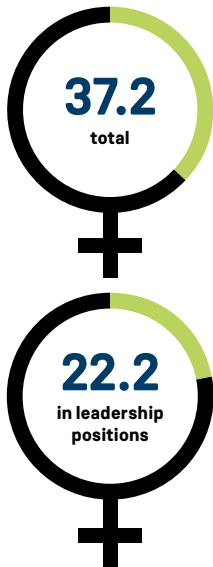
Administration

STAFF ACCORDING TO NATIONALITY



PROPORTION OF WOMEN

in per cent, FTE (full-time equivalent)



1,022
school students visited the
Schools Laboratory in 2020 until
the lockdown in mid-March.



850
Doctoral researchers
with employment contract
and salary



312
Postdocs

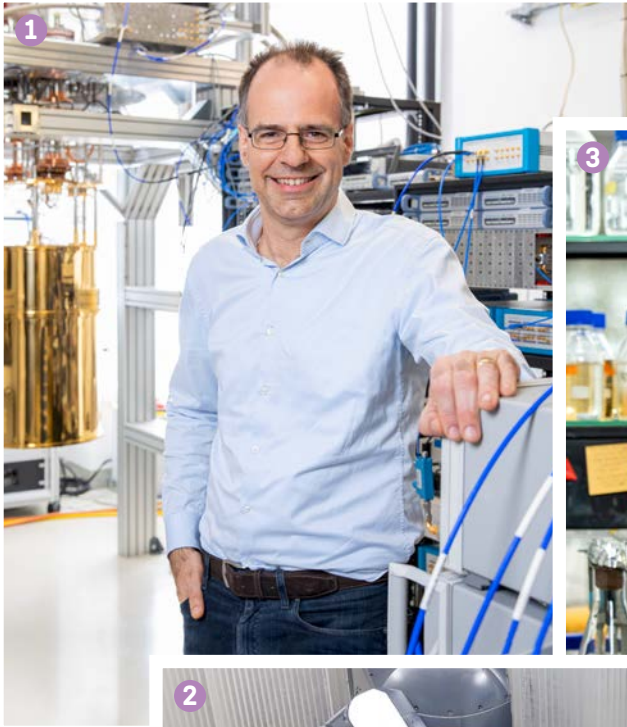
95
Apprenticeship
positions
(new hires)



in up to **23**
different professions

Stand 31.12.2020

WE LOVE RESEARCH



5



6



4



We are shaping change

- 1 Prof. Frank Wilhelm-Mauch, Peter Grünberg Institute: building the first freely programmable European quantum computer
- 2 Dr. Yannick Beßler, Central Institute of Engineering, Electronics and Analytics: high-precision milling machine for complex components
- 3 Prof. Julia Frunzke, Institute of Bio- and Geosciences: biotechnological production of active medical ingredients
- 4 Dr. Annika Wiese-Klinkenberg, Institute of Bio- and Geosciences: raw material extraction in plant research
- 5 Dr. Thomas Pütz, Institute of Bio- and Geosciences: using lysimeters to study the effects of climate change in the soil
- 6 Dr. Scarlet Stadler, Jülich Supercomputing Centre: decision trees as a technique for machine learning

JUELICH_HORIZONS: PROMOTING YOUNG TALENT

We want to get young people excited about science. They are the discoverers, idea generators and innovation drivers of the society of tomorrow – a society that is already changing today and one for which we are conducting research. Our goal is to promote excellence at all education, training and career levels and to

attract the best minds in international competition. From events of the Schools Laboratory to future-oriented apprenticeships and dual study programmes to career support for young executives, we offer a wide range of opportunities for young talent under the “Juelich_Horizons” umbrella.

SPARKING INTEREST IN CHILDREN AND YOUNG PEOPLE

In 2020, the JuLab Schools Laboratory reacted flexibly to the coronavirus situation with newly designed online offers. These included:

- **Mission Gehirn DIGITAL** The “DIGITAL Brain Mission” module was aimed at giving school

students an impression of the complexity of the human brain and providing them insight into methods and the current state and relevance of brain research. The participants were actively involved through a lab video plus live chat with researchers and with interactive elements from the field of neuropsychology.

- **Helmholtz-Schülerkongress DIGITAL** The interactive online event series “DIGITAL Helmholtz Student Congress”, focusing on the bioeconomy, sustainability and structural change, was offered on three dates for senior school students. It ranged from bioeconomy research and sustainability in everyday life to design options in structural change. Training and study opportunities in this field were also presented.



The JuLab is oriented towards the goals of the global sustainability agenda.

Against the background of the developments in the Rhineland region, the JuLab offers will be linked even more closely to the topics of structural change and education for sustainable development (BNE) with projects such as:

Diana Reinecke-Levi, an algae researcher from Jülich, explains to the school students how they can build a wastewater purification system with algae using simple materials from the construction store.



- **JuPilot** Through the JuPilot sub-project, JuLab is part of the Jülich living lab project “Living Lab Energy Campus” (LLEC). In 2020, for example, a wind turbine was erected next to the JuLab building. The turbine is to make it possible to experience how wind energy can be integrated into a modern energy system.
- **Projektkurs Bioökonomie** Since September 2020, students from three schools in the region have been working on their own one-year bioeconomy research projects in the “Bioeconomy Project Course”. They are supported by the JuLab and the Institute of Bio- and Geosciences. The aim is to sensitize young people to issues that the structural change in the region involves.

VOCATIONAL ORIENTATION AND INTERNSHIPS

Forschungszentrum Jülich offers a wide range of opportunities for career orientation. In 2020, 55 school students were accepted for their compulsory school internships, while 77 students were supervised in the context of

compulsory internships and voluntary study-related internships. Due to the Covid-19 pandemic, there were significantly fewer internships than are usually offered by Forschungszentrum Jülich.



Lars Osiewacz was named the nation's best mathematical-technical software developer (MATSE).

VOCATIONAL TRAINING AND DUAL STUDY PROGRAMMES

As the largest training company in the region, Forschungszentrum Jülich assumes special social responsibility in vocational training. It offers up to 115 apprenticeships in 23 different professions every year. More than 5,000 young people have received qualified vocational training here. Many of them are still employed at Forschungszentrum Jülich today.

In 2020, 85 apprentices completed their training. 61 of them (72 per cent) passed the exam with the top grades, “very good” or “good”. Several of the trainees at Forschungszentrum Jülich enjoyed a particular success when they were awarded the first and third Helmholtz Apprenticeship Award in autumn 2020.

About one third of the trainees combine practical vocational training at Forschungszentrum Jülich with one of eight dual courses of study leading to a bachelor's degree. One of them is Lars Osiewacz, who finished his stud-

ies and apprenticeship in 2020 as the nation's best mathematical-technical software developer (MATSE).

Vocational training positions

New trainees 2020

Occupations	Total	including a dual study programme
Laboratory technicians	26	5
Electricians	13	-
Metal workers	11	-
Office staff	11	-
Mathematical-technical software developers	27	27
Other	7	-
Total	95	32

STUDIES AND DOCTORATE

Every year, students from all over the world come to Jülich to gain experience in a research-intensive environment early on. The mobility of young researchers fosters their personal and scientific development, propels the transfer of ideas and intensifies the international collaborations of Forschungszentrum Jülich.

In March 2020, the BMBF extended the funding for the Palestinian-German Science Bridge (PGSB) until 2024. In 2020, three master's students, 28 doctoral researchers and one postdoc were in Jülich as part of the PGSB.

Within the context of the “Georgian-German Science Bridge” (GGSB), two master's scholarships were awarded to students from Georgia. In November 2020, 30 Georgian students took part in a virtual event organized by Forschungszentrum Jülich on “Health as a Global Challenge: Contributions by GGSB and its SMART|Labs”.

The “China Scholarship Council” (CSC) scholarship programme funded 17 doctoral researchers.

JUDOCs – JÜLICH CENTER FOR DOCTORAL RESEARCHERS AND SUPERVISORS

Centre-wide, structured doctoral support complements the subject-specific offers in the institutes, research training groups and graduate schools, such as HITEC (Helmholtz Interdisciplinary Doctoral Training in Energy and Climate Research) or HDS-LEE (Helmholtz School for Data Science in Life, Earth and Energy). At the “Just Landed” event, for example, international doctoral researchers learn more about the German science system. All Jülich doctoral researchers go through an interdisciplinary “Transferable Skills” programme. The pandemic-related switch to online formats proved beneficial in that these also reached doctoral researchers at other locations. In addition, a counselling service was



Vera D. Jäger, Juri Romazanov and Yulia Arinicheva (from left) were awarded the Excellence Prize of Forschungszentrum Jülich in 2020 for their outstanding dissertations and achievements in the postdoctoral phase.

1,137

**doctoral researchers worked
at Forschungszentrum Jülich in 2020,
of which around**

35

per cent were women and

44

per cent came from abroad.

established in 2020 for doctoral researchers and supervisors in conflict situations arising from doctorates.

In the course of 2020, 1,137¹⁾ supervised doctoral researchers worked at Forschungszentrum Jülich. Around 35 per cent of them were women and around 44 per cent came from abroad. They were supervised by the institutes, the doctoral supervisors and the academic supervisors at Jülich, adding up to around 460 people. As of 31 December 2020, there were 312 postdocs at Jülich, including 94 women. Some 45 per cent of all postdocs came from abroad.

1) This figure also includes doctoral researchers who do not have a contract with Forschungszentrum Jülich, but are financed through scholarships, for example.

PROMOTING YOUNG RESEARCHERS

In 2020, Forschungszentrum Jülich's Career Centre offered all counselling and events for doctoral researchers and postdocs as online formats. A total of 27 seminars and workshops were held on career paths in science, science management, industry and start-ups/spin-offs. Networking with other young researchers was also actively promoted. More than 700 participants showed how considerable the interest in this service is. In addition, there were 86 individual consultations. The Helmholtz Association has positively reviewed the Career Center 2020 in an extensive process.

YOUNG INVESTIGATORS GROUPS

Forschungszentrum Jülich offers excellent postdocs superb starting conditions for a scientific leadership career with the opportunity to set up their own young investigators group. In 2020, three new groups were established at Forschungszentrum Jülich, which meant a total of 19 young investigators groups. Seven of the group heads held a junior professorship, two a W2 professorship and one a W3 professorship; four were funded by the EU through an ERC Starting Grant.

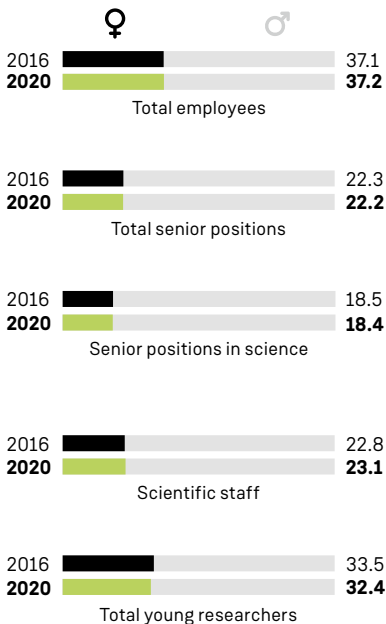
STAFF

Forschungszentrum Jülich offers a wide range of career opportunities in science, technical or administrative infrastructures and in research management. Our staff are committed to ensuring that our research meets the highest scientific standards and contributes to solving social problems. Their motivation, creativity and potential is the driving force behind the shaping of research

for a changing society. Collegiality and diversity are the basis for us, as a multidisciplinary research centre with an international workforce, to make the most of our opportunities. In addition to excellent research infrastructures, we offer support in balancing work and family life. We want to make real equality of opportunity possible.

Proportion of women in Forschungszentrum Jülich's workforce

in per cent, FTE (full-time equivalent)



Staff overview

as of: 31.12.2020

Area	Number ¹⁾
Scientists and technical staff	4,234
of which scientists incl. individuals in scientific training	2,669
· of which doctoral researchers	850
· of which scholarship holders	25
· of which student assistants	169
· of which joint appointments with universities ²⁾	157
· of which W3 professors	69
· of which W2 professors	79
· of which W1 professors	9
of which technical staff	1,565
Project management organizations	1,380
Administration	867
Trainees and placement students	315
Total	6,796

1) Only employees with a contract paid by Jülich are included.

2) Without members of the Board of Directors

APPOINTMENTS AND PROFESSORIAL APPOINTMENTS

APPOINTMENTS

Jülich scientists accepted the following chairs offered in 2020¹⁾:



1) Not including appointments to universities that resulted in a joint appointment with Forschungszentrum Jülich

JOINT PROFESSORIAL APPOINTMENTS WITH UNIVERSITIES

In the case of a joint appointment, the appointed person holds the office of a professor at a university and, at the same time, works at Forschungszentrum Jülich GmbH. In 2020,

the following scientists were jointly appointed to professorships by Forschungszentrum Jülich and other universities:

New appointments in 2020

Name	Institute	University
Prof. Ira Assent	Institute for Advanced Simulation	Aarhus University
Prof. Andreas Josef Forstner	Institute of Neuroscience and Medicine	University of Bonn
Prof. Eva Kröner	Institute of Bio- and Geosciences	University of Bonn
Prof. Samir Lounis	Institute for Advanced Simulation	University of Duisburg-Essen
Prof. Anna Mechler	Institute of Energy and Climate Research	RWTH Aachen University
Prof. Matteo Rizzi	Peter Grünberg Institute	University of Cologne
Prof. Giulia Rossetti	Institute for Advanced Simulation	RWTH Aachen University
Prof. Stefan Sandfeld	Institute for Advanced Simulation	RWTH Aachen University
Prof. Armin Lothar Seyfried	Institute for Advanced Simulation	University of Wuppertal
Prof. Frank Wilhelm-Mauch	Peter Grünberg Institute	Saarland University



Prof. Valentin Gordeliy studies biologically and medically relevant proteins at the Institute of Biological Information Processing.

HELMHOLTZ PROFESSORSHIP FOR PROF. VALENTIN GORDELIY

Structural biologist Prof. Valentin Gordeliy was awarded a Helmholtz Professorship at Forschungszentrum Jülich in autumn 2020. At the Institute of Biological Information Processing, he investigates the structures of biologically and medically relevant proteins as well as their dynamics and interactions with other molecules. For example, his “Molecular Biophysics” research group has been decoding the 3D structure of viral proteins of the coronavirus.

The researchers are testing how these proteins can be inhibited in order to slow down the multiplication of the virus.

A Helmholtz Professorship is a special distinction for scientists from Helmholtz Research Centres. It is awarded to them for their exceptional record and high productivity in their overall academic career. Helmholtz Professorships are usually limited to three years.

Number of joint professorial appointments with universities

as of: 31.12.2020

University	Number of professorial appointments ¹⁾	of which new appointments 2020
RWTH Aachen University	67	3
FH Aachen University	5	-
Ruhr Universität Bochum	5	-
University of Bonn	13	2
HHU Düsseldorf	22	-
University of Duisburg-Essen	6	1
FAU Erlangen-Nürnberg	5	-
University of Cologne	17	1
KU Leuven	1	-
UCL Louvain	1	-
JGU Mainz	1	-
University of Münster	1	-
Goethe University, Frankfurt	1	-
Universität Regensburg	1	-
Saarland University	1	1
University of Stuttgart	2	-
Aarhus University	1	1
University of Wuppertal	7	1
Total	157	10

1) Without members of the Board of Directors

ACCOLADES

International

Name	Award
Prof. Ludger Blum Institute of Energy and Climate Research	Christian Friedrich Schönbein Gold Medal of Honour of the 14th European SOFC & SOE Forum
Dr. Renato Duarte Institute of Neuroscience and Medicine	“Umbrella Award” of RWTH Aachen University, the Technion – Israel Institute of Technology and Forschungszentrum Jülich
Dr. Merle Hönig Institute of Neuroscience and Medicine	“Image of the Year Award” of the Society for Nuclear Medicine and Molecular Imaging (SNMMI) and Brain Imaging Council Young Investigator Award 2020 at the international conference of the Society for Nuclear Medicine and Molecular Imaging (SNMMI)
Prof. Wolfgang Marquardt Chairman of the Board of Directors	Admission to the National Academy of Engineering (NAE) of the USA
Dr. Gabriel Murphy Institute of Energy and Climate Research	2020 Australian Institute of Nuclear Science and Engineering (AINSE) Gold Medal
Dr. Retha Peach Institute of Energy and Climate Research	Georg Forster Research Fellowship of the Alexander von Humboldt Foundation
Prof. Ulrich Schurr Institute of Bio- and Geosciences	Member of the International Advisory Council for Global Bioeconomy
Prof. Birgit Strodel Institute of Biological Information Processing	“JCP Editor’s Choice Award 2020” of the Journal of Chemical Physics
Prof. Knut Urban formerly Institute for Microstructure Research/Ernst Ruska-Centre	Nanoscience Kavli Prize
Prof. Martin Winter Institute of Energy and Climate Research Helmholtz Institute Münster	Alessandro Volta Medal of the Electrochemical Society (ECS) and Unity Ambassador of the State of North Rhine-Westphalia

National

Name	Award
Dr. Sabrina Disch former Jülich Centre for Neutron Science	Wolfram Prandl Prize 2020 for young scientists
Laura Helleckes Institute of Bio- and Geosciences	Prize of the DECHEMA Biotechnology Future Forum Friedrich Wilhelm Prize of the Friedrich Wilhelm Foundation
Dr. Anne Klosterhalfen Institute of Bio- and Geosciences	Geoverbund ABC/J Young Academics Award, first prize
Prof. Susanne Pfalzner Jülich Supercomputing Centre/Institute of Energy and Climate Research	Albertus Magnus Teaching Award of the University of Cologne, Department of Physics
Dr. Vanessa Reindl Institute of Neuroscience and Medicine	August Humburger Award 2020
Prof. Michael Saliba Institute of Energy and Climate Research and Institute for Photovoltaics at the University of Stuttgart	Heinz Maier-Leibnitz Prize of the German Research Foundation
Dr. Steffen Schemme Institute of Energy and Climate Research	Energy Research Prize 2020 of the Ministry of Economic Affairs, Innovation, Digitalization and Energy (MWIDE) of the State of North Rhine-Westphalia for the topic of hydrogen
Prof. Dieter Willbold and his team at the Institute of Biological Information Processing	Innovation Prize of the BioRegions in Germany

Helmholtz Association awards

Name	Award
Dr. Yulia Arinicheva Institute of Energy and Climate Research	Excellence Prize of Forschungszentrum Jülich
Dr. Vera D. Jäger Institute for Molecular Enzyme Technology, Heinrich Heine University Düsseldorf	Excellence Prize of Forschungszentrum Jülich
Dr. Juri Romazanov Institute of Energy and Climate Research	Excellence Prize of Forschungszentrum Jülich

PUBLICATIONS

RESEARCH DATA, TRANSPARENT AND ACCESSIBLE

The National Research Data Infrastructure (NFDI) is intended to systematically develop, sustainably secure and make accessible the databases of science and research and to network them nationally and internationally. Previously, research data has often been stored in such a way that it cannot be reviewed or re-used by other researchers, or at least not without difficulty. This impedes scientific work. The NFDI wants to change that: it is intended to be a repository of knowledge for the entire research landscape. The NFDI is funded by the Federal Ministry of Education and Research. The DFG organizes the selection of consortia and the review process.

In June 2020, funding was approved for **NFDI-4Ing**, a consortium for the establishment and expansion of a research data infrastructure

Dr. Bernhard Mittermaier, head of Forschungszentrum Jülich's Central Library, is committed to making research results accessible in "Open Access" publications.



for engineering. Eight universities and three research institutions are involved. NFDI4Ing is one of nine initiatives that were successful in this first-time competition. At Forschungszentrum Jülich, teams from the Central Library and the Institute of Energy and Climate Research will be involved.

Jülich publications

in the past five years

Year	Total	In peer-reviewed journals	of which with other institutions	Books, other publications	Doctoral theses, habilitations
2016	2,202	1,580	1,290 81.6%	521	101
2017	2,442	1,861	1,499 80.5%	460	121
2018	2,319	1,714	1,351 78.8%	458	147
2019	2,398	1,891	1,443 76.3%	400	107
2020	2,473	1,827	1,391 76.1%	533	113



The Bioinformatics section of the Institute of Bio- and Geosciences is involved in the NFDI consortium **DataPLANT**, which started in October 2020. DataPLANT will provide a sustainable, user-oriented infrastructure for

complex plant research data. Data is collected, checked, adjusted and made visible in an understandable way via integrated methods. The consortium is coordinated by the University of Freiburg and led by the Universities of

The ten journals with the most publications from Jülich researchers in 2020

Journal	Number of publications
Physical Review B	41
Scientific Reports	33
Nature Communications	28
Physical Review Letters	23
Atmospheric Chemistry and Physics	19
Journal of the Electrochemical Society	19
Physical Review Research	19
Journal of Power Sources	15
Advanced Engineering Materials	14
NeuroImage	14

Tübingen and Kaiserslautern as well as Forschungszentrum Jülich.

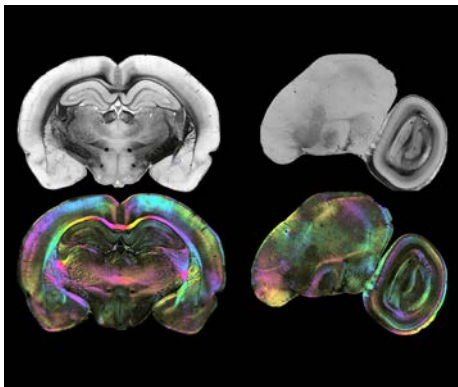
In the second round of calls for proposals in 2021, Forschungszentrum Jülich is involved in three further consortia. **DAPHNE4NFDI** is an initiative of the more than 5,500 neutron and photon users in Germany. The Jülich Centre for Neutron Science (JCNS) is involved in it. **PUNCH4NFDI** will develop a new joint science platform for particle physics, astroparticle physics, astrophysics and hadron and nuclear

physics. The Jülich Supercomputing Centre (JSC) will provide significant support for access to the science portal in various research fields. **NFDI-MatWerk** will develop a research data infrastructure that will make material data from experiments and simulations in materials science and materials engineering usable. The Institute of Energy and Climate Research and the Institute for Advanced Simulation are involved.

GROUNDBREAKING PUBLICATION

A publication by researchers from Bochum (RUB), Düsseldorf (HHU), Jülich (FZJ) and Aachen (RWTH) in the journal “Science” was ranked among the “TOP 10 Breakthroughs in 2020” by the journal. Prof. Katrin Amunts and Prof. Markus Axer from the Jülich Institute of Neuroscience and Medicine were involved.

The results showed, for the first time, striking similarities in how the brains of birds and mammals are organized: the neocortex of mammals and sensory brain areas of birds are both wired in horizontal layers and vertical columns. 150-year-old assumptions have thus been disproved. Decisive insights were provided by a method developed by Jülich and Düsseldorf scientists called 3D Polarized Light Imaging. It is capable of mapping the course and orientation of nerve fibres carrying signals for the entire brain.



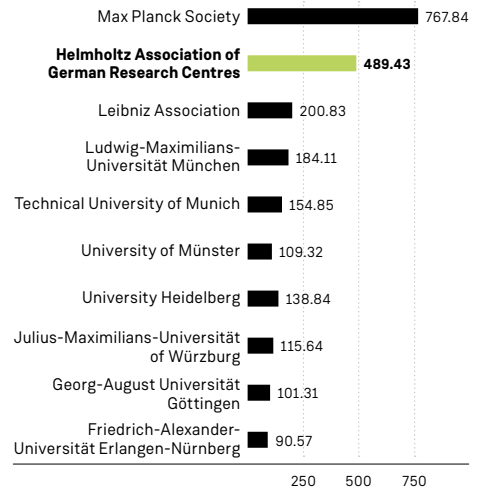
Nerve fibres in the brains of a rat (left) and a pigeon (right), visualized using 3D Polarized Light Imaging (3D-PLI)

JÜLICH IN THE TOP GROUP OF THE NATURE INDEX

Every year, the renowned journal “Nature” ranks the leading international research institutions in its “Nature Index”. It is based on the number of an institution’s publications in 82 scientific journals selected by an independent panel. In the “Nature Index 2021”, the Helmholtz Association, of which Forschungszentrum Jülich is a member, is runner-up to Max Planck Society among the German institutions and 6th in the international ranking. Among all 18 Helmholtz Centres, Jülich ranks 3rd with 363 publications. Forschungszentrum Jülich has thus maintained its position as a top-class location in the national research landscape.

The top 10 in Germany

Institutions with Share¹⁾ according to “Nature Index”



1) Proportion of authorship in each article

JÜLICH RESEARCHERS MUCH CITED

Among the most frequently cited researchers in the world are six Jülich scientists: Prof. Simon Eickhoff from the Institute of Neuroscience and Medicine, PD Dr. Martin Schultz from the Jülich Supercomputing Centre, Prof. Björn Usadel from the Institute of Bioinformatics,

6

Jülich researchers are among the “Highly Cited Researchers”.

Dr. Hendrik Poorter from the Institute of Plant Sciences, Prof. Michael Saliba from the Institute of Photovoltaics and Prof. Christoph Bräbe from the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy. They were listed as “Highly Cited Researchers” by the Web of Science Group, which is part of Clarivate Analytics. This means that their publications are among the one per cent of the most cited papers in their field in the year of publication. Only those scientists who are involved in several of these particularly influential publications will be accepted as one of the “Highly Cited Researchers”.

Qubits store information in quantum computers. Sometimes, however, they spontaneously change their state or are lost altogether. Together with colleagues from RWTH Aachen University and the Universities of Innsbruck and Bologna, Prof. Markus Müller from the Peter Grünberg Institute has developed a correction method that detects faulty qubits and saves the information stored in them – an essential protective function for large, robust quantum computers of the future.

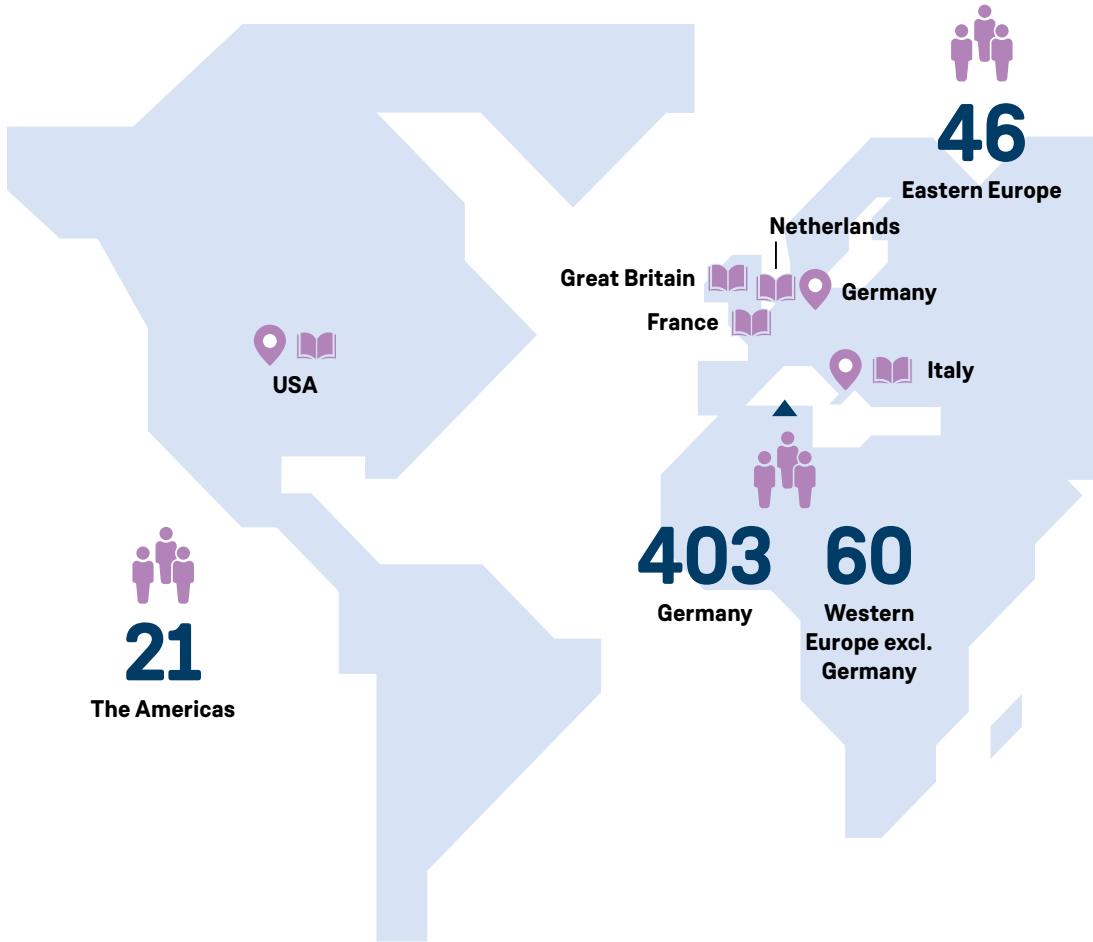


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Page
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In wanting our research to have an impact, we place a lot of emphasis on close cooperation with industry partners. We break new ground in the form of strategic partnerships with universities and maintain close collaborations with leading research institutions around the world. We are a member of numerous strategic partnerships and European research infrastructures.

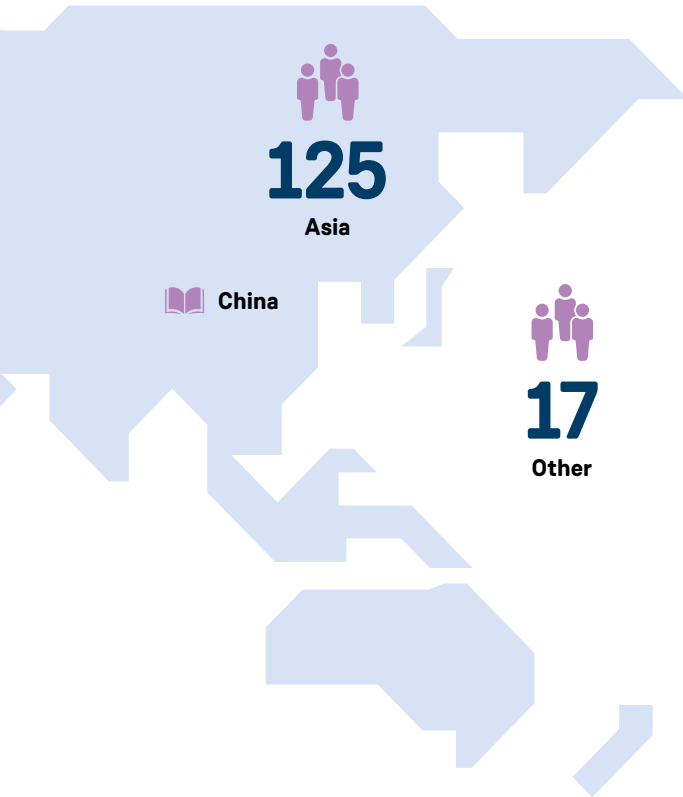
NETWORKS AT A GLANCE



Countries in which
Forschungszentrum Jülich
operates branch offices



Countries with which
Forschungszentrum Jülich
publishes most frequently



Visiting scientists
(absolute number)

NATIONAL RESEARCH PROJECTS



465

Project participations

36

Research associations
(coordinated by
Forschungszentrum Jülich)

EU PROJECTS



162

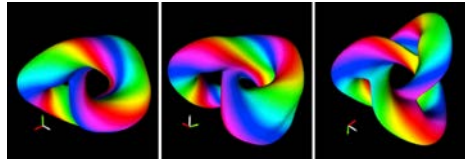
Project participations

32

Projects coordinated
(coordinated by
Forschungszentrum Jülich)

COOPERATIONS

Forschungszentrum Jülich works closely with numerous partners in Germany and abroad. In 2020, it was involved in 465 nationally funded research projects, 51 of which had a contract volume of €2 million or more. 102 projects were carried out together with several partners, and 36 research associations were coordinated by Jülich.



In the EU project "3D Magic" coordinated by Jülich, researchers are investigating nanoscale magnetic structures in 3D, so-called hopfions.

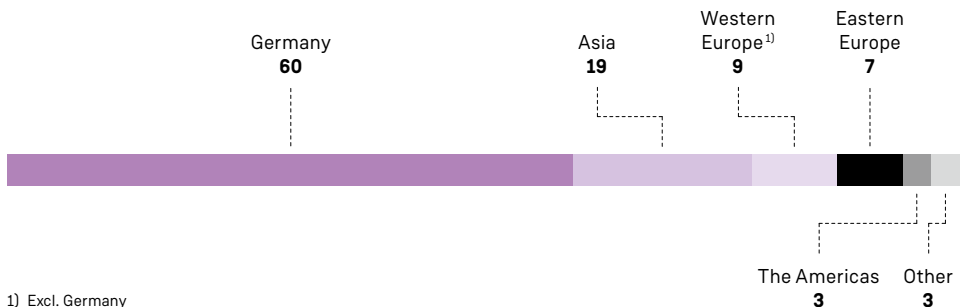
At the EU level in 2020, Forschungszentrum Jülich was involved in 162 projects from the current Horizon 2020 Framework Programme for Research and Innovation, including 40 for which the Jülich contract volume exceeded €1 million each. 21 of these projects were coordinated by Forschungszentrum Jülich, which coordinated a total of 32 EU projects.

40

EU projects with a Jülich contract volume exceeding €1 million

Visiting scientists in 2020

2020: a total of 672 from 62 countries
(broken down by percentage, rounded)



1) Excl. Germany

EU-funded projects involving Forschungszentrum Jülich in 2020

Funding grant exceeding €1 million

Acronym	Project title	Jülich contract volume (in euros)
EUROfusion	European Consortium for the Development of Fusion Energy	23,167,296
HBP SGA3	Human Brain Project Specific Grant Agreement 3	18,439,806
C PPI4HPC	Public Procurement of Innovative Solutions for High-Performance Computing	8,451,195
HBP SGA2	Human Brain Project Specific Grant Agreement 2	7,101,976
C 3D MAGiC	Three-Dimensional Magnetization Textures: Discovery and Control on the Nanoscale	6,841,603
ICEI	Interactive Computing E-Infrastructure for the Human Brain Project	5,203,968
VirtualBrain Cloud	Personalized Recommendations for Neurodegenerative Disease	3,736,729
C ERA CoBioTech	Cofund on Biotechnologies	3,621,683
C DEEP-EST	DEEP – Extreme Scale Technologies	3,183,961
ACT	Accelerating CCS Technologies as a New Low-Carbon Energy Vector	3,015,036
C EUSMI	European Infrastructure for Spectroscopy, Scattering and Imaging of Soft Matter	2,758,397
C IntelliAQ	Artificial Intelligence for Air Quality	2,498,761
C PRACE-6IP	PRACE 6th Implementation Phase Project	2,076,741
Solar Cofund 2	SOLAR-ERA.NET Cofund 2	2,016,413
C Dynasore	Dynamical Magnetic Excitations with Spin-Orbit Interaction in Realistic Nanostructures	1,994,879
C ENVRI-FAIR	ENVIRONMENTAL RESEARCH INFRASTRUCTURES BUILDING FAIR SERVICES ACCESSIBLE FOR SOCIETY, INNOVATION AND RESEARCH	1,914,475
C SARLEP	Simulation and Understanding of the Atmospheric Radical Budget for Regions with Large Emissions from Plants	1,850,000
C ProPlantStress	Proteolytic Processing in Plant Stress Signal Transduction and Responses to Abiotic Stress and Pathogen Attack	1,804,663
CSP ERANET	Joint Programming Actions to Foster Innovative CSP Solutions	1,783,693
EoCoE-II	Energy Oriented Center of Excellence: Toward Exascale for Energy	1,674,700

NETWORK

Acronym	Project title	Jülich contract volume (in euros)
C EMPHASIS-PREP	European Infrastructure for Multi-scale Plant Phenomics and Simulation for Food Security in a Changing Climate	1,647,738
C LightCas	Light-Controlled Synthetic Enzyme Cascades	1,498,125
C QNets	Open Quantum Neural Networks: from Fundamental Concepts to Implementations with Atoms and Photons	1,486,439
C PRO_PHAGE	Impact and Interaction of Prophage Elements in Bacterial Host Strains of Biotechnological Relevance	1,482,672
C CUSTOM-SENSE	Custom-Made Biosensors – Accelerating the Transition to a Bio-Based Economy	1,482,220
C CM3	Controlled Mechanical Manipulation of Molecules	1,465,944
GEOTHERMICA	GEOTHERMICA – ERA NET Cofund Geothermal	1,463,494
EPPN2020	European Plant Phenotyping Network 2020	1,449,689
SmartGridPlus	ERA-Net Smart Grids Plus: Support Deep Knowledge Sharing between Regional and European Smart Grids Initiatives	1,329,951
EURAD	European Joint Programme on Radioactive Waste Management	1,321,783
EPI SGA1	Specific Grant Agreement 1 of the European Processor Initiative	1,296,750
SOLAR-ERA.NET Cofund	SOLAR-ERA.NET Cofund	1,268,804
OpenSuperQ	An Open Superconducting Quantum Computer	1,196,431
POP2	Performance Optimisation and Productivity 2	1,193,710
C VIRTUALTIMES	Exploring and Modifying the Sense of Time in Virtual Environments	1,161,574
BlueBio	ERA-NET Cofund on Blue Bioeconomy – Unlocking the Potential of Aquatic Bioresources	1,096,938
C srEDM	Search for Electric Dipole Moments Using Storage Rings	1,072,207
TELEGRAM	Toward Efficient Electrochemical Green Ammonia Cycle	1,061,114
C FACCE SURPLUS	Sustainable and Resilient Agriculture for Food and Non-Food Systems	1,049,490
C SusCrop	ERA-NET Cofund on Sustainable Crop Production	1,007,800

C Forschungszentrum Jülich as coordinator



Participation in EU programmes in 2020

in the Framework Programme for Research and Innovation, Horizon 2020

Programme	Number of project grants	Coordinated by Forschungszentrum Jülich	Funding amount Forschungszentrum Jülich (in euros)
EMPIR	2	-	131,250
EURATOM	11	-	26,519,524
Excellent Science	75	23	102,037,937
Industrial Leadership	16	1	9,732,189
Joint Technology Platforms	6	-	2,642,545
Societal Challenges	50	8	29,739,421
Spreading Excellence and Widening Participation	2	-	836,758
Horizon 2020 total	162	32	171,639,623



**JUWELS
supercomputer
in the computer
hall of the Jülich
Supercomputing
Centre**

Industry cooperations

Important cooperation partners in 2020

Company	Project	Project description
Freudenberg FST	HyRunCell	Production of medium-temperature polymer electrolyte fuel cells: optimization of materials proven for the low-temperature range of up to 90 °C for operating temperatures of up to 130 °C, for example to simplify the cooling of fuel cells in cars. (HI ERN: material and process optimization for membrane electrode units, analysis of individual cells; cooperation partner: Freudenberg FST, University of Bayreuth, 3M company)
Rolls Royce Deutschland Ltd Co & KG	MakTurb – research and development	Development of novel inlet coatings for the high-pressure turbine of modern aircraft engines. Inlet layers minimize the sealing gap in turbines and can significantly increase efficiency.

Table continued on page 80 >

Continued from page 79 >

Company	Project	Project description
Dataport (NL Billstraße)	Further development of modelling approaches for the optimized simulation of nutrient inputs into the surface waters of Schleswig-Holstein	Research into the causes of excessive phosphate concentrations and modelling of phosphate pollution of rivers in Schleswig-Holstein
Rolls-Royce plc	CMAS Burner Rig Testing of EB-PVD TBC Systems – phases 2 and 3	Tests on the corrosion behaviour of ceramic protective coatings in the high-pressure section of aero gas turbines with occurring deposits of silicate slags
Scienta Scientific AB Omicron GmbH	Manufacturing and delivery of a monochromatized electron source “MES”	Manufacture and sale of an instrument for measuring vibrations of the first atomic layers of a material with an atomically clean surface
Miba Sinter Austria GmbH R&D Miba Sinter Group	Development of a tape casting slurry	Study on the production of porous transport layers in electrolyzers in the area of water decomposition to contact the membrane electrically and feed the water to the membrane
Atos	Joint development of a booster module for the Jülich supercomputer JUWELS	Booster and cluster module for JUWELS, based on the BullSequana X infrastructure, hot-water-cooled for low energy consumption
ParTec		Software system ParaStation Modulo for the cooperation of JUWELS booster and cluster modules
NVIDIA		Tensor Core GPU for JUWELS booster module; over 3,700 GPUs for peak performance at 73 petaflops
D-WAVE		Quantum annealer for JUNIQ, the Jülich user infrastructure for quantum computing
BioNTech	Increase in the transfection efficiency of mRNA vaccines	Structural analyses on the Jülich neutron small angle scattering instrument KWS-2 to investigate new approaches for introducing mRNA into cells using lipid nanoparticles
AstraZeneca	Contributions to the development of mRNA drugs	Using neutron contrast variation to test the enhancement of subcutaneous delivery of mRNA with lipid nanoparticles containing anti-inflammatory components

PATENTS AND LICENCES

PATENT PORTFOLIO

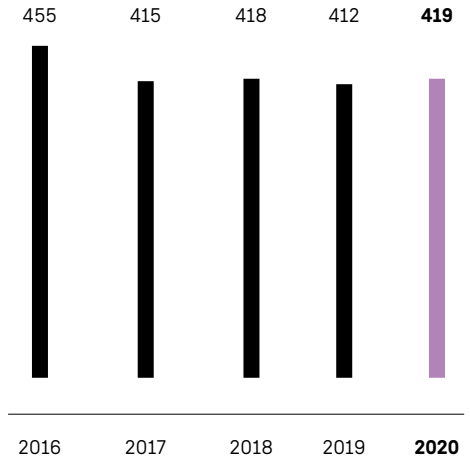
Jülich research generates innovations from which industry and society benefit and which result in property rights and licence agreements. Property rights include inventions for which patent applications have been filed as well as patents granted. An invention is patentable if it is novel, involves an inventive step and is commercially usable.

The patent portfolio is made up of the patent families and the total number of property rights. A patent family, in turn, consists of one or more patents in Germany or abroad that relate to one patentable technology. The total number also includes European patent applications and international applications under the Patent Cooperation Treaty (PCT), each of which comprises several individual property rights. The PCT is an international treaty that makes it possible to apply for a patent for all contracting states of the PCT by filing a single patent application.

A licence grants the licensee the use of an industrial property right, of know-how or software. For example, a company or research institution can use a patent of Forschungszentrum Jülich as a licensee.

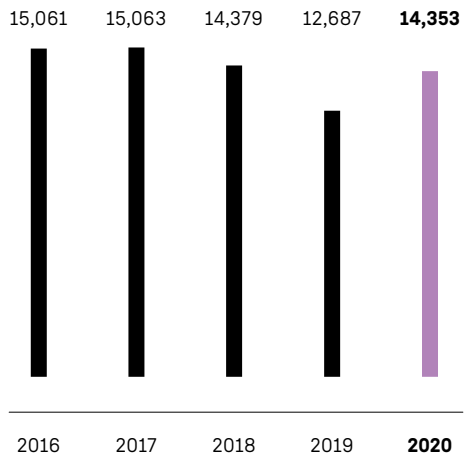
Patent families

2016-2020



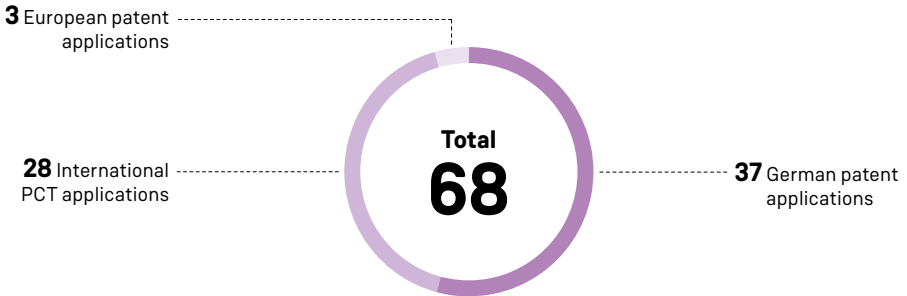
Total number of property rights

2016-2020

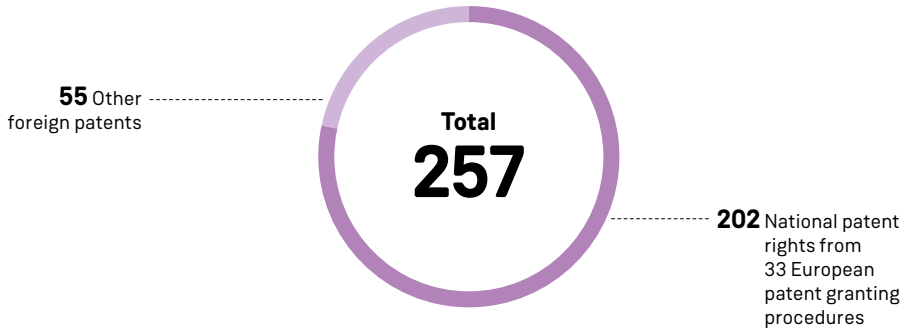


CURRENT PATENT ACTIVITIES

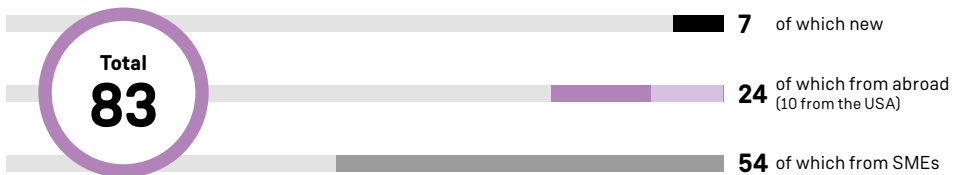
New patent applications in 2020



Patents granted in 2020



Total number of licences in 2020



JARA – JÜLICH AACHEN RESEARCH ALLIANCE

The University of Excellence RWTH Aachen University and Forschungszentrum Jülich have been pooling their expertise in the Jülich

Aachen Research Alliance (JARA) since 2007. Oriented towards the major challenges facing society, they carry out joint projects in the five research sections of brain research (JARA-BRAIN), sustainable energy (JARA-ENERGY), particle physics and antimatter (JARA-FAME), future information technologies (JARA-FIT) and soft matter research (JARA-SOFT) as well as in the JARA Center for Simulation and Data Sciences (JARA-CSD). JARA was one of the first cooperations between a university and a research institution in Germany. It contributes to developing the German scientific landscape further towards overcoming the juxtaposition of university and non-university teaching and research.

JARA in figures

as of: 31.12.2020

Professorial appointments	
Joint professorial appointments ¹⁾	67 ²⁾
Publications	2020
All institutions involved in JARA ²⁾	2,633
Joint publications	987

1) Without members of the Executive Board

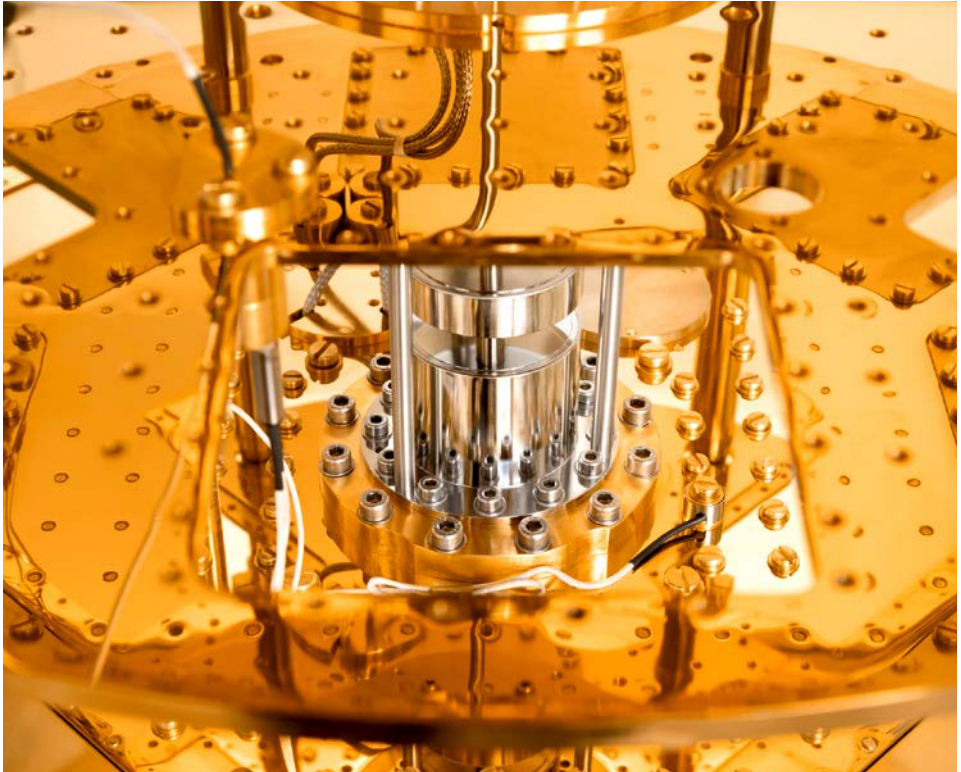
2) Peer-reviewed publications

JARA-FIT

A CENTRE FOR QUANTUM RESEARCH

The realm of quanta has its own logic – after all, quanta can assume different states at the same time. Understanding and using this logic offers enormous opportunities. Quantum technology will change our world – in science, industry, business and everyday life. In order for the high expectations to be fulfilled, theoretical knowledge and practical competence must be optimally combined. That is the goal of the new “Helmholtz Quantum Center”, HQC for short, which was launched in 2020. It

takes into account the increased importance of quantum technology: from researching different quantum materials and testing various qubit concepts to building a European quantum computer. Basic research, theory and development are to be drawn together in the HQC. Six research fields and seven technology clusters are linked to this end. In addition to other top-class scientists, Prof. Stefan Tautz from the JARA-FIT section as well as Prof. David DiVincenzo and Prof. Hendrik



Detailed view of the European quantum computer OpenSuperQ, which is being built at the Peter Grünberg Institute in Jülich

Bluhm, directors of the Institute for Quantum Information, are significantly involved in the HQC.

The project is funded by the Helmholtz Association (HGF) with about €50 million and includes, among other things, the construction of a new building with the latest experimental equipment on the Jülich campus. It will also house the JARA-FIT Institute for Quantum Information and the laboratory facilities of the

European “Quantum Flagship”. The new building will offer laboratory and office space to partners from the region, Germany and Europe for visiting scientists. It is planned that the HQC will go into full operation in 2025.

In 2020, one of the Helmholtz Association’s Helmholtz International Fellow Awards was also given to an expert in the field of quantum information: the awardee is Prof. Andreas Wallraff from ETH Zurich. The Board of Direc-

tors of Forschungszentrum Jülich had nominated Andreas Wallraff for the award at the recommendation of JARA Professor David DiVincenzo, director at Jülich's Peter Grünberg Institute. The award helps to expand the existing cooperation with scientists at Jülich and within the HGF.



Quantum researcher Prof. Andreas Wallraff from ETH Zurich

JARA-SOFT

RESEARCH TRAINING GROUP FOR ARTIFICIAL VISION

When eyesight is impaired, new surgical and implantation techniques such as retinal implants are supposed to help. So far, however, success often falls short of expectations. The new research training group “Innovative Retinal Interfaces for Optimized Artificial Vision – InnoRetVision” is now contributing to advancing this field of research, from basic research to novel technologies that optimize artificial vision. With experts from engineering, neurobiology and medicine, it takes an interdisciplinary approach to research and graduate training. For example, the biomedical mechanisms of retinal degeneration and their consequences for the wiring in the brain will be analyzed in more detail and new types of electrodes and circuit systems for implants will be developed. The aim is to significantly improve artificial vision.

The group for young researchers has been funded by the German Research Foundation since October 2020 for four and a half years with €5.6 million. With Prof. Andreas Offenhäusser from the Jülich Institute of Biological Information Processing, a JARA-SOFT scientist is also involved. The spokesperson of the research training group is Prof. Peter Walter from the Eye Clinic at RWTH Aachen University. In addition to RWTH Aachen University and Forschungszentrum Jülich, the University of Duisburg-Essen is also involved in the research training group.



JARA-SOFT/JARA-BRAIN

HOW SODIUM IONS DRIVE GLUTAMATE TRANSPORT IN THE BRAIN

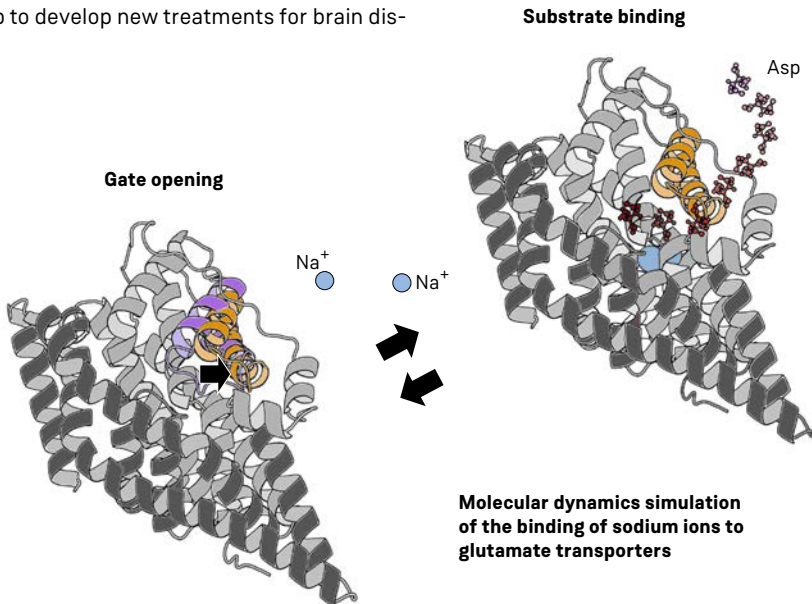
Led by Prof. Christoph Fahlke, who is a member of JARA-BRAIN and JARA-SOFT, Jülich researchers from the Institute of Biological Information Processing, Molecular and Cellular Physiology have discovered how sodium ions drive the transport of glutamate in the brain. The messenger substance glutamate enables activating signals to be transmitted

from one nerve cell to another. To ensure that the signal transmission will stop again, glutamate must then be quickly transported away from the synaptic cleft between the nerve cells. Specialized proteins in the cell membrane are responsible for this, the so-called Excitatory Amino Acid Transporters, or EAATs.

Outside the cell, the transporters bind glutamate and three sodium ions and transport everything together into the cell interior. The fact that the sodium-ion concentration outside the cell is significantly higher than inside acts as a driving force. With the aid of X-ray crystallography, it has now been possible to elucidate, with unprecedented accuracy, the structure of a sodium-bound transporter immediately before the binding of the glutamate. Simulations on the supercomputer JU-RECA and further experiments were able to show how the binding of two sodium ions enables the subsequent binding of glutamate and a third sodium ion. The results provide important insights into molecular processes of information processing in the brain and could help to develop new treatments for brain dis-

eases such as stroke, in which increased glutamate concentrations occur. They were published in the journal “Science Advances”.

A mutation that causes a glutamate transporter, EAAT1, to no longer transport glutamate correctly is the cause of a rare severe disease, episodic ataxia (type 6). It is associated with movement disorders, migraines and epilepsy. Fahlke’s team was able to resolve the way the mutation in one gene causes complex neurological symptoms. The results were published in the journal “Brain Communications”.



PROJECT MANAGEMENT JÜLICH

As one of the largest project management organizations in Germany, Project Management Jülich (PtJ) supports its clients in the federal and state governments and the European Commission in realizing their funding policy goals. PtJ implements research and innovation funding programmes that are geared towards socio-political needs, integrating national and European funding. The funded projects cover the entire innovation chain from basic research to market entry. One of the goals is the advancement of funding instruments to accelerate the innovation process. Through regional networking of science and industry, the aim here is to exploit local innovation potential in particular.

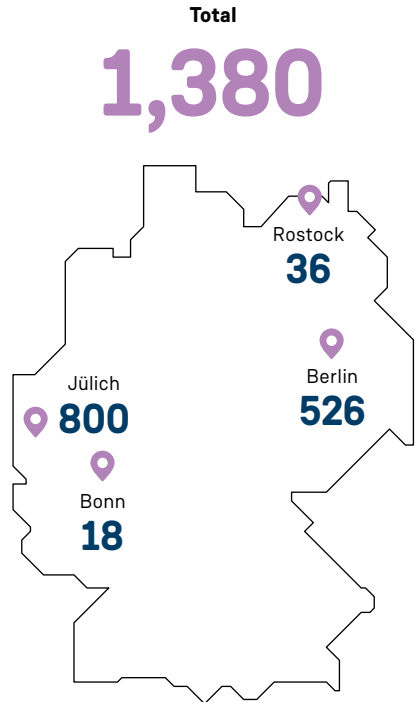
Since the summer of 2020, Project Management Energy, Technology, Sustainability (ETN) and Project Management Jülich (PtJ), both previously independent and based at Forschungszentrum Jülich, have been pooling their experience and expertise under the joint umbrella of Project Management Jülich. The Project Management ETN has so far been solely active for the State of North Rhine-Westphalia. Together with the former PtJ area of expertise “Technological and Regional Innovations”, it forms the new PtJ area of expertise “Research and Society NRW”. With this merger, the project management organizations are now jointly positioning themselves as competent service providers for North Rhine-Westphalia.

PROJECT MANAGEMENT JÜLICH IN FIGURES

The funding volume managed by PtJ rose to €2.192 billion in 2020. The number of ongoing projects increased to 30,350. Of these, 23,307 projects with a funding volume of around €1.915 billion were accounted for by federal programmes. For the programmes of federal

PtJ employees

according to location, 2020



states, PtJ managed a total of 7,043 projects with a funding volume of around €276.90 million.

PtJ's main client was the Federal Ministry of Education and Research (BMBF) with a share of 37.7 per cent of the funding volume managed, followed by the Federal Ministry for Economic Affairs and Energy (BMWi) with 34.8 per cent as well as the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Transport and Digital Infrastructure (BMVI) with 6.4 per cent each. Other federal authorities accounted for 2.1 per cent. The states had a share of 12.6 per cent in 2020.

€1.03 billion of the funding volume went to the area of expertise “Sustainable Development and Innovation”, €917.40 million to the area of expertise “Energy and Climate” and



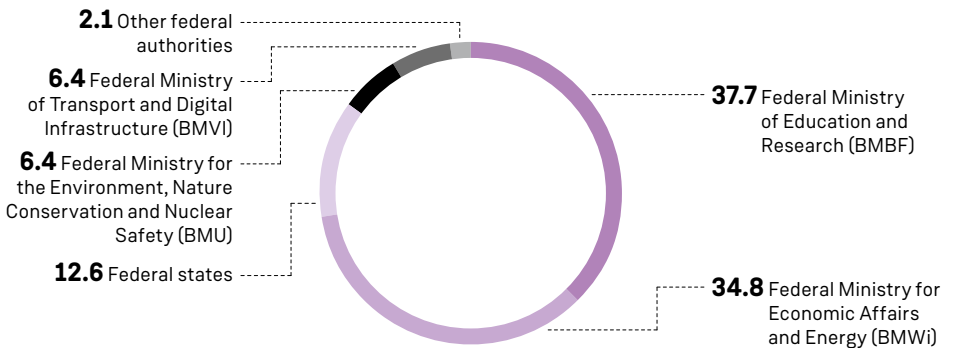
PtJ staff members in conversation: Güllü Arslan, Dr. Klaus Korfhage, Dr. Kambulakwao Chakanga, Ute Diesel and Dr. Heiko Geenen (from left)

€240.90 million to the area of expertise “Research and Society NRW”.

On 31 December 2020, PtJ had 1,380 employees at its four locations in Jülich, Berlin, Rosstock and Bonn.

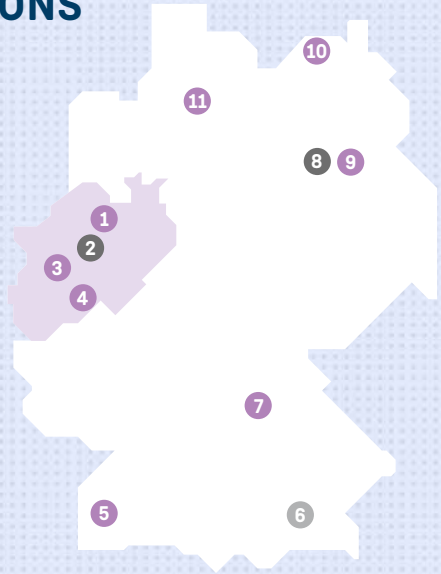
Funding sources

2020, in per cent



WORK AT OTHER LOCATIONS

Forschungszentrum Jülich operates branch offices in Germany and abroad with unique large-scale facilities, plus joint institutes with universities and the sites of the project managements.



1 Münster
Helmholtz-Institute Münster (HI MS): Ionics in Energy Storage, in cooperation with RWTH Aachen University and the University of Münster (WWU Münster)

2 Dortmund
Peter Grünberg Institute operates Beamline at the synchrotron radiation source DELTA at TU Dortmund University

3 Düsseldorf
External Funding Management division operates a branch office of the **biotechnology cluster BIO.NRW**

4 Bonn
Project Management Jülich

5 Freiburg
Institute of Neuroscience and Medicine operates the **Coordination Site of the Bernstein Network** at the University of Freiburg for solving neuronal processes

6 Garching
Jülich Centre for Neutron Science (JCNS) operates the **Heinz Maier-Leibnitz Zentrum** at the research reactor in Garching along with the Technical University of Munich and the Helmholtz-Zentrum Geesthacht

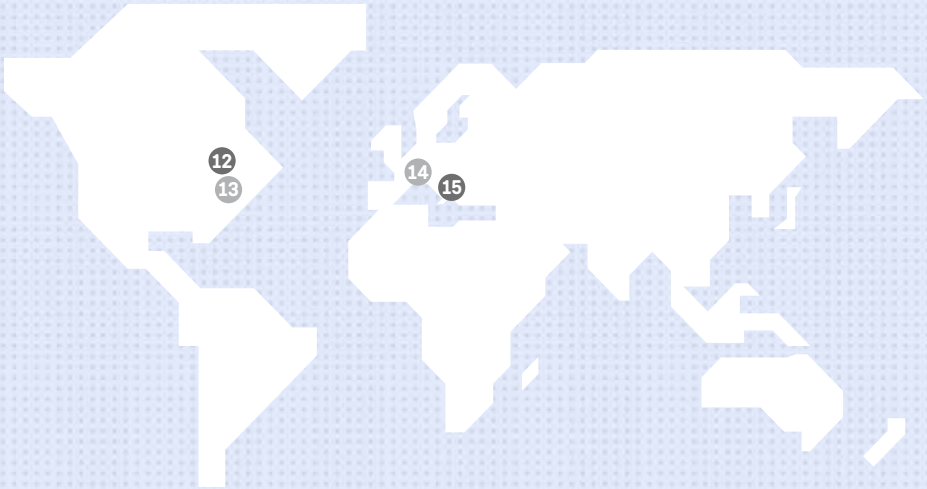
7 Erlangen/Nuremberg
Helmholtz-Institute Erlangen-Nürnberg for Renewable Energy (HI ERN) in cooperation with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Helmholtz-Zentrum Berlin (HZB)

8 Berlin
Peter Grünberg Institute and Central Institute of Engineering operate a beamline at the electron storage ring BESSY II

9 Berlin
Project Management Jülich

10 Rostock
Project Management Jülich

11 Hamburg
Institute of Biological Information Processing Centre for Structural Systems Biology (CSSB) with the X-ray source “European



XFEL” for deciphering molecular mechanisms, operated together with nine partner institutions

12 Argonne (USA)

Peter Grünberg Institute

separate beamline at Argonne National Laboratory

13 Oak Ridge (USA)

Jülich Centre for Neutron Science (JCNS)

operates a measuring instrument at the spallation neutron source SNS at Oak Ridge National Laboratory (ORNL)

14 Grenoble (France)

Jülich Centre for Neutron Science (JCNS)

operates an instrument at the high-flux reactor of the Institut Laue-Langevin (ILL); shareholder along with the Commissariat à l’Energie Atomique (CEA, France), the Centre National de la Recherche

Scientifique (CNRS, France) and the Science and Technology Facilities Council (STFC, UK)

15 Trieste (Italy)

Peter Grünberg Institute

operates a beamline at the Elettra Synchrotron Trieste

● The activities of the Peter Grünberg Institute in the area of synchrotron radiation in Dortmund, Berlin, Trieste and Argonne are coordinated by the Jülich Synchrotron Radiation Laboratory (JSRL).

● The JCNS operates neutron scattering instruments at the neutron sources FRM II, ILL and SNS under the one roof of a common strategy.

● Other locations of Forschungszentrum Jülich

BODIES AND COMMITTEES

BODIES

PARTNERS' MEETING

The Partners' Meeting is the principal decision-making body of Forschungszentrum Jülich GmbH. It is composed of members representing the Federal Republic of Germany and the federal state of North Rhine-Westphalia.

SUPERVISORY BOARD

MinDir Volker Rieke

Chairman,
Federal Ministry of Education and Research

The Supervisory Board supervises the lawfulness, expedience and economic efficiency of management. It makes decisions on important research-related and financial issues of the company.

> www.fz-juelich.de/supervisory-board

BOARD OF DIRECTORS

Prof. Dr.-Ing. Wolfgang Marquardt

Chairman

The Board of Directors conduct the business affairs of Forschungszentrum Jülich GmbH in accordance with the partnership agreement. They report to the Supervisory Board. The contact for all questions and concerns relating to the Board of Directors is the Office of the Board of Directors.

> www.fz-juelich.de/board-of-directors

COMMITTEES

SCIENTIFIC AND TECHNICAL COUNCIL

Prof. Dr. Astrid Kiendler-Scharr

Chair,
Institute of Energy and Climate Research

The Scientific and Technical Council (WTR) advises the Partners' Meeting, the Supervisory Board and the Board of Directors on all issues associated with the strategic orientation of Forschungszentrum Jülich and on all scientific and technical issues of general importance.

> www.fz-juelich.de/st-council

SCIENTIFIC ADVISORY COUNCIL

Dr. Heike Riel

Chair,
IBM Research – Zurich, Switzerland

The Scientific Advisory Council advises Forschungszentrum Jülich on all scientific and technical issues of general importance. This includes Jülich's strategy and planning of research and development activities, the promotion of the optimal usage of research facilities, and any questions related to collaborations with universities and other research institutions.

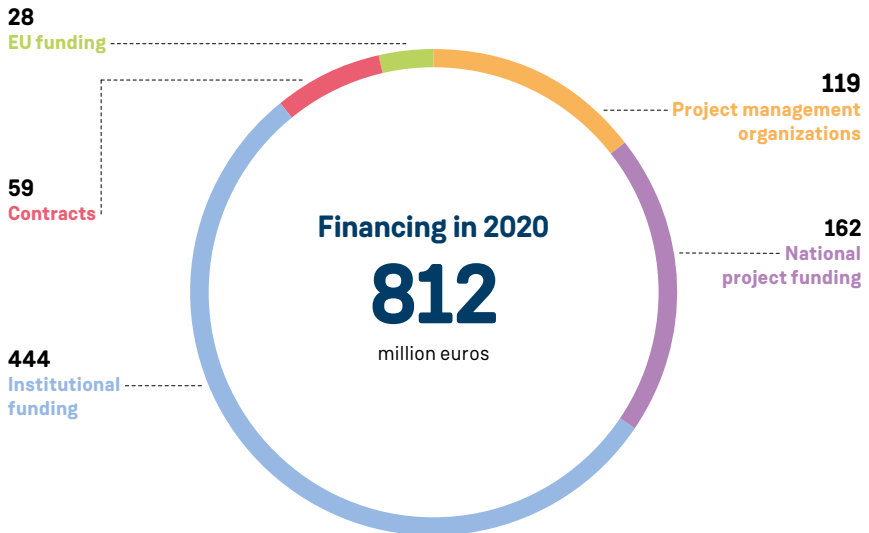
> www.fz-juelich.de/scientific-advisory-council

FINANCES

FINANCING IN 2020

In 2020, Forschungszentrum Jülich received institutional funding from the federal and state governments amounting to €444 million, which represented 55 per cent of total financing, to cover operating expenses and to implement investment measures. In addition, Forschungszentrum Jülich's third-party funding totalled €368 million, representing 45 per cent of the total funding.

Third-party funding consists of the acquisition of international (EU funding) and national project funding, of R&D and infrastructure services (contracts), and of project management on behalf of the Federal Republic of Germany and the federal state of North Rhine-Westphalia. National project funding includes funding from the federal government, the state government, the DFG and other domestic bodies.



Financing in 2020 covers all research areas of Forschungszentrum Jülich as well as other statutory tasks. The majority of Forschungs-

zentrum Jülich's financing (>90 per cent) comes from public funds. The remainder originates from cooperations with the industry.

BASIC AND THIRD-PARTY FUNDING OF THE RESEARCH AREAS IN 2020

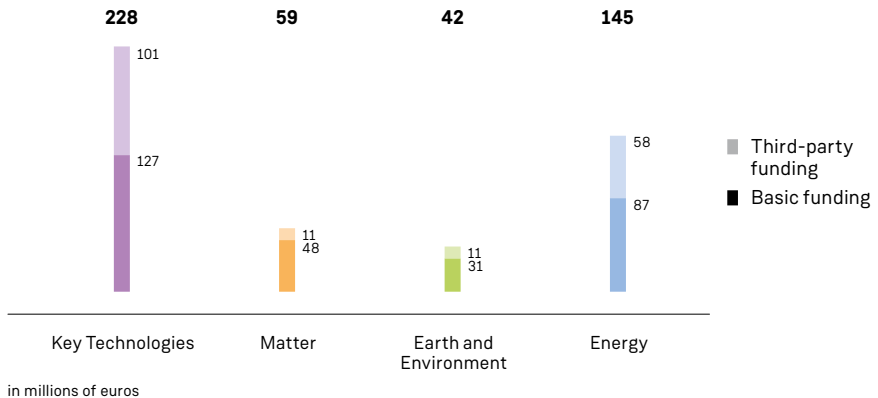
In 2020, all research fields of the Helmholtz Association in which Forschungszentrum Jülich is involved (Energy, Earth and Environment, Matter and Key Technologies) are in the third round of programme-oriented fund-

ing (POF III) with their programmes. The full costs of Forschungszentrum Jülich are shown below in their percentage distribution.



The full costs of Forschungszentrum Jülich in the research areas amounted to €447 million in 2020. Below is a breakdown of basic

and third-party funding into individual research areas.



Third-party funding per research area is between 19 and 44 per cent. Only third-party

funds that are allocated programmatically were taken into account.

CONTACT

CORPORATE COMMUNICATIONS

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Fax: +49 2461 61-4666
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As of: August 2021



In 2010, Forschungszentrum Jülich was certified as part of the “audit berufundfamilie” initiative. The fourth successful re-audit took place on 15 June 2020.

