effzett

FORSCHUNGSZENTRUM JÜLICH'S MAGAZINE

2-22

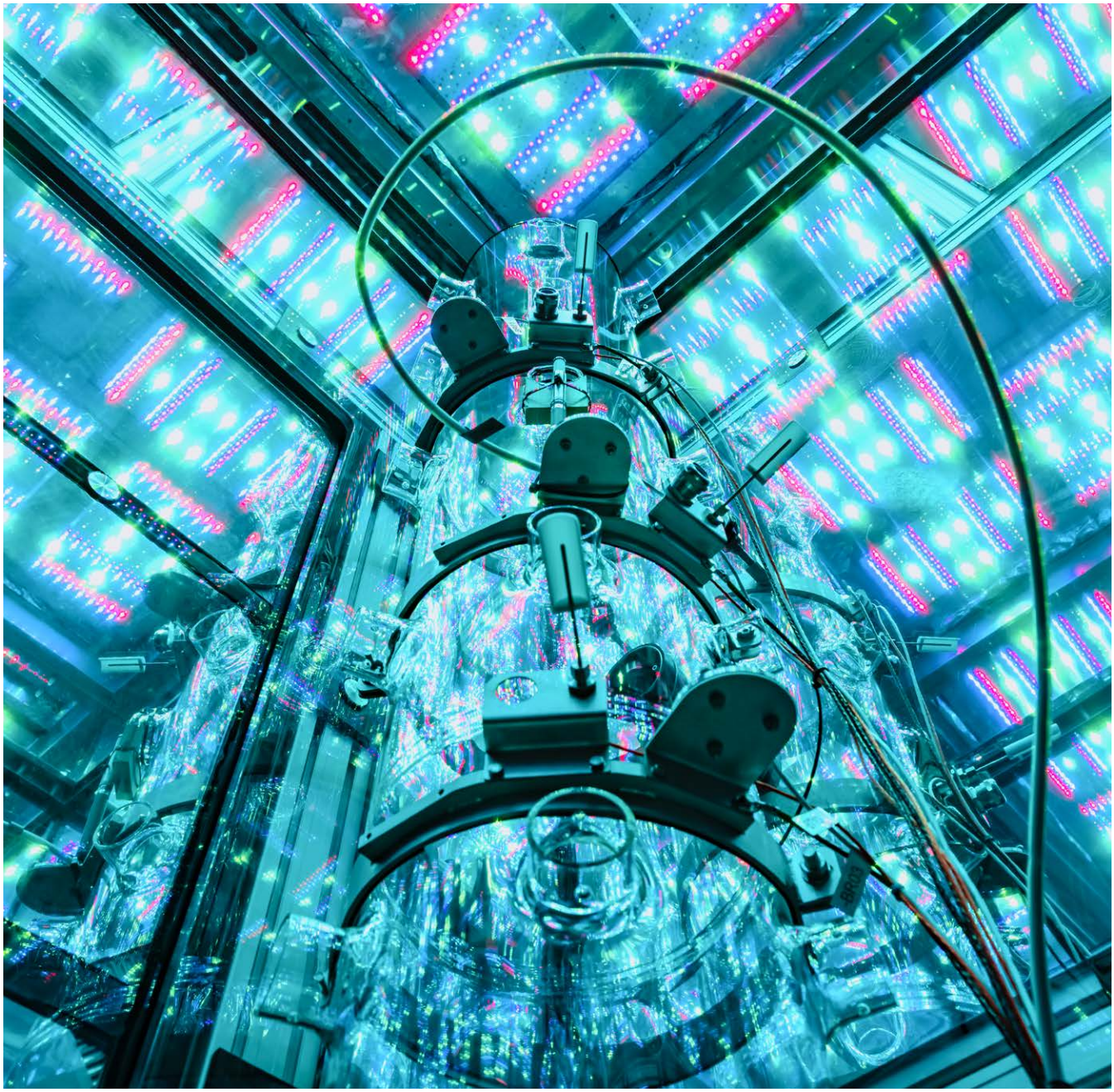
Well connected!

That is how the energy system of the future must be designed. Jülich is testing how this works on its own campus.

CONTROLLING
The estimates of air quality

COMMUNICATING
The successful model of brain researcher Katrin Amunts

CORRECTING
The calculation errors of quantum computers



↑

The plant time machine

Bright lights, many cables, pipes and containers – the complex structure could be part of a science fiction film. This construction, however, is real. It provides a glimpse into the future – at least with regard to crops. In it, researchers can create future climate conditions and study the atmosphere, plants and soil as an integral system. Kicking off in 2024, for example, the large-scale experiment AgraSim will investigate how wheat, maize, barley or potatoes will react to climate change. The facility was developed and built by the Institute of Bio- and Geosciences (IBG-3) and the Central Institute for Engineering, Electronics and Analytics (ZEA-1).

Read more about AgraSim and the facility on the Internet: go.fzj.de/plant-time-machine

Efficient and intelligent!

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Extremely high energy prices have been a burden on people and the economy. A solution for electricity is to step up production, which is supposed to bring prices down. Two other measures offer at least as much potential: increasing efficiency and reducing demand. In a brief study, economists at the University of Erlangen concluded that pushing these two measures, combined with an expansion of renewable energies, would actually offer the greatest potential. The Jülich Living Lab Energy Campus (LLEC) shows how this could work in the future. Thanks to an intelligent energy system combining sustainability and economic efficiency, the participating buildings and laboratories of Forschungszentrum Jülich manage with less energy – without restrictions for the employees, but with more user comfort. To this end, sectors such as electricity and heat are intelligently connected, energy is used according to demand, and consumption is largely controlled automatically. The approach of the living lab might serve as a blueprint for small districts or settlements.

Jülich researchers are developing intelligent approaches in other areas as well: for example, in reviewing data on air quality in Germany, in further developing quantum computers, or in advancing brain research.

We hope you enjoy reading this issue.
Your effzett editorial team

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ATMOSPHERIC RESEARCH

Ready for take-off

Two interconnected weather balloons are ready to begin their journey up to an altitude of 36 kilometres at the airfield in Timmins, Canada. There, the GLORIA-B infrared spectrometer lifted up by the balloons will collect data that will be used to analyze the effects of greenhouse gases, air pollutants and volcanic eruptions on the Earth's atmosphere. GLORIA-B is a joint development by experts from Jülich and Karlsruhe. The measurement flights in late summer 2022 served to prepare satellite missions such as CAIRT and FORUM, which are to collect data of this kind from space in the future.

– INSTITUTE OF ENERGY AND CLIMATE RESEARCH/ CENTRAL INSTITUTE FOR ENGINEERING, ELECTRONICS AND ANALYTICS –

GEOSCIENCES

New member of the Leopoldina

The German National Academy of Sciences Leopoldina has accepted the Jülich soil scientist Prof. Wulf Amelung as a new member to the Agricultural and Food Sciences Section. The Academy elects researchers as members who have distinguished themselves through significant scientific achievements.

– INSTITUTE OF BIO- AND GEOSCIENCES –

300

million synapses …

… in one neural network were simulated by Jülich researchers at unprecedented speed. On a prototype of IBM's INC-3000 "neural" supercomputer, they were able to calculate network activity four times faster than real time. The simulations should help to further a better understanding of learning and brain development.

Interview with Dr. Arne Heittmann about the record-breaking simulations:
go.fzj.de/nc-interview-EN

– PETER GRÜNBERG INSTITUTE –

INFORMATION TECHNOLOGY

Fast detection of dangerous infections

Germany is to get a local early warning system to control outbreaks of infection (Lokales Frühwarnsystem zur Kontrolle von Infektionsausbrüchen; LOKI). The aim is to support health authorities in detecting local outbreaks and predicting the further course of infection with the help of computer models. In this way, it should be possible to develop measures tailored to a specific region. The pilot project set up for this purpose, in which Forschungszentrum Jülich and five other partners are involved, started in the summer of 2022 and is scheduled to run until the end of 2025.

– Institute of Energy and Climate Research/
Jülich Supercomputing Centre/
Institute of Bio- and Geosciences –

New rule for orbital formation

Electron orbitals show where and how electrons move around atomic nuclei and molecules. In order for orbitals to be combined in chemical reactions – that is, in the breaking and forming of electron bonds – they must match in terms of energy and spatial extent. Researchers from Graz and Jülich have discovered in experiments that the orbitals need yet another match for new bonds to form: they must also have the same momentum space distribution.

– PETER GRÜNBERG INSTITUTE –

CLIMATE RESEARCH

Fact report updated

The consequences of global warming could be felt clearly this year: heat and drought in China, Europe and North America; floods and record temperatures in South Asia. The fact report “Was wir heute übers Klima wissen” (What we know about the climate today), published in 2020, has been updated with the latest data and findings from the Intergovernmental Panel on Climate Change’s Assessment Report and other studies. It summarizes the relevant interrelationships and consequences for people and nature in clear and understandable language. A separate chapter is devoted to the latest developments in Germany. The paper’s editors are the German Climate Consortium, the Helmholtz Climate Initiative, the National Meteorological Service of Germany, the German Meteorological Society, the ExtremeWeatherCongress Hamburg and klimafakten.de/en.

More on this topic (German PDF): go.fzj.de/faktenpapier-klimawissen

– INSTITUTE OF ENERGY AND CLIMATE RESEARCH –

SUPERCOMPUTING

First European exascale computer

Forschungszentrum Jülich will be home to the first European exascale computer. This was decided by the European supercomputing initiative, EuroHPC JU. Expected to surpass 1 trillion computing operations per second, the supercomputer is to help develop solutions to climate change, pandemic management and sustainable energy production. The use of artificial intelligence and the analysis of large amounts of data is also planned.

Prof. Thomas Lippert and Prof. Estela Suarez explain the challenges of an exascale system: go.fzj.de/interview-exascale-EN

– JÜLICH SUPERCOMPUTING CENTRE –

“With its demonstrators of innovative transport and storage technologies for hydrogen, the Helmholtz Cluster HC-H2 will become a nucleus for new entrepreneurial activities in the Rhineland region.”

Prof. Peter Wasserscheid, spokesperson of the Helmholtz Hydrogen Cluster HC-H2 at the ceremonial opening of the cluster at Brainergy Park Jülich in mid-September

Connected energy

In the future, we will use many distributed energy systems to meet our needs, and it will be essential to optimally link all sectors with each other. Experts from Jülich are testing how this works out most efficiently in practice. To do this, they transform their own campus into a living lab.

Even in times of energy being scarce and expensive, you don't have to sit in a cold office in the morning in winter," says physicist Stefan Kasselmann. "In the future, when you arrive at work at Jülich, the heating will already be on and the room will be comfortably warm – with less energy consumption." This is already being tested in individual buildings, and it works because the energy is used according to demand. The key to efficiency: intelligent connectivity and largely automated control systems.

"We're currently testing that in real operation on the Jülich campus," says Kasselmann, the scientific project manager of the Jülich Living Lab Energy Campus (LLEC). The aim of the LLEC is an intelligent energy system that combines sustainability, economic efficiency and user comfort.

The supply and consumption of individual offices is only one aspect, however. "With the LLLEC, we want to test how energy can be efficiently distributed and used within a city district or a small settlement in the future under real-world conditions. Around 7,000 people work at Jülich, so it's fairly comparable to a small town. There are offices, laboratories and different kinds of energy demands. This allows us to simulate different scenarios in a real environment, from industrial areas to residential neighbourhoods."

← The man pulling all the strings: Dr. Stefan Kasselmann, scientific project manager of the Living Lab Energy Campus.

On the dashboard, which Eziama Ubachukwu helped to develop, users can view various data from the living lab and, for example, select settings for their office. →

← The photovoltaic systems on the campus produce 1.5 megawatts of peak power (pictured from left: Susanne Hoffmann, Simon Rottland and Dr. Andreas Gerber).

Almost everywhere in Germany, the energy supply is currently still characterized by large power plants that burn fossil fuels such as coal, oil and natural gas to generate electricity and heat. In the future, however, wind and solar power will dominate the energy grid – which means that the energy will be produced in a far more decentralized way. The experts at LLEC want to find out how the energy flow between the individual grid nodes can be optimized and how electricity and heat generation can be better interconnected. “This is also referred to as sector coupling. A good example of this is the low-temperature district heating network that we are currently building on campus. It also shows how sources that have not been factored in so far can be integrated so that there's no energy waste,” Kasselmann explains.

“If the power grid is under heavy load, we can turn down the heat pumps for a while without leaving the comfort zone in terms of temperature.”

ANDRÉ XHONNEUX

REUSING WASTE HEAT

In the future, the low-temperature district heating (LTDH) network will be used to supply the Jülich Supercomputing Centre (JSC) and eight surrounding buildings with thermal energy. The heating power comes from the cooling of the supercomputer JUWELS. When computationally intensive simulations run on its processors, the electronics emit a lot of waste heat to the cooling water. This pre-warmed liquid is fed into the LTDH network on campus afterwards and distributed.

“The water has a temperature of just around 40 degrees Celsius,” explains André Xhonneux from the Institute of Energy and Climate Research (IEK-10), who is responsible for the “Software and Simulation” team at LLEC. This water, only just lukewarm, is enough to keep energy-efficient buildings at a comfortable temperature. However, it is too cold for the heating systems of older buildings: “These require water of up to 85 degrees Celsius in order to heat all rooms sufficiently. That’s why we use heat pumps to bring the water to this temperature,” says the mechanical engineer. “This also allows us to continue using the buildings’ existing heating systems and building envelope for the time being.”

This is particularly important in order to be able to transfer the knowledge gained at LLEC to urban neighbourhoods: one have to work with existing buildings there, too, that cannot be properly converted in a short time. In this case, the waste heat could come from companies and businesses. “In our region, for example, Jülich’s sugar factory would be worth considering. Beyond that, however, there are count-

less untapped sources that can be identified through the German heat cadastre."

Another advantage: since the heat pumps link the electricity and heat sectors, the system can also stabilize the electricity grid. "A room doesn't cool down straightaway if it isn't heated around the clock. If the electricity grid is under heavy load, we can save electricity by turning down the heat pumps for a while without leaving the comfort zone in terms of temperature," explains Xhonneux. There may be heavy load on the electricity grid when the supply of renewable energies is scarce, for example.

"We installed photovoltaic systems on campus. With these, we can generate a peak output of one and a half megawatts. This is only a small amount compared to the total consumption of the campus, but for our research purposes, it is close enough to reality," says Stefan Kasselmann.

Some of the solar modules are located at an open area, the rest is spread across various buildings on the campus. "The systems are easy to integrate when it comes to new buildings," explains Andreas Gerber from IEK-5, LLEC team manager for photovoltaics. "Either on the roof, as semi-transparent modules in the skylights or in the facade. But of course we would also like to continue equipping older buildings as well."

At Forschungszentrum Jülich, this has turned out to be a challenge, as many roofs already support infrastructure for the laboratories below, such as air conditioning and air purification systems. This causes shading. Other roofs were not designed for bearing such high loads. In an urban area, however, the situation might be very different: "While there are usually no large open spaces there, you can, for example, perfectly use the roof of a car park or make increased use of the roofs of shopping centres and industrial plants. Novel lightweight photovoltaic systems are therefore also being tested for our campus."

SCHOOLS LABORATORY AS A PIONEER

One building that has already been converted at Jülich is the JuLab Schools Laboratory. Its roof terrace supports a photovoltaic pergola made of semi-transparent modules plus a photovoltaic roof system, and right next door, the rotor of a small wind turbine is turning. "We built an LLEC on a small scale here. With it, important components of the system are tested in advance before the technologies are used on a larger scale on campus," Kasselmann explains.

For example, the conference rooms are equipped with special sensors: they recognize, among other things, how many people are in the room. "A room will heat up slowly through body heat alone," says the physicist, "so the heating is then automatically turned down. This saves heating energy without anybody noticing it."

Sensors measure not only the temperature of the rooms and the heating, but also data such as CO_2 concentration, humidity, brightness and whether the doors and windows are open – not only at JuLab, but also in many other rooms of the LLEC. Information on the weather is incorporated as well.

→ The low-temperature district heating network, which Dr.-Ing. André Xhonneux is helping to set up, supplies buildings with heat. The network uses the waste heat from the JUWELS supercomputer to do this.

LLEC members report on the progress of the project in their blog (in German): blogs.fz-juelich.de/llec

The data is processed by the LLEC's "brain": the cloud-based information and communication platform (IKT) and its control software ensure the right balance of energy flows between the nodes of the grid. "To achieve optimal results, we work with a 'digital twin' of the entire system, with a mathematical model of the LLEC's buildings and facilities", says André Xhonneux. "Based on a target and certain framework conditions, operation is automatically optimized. User specifications are also taken into account. If the thermostat is turned up, the system will not lower the temperature."

One user interface is the "energy dashboard", which is accessible on the intranet. The start screen shows a map of Forschungszentrum Jülich with all the buildings: "We can display the consumption for each location here," says Stefan Kasselmann. "We do this to raise awareness about how energy is used."

The next step is to extend this system to individual rooms: "Then everyone will be able to look at the consumption profile and comfort parameters of their own office and also make adjustments." At the same time, energy-saving behaviour is to be rewarded through an online simulation game: employees can design a virtual energy system for the campus – and even contribute their real-life usage behaviour. Significant efficiency gains can only be realized by actively involving users.

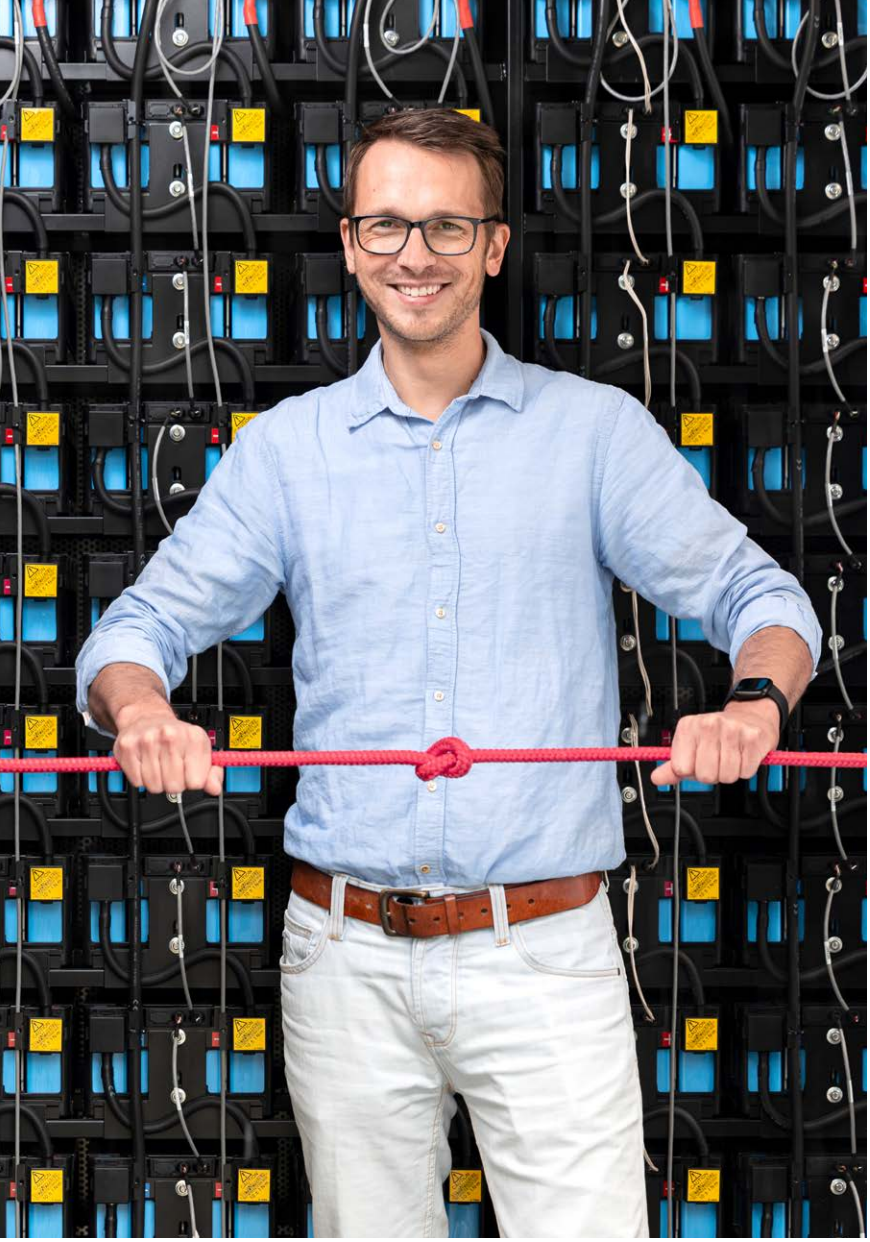
VARIOUS STORAGE SYSTEMS

Sun and wind do not always supply consistent amounts of energy. "If more electricity is generated than is needed, we have to store it – for a rainy day, so to speak. We are building up various storage facilities at the LLEC for this purpose," explains Stefan Kasselmann. "For example, we can store electricity in two large batteries or, in the future, also chemically in the form of hydrogen. The hydrogen storage system can provide energy during renewable droughts, when no wind and no solar energy is available for days or even weeks."

The hydrogen is produced from water with the help of electrolysis cells. It can then be stored chemically, bonded to an organic carrier liquid, known as Liquid Organic Hydrogen Carrier (LOHC). A globally unique demonstrator is being set up at Jülich. The hydrogen can be released again on demand from the LOHC.

The gas can be converted back into electricity using a fuel cell. "However, we could also burn it and thus replace some of the natural gas that the energy centre built on campus will use to generate electricity, heating and cooling. Therefore, hydrogen plays a very central role in sector coupling," says Holger Janßen, group leader of Stacks and Systems (electrolysis) at IEK-14.

← Surplus energy is to be used to produce hydrogen with the help of an electrolyzer. Dr. Holger Janßen and his colleagues are working on this.



“The high-power battery is particularly suitable for so-called peak shaving, that is, to compensate for short-term fluctuations in the power grid of seconds to minutes.”

DR. LUC RAIJMAKERS

← Dr. Luc Raijmakers focuses on energy storage: the LLEC has purchased two enormous batteries with a total capacity of 3,125 kilowatt hours.

The other storage system – two stationary battery systems based on lithium-ion technology – is located in containers. “They have different characteristics,” says Luc Raijmakers (IEK-9), LLEC team manager for battery systems. “The high-performance battery is particularly suitable for so-called peak shaving, that is, to compensate for short-term fluctuations in the power grid of seconds to minutes. It also serves as an uninterruptible power supply. There is also a high-energy battery that serves as an energy buffer for a period of several hours.”

In the high-performance system, twelve individual battery cells are combined to form one module. These modules cover an entire wall in the container. The special challenge: “The cells all have to be charged and discharged evenly within a certain voltage range,” explains Luc Raijmakers.

“We already installed charging points for e-vehicles to test bidirectional charging”, adds Stefan Kasselmann. “During the day, when the vehicle is parked and the power demand is high, energy from the vehicle battery can thus be temporarily fed back into the grid for stabilization. With a large number of vehicles, this could make a significant contribution in the future. Although there are still regulatory hurdles, this is one of the advantages of a living lab: we identify new challenges in the interplay of science, technology and society that we would probably not have seen without direct reference to practice.”

ARNDT REUNING

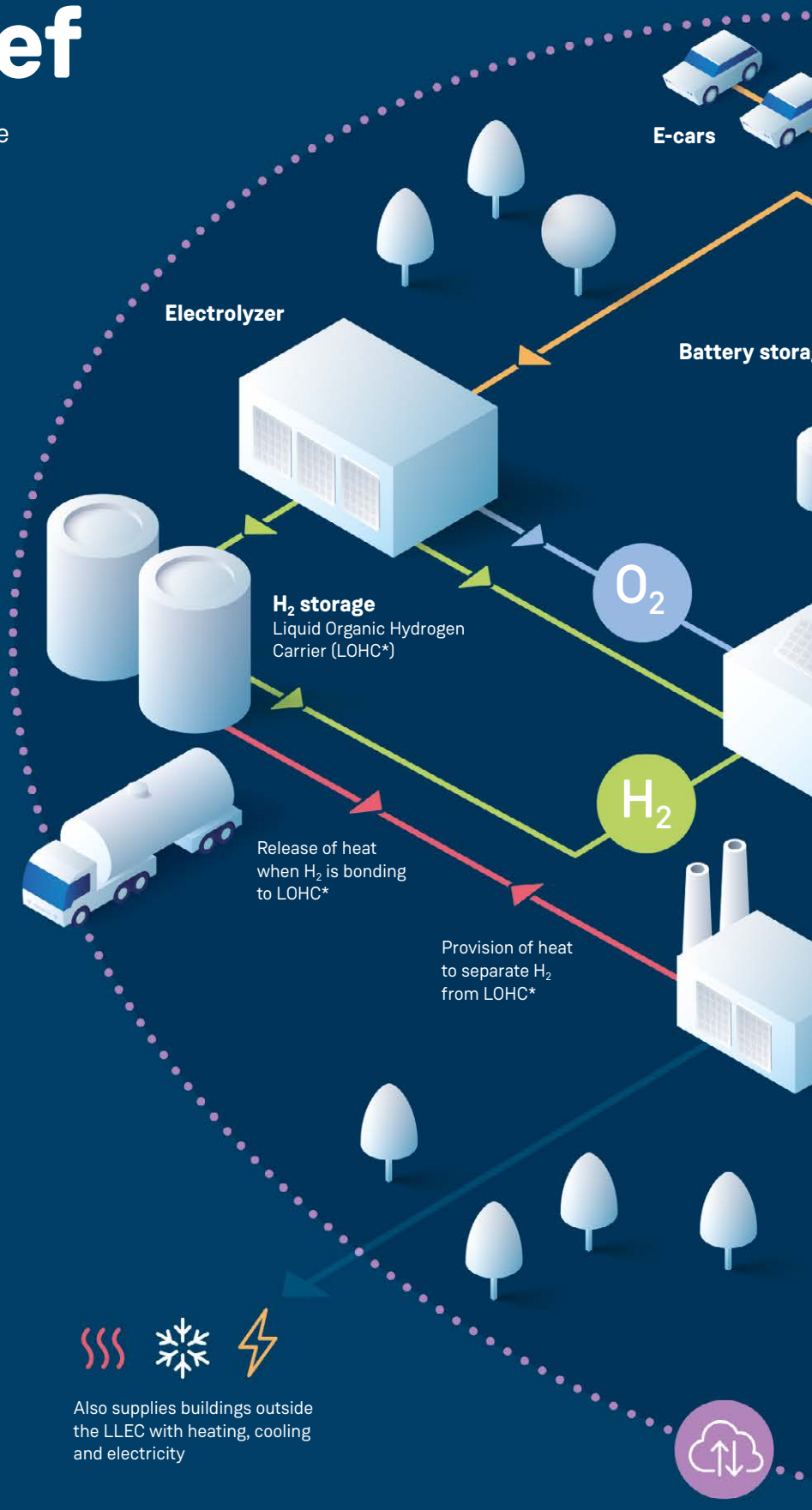
LLEC in brief

An intelligent energy system for the future

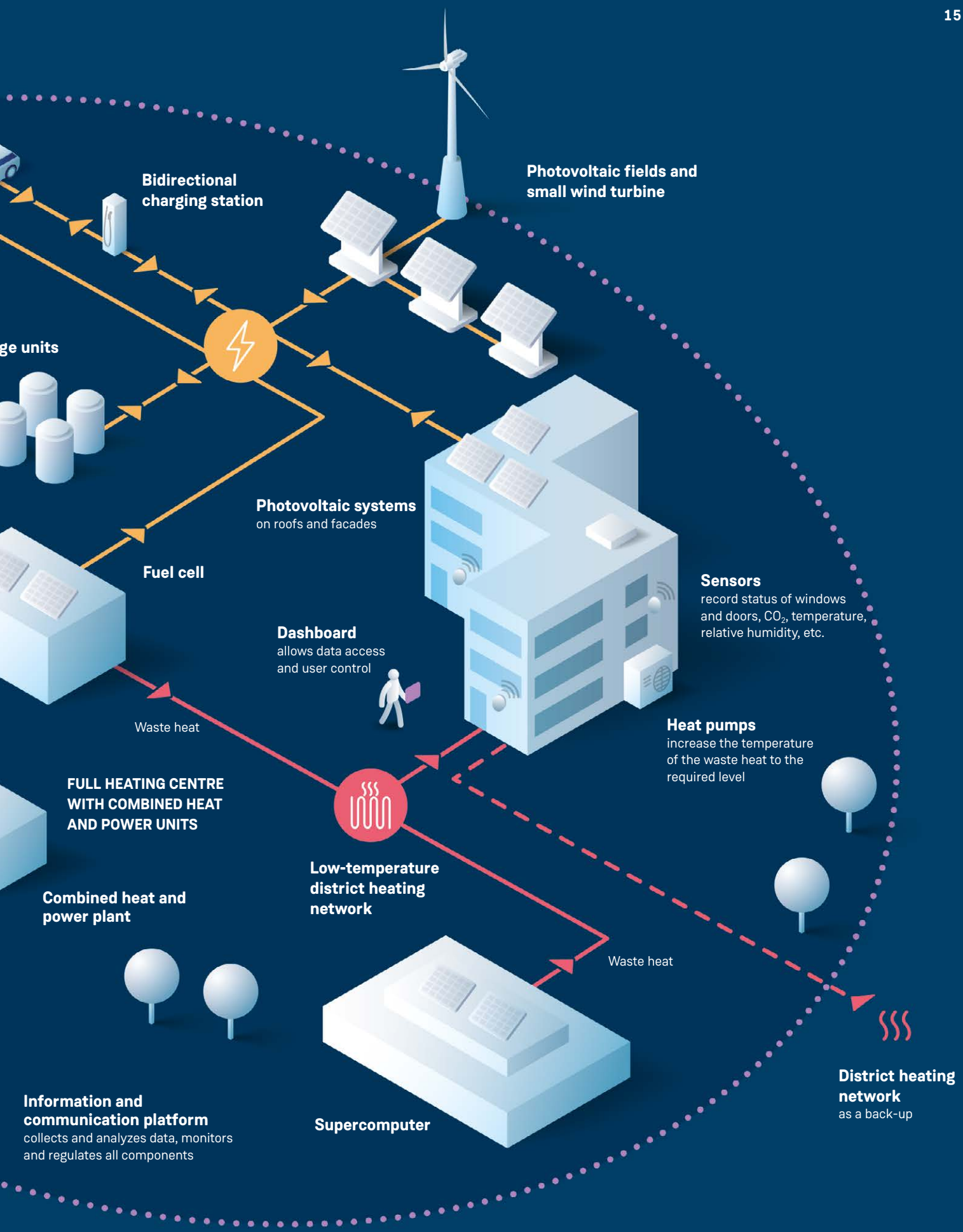
The Living Lab Energy Campus (LLEC) is about building a sustainable energy system and testing it under real-life conditions. In short: energy transition is being tested. More than ten participating institutes and organizational units of Forschungszentrum Jülich are seeking to find out how technology, energy sources and consumption can be optimally designed and coordinated. The findings are intended to serve as a blueprint for residential and industrial areas.

A key factor is the coupling of different sectors. On the Jülich campus, electricity, heat and chemical energy are coupled using various storage technologies, while the mobility sector is also integrated. Forschungszentrum Jülich has not only been building new technologies for its living lab since 2018, it is also retrofitting 20 existing buildings and integrating them into the system.

The brain of the living lab is the information and communication platform. Behind this is an intelligent IT system with predictive, adaptive algorithms regulating the energy systems. Intelligent networking and largely automatic control based on various parameters – such as weather and incidence of light, but also humidity and the number of people in a room – is essential for optimally coupling the sectors, using energy as efficiently as possible and reducing consumption. Much of the technology and equipment is already in place at the LLEC, which is funded by the Federal Government, the state of North Rhine-Westphalia and the Helmholtz Association. By the end of 2023, all components are to be in operation, and a climate-neutral new administration building is schedulded for completion by the end of 2024.



* LOHC: a liquid storage medium for H_2, able to absorb the gas through chemical reactions and also release it again.


Bidirectional charging station
Photovoltaic fields and small wind turbine
ge units
Photovoltaic systems
on roofs and facades
Fuel cell
Sensors
record status of windows and doors, CO_2, temperature, relative humidity, etc.
Dashboard
allows data access and user control
Waste heat
Heat pumps
increase the temperature of the waste heat to the required level
FULL HEATING CENTRE WITH COMBINED HEAT AND POWER UNITS
Low-temperature district heating network
Combined heat and power plant
Waste heat
Information and communication platform
collects and analyzes data, monitors and regulates all components
Supercomputer
District heating network
as a back-up

Neat estimates!

Polluted air is a danger to health. The sources of the air pollutants are largely known, but how much the sources emit is only estimated. Researchers from Jülich have reviewed these estimates, thus providing an important tool for identifying measures that improve air quality.

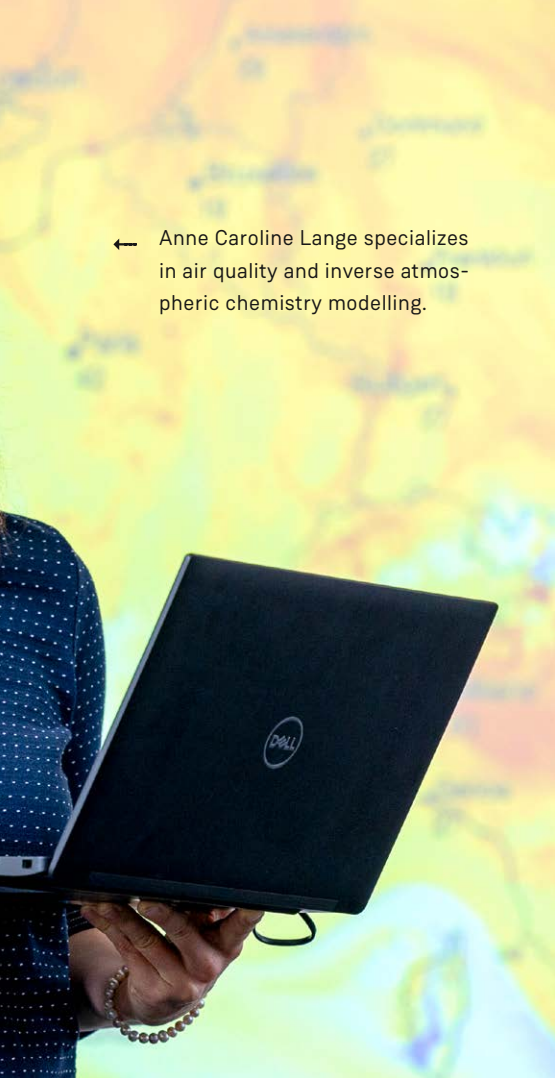
The diesel scandal, criticism aimed at the location of measuring stations, lawsuits for exceeding threshold values – the topic of air quality keeps causing a stir. Even though Germany's pollution levels of particulate matter and nitrogen dioxide (NO_2), for example, have been decreasing for years, the federal and state governments will probably have to tighten their measures. In October 2022, the EU Commission proposed stricter limits. If these were to come into force from 2030 onward, pollution levels would be too high in many places.

The German Environment Agency (UBA) and the federal states operate around 600 measuring stations. In addition to the quantities of particulate matter and NO_2, they also assess ozone, carbon monoxide and sulphur dioxide. Most of the stations are located in conurbations, and thus assess air pollution concentrations that directly affect people. What they do not measure, however, is where the pollutants come from and how much each source emits. Yet understanding the relationship between emissions and measured pollutants is crucial – it is the basis for taking sensible measures to improve air quality. For this reason, the UBA estimates emission levels on the basis of many different data having to do with pollutant sources, such as the number of households and what each one uses for heating, traffic density or what kind of local industry there is. Information is drawn not only from administrative bodies, but also from companies like car manufacturers who share data on the pollutant emissions of their vehicles.

UBA has commissioned Jülich atmospheric researchers to assess how good the estimates are. For this purpose, they used the complex EURAD-IM atmospheric chemistry model, which they developed themselves (see box). "Our chemical transport model takes into account more than 100 different chemical compounds in the air and how they react with each other," says Dr. Anne Caroline Lange from the Institute of Energy and Climate Research (IEK-8).

TRACING BACK TO THE SOURCE

The biggest advantage of the model: "We can calculate backwards in time with it. For example, we start with the measured concentration of nitrogen oxides taken from one point. The model then uses meteorological data and the known reactions of nitrogen oxides in the air to calculate their previous path, how they are distributed and with which substances they have reacted." The researchers can then compare these simulated emission data with the UBA's estimated emission data.



← Anne Caroline Lange specializes in air quality and inverse atmospheric chemistry modelling.

In addition, other chemical transport models will be used to examine whether they produce similar results. Not only can the simulations test how good the estimates are, but they could also help politicians and authorities decide which measures and mitigation strategies are effective in order to improve air quality.

With the present report on 2016, however, UBA can already analyze how the spatial distribution of pollutants can be better estimated in the future. “It may be that baseline information needs to be looked at in a more regionally differentiated way, for example in agriculture: what plants are grown in the region, what fertilizers are used?” says Lange. Measures to comply with new threshold values can then be planned more specifically.

BARBARA SCHUNK / CHRISTIAN HOHLFELD

In their first analysis, the Jülich researchers had initially concentrated on the year 2016. “We chose an average year in which climate change was already evident, but which had no extreme events such as heat, drought, volcanic eruptions or Saharan dust,” says Lange. Besides, even a single year means enormous computing effort. “We calculated the average annual emissions for each town and district at a resolution of 5 by 5 kilometres – but even that took Jülich supercomputers several months.”

The good news: “The results of our model calculations agree well with the emission values determined by the German Environment Agency,” says Lange. Still, “the spatial distribution of pollutant emissions could be even more precise.” There were unexpected discrepancies at first, Lange reports: “Our calculations showed higher nitrogen oxide emissions than estimated by the UBA. It turned out that the deviation may be attributable to the diesel scandal in 2016: the exhaust emissions of diesel vehicles were, in some cases, significantly higher than stated by manufacturers. These emissions were missing from the UBA estimates available at the start of the project.”

The scientists now plan to compare the UBA estimates from other years with the calculations of their model.

Air quality forecast

EURAD-IM (EURopean Air pollution Dispersion – Inverse Model) is an air quality prediction and analysis system. The regional chemical transport model calculates which gases and aerosols occur in the lower atmospheric layer three-day (troposphere), and in which quantities, and simulates their dispersion. The calculations include daily weather data and data updates from satellites as well as from measuring stations on the ground. This enables 3-days forecasts of air quality, which Jülich researchers make available online every day and send to the European Union for consultative purposes.

The model continuously checks its own predictions by retroactively comparing the calculated values with the measured values in analyses and adjusting parameters if necessary.

EURAD-IM air quality forecasts:
go.fzj.de/eurad-im-airquality

Networks as a model of success

Providing impetus, breaking new ground and taking criticism seriously – for neuroscientist Katrin Amunts, this is the basis needed to advance research. Equally indispensable for her is the exchange with others. She is breaking new ground to do so in her current project.

She is one of the most important international representatives of interdisciplinary brain research: Prof. Katrin Amunts, director of the Institute of Neuroscience and Medicine (INM-1) at Forschungszentrum Jülich and of the Cécile and Oskar Vogt Institute of Brain Research at Heinrich Heine University Düsseldorf. "Experts from research and medicine all over the world use her findings in the field of brain mapping," emphasized the North Rhine-Westphalian Minister of Science Isabel Pfeiffer-Poensgen when awarding Katrin Amunts the Federal Cross of Merit 1st Class in March 2022.

Only a few weeks earlier, Katrin Amunts had been awarded the Hector Science Prize. "These recognitions give confidence and encouragement to keep going", says the Potsdam native. "However, I see the awards mainly as a credit to the teams involved. I mean that very seriously, because you can't make an atlas like this by yourself."

Fame and honour have no priority in her mind, anyway; Katrin Amunts' driving force is the desire to do excellent science. She wants to fulfil a mission for society as a whole with her research: namely, to contribute to a better understanding of the brain with its 86 billion neurons and trillions of contact points. This knowledge is expected, for example, to help better predict the course of neurodegenerative diseases such as Parkinson's or Alzheimer's or even to cure them.

Prof. Amunts and Prof. Markus Axer, a colleague from INM-1, have just published a joint paper on connectivity in the brain in a special issue of the journal Science. The magazine was published in November on the occasion of the Neuroscience 2022 conference in San Diego, USA where around 150,000 neuroscientists meet every year to discuss the latest scientific developments.

"In 'Science', we illustrate how our brain is networked – from the contact points of individual nerve cells to the connections between different brain regions – and what methods are needed to understand this intricate organization," explains Katrin Amunts.

A unique method developed by the Jülich team provides important data: three-dimensional Polarized Light Imaging (PLI). It allows for the high-resolution visualization and examination of the elongated projections of nerve cells, the axons. The information about their pathways has been missing so far, despite being crucial for the interconnection in the network. PLI is part of the digital research infrastructure EBRAINS, which was developed in the Human Brain Project (HBP). EBRAINS brings together data and tools for brain analysis and simulation, and it offers researchers worldwide free access to them.

> **"Anyone who doesn't take criticism seriously is going down the wrong path."**
>
> KATRIN AMUNTS

"This wealth of data and the methods developed were also an important basis for the article in Science, which once again proves that the HBP facilitates internationally excellent science," emphasizes Amunts. In 2023, its EU funding will expire.

What will remain: “The HBP leaves behind not only important knowledge and, with EBRAINS, a publicly accessible infrastructure, but also a community that otherwise wouldn’t have come together in this way.”

There is another great merit to the HBP: it has made a decisive contribution to bringing supercomputing and neuroscience together, thus creating new technical prerequisites for a better understanding of the brain. This was also an important impetus for the establishment of the European supercomputing network FENIX, which offers a range of data and computing services and is the IT base of EBRAINS. “These are developments that have been driven forward by us neuroscientists in particular. We are proud to have provided the impetus,” the scientist sums up.

In fact, FENIX is supposed to enable brain researchers to use the new Jülich exascale computer. Together with JSC director Thomas Lippert, Amunts had already pointed out in a Science paper a year ago that brain research would need this computing power.

Giving stimulus and breaking new ground, but also dealing constructively with criticism – this belongs to everyday scientific life for Katrin Amunts: “Anyone who doesn’t take criticism seriously is going down the wrong path.” This is why Amunts attaches great importance to regularly taking a step back and looking at a problem from a different perspective. The exchange with her team is indispensable in this, be it at Jülich, Düsseldorf or internationally at the HBP.

As the first author of a so-called living paper – an open and public paper in which not only her own team but the entire brain research community can participate – Amunts has taken a completely new approach to the exchange of ideas. “We were deliberating the upcoming challenges in brain research in the HBP and wanted to discuss this question not only within the HBP, but internationally. That’s when the idea of the living paper came up,” says Amunts.

Since March 2022, researchers worldwide have been invited to add to or comment on the position paper published on the open access platform Zenodo. “Everyone can read it, everyone can say what might be missing,” says Amunts. The feedback is sometimes only a few lines long and sometimes five pages. The original number of authors has grown from about a dozen to over 70. Amunt’s conclusion so far: “The living paper is an open process – discussions included. This is not always easy, but in our view, it’s the right way to generate openness and transparency in order to set the course for brain research in the coming decade.”

KATJA LÜERS

↑ Excellent brain research needs the exchange of ideas – Katrin Amunts, scientific director of the European Human Brain Project, is convinced of this.

Parkinson's puzzle piece found

Parkinson's disease starts in the brain, barely noticed, and gradually affects the whole body. In a long-term study, researchers have found patterns of how the disease changes regional brain volume over the years.

Parkinson's disease is a neurodegenerative disorder in which nerve cells are damaged in certain regions of the brain for unknown reasons. "Research on Parkinson's disease is like a giant jigsaw puzzle, with each study providing a new piece. Hopefully one day we'll be able to put the pieces together to cure or prevent the disease," says Dr. Peter Pieperhoff from the Institute of Neurosciences and Medicine (INM-1). Together with colleagues from Jülich, Heinrich Heine University Düsseldorf and the Ernst von Bergmann Hospital in Potsdam, he added another piece to the puzzle: they detected a specific regional pattern of volume changes in the brains of Parkinson's patients. The scientists could also provide evidence of a link between the decrease in brain volume in certain areas and the progression of the symptoms typical of Parkinson's disease.

For their study, the researchers examined a total of 37 Parkinson's disease patients and 27 healthy people since 2005. Using magnetic resonance imaging, their brain volumes were determined at up to 15 different time points over a period of up to almost nine years. "Previous studies only examined the volumes either at fewer points in time or over shorter periods," explains Pieperhoff. The researchers calculated the regional changes in brain structure using neuroanatomical atlases such as the Julich Brain Atlas. "In the end, we were able to identify a very specific pattern of volume changes in the patients. Over time, this pattern became increasingly different from that of the healthy ageing subjects," Pieperhoff reports.

At the same time, the results confirmed a study by the neuropathologist Prof. Heiko Braak from 2003. He had examined the brains of deceased Parkinson's disease patients under the microscope and used the data to divide the course of the disease into six stages. "There's a striking correspondence between the two studies," says Pieperhoff. The researchers now plan to apply the methods they have developed to larger groups of patients – in the hope of finding the next piece of the puzzle.

KATJA LÜERS

↑ Peter Pieperhoff researches neurodegenerative diseases such as Alzheimer's and Parkinson's.

↑

What are you researching right now, Mr Islam?

Muhammad Islam, doctoral researcher at the Institute of Bio- and Geosciences (IBG-3)

"I am investigating whether wine-growing regions – or more precisely, their soils – are suitable for slowing down climate change. Soils are the Earth's second largest carbon reservoir. If we incorporate additional carbon into the soil in the form of compost or other organic substrates, it could be bound there in the long term, thus reducing the CO_2 concentration in the atmosphere. Soils of vineyards are potentially suitable because they are not repeatedly tilled in greater depths. In this way, the carbon can remain undisturbed in the soil."

More on Muhammad Islam's research in the VitiSoil project: go.fzj.de/CO2-in-vineyard-soils

From the quantum world

They laid the foundations for new quantum technologies with their groundbreaking experiments, for which they will receive the Nobel Prize in Physics in 2022: quantum researchers Prof. Alain Aspect, Prof. John Clauser and Prof. Anton Zeilinger. The question now is to make use of the possibilities of the quantum world, for example the quantum computer. Jülich scientists have found various approaches to getting closer to powerful quantum computers that solve real-world problems.

A decisive puzzle piece for the leap toward millions of qubits

Millions of quantum bits are required for quantum computers to prove useful in practical applications. Scaling current prototypes with few computing units to millions of qubits, however, has been a problem so far. On the one hand, the qubits on a chip need to be close together in order to couple them. On the other hand, they have to pull apart to make room for the necessary control and measuring electronics. This is because, for space reasons, integrated electronics are very advantageous in building computers with millions of qubits. Researchers at Forschungszentrum Jülich and RWTH Aachen University have come a significant step closer to finding a solution to these two conflicting requirements. They succeeded in transporting electrons – the carriers of quantum information – over several micrometres on one semiconductor quantum chip. Their "quantum bus" could be the crucial piece of the puzzle to increase the possible distance between qubits and thus master the leap to millions of qubits.

Read more at:
go.fzj.de/effzett-quantum-bus-EN

Shrunk to the size of a tabletop device: cooling system (dilution refrigerator) for the development and future operation of quantum computers at the JARA Institute for Quantum Information. →

First hybrid quantum bit based on topological insulators

With their superior properties, topological qubits could help achieve a breakthrough in the development of a quantum computer designed for universal applications. So far, no one has yet succeeded in realizing a quantum bit, or qubit for short, of this kind in a lab. However, scientists from Forschungszentrum Jülich have now gained some headway in making this a reality. For the first time, they succeeded in integrating a topological insulator into a conventional superconducting qubit – an important step on the way towards building a topological qubit.

Read more at:
go.fzj.de/effzett-hybrid-qubit-EN

QUANTUM COMPUTING

It all comes down to balance

Quantum computer chips need just the right mix of order and disorder. This is what researchers in the Cluster of Excellence “Matter and Light for Quantum Computing” (ML4Q) have discovered. Jülich scientists are involved in the cluster. Too much order has a similar effect on the chips as a crowd marching in step on a bridge: vibrations build up that destabilize the construction. In chips, couplings between qubit states trigger oscillations, which destroys the quantum information. It is therefore important to specifically plan for qubit-to-qubit imperfections as early as the chip design stage.

Read more (in German) at:
go.fzj.de/unordnung-quantenchips

100

qubits …

… at the least has the quantum simulator that will be integrated with the JUWELS supercomputer at Forschungszentrum Jülich. It is one of two quantum simulators from the French start-up company PASQAL that are being connected to a supercomputer in the EU project “High-Performance Computer and Quantum Simulator hybrid” (HPCQS). The second simulator will be linked to the French supercomputer JOLIOT-CURIE. Hybrid computers of this kind are considered a milestone for using quantum computers for practical applications.

More about Jülich quantum research:
go.fzj.de/quantum-research

Breakthroughs in error correction

Quantum computers are significantly more susceptible to perturbations than conventional computers, and so as well to computational errors. The correction of these is an essential hurdle to the breakthrough of quantum computers. In international teams, Jülich researchers led by Prof. Markus Müller from the Peter Grünberg Institute (PGI-2/IAS-3) and RWTH Aachen University have developed two promising solutions.

Prof. Müller, what are these solutions?
Firstly, an international team has presented a method on a superconducting quantum computer chip that automatically compensates for errors while storing quantum information. What's special about this: the technique, which was implemented by the team led by Prof. Andreas Wallraff of ETH Zurich, detects and corrects both basic types of error, the bit flip and the phase error. Previous procedures were not able to do so.

This procedure was described as a milestone. Why?
Thanks to this technique, we can be sure that the results of our quantum calculations are correct, meaning that they can effectively be used in practice. The experiments at ETH Zurich are impressive and confirm how great the potential of quantum error correction techniques is.

How does the method work?
The quantum information of a qubit is actually lost when you read it out – which is also the case when you want to check whether an error has occurred. However, the method doesn't use individual qubits, but several together. A chip with 17 superconducting qubits was developed for this purpose. Nine qubits form what's called a logical qubit, that is, the unit with which an error-corrected quantum computer calculates. The remaining eight qubits detect errors without disturbing the information stored in the logical qubit by the readout process. To do this, they are measured repeatedly and quickly. This measurement information allows one to deduce which errors most likely occurred and and where they occurred on the chip. The effects of the detected errors can then be corrected.

What part did you have in the development?
My team contributed characterization techniques we had previously explored in our group, in our group, to assess the quality of the logical qubit. Our techniques also made it possible to distinguish and evaluate the nature of errors that may occasionally occur despite the high quality of the experiment.

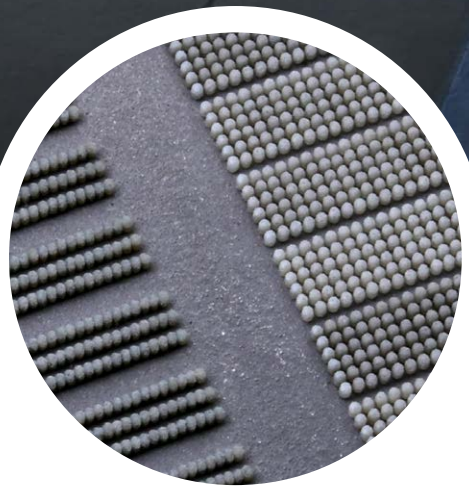
What is the other solution?
It identifies errors already during the calculations of the quantum computer. Together with colleagues from the University of Innsbruck, we have shown how an algorithm can be programmed on a quantum computer in such a way that any quantum errors that occur don't falsify the result of the calculations – which means error-tolerant quantum computing. For this purpose and for the first time, we have realized a universal set of computational operations on two logical quantum bits of an ion trap quantum computer. Any desired quantum algorithms can be constructed from these operations – an important step towards making error-corrected quantum computers freely programmable and usable for a wide variety of practical problems.

INTERVIEW CONDUCTED BY TOBIAS SCHLÖSSER

You can find the complete interview at:
go.fzj.de/effzett-quantum-error-correction

Faster repair for turbines

With little effort, a new laser method creates protective ceramic structures.



↑ Sample with microcolumns

They can take a lot: thin ceramic layers protect components in aircraft turbines or power plants from the hot temperatures of around 1,500 degrees Celsius at which paraffin or natural gas is burnt. After thousands of hours of operation, however, ageing processes can damage the coatings. Repairs are complex and expensive. In the future, with a new method from Jülich, small damages could be repaired easily and quickly.

The method developed by Dr. Christoph Vorkötter, Dr. Daniel Emil Mack and Martin Tandler from the Institute of Energy and Climate Research (IEK-1) uses a laser-cladding-based additive manufacturing technique. "We use an argon gas jet to blow ceramic powder onto a sample and melt the powder with a laser beam," Vorkötter explains. In the process, the laser beam and the powder feed move away from the sample surface at a speed of five millimetres per second. In this way, microcolumns a few millimetres in size form in a close pattern. "Column structures like these remain stable even at high temperatures and can withstand frequent temperature changes, such as those that occur in gas turbines. We can produce the columns in different dimensions and arrange them flexibly," says Vorkötter.

Unlike other coating methods for ceramics, the new method does not require a vacuum. Due to its low energy demand, it could also be applied directly at the site of a gas turbine. The researchers have already filed a patent application for it and are now looking for partners from industry.

TOBIAS SCHLÖSSER

KNOWING-IT-ALL

SYNAPSE

A synapse is the place where a nerve cell is in contact with another cell. Its task: to forward signals.

HOW IT WORKS

A signal travels along the finely branched extensions of the cell to the synapse as an electrical impulse. It can be passed on to the neighbouring cell there.

However, a tiny gap must be bridged. This job is taken on by molecules called neurotransmitters. Released by the electrical signal, they migrate to the neighboring cell.

The neurotransmitters dock there. This generates an electrical signal.

A cell has an average of

1,000 TO 100,000

synapses.

There are about

100 TRILLION

synapses in the adult brain.

LEARNING...

... does not work without synapses: exercise improves the transmission of signals and can also lead to the formation of more synapses between two cells.

JÜLICH RESEARCHERS

... are investigating the structure and function of synapses in the brain. They are also developing artificial synapses for computers modelled on the brain.

THUMBS UP

CHILDREN'S FILM ON PHOTOVOLTAICS

Fox and hare make you smart

When the two photovoltaics researchers Nelli Hambach and Florian Seidler were looking for a way to present their work to young visitors at Forschungszentrum Jülich's Open Day, it quickly became clear: the two needed to pool their talents. The result is a children's film for which the passionate watercolourist Hambach drew the pictures and amateur singer Seidler wrote and recorded the story. The result was so well received that there are now plans to publish the film as a children's book.

– GO.FZJ.DE/KINDERFILM (IN GERMAN) –

AWARD-WINNING INSTAGRAM CHANNEL

Climate policy short and sweet

What does the climate crisis have to do with me? How important is nuclear power? Which politicians do not do their (climate) homework? WDR's Instagram channel Klima.neutral addresses pressing issues of the climate crisis in varying themed weeks. The motto "explaining simply, but diversely and along with the stories" does not just appeal to us: the entertaining content also won over the jury of the K3 Prize for Climate Communication. Klima.neutral came second in the Swiss competition.

– INSTAGRAM.COM/KLIMA.NEUTRAL –

AI MODIFIES IMAGES

Choose a style

How would you look if a famous artist like Edvard Munch or Marc Chagall had painted you? Thanks to artificial intelligence (AI), you can try it out: upload a photo to the Jülich Supercomputing Centre (JSC) website and the AI technique "Neural Style Transfer" will take over. The intelligent algorithms modify the picture in such a way that the style of another picture is imitated. Different works by well-known artists are available to choose from. The complex calculation is carried out by an artificial neural network running on computers at the Supercomputing Centre.

– STYLR.FZ-JUELICH.DE –

RESEARCH IN A TWEET

Double award! The development of the malaria sensor was awarded the Innovation Prize of the State of North Rhine-Westphalia and the Umbrella Award.

The new biosensor can detect malaria using a small blood sample. It even reveals the amount of the pathogen. It was developed by Jülich researcher Dr. Gabriela Figueroa Miranda and her team. She and her colleague Dr. Viviana Rincón Montes have applied for a patent for the sensor and are planning a start-up.

After the Future Prize, the NRW Innovation Award is the most highly endowed award of its kind in Germany. The German-Israeli Umbrella Cooperation awards prizes to outstanding young researchers every year.

effzett.fz-juelich.de/en/3-21/a-start-up-for-malaria-testing

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Shaping Change