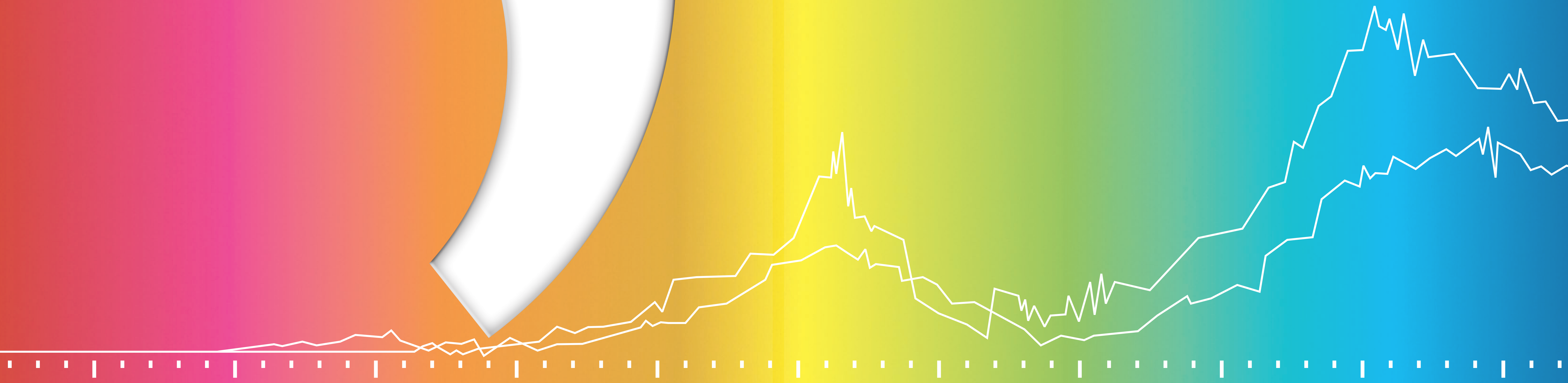
HZB Helmholtz Zentrum Berlin

ENERGY IS OUR MATTER

ENERGY
IS OUR MATTER.
RESEARCH
IS OUR FUTURE.

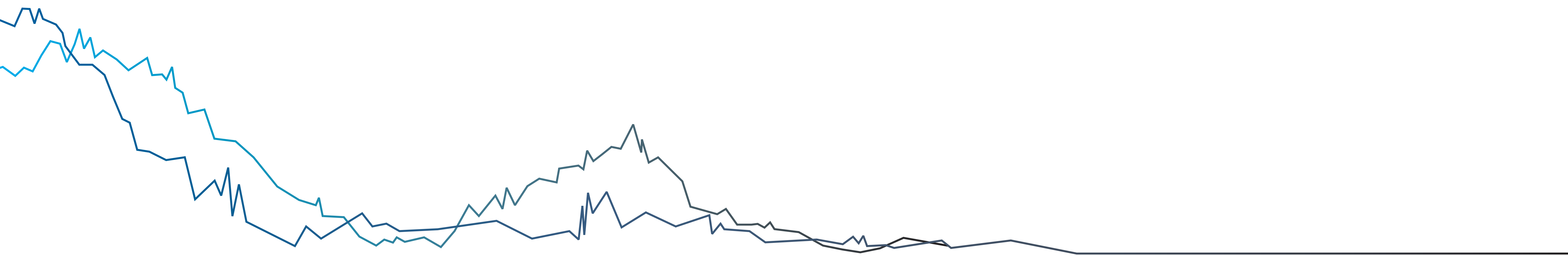


VISION

HZB is a world-class research centre for energy materials research, thus contributing to knowledge-based solutions to great societal challenges.

HZB provides world-class large-scale research infrastructure for the national as well as international scientific community and industry.

HZB exploits synergies by integrating excellent research with the operation of dedicated infrastructures, thus creating a unique research environment.



RESEARCH FOR SUSTAINABLE ENERGY

THE SOLUTIONS WE NEED FOR THE ENERGY TRANSITION ARE NOT IN THE STARS, THEY ARE IN OUR OWN HANDS

A secure and sustainable supply of energy is one of the greatest challenges for society. The mission of the HZB is to understand, improve, and develop new energy materials. We are able to bring the most modern infrastructure and instruments to bear on this research, in particular with the BESSY II electron storage ring, which is a particle accelerator that delivers synchrotron radiation in the soft X-ray and VUV regions.

We work together with specialists in energy materials research and accelerator development from the world over. About 2,000 scientists annually from research institutions throughout the world come as guest researchers to conduct their experiments at the BESSY II electron storage ring, with many of them making return visits. Our CoreLabs as well as instrument time on the BER II neutron source can also be booked by external scientists.

CUTTING-EDGE RESEARCH AT LARGE-SCALE FACILITIES AND IN LABORATORIES

You will find powerful large-scale facilities and laboratories at the Helmholtz-Zentrum Berlin that offer modern methods of analysis and synthesis. We invite scientists from the world over to utilise these instruments and to develop them further through a continuous exchange of ideas.

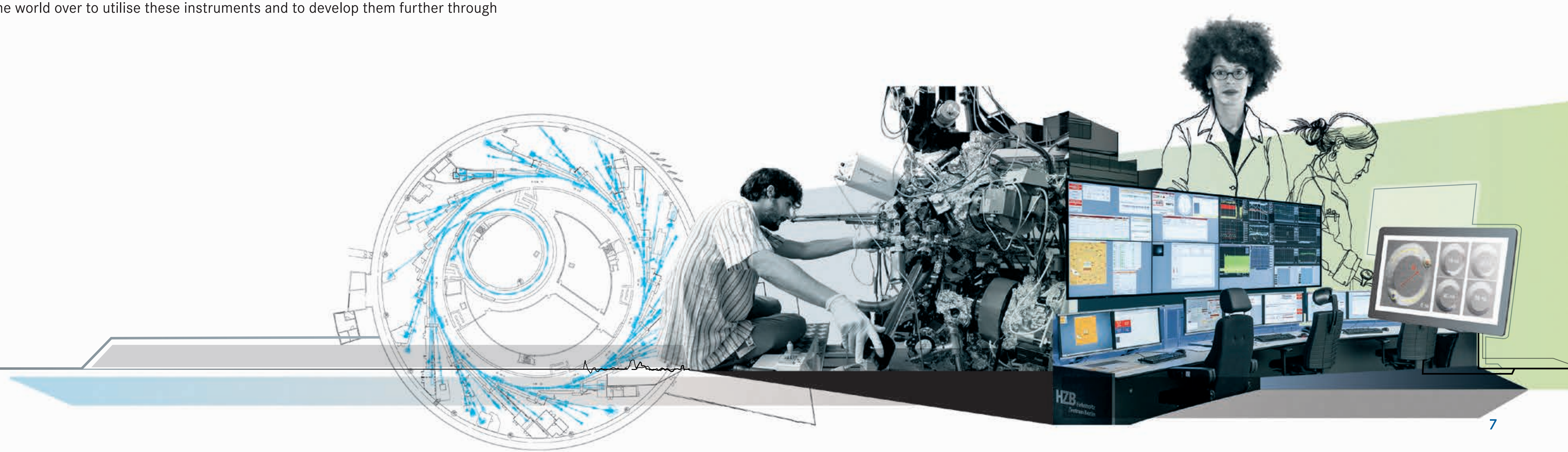
THE BESSY II LIGHT SOURCE

BESSY II is a powerful 3rd-generation synchrotron radiation source. The facilities are especially intended for experiments with soft X-rays and vacuum ultraviolet (VUV) radiation. At the heart of BESSY II is a particle accelerator that accelerates the electrons to nearly the speed of light. The electrons are injected into the storage ring and pass through electromagnetic fields there. These induce the electrons to emit brilliant pulses of light. The light is guided through 50 beamlines to the measurement equipment. There, the researchers can illuminate their samples.

Scientists of the HZB also utilise the instruments at BESSY II. They are involved in the study of energy materials, particularly in the form of thin-films. These can be investigated especially well using the soft X-rays from BESSY II. This wavelength region is ideally suited for analysing many chemical and electronic processes that occur at surfaces and boundary regions of energy materials. These insights are helpful in order to develop materials having specific properties.

SERVICE FOR THE SCIENCES: OUR USER SERVICE

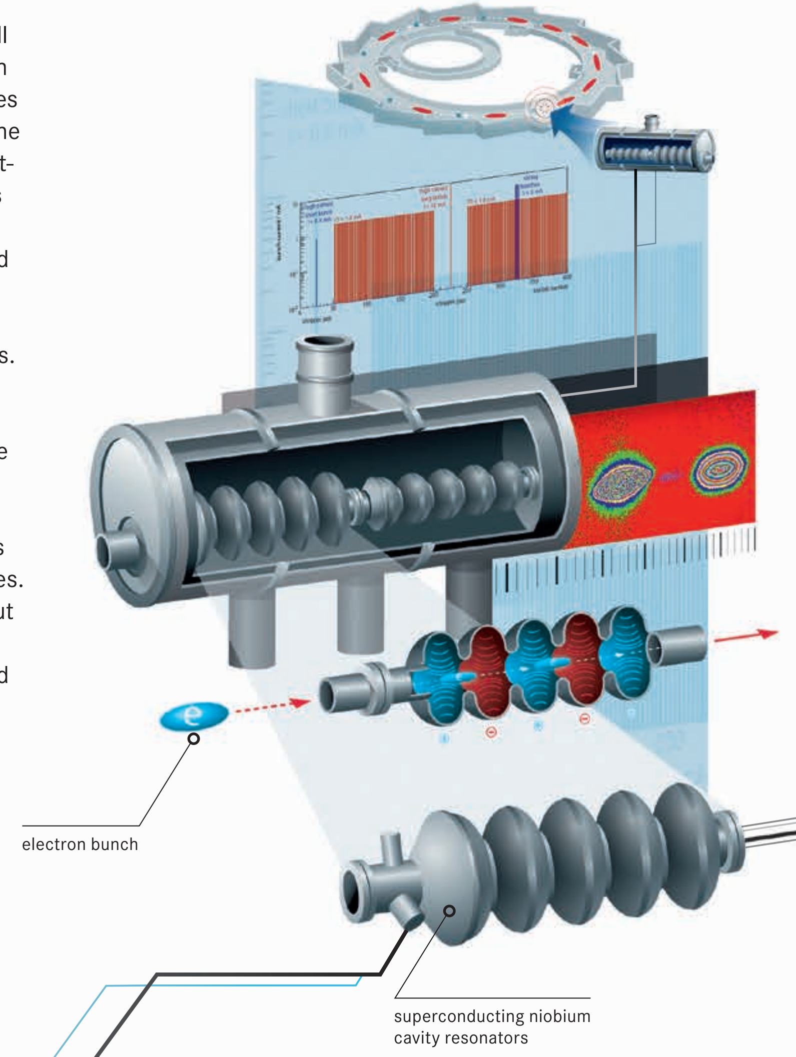
2,000 visiting scientists come to Berlin from the world over each year to investigate their samples using BESSY II. The researchers must apply for instrument time. An international review committee evaluates the applications for their scientific merit, as the available time on BESSY II is limited. Only the best applications are approved. The researchers may then study their samples at BESSY II free of charge. HZB beamline scientists offer technical support during user experiments.



NEW FLEXIBILITY: UPGRADING TO A VARIABLE PULSE-LENGTH STORAGE RING

The HZB will be enhancing BESSY II to become a variable pulse-length storage ring (BESSY-VSR). The light source will become even more attractive for energy materials research through this upgrade. BESSY II thus far has offered light pulses as short as 17 picoseconds (1 picosecond corresponds to one billionth of a millisecond). That is still too long for investigating several kinds of problems. For that reason, researchers **at every individual beamline** and **for every experiment** will be able to choose between longer (15 picoseconds) and shorter (1.5 picoseconds) light pulses – and do so **without any loss of light intensity**. BESSY-VSR will thereby fill the gap between existing storage rings and free-electron lasers.

BESSY-VSR will make new kinds of experiments on energy materials feasible. Researchers will then be able to observe how the electronic structure of a catalyst changes during a chemical reaction. In addition, it will be possible to investigate quantum effects and analyse fast switching processes in new kinds of materials for future information technologies. The fundamental principle of BESSY-VSR sounds simple, but the implementation is very challenging. Experts at the HZB are collaborating with accelerator centres all over the world to realise this design.



LINEAR ACCELERATOR WITH ENERGY RECOVERY, AND THE PATH TO BESSY III

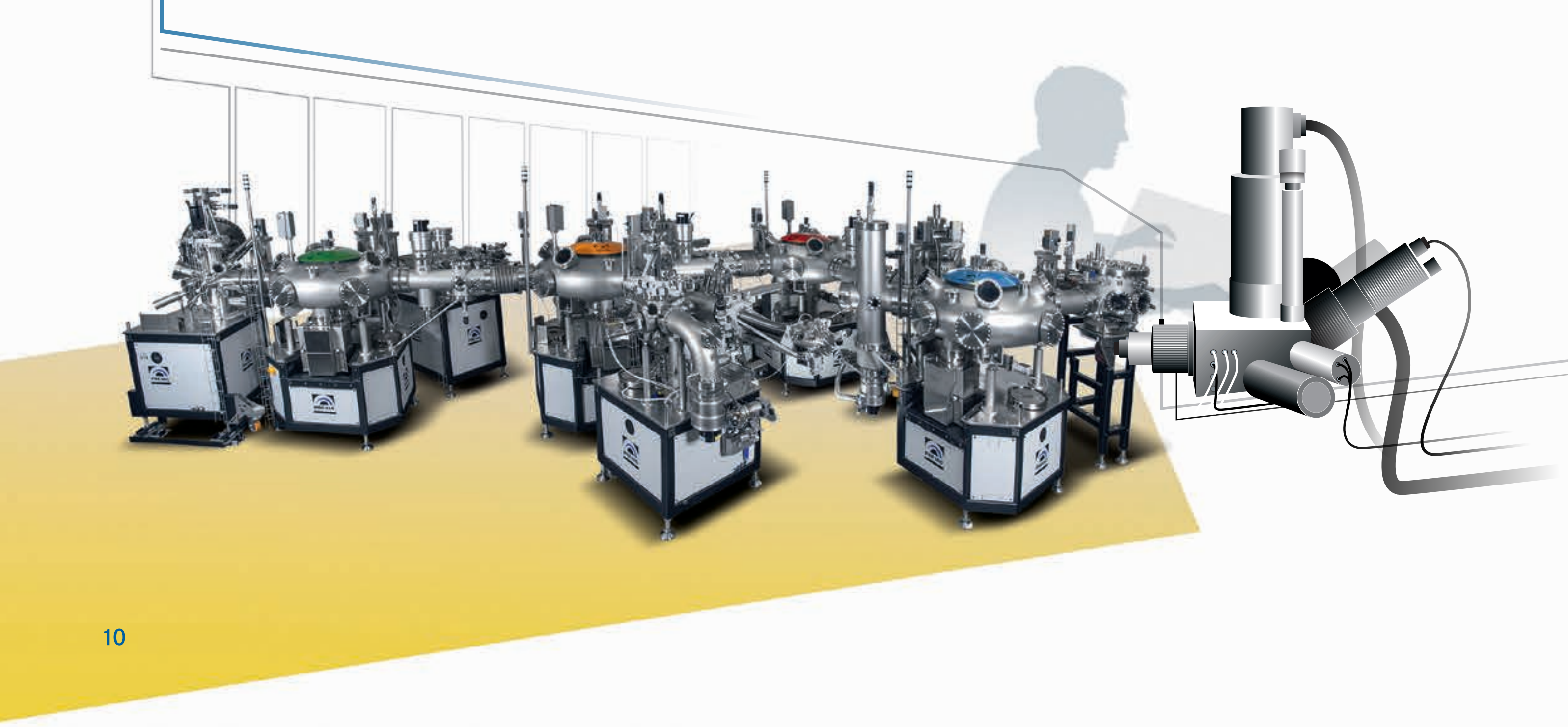
bERLinPro is an advanced project in which HZB experts are testing out a new design for an accelerator that recovers much of the energy it expends. To achieve this, they are developing novel superconducting RF cavity resonators for example, in order to control the energy and the configuration of the electron bunches. These cavity resonators are dual-mission, because they are also required for upgrading to BESSY-VSR. With bERLinPro, we systematically gain experience in the development of accelerator components for photon sources. This experience will be needed to develop and test new ideas for the successor, BESSY III.

CORELABS FOR SYNTHESIS AND CHARACTERISATION OF ENERGY MATERIALS

There is no one universal method that leads to success – and this applies especially to materials research. Researchers at the HZB combine many analytical processes to obtain as much information as possible from a material sample. It is for this reason that the HZB has set up several CoreLabs to supplement BESSY II. These are large centralised laboratories with state-of-the-art instruments and equipment, permitting energy materials to be fabricated, analysed, and further developed. This high-tech equipment complex is also of interest to users from industry and for university-based research.

Synopsis of some CoreLabs

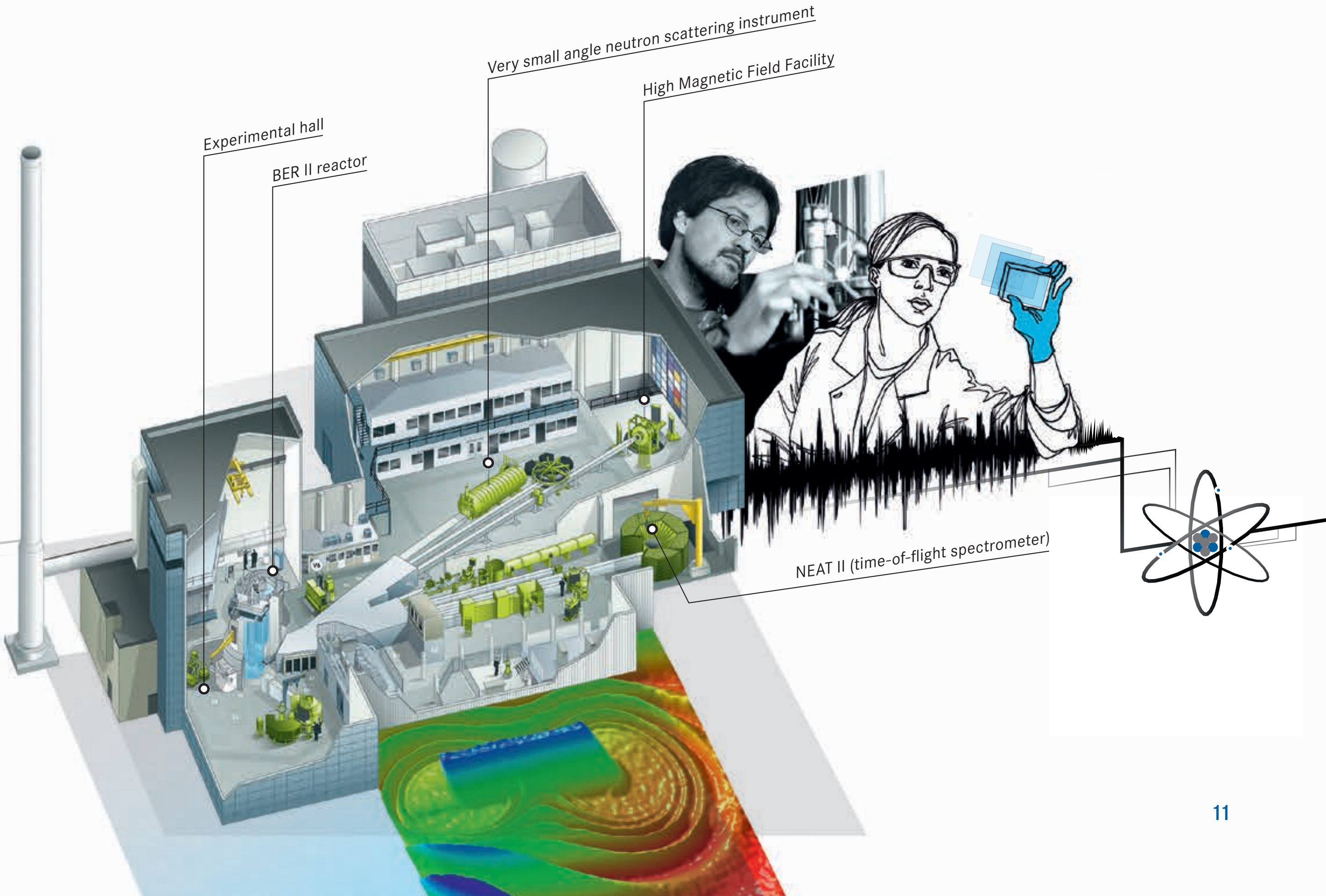
The **Energy Materials In-Situ Laboratory Berlin (EMIL)** directly adjoins the BESSY II synchrotron radiation source and enables insights into thin-film materials to be obtained during their actual fabrication processes. Modern X-ray diffractometers are available in the **X-Ray CoreLab** for crystallography analyses. The **Correlative Microscopy and Spectroscopy CoreLab (CCMS)** is being operated in collaboration with ZEISS company. Researchers are able to fabricate and image nanomaterials using the very newest electron and ion microscopes. The development of hybrid solar cells and systems for solar fuel generation will be the task of the **HySPRINT CoreLab**. The **Competence Centre for Thin-film and Nanotechnology Berlin (PVcomB)** is the primary external resource for industrial companies to conduct joint R&D projects in photovoltaics and in the area of solar fuel technologies.



THE BER II NEUTRON SOURCE

The HZB will continue operating the BER II research reactor until the end of 2019. It provides neutrons for addressing many scientific problems. Samples can be analysed under the influence of extremely strong magnetic fields and high pressures, or at cryogenic temperatures, which particularly facilitates observation of quantum effects. Ten instruments at BER II will continue to be available to users up to the end of 2019; thereafter, operations will be discontinued. Planning for decommissioning and dismantling has already begun.

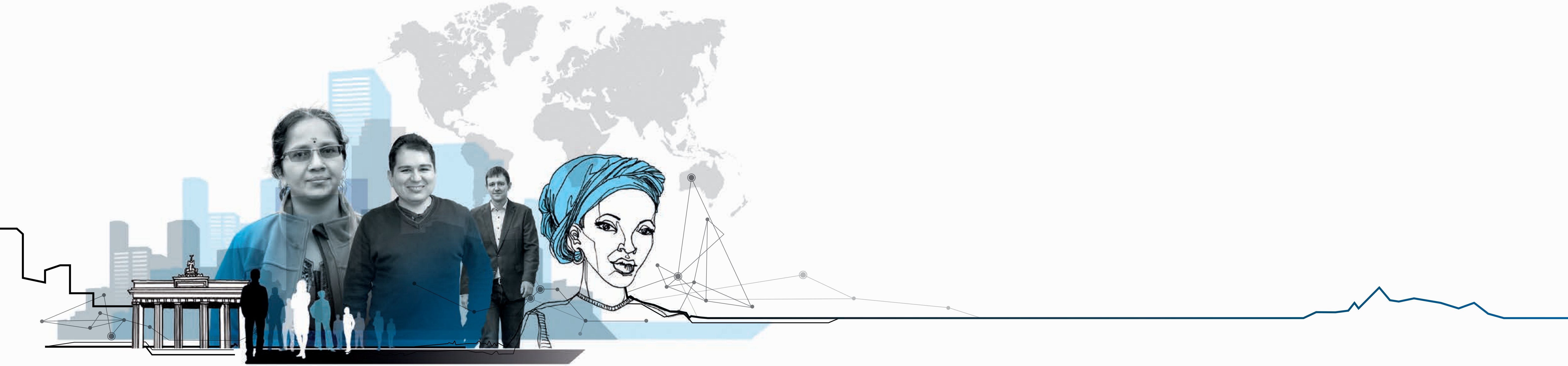
The Lise Meitner Campus at the HZB Wannsee site will be developed further. The HZB is making a large investment in the expansion of the infrastructure at the Wannsee site for energy materials research. The site will accommodate several CoreLabs for synthesising energy materials, including construction of a new laboratory building for research on efficient information technologies for the future.



RESEARCH COLLABORATIONS: FROM NATIONAL TO INTERNATIONAL

The HZB collaborates with many research institutions – regionally, nationally, as well as internationally. Being locally anchored in the Berlin-Brandenburg region is very important to us. This is because the concentration of excellent institutions for the sciences and for teaching in Berlin and Brandenburg offers the most direct connections and synergies. It is for this reason that we have developed several forms of cooperation with regional teaching and research institutions, including joint research laboratories (Joint Labs), research teams, projects, and Young Investigator Groups. Many HZB scientists are engaged in teaching at universities.

The Helmholtz-Zentrum Berlin is part of the largest research organisation in Germany, the Helmholtz Association. We coordinate our research programme with other Helmholtz Centres, focussing our resources primarily on energy materials and accelerator development.
Researchers from the HZB participate as well in large EU projects, such as achieving a technological breakthrough in the generation of solar fuels. There are also many fruitful collaborative projects with non-European institutions, such as with the Thomas Jefferson National Accelerator Facility in the USA or ANSTO in Australia.



ENERGY MATERIALS FOR THE FUTURE

By the term **energy materials**, we mean systems of materials that convert or store energy, or enable energy-efficient switching processes in future information technologies. We are focussing our research on thin-films and thin-film technologies. A synopsis of our most important research topics:

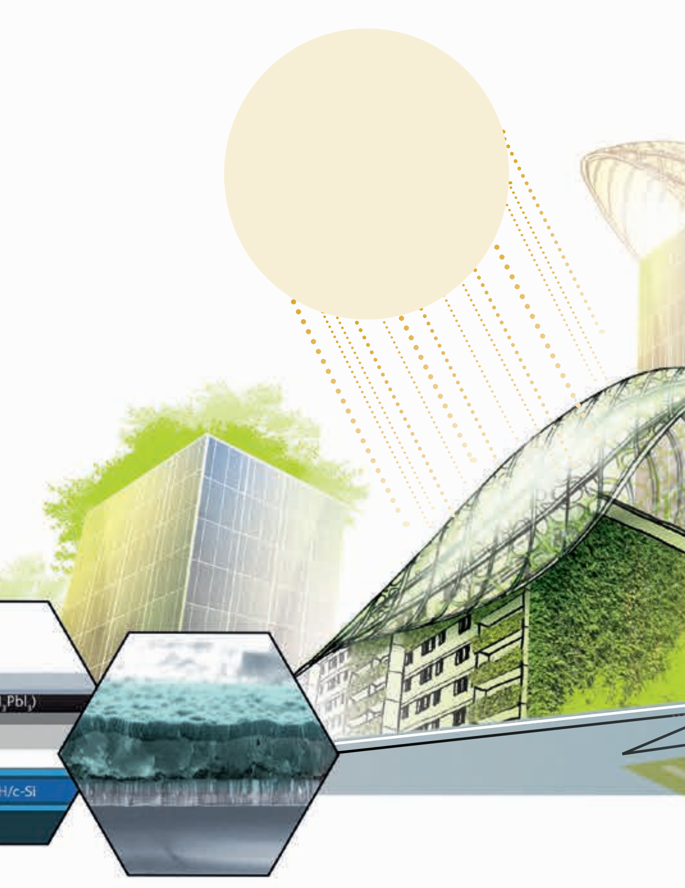
OUR MOST PRODUCTIVE EMPLOYEE ARRIVES IN THE LAB AT THE SPEED OF LIGHT

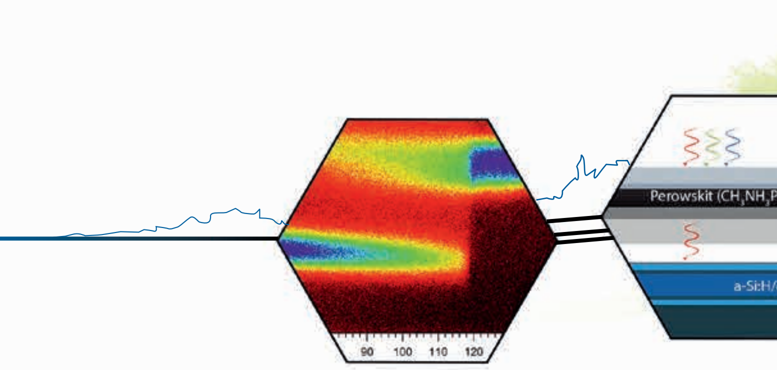
SOLAR CELLS: ELECTRICAL POWER FROM SUNLIGHT

Solar cells convert sunlight to electrical energy. The solar power generated in Germany on sunny days meets almost half of the total power demand in the country. Solar panels made of crystalline silicon cells are widely available in the market. They offer high levels of efficiency, but the manufacturing costs cannot be easily reduced any further. To expand the use of solar energy further, new technologies are therefore needed. For this reason, researchers at the HZB are developing combinations of materials that offer the prospect of being less expensive.

We are concentrating on **thin-film solar cells made of various systems of materials**. The extremely thin layers require less material and energy for their fabrication. We are conducting advanced development on **silicon thin-film cells**, while investigating cells made of combinations of materials such as copper, indium, gallium, sulphur, and selenium **(CIGS cells)**, those of copper, zinc, tin, and sulphur **(kesterite)**, and solar cells made of **perovskites**, a new organic material. The combination of various materials is especially promising. **Tandem solar cells** of **silicon** and **perovskites** can utilise a wider portion of the solar spectrum than silicon solar cells alone, for example.

However, thin-film solar cells have not yet achieved the efficiency levels that are theoretically possible. The cause: many electrons are lost through various layers of material or at boundary layers. Using the soft X-rays of BESSY II, researchers can analyse exactly why these losses occur. This helps to further improve the solar cells.





OUR GREATEST INSPIRATION IS NATURE ITSELF

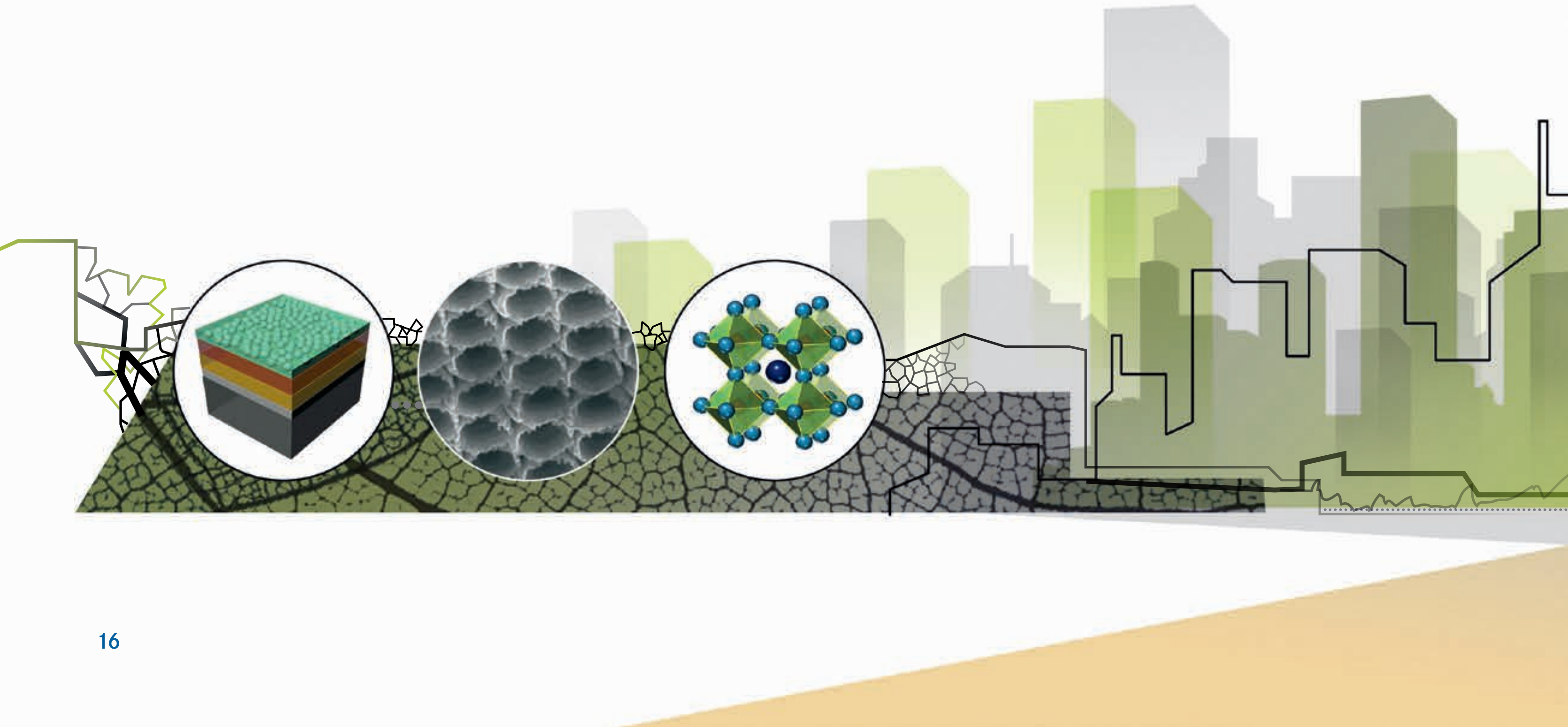
SOLAR FUELS

Solar energy is not available 24/7. However, it can be stored – through a process that also takes place in green plants. Light is able to split water molecules, producing oxygen and hydrogen. This hydrogen gas can be stored or transported. It can be fed into the natural-gas distribution network, or processed to produce methane. Motor vehicles can be operated on hydrogen. And last but not least, fuel cells can produce pollution-free electrical power using hydrogen.

To produce solar hydrogen, we combine semiconducting layers with photoelectrodes and catalysts to produce an **artificial leaf**. These systems of materials are not stable and effective enough to be deployed yet. Several research groups at the HZB are working to change that. They are developing electrodes and catalysts from economical metal-oxide compounds, for example.

CONVERSION OF CARBON DIOXIDE INTO CHEMICAL FEEDSTOCK

Reducing the emission of carbon dioxide (CO_2) that drives climate change is an enormous challenge for society. One idea of how to do this is to use renewable energy to electrochemically convert water and carbon dioxide (such as from power stations). This produces hydrocarbons like methane, methanol, and ethylene – important raw materials for the chemical industry. Fundamental research is still needed to improve the energy efficiency, reaction speed, and yield of the CO_2 catalysis. The HZB will be expanding its efforts on this research priority in the coming years.



OUR GOAL: PROCESS BIG DATA WITH LITTLE ENERGY

MATERIALS FOR ENERGY-EFFICIENT INFORMATION TECHNOLOGIES

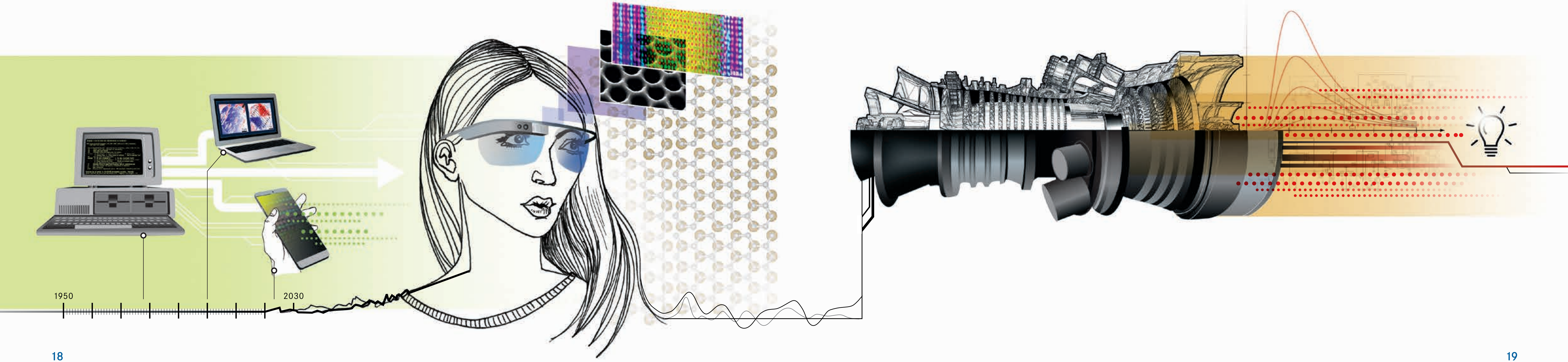
Microchips are everywhere – in smartphones, household appliances, and server farms. Information and communications technologies already represent more than ten per cent of total power consumption, and are increasing. The keystone of these devices is the microchip – densely packed, microchips require a lot of power. Heat develops and the systems must be elaborately cooled. Only one third of the energy used by computing centres is for information processing, while two third of the energy is utilised for cooling the servers.

This should change in the future. The HZB is researching classes of materials that might use considerably less energy to process data. These include **topological insulators**, carbon-based materials like **graphene**, and thin-film systems made of **functional metal oxides**.
The magnetic moments (spins) of the electrons play a crucial role in these classes of materials. The electrons themselves do not need to move. As a result, less energy is required and hardly any waste heat develops. This technology is labelled “spintronics” – parallel to the term “electronics”.

HOT NEW MATERIALS FOR ELECTRICAL POWER

THERMOELECTRICS

An additional interesting class of energy materials is named **thermoelectrics**. These materials convert heat into electrical energy. They can be employed to utilise the waste heat from motors or expelled by industry, or even use body heat, such as for operating pacemakers, watches, and smartphones, for example. Until now, thermoelectrics have not been efficient enough and are hardly used. Staff members at the HZB are dedicating their expertise in materials research to investigating and understanding the physical processes in thermoelectric materials. Theoretical simulations are providing a promising means of discovering interesting combinations of materials. We are developing novel thermoelectrics on this basis that convert heat into electrical power more efficiently by means of nanostructures and periodic distortions of crystal lattices, for example.



THE PEOPLE AT THE HELMHOLTZ-ZENTRUM BERLIN

STARTING YOUR CAREER AT THE HZB

JUNIOR SCIENTISTS

We train experts – not just for an academic career but for the economy as well, both of which depend on highly qualified specialists. Over one hundred doctoral students are conducting research at the HZB, with more than a third from abroad. In order to offer them the best academic advising, we collaborate with the general and technical universities in Berlin and Brandenburg, and offer places in several graduate schools. Our doctoral students take part in international conferences and scientific symposiums, and receive support for specific advanced training.

There are good career prospects at the HZB after completion of doctoral studies as well. Postdocs from Germany and abroad take on responsible assignments in research, they network internationally, and can advance their scientific careers. A post-doc initiative helps them get oriented in Berlin and at the HZB. In addition, the HZB supports Young Investigator Groups, whose heads are also appointed as junior professors.

VOCATIONAL TRAINING

We train young people in nine different vocations at the HZB and offer places in three work/study curricula where theory dovetails closely with practical application. We enable many young people each year to make a successful start in their careers.

EQUAL OPPORTUNITY, FAMILY-FRIENDLY POLICIES, AND CAREER DEVELOPMENT

The HZB wishes to facilitate equal opportunity for women and men, and has considerably raised the proportion of women in leadership positions during the last several years. Staff members with children are welcome at the HZB. We also support our staff members when they need to care for family members at home. We offer various solutions for harmonising family responsibilities with work. These include flexible working hours, family-friendly meeting schedules, the option of working from home, and mobile work. The HZB has been certified under the "berufundfamilie" programme (career and family) of the non-profit Hertie Foundation since 2011.

The HZB explicitly supports staff members in obtaining advanced training and expanding their expertise in technological, methodological, and communication skills. Our staff members work together with people from many nationalities and different cultures to enrich life at the HZB.

FACTS & FIGURES

Helmholtz-Zentrum Berlin für Materialien und Energie – a Research Centre of the Helmholtz Association

The HZB was founded in 2009 through the merger of the Hahn Meitner Institute and the Berlin Electron Storage Ring Association for Synchrotron Radiation

Sites:
Berlin/Wannsee and Berlin/Adlershof

BERLIN

Employees:
Approx. 1,200 staff members, of which 600 are in Berlin/Wannsee and 600 in Berlin/Adlershof. One third of the staff members are scientists.

Visiting researchers:
Approx. 3,000 user visits from approx. 30 countries annually

Budget:
Approx. 146 million EUR annually
Funding:
90 per cent from the German federal government (German Federal Ministry for Education and Research/BMBF) and 10 per cent from the State of Berlin

Collaborations:
230 research collaborations and 120 collaborations with industry

More information:
www.helmholtz-berlin.de/zentrum

WWW

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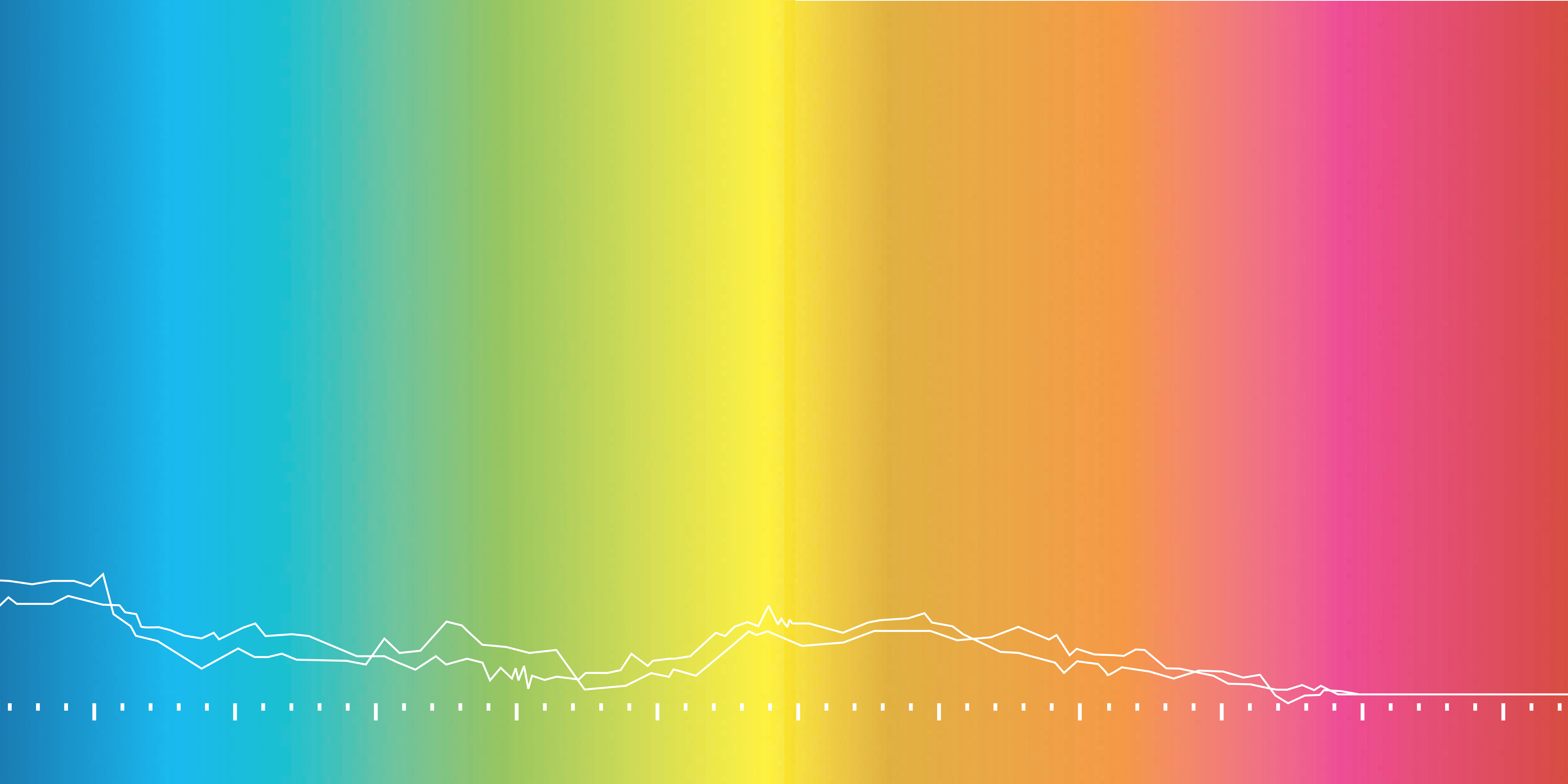

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