Federal Report on Research and Innovation 2024

Short version

Federal Ministry
of Education
and Research

Foreword

Dear reader,

If you follow our federal reports, you will know that geopolitics affects research and innovation in many ways. The 2022 report marked a historic turning point following the Russian war of aggression against Ukraine. Meanwhile, the escalating conflict in the Middle East also affects both our society and our research system. We can sense that fundamental system rivalries are intensifying. We are continually called upon to take a stand – from supporting Ukraine to taking a clear stance against antisemitism to a new discussion about the traditionally strict separation of military and civilian research in Germany.

The Federal Government's innovation policy addresses such issues and promotes intensive cooperation with the Länder and scientific institutions, particularly on strategic aspects. Together, we are tackling complex issues such as dealing with hybrid threats, establishing technological sovereignty and enhancing social resilience. Given the many conflicts and upheavals around the world, it is particularly important that we build on our strengths and develop new ones where necessary. Innovation is the key to value creation, growth and prosperity.

Innovation gives us the creative scope we need to tackle humanity's challenges, such as climate change. That is why I advocate for key technologies, such as green hydrogen and fusion energy, but also artificial intelligence, which has such great potential that we not only want to utilise but actively shape. We have developed the framework for this with our Future Research and Innovation Strategy, which spans departments and aims to overcome silos within institutions, disciplines and sectors.

The scope of this report is correspondingly broad. It discusses the latest report by the Expert Commission on Research and Innovation and provides fact-based guidance for policymakers, science and business. In short, it is for anyone who wants to understand Germany as a multi-faceted location for innovation.

We have also introduced a small innovation of our own: the report is being published in digital form in full for the first time. In addition, we have expanded our online presence. I hope you enjoy browsing the pages.

Bettina Stark-Watzinger
Member of the German Bundestag
Federal Minister of Education and Research

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Reflector of a solar thermal system of the Jucosol project of Fraunhofer Chile Research

1 Shaping the future: new paths, new opportunities

Research and innovation (R&I) pave the way for our future. They open up opportunities for each and every individual and for Germany as a whole. One thing is certain – in the decades ahead, we will be facing countless major challenges in society. And R&I is the fundamental key to successfully tackling them. Research insights can transform the societal and global challenges of our time into opportunities. R&I provides solutions, creates prosperity and maintains competitiveness. It secures the technological sovereignty of Europe, protects the natural foundations of life and improves the quality of life for all citizens.

For this reason, the Federal Government has set the *Future Research and Innovation Strategy* as the R&I policy framework for boldly driving progress. The strategy reinforces Germany's innovative strength and enables us to meaningfully contribute to achieving the United Nations' Sustainable Development Goals on a global level. The current challenges are reflected in six missions – aligned with the key emerging areas of development outlined in the *Coalition Agreement* for the 20th legislative period and corresponding to other initiatives of the Federal Government. In the implementation of these missions, the Federal Government expressly promotes an agile policy style that transcends departmental boundaries and facilitates coordinated joint policy. The *Future Research and Innovation Strategy* is an agile strategy that adapts to changing circumstances and new needs. Interdepartmental teams prioritise the specific goals of the missions. They coordinate their implementation in close cooperation with the specialist departmental units and monitor the progress of the missions. They are flanked and advised by the Forum #Zukunftsstrategie, an executive body made up of experts from the research community, the private sector and civil society, and they engage in exchange with important stakeholders.

Developments in the central research and innovation policy framework are measured and evaluated against 17 universal R&I indicators.

↗ An overview of the indicators can be found in the ***data volume of the Federal Report on Research and Innovation*** (in German only).

Germany is one of the world's leading innovation nations. Building on its excellent science system, Germany benefits from an economy with a strong commitment to R&I. This commitment drives innovation forward and consequently contributes to the nation's future viability and competitiveness. According to current figures, in 2022, the Federal Government, universities and the private sector invested a total of 121.4 billion euros in research and development (R&D). Never before has so much been spent on R&D in Germany. This brings the provisional R&D intensity – gross domestic expenditure on R&D, expressed as a percentage of gross domestic product (GDP) – to 3.13%. The *Future Research and Innovation Strategy* reaffirms the Federal Government's goal of increasing the R&D intensity to 3.5%. Traditionally the private sector has made the highest contribution to Germany's R&D expenditure, with this sum rising significantly to 81.8 billion euros in 2022. Private sector innovation spending amounted to 190.7 billion euros in 2022 – this, too, sets a new record. In addition, one in two companies introduced social innovations between 2020 and 2021. In recent years, the number of people employed in R&D in all sectors of the economy has risen sharply, and preliminary estimates put the most recent figure at a high of 785,000 full-time equivalents (FTEs) in 2022.

Those measures specified in this report that have financial implications for the federal budget and for social security schemes must comply with the stipulations for budgetary and financial planning. Therefore, all measures fall within the remit of the Federal Government and are subject to funding approval and the Federal Government's reservation of competence under financial constitutional law. Any potential measures must remain within the limits of the available budgets and planning resources, including planning for posts and positions. The inclusion of measures in this report is without prejudice to current or future budget negotiations.

↗ Further data and facts on the German R&I system can be found in the ***data volume of the Federal Report on Research and Innovation*** (in German only).

Determining the ignition behaviour of rapeseed oil fuel in the laboratory of the Technology and Support Centre (TFZ)

2 Designing research for real-world transfer

2.1 Cutting-edge research and infrastructures as trailblazers for the technologies of tomorrow

Employees working in the cleanroom at AMO GmbH, a research institute for nanotechnology

Excellent, open and internationally connected fundamental research pushes the boundaries of what we know and what is technically feasible. This contributes to the development of future technologies and innovations in business and society. Fundamental research is thus a long-term investment in solutions that deal with the transformation processes lying ahead. It also makes a significant contribution to the technological sovereignty of both Germany and Europe and to creating a sustainable future.

Modern, independent and innovative higher education and research institutions – with access to a strong research infrastructure – make up the heart of the German science system and are the prerequisite for excellent fundamental research. That is why it is important to operate large-scale research facilities, including particle accelerator systems, large telescopes and research satellites, both in Germany and with German cooperation in international networks. This facilitates the international integrability of top-tier research. It is also important to create scope for social infrastructures so as to promote the exchange of leading German and international researchers and early-career scientists.

Data is a key resource which, when combined with appropriate and efficient infrastructures, is increasingly proving to be fundamental to the future viability of research and the economy. This is particularly evident in the current developments surrounding artificial intelligence (AI). That is why both the Federal Government and the Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation – EFI) are in agreement that Germany's capacity for innovation depends on the availability of data for research, civil society, and the public and private sectors, including the guarantee that this data will be responsibly used. The diverse developments around AI, data spaces, data fiduciaries and data access can create momentum to drive data availability and use.

Many data sets, for example from industry, mobility or medicine, have so far remained underutilised. To utilise their full potential, it is necessary to access

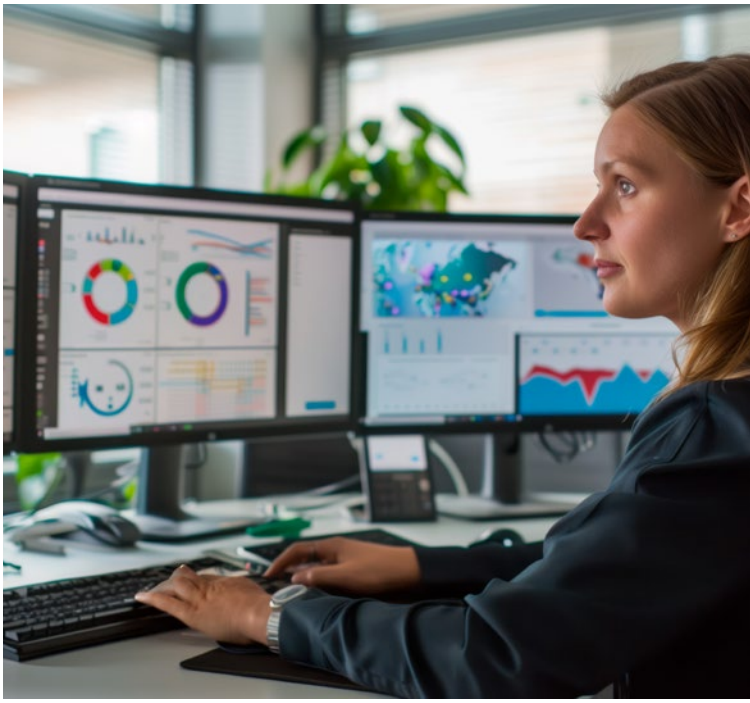
and link different data assets in compliance with data protection regulations by means of appropriate (research) data infrastructures. Data should be prepared according to the FAIR principles – findable, accessible, interoperable and reusable – in order to ensure it is integrable and interoperable with new data and other transnational or global data assets. Data infrastructures should not only be accessible for researchers, but also for public administration, civil society and the private sector, in particular for small and medium-sized enterprises (SMEs) and start-ups. An agile, powerful player is being established in the form of the Data Institute, which is intended to drive the availability, usability and standardisation of data and to enable intersectoral exchange.

The Federal Government aims to secure and develop the productive efficiency of the German research landscape for the future as well. To this end, it is involved in establishing and expanding data infrastructures at national and European level. *The ErUM-Data Plan of Action – from Big Data to Smart Data* aims to exploit the opportunities of digitalisation more effectively, in particular the use of the data and methods of AI and machine learning, as well as the creation of federated digital infrastructures for basic scientific research using large-scale facilities.

The Federal Government's *Data Strategy (2023)*, which was updated in 2023, includes a focus on the development of national and European data infrastructures: as part of the *National Research Data Infrastructure (NFDI)*, research data assets are being secured, indexed, networked and made accessible for the German science and research system. This must take place in compliance with principles of quality, standardisation, interoperability and data protection. A structural evaluation to be carried out by the German Science and Humanities Council in 2024 and 2025 will lay the basis for the decision of the Joint Science Conference on the further development of the *NFDI* from 2029 onwards. In addition, the Federal Government is making an important contribution to the development of European data infrastructures, for instance in the form of the European Open Science Cloud (EOSC), European data spaces such as the European Health Data Space (EHDS), and Gaia-X, a cross-industry and cross-sectoral cloud and data infrastructure that is more strongly geared to real-world economic practice and oriented towards European values.

Through the planned *Research Data Act* – one of the key research and innovation policy projects of this legislative period – the Federal Government intends to facilitate access to data for public and private research in the future and to improve the legal framework for accessing data for research. In particular, this involves public sector data, which holds enormous potential for research. It is therefore also important to facilitate the use of this data for research purposes through regulatory measures. To this end, the regulatory framework governing the use of this data, and compliance with data protection, will be improved for the benefit of research. Interoperable standards and quality assurance will also make it easier to link different data assets with each other. The *Research Data Act* is expected to be adopted by the Federal Cabinet by the end of this year. In the field of medical research, the *Health Data Use Act*, which came into force in 2024, will improve the availability of health data for research and innovation and expand access to this data. To achieve this, the decentralised health data infrastructure will be expanded and designed to be interoperable on a European level.

The Federal Government and the EFI agree that access to computing capacity in high-performance computing (HPC) centres must be guaranteed. Extremely powerful computers are needed to run



high-resolution climate models, to carry out simulations in particle physics or the life sciences, and to train complex AI models. HPC is an integral part of a broad range of research fields and is therefore a critical factor for Germany as a science location. The *High Performance Computing for the Digital Age* programme will boost HPC infrastructures and align them with the use of AI. The aim is to create the conditions for international excellence and competitiveness in the research, development and practical application of AI by establishing a top-tier computing infrastructure. The first European exascale supercomputer at the Gauss Centre for Supercomputing (GCS) in Jülich is an outstanding example of this.

↗ Discover the key data on research and innovation in Germany and download customised charts from the ***Online Tools*** of the report.

2.2 Breaking new ground for holistic innovation

Plectonic team developing nanorobots for cancer therapy in a *SPRIND* project

The Federal Government sees a priority in broadly strengthening innovative capacity in order to actively shape social change and to modernise the state, the economy and society in a sustainable way. This means taking advantage of the opportunities offered by new digital KETs (key enabling technologies). It is therefore important to further expand the existing structures for promoting innovation, transfer and start-ups and to supplement them with new initiatives such as innovation agencies. The guiding principle in this endeavour must be to improve the conditions for transfer through appropriate incentives and regulatory frameworks. In this context, start-up and transfer infrastructures at universities and the provision of easier access to venture capital gain particular importance.

Policy measures take a holistic view of innovation development, which also includes, for example, reinforcing ecological and social innovations. The EFI Report 2024 once again highlighted the great importance of social innovations as an essential element in tackling societal challenges, such as climate change and an ageing population. It is also important to focus more on the regions (both urban and rural) as places where work on innovative ideas for the future is being done and to strengthen cooperation involving all stakeholders in science, business, administration and civil society.

The Federal Government has broken new ground in promoting innovation by establishing and expanding the development of innovation agencies. Since 2019, the *Federal Agency for Disruptive Innovation (SPRIND)* has been identifying and further developing promising innovations that have game-changing potential (so-called disruptive innovations) as solutions to the challenges of our time. Particularly promising ideas with disruptive innovation potential are further developed by *SPRIND* through validation contracts. In addition, *SPRIND* also promotes the implementation of particularly promising projects in its meanwhile 13 subsidiaries (as at end of April 2024). As part of seven innovation competitions (so-called challenges) that have been launched to date, the Federal Agency is also funding a competitive process for the devel-

opment of solutions to particularly challenging problems of high societal importance as specified by the Federal Agency. The new *SPRIND Freedom Act*, which came into force in 2023, confers administrative freedom on the agency and will significantly advance its development. The expanded powers of self-administration, the participation of companies and the use of new, tailor-made financing instruments open up greater latitude for *SPRIND*.

The *Agency for Innovation in Cybersecurity GmbH (Cyberagentur)* founded by the Federal Government has now reached its full capacity and awards commissioned research on strategic cybersecurity issues to universities, research institutions, start-ups and other companies. The *Cyberagentur* will be further expanded in order to implement the goals of the *National Security Strategy* and the *Cyber Security Strategy for Germany* and to strengthen digital sovereignty. In addition, the *Bundeswehr Cyber Innovation Hub (CIHBw)* is another instrument that has been launched to also promote the innovation and start-up culture within the Bundeswehr.

To safeguard venture investments in technological developments, it is crucial for innovative companies to protect intellectual property. A strong and balanced legal framework for the granting of industrial property rights is therefore one of the key general requirements for promoting innovation. All stakeholders involved need to step up their efforts to communicate this interdependency at all levels.

In the context of spin-out processes at research facilities and places of higher education, the transfer of intellectual property (IP transfer) from these institutions plays a crucial role. There is room for improvement, for example, by accelerating commercialisation pathways from the research setting into the private sector and civil society or by reducing bureaucracy. This is also underlined by the EFI in its current report. The Federal Government is implementing a variety of measures to make the spin-out process more efficient. The Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry of Education and Research (BMBF) have set up the IP Transfer task force, which includes entrepreneurs, transfer agencies, legal experts, the German Startup Association and the Transfer Alliance. Among other things, the task force has drafted

sample contracts and process guidelines in order to accelerate IP transfer. The development of a 'deal database' is also in the pipeline. Under the auspices of *SPRIND* as part of the BMBF-funded pilot project 'IP Transfer 3.0', which serves as a kind of regulatory sandbox, research institutions are developing and implementing new models for more efficient IP transfer. In addition, the Federal Government will leverage these knowledge transfer bridges to specifically promote transfer activities at universities and non-university research institutions, and to better tap into individual transfer and start-up potential.

Innovation networks in emerging areas of technology are being established as part of the *Clusters4Future* initiative, which has been running since 2021. This networking of all stakeholders involved in the creation of new value chains (with representatives from top-tier research, industry, SMEs and civil society) contributes to accelerating the transfer of research insights into real-world practice. The open-technology and open-topic approach relies on interdisciplinary collaboration to identify and leverage innovation

potential at the interfaces of different technology fields and in industries with great potential for growth and new solutions. The Federal Government's *go-cluster* excellence initiative is building the qualifications of 72 participating cluster management organisations in areas that include professional development, recruitment of skilled workers and digital technologies.

One instrument for boosting the number of innovative ideas that are translated into real-world practice and thus getting them out to companies and individuals is the *German Agency for Transfer and Innovation (DATI)*, which is currently being set up. The funding directive *DATIpilot*, which was launched in July 2023, is a pilot measure being run inthe lead-up to establishing *DATI*. It supports innovative ideas for transfer projects in the various regions of Germany. In addition, it serves as a repository of ideas for the future agency by testing simplified and flexible funding approaches. *DATIpilot* attracted a great deal of interest right from the start. Almost 3,000 outlines have been received for *Innovation Sprints* (module 1) and almost 500 applications for *Innovation Communities* (module 2). Now that the commission tasked with its establishment has been appointed and Erfurt has been chosen as the future head office of the agency, further preparations for setting up *DATI* are currently underway. The agency is to be based on an open-topic, open-stakeholder approach and explicitly includes social innovations in its understanding of transfer and innovation.

At the end of March 2024, the *Growth Opportunities Act (Wachstumschancengesetz)* came into force with the aim of strengthening Germany's research infrastructure and relieving the burden on the economy. As well as changes in tax legislation, the expansion of the research allowance is an essential part of the law. The research allowance, which is offset against the company's own income tax liability, is intended to serve as an incentive for entrepreneurs to intensify or expand their own research activities. This includes incentives such as increasing the funding rate for small and medium-sized enterprises (SMEs) by 10 percentage points to 35% upon application, raising the maximum assessment basis from 4 million to 10 million euros, and extending technology-neutral funding to include certain material costs. In total, the savings for research-based companies amount to almost one billion euros. This makes the *Growth Opportunities Act* the largest research funding measure since the introduction of the research allowance.

2.3 Benefiting from diversity in research and innovation

In order to gain scientific knowledge while not only maintaining Germany's innovative capacity but also continuously developing it, research and innovation processes must be even further expanded, and broad participation of all social and economic actors must be made possible even more effectively than before. A step towards this is the BMBF-funded initiative *Diversity at German Universities*, which is implemented by the German Rectors' Conference (HRK), the association of state and state-recognised universities in Germany. It supports participating universities in further developing holistic diversity concepts and strengthens inter-university dialogue in Germany. The active exchange between representatives from society, science, politics and administration offers opportunities for shaping research policy and contributes to research output with direct societal relevance. Above all, direct involvement in transdisciplinary research processes can directly increase the impact of research on societal transformation processes. Successful participation can boost both the quality and legitimacy of research policy and research.

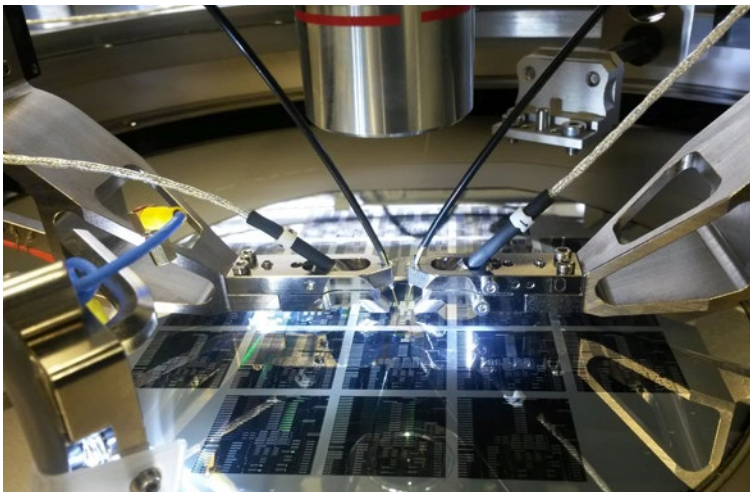
The German economy will remain competitive if it conducts ambitious research that in turn leads to the development of innovative products for national and international markets. This applies in particular to middle-market companies, which generate a significant share of the prosperity of our society. It also plays a decisive role in the restructuring of our economy towards greater climate protection and sustainability in line with the *UN Agenda 2030*.

The promotion of innovation for SMEs continues to be a priority of the Federal Government's R&I policy. This includes such initiatives as the *Central Innovation Programme for Small and Medium-sized Enterprises (SMEs)*, which is open to all topics, technologies and sectors; the *Industrial Collective Research (IGF) programme*; and the *SME-innovative* funding initiative for innovative SMEs, which aims to promote high-risk R&D projects in forward-facing fields of technology. In structurally weak regions, the policy instrument *Improvement of Regional Economic Structures (GRW)*, a joint task of the Federal Government and the Länder, offers SMEs additional funding options for applied R&D projects and simplified eligibility requirements for research-intensive companies. The funding directive *Spotlight on Innovative Women* contributes to making the scientific achievements and innovative

ideas of women more visible in society. In order to expand its support for innovative SMEs, the Federal Government is planning the new transfer initiative *Boost for Innovation*, which will focus more strongly on eliminating transfer obstacles and further improve the conditions for successful technology transfer.

An open and diverse culture of innovation reflects the diversity of our society. Unlocking the full potential of innovation requires recruiting the greatest talent for research and innovation. In particular, this means ensuring that gender and diversity equality are embraced even more fully than before and are reflected in the funding structures. In the reporting period, the Federal Government launched a series of measures to boost the participation of women in innovation activities. The *Women in SMEs, Crafts, New Businesses and Start-ups* initiative, the *More Women Entrepreneurs for our SMEs* action plan, and the extension of the *EXIST* funding programme to include the *EXIST-Women* directive are intended to make entrepreneurship and start-up activities more female-friendly.

In the interests of fostering a vibrant culture of participation, the Federal Government is continuing its efforts to increase the involvement of citizens in research and research policy. To this end, it presented the *Strategy for Participation in Research* in 2023. The strategy aims to improve the regulatory conditions for societal participation in research and research policy, develop innovative participatory formats and apply them in line with requirements.



Wafer-level characterisation of integrated photonic components on the automatic wafer prober at the Fraunhofer Institute for Electronic Nano Systems ENAS

In this spirit, a broad, multistage dialogue process on the strategic orientation and design of *DATI* was launched in July 2022 and ran until February 2023. The findings from the many intensive discussions held with stakeholders and from the two preliminary online surveys proved to be an important component in conceptualising a needs-based innovation agency. The Federal Government also consistently involves stakeholders in the development and implementation of R&I policy strategies and policy initiatives. Involving stakeholders was not only part of the process for the *Future Research and Innovation Strategy*, but also in the case of, for instance, the *Start-up Strategy* and the dialogue process *New Work – New Security*.

↗ Discover the German R&I system and its actors in the ***Online Tools*** of the report.

2.4 Securing skilled workers, fostering talent, developing future capabilities

Employees carrying out measurements on a component

Digitalisation and decarbonisation are changing living and working environments in society and ultimately also in Germany as a business and innovation location. To ensure we are able to play a self-determined role in shaping these far-reaching changes, it is essential that we develop a comprehensive range of future-oriented skills. It is not just skills in science, technology, engineering and mathematics (STEM) that are essential but also digital, social, ecological, economic and cultural skills. At the same time, demographic change is altering the structure of the workforce, requiring the development and exploitation of the domestic potential for skilled professionals on the one hand and the recruitment of international skilled professionals and top researchers on the other. The 2024 EFI report shows that, while Germany has made progress in this area, further effort is required. If we wish to attract top talent in international competition and recruit and retain qualified specialists from abroad, it is crucial that we offer good working conditions and reliable, transparent career paths for researchers in science. It is also essential that we streamline the requirements for the immigration of foreign academics and skilled workers and simplify the recognition of their professional qualifications. At the same time it is imperative to break down gender stereotypes, thus enabling cliché-free career choices, for instance, attracting more men to caregiving professions. It is also important to make even better use of the talent potential of international students as the professionals of tomorrow.

The German government is pursuing the modernisation and digitalisation of the education system and strengthening the digital and data-related skills of teachers and learners. To this end, the Federal Government is supporting the establishment and expansion of digital infrastructures and platforms, digital media and materials, and future-oriented skills and expertise. It is promoting the creation and use of open educational resources – free content and educational materials, as well as IT architectures for the development of digital education – as part of the *Open Educational Resources (OER) Strategy*. It is also creating appropriate incentive systems for this purpose, fostering a culture of openness, cooperation and sharing. In this way, it is boosting and supporting change management in the educational landscape.

Through its *Competence Centres for Digital and Digitally Supported Teaching in Schools and Continuing Training*, the Federal Government is working with the Länder to boost the quality of the continuing education landscape for teachers. Four thematic competence centres and a transfer agency are shaping the evidence-based digital transformation of teacher education under the banner of 'lernen: digital – Competence Network for a Digital Transformation of Schools and Teacher Training'.

In light of the transformation of the economy and the labour market, the teaching of future-facing skills in all areas of education also plays a prominent role in society. In the *STEM Action Plan 2.0*, the Federal Government focuses on boosting STEM competencies and supporting access to good STEM education along the education chain. To this end, measures are being implemented in the fields of cooperation, quality, research, family and early start.

The Federal Government's *'Startchancen' Programme* is setting the stage for educational success: from the 2024/2025 school year, the Federal Government and the Länder will each provide 1 billion euros of targeted joint funding for schools with a high proportion of socially disadvantaged children. The goal is to decouple educational success from social background to a far greater extent than previously, thus equipping children and young people with the necessary skills for a successful professional life and democratic participation. In addition to building up basic skills, the programme also focuses on aspects such as career guidance. Scientific evaluation is an integral part of the *'Startchancen' Programme*. It fosters the evidence-based, impact-oriented implementation of the programme at the interface between research and its practical application, as well as supporting the transfer of results and findings well beyond the boundaries of the *'Startchancen' Programme*.

The Federal Government's *Financial Literacy Initiative* has given priority to the topic of financial literacy for the first time and coordinates the activities related to it. Financial literacy is seen as a lifelong challenge within the framework of the initiative. The cornerstones of the initiative are the development of a national financial literacy strategy, the establishment of a central financial literacy hub and the funding of research on the topic.

The national platform Education for Sustainable Development (ESD) focuses on continuing, adult and further education for sustainable development. The initiative is an important response to the major challenges facing society and contributes to intensifying the network among providers of future-facing skills and core competencies.

The Federal Government attaches great importance to vocational education and training (VET), continuing vocational education and training (CVET) and lifelong learning. In 2022, it therefore expanded the *National Skills Strategy (NWS)* and adopted measures to enable workforce participation for even more people in times of digital, demographic and ecological change.

A series of measures anchored in the *Citizen's Benefit Act* and the *Act to Strengthen Support for Initial and Continuing Training* have boosted the financial incentives and regulatory conditions for CVET and have expanded the instruments for funding VET and CVET – not only for companies but also for those seeking apprenticeships and VET, for employees and for jobseekers.

The *Amendment to the 'Federal Training Assistance Act (BAföG)' (BAföG Amendment Act)* passed by the Federal Cabinet at the beginning of March 2024 aims to support more young people in pursuing higher education. In addition to expanding the group of beneficiaries by raising the threshold for the parental means test by 5%, a study-start grant for young people receiving social benefits will be introduced as a one-off grant of 1,000 euros and more flexible funding regulations will be introduced. In addition, the *'Lebenschancen' BAföG* is being developed, a funding support programme that aims to address the need for further training in future-facing skills.

To increase the attractiveness of work-integrated VET (generally referred to in Germany as the dual system) for all young people, the Federal Government presented the *Excellence Initiative on Vocational Education and Training* at the end of 2022 as a component of the *Skilled Labour Strategy*. The focus is on promoting individual opportunities, advancing the structures, content and formats of VET, and enhancing international visibility and mobility.

As a further component of the *Skilled Labour Strategy*, the Federal Government is relying on a modern immigration policy to ensure our success in the international competition for qualified skilled professionals and to improve the general conditions for skilled professionals coming to Germany.

Under the provisions provided by the *New Skilled Immigration Act*, which was initially passed in 2023 and is being successively phased in, the Federal Government is facilitating the immigration of qualified professionals from abroad who are urgently sought after on the labour market in Germany. Better access to language-learning programmes and secondary employment will greatly increase the profile of VET and university studies in Germany and facilitate transition into the workforce. A new instrument being introduced in June 2024 is the Opportunity Card, which will significantly improve immigration rights. Based on a transparent points system, candidates from non-EU/non-EEA countries may be issued with an Opportunity Card, allowing them to enter Germany to look for suitable employment. This will expand the pool of skilled professionals in Germany and allow vacancies to be filled more quickly and with less effort.

The recognition of professional qualifications is an important tool for the long-term prospects of immigrant skilled professionals and the quality of professional practice in Germany. For this reason, recognition processes for foreign educational and professional qualifications will be fast-tracked and simplified. The Federal Government has also set up various information portals, such as 'Make it in Germany', 'Research in Germany' and 'Recognition in Germany'.

The Federal Government programme *Tailored Placements and Welcome Guides*, which was amended in 2024, offers counselling services at chambers of commerce and business organisations for companies seeking domestic or foreign trainees to fill their vacant training positions.

Moreover, the Federal Government is focusing on international students as the skilled professionals of tomorrow. The DAAD German Academic Exchange Service is boosting the recruitment of international students and graduates in Germany for the German labour market through support structures at German universities as part of the *Campus Initiative for International Talents*.

In addition to providing institutional funding to research organisations and intermediaries, the Federal Government is pursuing a number of initiatives that focus on early-career researchers and international competition for top talent. These include the *Tenure-Track Programme for the Support of Young Scientists*, the recruitment and professional development of professorial staff at universities of applied sciences and the *Excellence Strategy*. The Federal Government further expanded its *Programme for Women Professors* in 2023 and extended it until 2030. The initiative aims to promote female scientists on their way to tenured professorships at German universities, to retain them in the science system, and to anchor equality between women and men even more firmly in university structures. In addition, the funding directive *MissionSTEM* aims to permanently raise the number of women who choose academic STEM professions.

The planned reform of the *Academic Fixed-term Contract Act* will improve the regulations for fixed-term employment contracts in academia and research. This is an important building block for creating attractive and internationally competitive working conditions and thus being able to recruit and retain the best minds. The aim of the amendments is to create more reliability, predictability and transparency for scientists, researchers and academics in early career phases. This includes defining appropriate contract terms, for example minimum contract terms, and improving the compatibility of work and family life.

2.5 Joint solutions to global challenges: European and international cooperation

European and international cooperation in research and innovation opens up a wide range of opportunities – in particular for tackling global challenges and crises, such as combating climate change and the loss of biodiversity, protecting the environment and the oceans, fighting poverty, addressing food security and securing a climate-friendly and socially responsible energy supply. It is also indispensable when it comes to securing the competitiveness of Germany and Europe, driving forward the development of key enabling technologies (KETs) and shaping this development on the basis of common values. Multilateral forums such as the G7, the G20 and the OECD demonstrate their importance in this context as platforms for knowledge exchange and coordination on internationally relevant research topics and activities.

Increasing the visibility and attractiveness of our education, science and innovation system for top-tier international talent is of particular importance. Germany's close involvement in the European Research Area (ERA) is essential here – this promotes international mobility and the exchange of talent in and beyond the EU. To achieve outstanding research, German and European scientists must be involved in the global flow of knowledge and innovation processes and actively play a role in shaping them.

At the same time, the current geopolitical conditions, coupled with the so-called *Zeitenwende* – the historic turning point in Germany's foreign policy – require a more strategic approach. This approach must align European and international cooperation in research and innovation, including the valuable asset of scientific freedom, with our security and research policy interests. To decrease our dependence on systemic rivals and reduce risks to our economic and national security, cooperation partnerships must be carefully considered. At the same time, making our contribution to achieving the UN Sustainable Development Goals on the global level continues to be a high priority. Germany is committed to its role as a cooperation partner in advancing research and innovation in non-European partner countries. As part of science

diplomacy and development cooperation, Germany advocates for the development and expansion of sustainable science and innovation infrastructures worldwide. The Federal Government has created important frameworks for this in the *National Sustainable Development Strategy*, the *Strategy on Climate Foreign Policy*, the *National Security Strategy* and the *Strategy on China*.

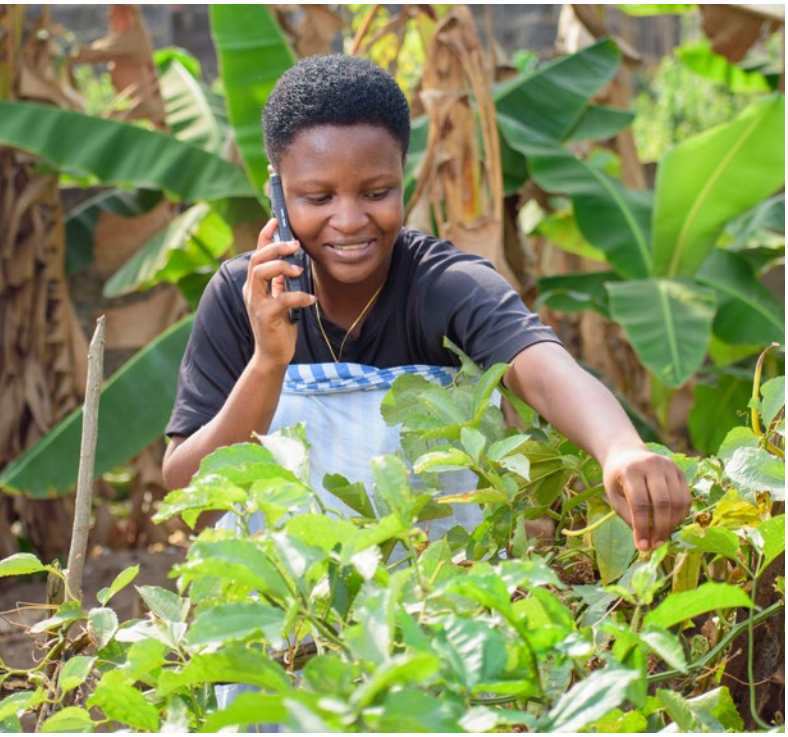
With its commitment to research and innovation in Europe and the world, Germany is helping to expand global knowledge and address the global challenges via cooperation in education, science and research projects. To this end, and to maintain its competitiveness, Germany is collaborating bilaterally and multilaterally with partner countries in all regions of the world. The *National Action Plan for the European Research Area (ERA)* was adopted in 2023 as the basis for the strategic orientation of German EU research and innovation policy until 2027. Cooperation with European partners is being fostered along the guidelines of 'Strengthening an innovative Europe', 'Enabling research excellence in Europe' and 'Promoting a free Europe'.

In cooperation with the EU Commission and the EU member states, Germany is advancing a common research policy agenda for the implementation of ERA, the *ERA Policy Agenda*. Measures in the *ERA Policy Agenda 2022–2024* initiated important developments in research and innovation policy and created structural improvements for researchers in Europe. Germany is involved in the negotiations on the *ERA Policy Agenda 2025–2027* in order to set future-facing priorities in European cooperation and to create a close link with the EU funding programme for research and innovation. As a member of the various programme committees, the Federal Government is closely involved in the design and continuing development of the current EU R&I programme, *Horizon Europe* (2021–2027). It is also actively involved in planning thematic work programmes and improving the general conditions for funding. Based on the evaluation of the previous funding programmes, the Federal Government is also positioning itself early in preparation for the successor programme, the 10th EU Framework Programme for Research and Innovation, which will enter into effect in 2028.

One thematic focus is cooperation in the field of hydrogen and its derivatives. To achieve this, a raft of agreements on research and innovation cooperation have been signed with partner countries, primarily to promote the development of international production capacities and the import of certified hydrogen. In addition, the Federal Government has entered into strategic research and energy partnerships, for instance with Namibia and South Africa, with Korea, Canada, Japan, and with Chile, Brazil, Australia, New Zealand and Central Asia. An important basis for this at the European level has been created with the *Strategic Research and Innovation Agenda (SRIA)* for green hydrogen. In addition, bilateral cooperation partnerships have been established on issues along the entire value chain. Large-scale projects in the field of green hydrogen are being launched within the framework of the *PtX Development Fund* with the aim of creating local value chains and the regulatory framework for economic policy that will enable the development of local hydrogen economies.

In response to the Russian war of aggression, the German government is supporting Ukraine and is working with the international community to rebuild the Ukrainian science and innovation system. Central building blocks of this effort are the establishment of four German–Ukrainian centres of excellence, the deepening of research cooperation and the establishment of an independent climate and energy think tank. In addition to rebuilding research capacities, the focus is on improving the general framework for R&D and integration into the ERA. Germany will enter into a new science and technology cooperation (STC) agreement with Ukraine in order to expand the long-standing cooperation between the two countries in research, education and innovation.

As a consequence of the *Zeitenwende*, the Federal Government is also realigning its cooperation partnerships with the other countries in the Eastern Partnership and with the Central Asian states. This will assist these countries in reforming their science systems and support the integration of the Eastern Partnership countries into the ERA. At the same time, it will foster the economic and civil society development of the states of both regions in line with European values.



The growing importance of China – not just as a partner, but also as a competitor and a systemic rival – is increasing the need for people with sound, up-to-date and independent China expertise. Language competence, intercultural competence, regional expertise and practical experience in bilateral cooperation with China are essential for mutual understanding and for Germany to be able to successfully safeguard and pursue its interests. This also applies to scientific cooperation, which takes place under increasingly complex conditions and requires a differentiated view of the opportunities and risks. Therefore, the establishment and expansion of independent China expertise as a cross-sectional task is an important concern in the Federal Government's *Strategy on China*, published in 2023. To this end, it launched the *Informed Self-confidence in Research and Innovation Cooperation with China (China-Orientation)*, a package of measures aiming at achieving an informed, confident basis for cooperation partnerships with China in research and innovation. The *China Orientation* provides a framework for regular exchange and dialogue formats to be held with representatives from the German science and research community. In addition, the Federal Government is specifically promoting the expansion of China expertise at universities and research institutions and also the establishment of think tanks.

One regional focus of international R&I cooperation is Africa. On the one hand, many global challenges such as the climate crisis or food security are particularly evident here. On the other hand, Africa's young population presents a high potential for innovation in the sustainable development of the continent. For this reason, the Federal Government is supporting the development and strengthening of capacities and structures for science and research. Examples include the Science Service Centres for Climate Change and Adaptive Land Management SASSCAL and WASCAL, the African–German Centre of Excellence for Sustainable and Resilient Food Systems and Applied Agricultural and Food Data Science, currently in planning, and the Africa-based institutes of the Consultative Group on International Agricultural Research (CGIAR).

The USA and Canada are key strategic value partners that are critical to our security and prosperity and to Germany's standing as an important research and innovation location. The intensification and expansion of transatlantic cooperation, especially in the area of emerging technologies, is intended to further strengthen technological sovereignty and innovation dynamics in Germany and Europe. This includes such initiatives as establishing an umbrella brand (Transatlantic Innovation Bridge) and new instruments for connecting innovation locations.

Latin America and the Caribbean are key partners in developing joint solutions in the areas of environmental protection, resource conservation and climate change. As part of the *Lateinamerika.PotenziAL* initiative, a large number of bilateral and multilateral measures have already been funded to establish and strengthen research networks and scientific cooperation between German and Latin American partners. Brazil, Chile and Uruguay in particular are considered key cooperation partners in the region in the field of renewable energies and green hydrogen. They are indispensable partners in ensuring Germany's resource and energy security.

In recent years, there has also been a noticeable change in the global framework for international university cooperation. Against this background, the Federal Government and the Länder have agreed on a repositioning of their joint *Strategy of the Federal and Länder*

Ministers of Science for the Internationalization of the Higher Education Institutions in Germany, which is to be adopted in 2024 and will set a framework for internationalisation activities by the Federal Government, the Länder and universities. The Federal Government is also strengthening cross-border cooperation in near-market research, innovation and transfer. Beginning in July 2024, Germany and Canada will take over as joint chairs of the international innovation network *Eureka* for one year, with the organisation celebrating its 40th anniversary in 2025.

In order to implement the joint research agenda for green hydrogen and its derivatives in the European Research Area, Germany is coordinating the formation of a working group for the implementation of the *Strategic Energy Technology Plan (SET Plan)*. In 2024, the SET Plan Implementation Working Group on Hydrogen is developing an implementation plan with specific research and innovation topics, thus making an important contribution to achieving the European goals for sustainable energy supply.

Cooperation with Israel is a particular political priority for the Federal Government – especially in times of conflict. Following the attacks on Israel, the Federal Government temporarily increased its financial support for cooperation with Israel. The multifaceted nature of the cooperation architecture is reflected in a variety of scientific collaborations and focuses on such specialist areas as nanotechnology, water technology, cancer research, battery research and marine research.

2.6 Modern research and innovation policy: digital, agile, open

The many crises of recent years have shown that flexibility, openness and agility in political ways of thinking and acting are essential for actively shaping future transformation processes. The transformation-led and mission-oriented approach to R&D policy chosen by the Federal Government to address the challenges of transformation has been praised by external stakeholders such as the Commission of Experts for Research and Innovation (EFI). This includes the *Future Research and Innovation Strategy*, with its agile governance structure, as well as the instrument of regulatory sandboxes. This praise also extends to the development of the innovation agencies *SPRIND* and *DATI*, which the Federal Government intends to systematically pursue. Digital transformation can further accelerate these processes.

Modernising the existing legal and regulatory framework – or developing one for the first time – may be necessary for the development of new technologies, for instance, for digital technologies, AI, mobility and logistics, or in the fields of social innovation and the energy transition. The Federal Government supports regulatory sandboxes and other such controlled experimental environments that provide opportunities to test innovations and develop the right regulatory frameworks. This creates the scope and incentives for trialling innovations, removes barriers and strengthens social acceptance. The German government is planning to pass a *Regulatory Sandboxes Act* to create a consistent and innovation-friendly framework for regulatory sandboxes and similar controlled testing environments, thus speeding up innovation processes to achieve real-world application. This is expressly welcomed in the current EFI report.

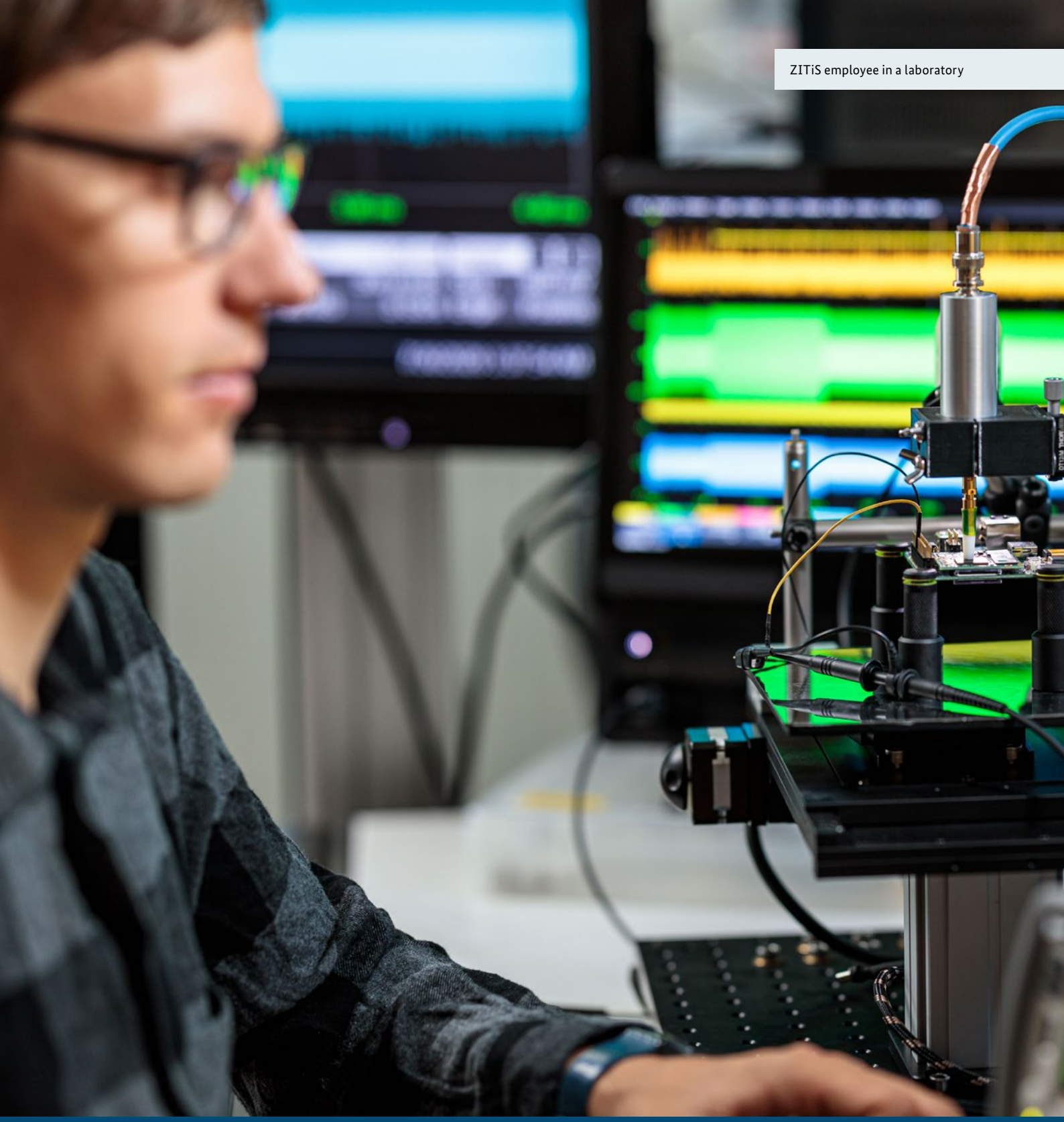
The Federal Government is driving forward the digitalisation and modernisation of public administration – with the involvement of the users – through the *2023* Amendment *to the Act to Improve Online Access to Administrative Services (OZG 2.0).* To achieve this, modern, agile methods are used in digital laboratories to develop digital solutions in a collaborative and open-outcome approach. In order to create an interoperable, modular federated cloud infrastructure for public administration based on common standards and open interfaces, the Federal Government presented the *German Administrative*

Cloud Strategy (DVS) and has undertaken initial steps towards its implementation. In 2022, the open-source platform *Open CoDE* was launched, thus simplifying the wider use of open-source software in public administration. The platform is a central repository for the collaborative development, exchange and (re-)use of software solutions.

The Federal Government has examined the potential and opportunities offered by the use of AI in administration, for instance, for increasing the efficiency of processes, reducing workloads and improving the quality of services. The establishment of the *Advisory Centre for Artificial Intelligence (BeKI)* has created a central point of contact and coordination for AI projects in federal public administration.

The first pilot project to be set up will be an 'AI Marketplace of Opportunities' designed to create transparency around existing AI applications in federal public administration and match ministries and government bodies with AI applications that are tailored to their needs. The launch of the implementation project for the *DVS* will also contribute to increasing efficiency in public administration, especially in the long term. The standardisation of interfaces among various federated cloud solutions will enable faster commissioning and the faster changeover of software solutions in the future, therefore allowing more flexible and agile action at the administrative level.

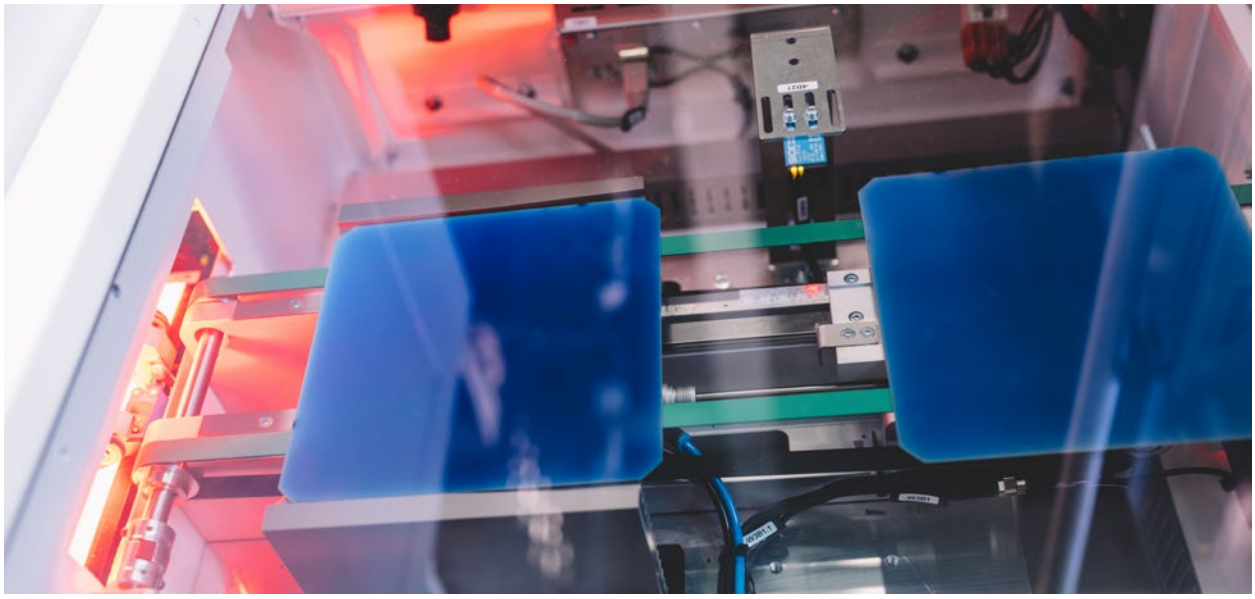
The Federal Government is also actively engaged in the discussion initiated by the EFI that questions the strict separation between civilian and military research in Germany with the aim of leveraging more synergies. Especially in times when international competition for key enabling technologies (KETs) is setting the stage for the future, the responsible actors should reassess their positions with an open mind.



ZITiS employee in a laboratory

3 Shaping transformation processes with research and innovation

3.1 Research for sustainable transformation in industry and mobility



Solar cells on the conveyor belts of a screen printer before the application of metal pastes

Germany has committed itself to clear policy goals on climate and sustainable development and aims to be climate-neutral by 2045. In order to achieve this, far-reaching transformation processes are required to transform the practices of industry, energy and heat supply, mobility and construction towards creating a greenhouse gas-neutral and resource-saving economic system and lifestyle. The research and development (R&D) of future-ready technologies and social innovations and their rapid transfer into real-world practice are crucial for actively shaping this transition – especially to ensure future competitiveness, employment and prosperity in our country. Research and development in KETs – including new materials and industrial processes in biotechnology, biological raw materials and closed-loop systems, hydrogen and battery technologies, and digital technologies – plays a decisive role as the technological basis for transformation processes. The implementation of the transformation must often be designed locally in the cities and regions. Existing innovative potential must be leveraged, requiring targeted support for the local and regional innovation ecosystems.

Working together with industry partners, the Federal Government is supporting the climate-neutral conversion of the economy, in particular the energy-intensive industrial sector, by funding R&D on technological solutions, knowledge and technology transfer, and model implementation in test facilities and pilot plants. This support focuses on R&D funding for new technologies, such as new materials and lightweight construction, improvements in renewable energy technologies, industrial biotechnology, the switch to non-fossil raw materials in line with a bioeconomy and the implementation of a circular economy.

In order to bundle its initiatives for a circular economy and resource conservation, the German government adopted the *National Circular Economy Strategy (NKWS)* in 2024. The *NKWS* aims to develop technological and social innovations, new business models and marketplaces, and the opportunities of digitalisation for the production and use of secondary materials. As part of the mission of the *Future Research and Innovation Strategy*, a circular economy workshop involving stakeholders is planned for June 2024 with the aim of identifying thematic gaps in the circular economy.

In addition, the Federal Government is investing in the development of research and capacity structures. The large-scale *Center for the Transformation of*

Chemistry (CTC), a research centre that is to be established within the framework of the *Coal Regions Investment Act*, will drive forward the transformation of the chemical industry towards a circular economy and create a new, internationally visible flagship for sustainable business in Germany. The Federal Government is also supporting the establishment of the Federal Research Centre for Climate-Neutral and Resource-Efficient Construction, known as LAB – Living Art of Building, which will promote the transfer of innovative and efficient solutions into real-world construction through research and development.

Innovations in the bioeconomy can also make important contributions to climate neutrality and resource efficiency, for instance in industry, in timber construction and in the use of renewable raw materials. In industry, such fields as white biotechnology open up new opportunities for the particularly efficient production of high-quality products. Various initiatives such as the BMBF's funding priority *'Climate Neutral Products through Biotechnology (CO2BioTech)'*, which was launched in 2024, are being implemented as part of the *National Bioeconomy Strategy*.

The Federal Government positions hydrogen as an important building block for the decarbonisation of energy-intensive industries and for sector coupling between industry, transport, heat supply and electricity. For this reason, it is actively ramping up the funding of technology and innovation in the field of hydrogen, as well as the training of skilled professionals as part of the *National Hydrogen Strategy (NWS)*, which was continued in 2023. The R&I policy measures anchored in *NWS*, such as the so-called *Hydrogen Flagship Projects* and the *IPCEI Hydrogen*, address the entire value chain – from the production of hydrogen and its derivatives to its transport and real-world application.

As a strategic element of energy policy, the Federal Government's energy research funding – extending from fundamental research to applied research – is consistently geared towards completing the energy transition and, in terms of provision for the future, beyond.

The Federal Government intends to establish Germany as a leading provider of hydrogen technologies by

The Hydrogen Lab Bremerhaven at Fraunhofer Institute for Wind Energy Systems IWES

2030, such that hydrogen technologies 'Made in Germany' remain in demand internationally in the future. In addition, domestic electrolysis capacities are to be further increased and expanded. Accordingly, the Federal Government is further developing the *NWS* as an R&I policy framework, as well as strengthening basic and applied research, rapid industrial implementation and capacity building. To this end, the established research initiatives on the production, storage, transport and use of hydrogen in industrial applications and infrastructure are being systematically continued – above all the *H2Giga* flagship hydrogen projects for the series production of large-scale electrolysers for hydrogen production, *H2Mare* for the production of hydrogen at sea and *TransHyDe* for technologies for the storage and transport of hydrogen. The Federal Government is also continuing R&D funding in the transport sector within the framework of the *'National Hydrogen and Fuel Cell Technology Innovation Programme' (NIP)* and the research competition *HyLand – Hydrogen Regions in Germany*. In addition, it is ramping up the establishment of the *Hydrogen Innovation and Technology Center (ITZ)* and the Power-to-Liquid (PtL) development platform. Funding for the *Regulatory Sandboxes for the Energy Transition* will continue and be placed on a permanent footing, and the funding instrument will be systematically developed. This also applies to demonstration and pilot projects in the field of decentralised energy supply with hydrogen and fuel cell technologies.

In the field of applied energy research, the mission-oriented *8th Energy Research Programme for Applied Energy Research* provides the framework for effectively supporting the transformation of the energy system. The programme is systematically geared towards energy policy goals and consists of five mission topics: energy systems, heat transition, electricity transition, hydrogen and transfer into real-world practice. In particular, the funding is intended to trigger and accelerate the development and transfer of technology that will contribute to Germany's transformation to a climate-neutral energy sector by 2045. The aim is also to create a favourable innovation environment.

Fusion technology is also seen as having potential to be part of the solution to our energy problems. In addition to the many years of institutional funding, the Federal Government has been supporting fusion research with its own funding programme since 2024. This is taking place parallel to the EU's involvement in the construction of the International Thermonuclear Experimental Reactor (ITER) and is intended to pave the way for the construction of a fusion power plant. The aim of the new funding programme is to establish a fusion ecosystem with a focus on technology development, the promotion of early-career scientists and international cooperation. The programme is essentially geared towards application-oriented collaborative research.

As an additional component for the energy transition in the transport sector and in industrial applications, the Federal Government is also fostering battery research. It has presented the *Umbrella Concept for Battery Research* as the funding policy framework for all aspects of this area. The Research Institution for Battery Cell Production FFB, which is currently under construction, is intended to boost technology development at the interface between research and industrial production.

In order to drive the transformation in the vehicle and mobility sector on both road and rail, the Federal Government is funding cross-departmental research, development and model implementation for innovative vehicles and novel mobility concepts and systems – including through the *New Vehicle and System Technologies* specialist programme. This includes, for example, developing technologies for powertrains, storage and lightweight construction, exploring new concepts for mobility and logistics, and advancing autonomous connected vehicles along with their network infrastructure. Other thematic priorities include the research and application of AI solutions, the integration of vehicles into data and mobility systems, and the digitalisation of vehicles and the mobility system. To this end, the German government has set up such initiatives as digital test beds on federal motorways, on waterways and for rail transport and is funding R&D projects, most recently with a focus on public transport. In order to ramp up the transformation of mobility and increase the viability of rail as a sustainable mode of transport, the Federal Government has established the *German Centre for Rail Traffic Research (DZSF)* to expand its departmental research.

In addition, the Federal Government is supporting the development of a mobility data ecosystem in Germany through two data infrastructures, *Mobility Data Space (MDS)* and *Mobilithek*. In cases where there is no obligation to provide data, but where it is in the interests of economic and transport policy to do so, the MDS supports the voluntary exchange of this data whilst maintaining data sovereignty. *Mobilithek* is a national access point for mobility data which was set up as a data exchange platform among mobility providers, infrastructure operators, transport authorities and information providers. In addition, the planned *Mobility Data Act* is also intended to create a binding legal framework for the handling of mobility data.

Cities, communities and regions play a decisive role in implementing innovative solutions and successfully transforming business and society. In order to develop new solutions with scale-up potential and to improve the conditions for the emergence and application of social and technological innovations, the BMBF is bundling cross-sectoral research in cities, municipalities and functionally connected areas within the urban and regional transformation initiative '*Urban Rural Future*'.

↗ A presentation of all research institutions and their research profiles can be found in the ***Online Tools*** of the report.

3.2 Climate, biodiversity and food security: solutions for a sustainable future

Research on the responses of trees and forests to climate change in the laboratory of the KIT Campus Alpin at Karlsruhe Institute of Technology

Global warming, loss of biodiversity and increasing food uncertainty in parts of the world are among the existential global crises of our time. Finding sustainable and socially equitable solutions for protecting the climate, the environment, natural resources and biodiversity and for facilitating the sustainable transformation of our agricultural and nutritional systems can only be achieved on the basis of scientific knowledge. Research and innovation – for instance, climate and climate impact research, as well as new technological developments and social innovations for climate protection, adaptation strategies, sustainable energy systems and agriculture – contribute significantly to achieving the UN Sustainable Development Goals, European climate and energy policy, the *EU Biodiversity Strategy for 2030* and the EU missions on climate adaptation and soil health and nutrition.

The use of digital technologies offers far-reaching opportunities for agricultural and food systems as well, for instance by increasing productivity and fostering the sustainable use of resources. In its 2024 report, the EFI therefore also emphasises the need to make greater use of digitalisation in agriculture. This is to be achieved by expanding the digital infrastructure, creating a standardised data space across the Länder, built on clear regulations around data protection and data sovereignty, and by capacity building in the use of digital and smart technologies.

Climate knowledge is the basis for effective climate policy. Climate data and climate models provide information and knowledge bases for the necessary strategies and solutions on our path to climate neutrality, for our adaptation to climate change and the mitigation of risks. For this reason, the Federal Government is supporting the development of new global climate models, such as *WarmWorld*, which make use of technological opportunities, in particular high-performance computing (HPC) and AI. The Federal Government is laying the foundations for the collection of climate data by funding the establishment and expansion of research infrastructures such as the observation network ACTRIS-D (which provides measurement data on short-lived atmospheric constituents) and the Integrated Greenhouse Gas Monitoring System (IMTS).

New technological capabilities, such as the expansion of HPC capacities and the use of AI, are opening doors to new generations of global, high-resolution climate models and future climate projections. For this reason, the Federal Government is devising the *National Climate-modelling Strategy (NMS)* to guide its commitment to the development and use of new climate models in Germany and to their professional use as an advisory tool.

To deal with hard-to-abate and residual emissions in industry, the Federal Government is preparing a *Carbon Management Strategy* and a *Long-term Strategy on Negative Emissions*. To implement these strategies, it is supporting the research and development of technologies for the capture and subsequent storage or use of carbon dioxide in the energy-intensive basic industries: carbon dioxide removal (CDR), carbon capture and utilisation (CCU) and carbon capture and storage (CCS).

Research, scientific oversight, monitoring and capacity building are also key components of the revised *National Biodiversity Strategy (NBS 2030)* and the *Federal Action Plan on Nature-based Solutions for Climate and Biodiversity*, through which the Federal Government is pursuing the implementation of its international and European agreements on the conservation and sustainable use of biological diversity, as well as its climate targets. In its research funding for sustainability and climate protection, the Federal Government is prioritising the use of digital technologies. Significant contributions are being made, for example, through research and development in the framework of the *Natural.Digital.Sustainable* action plan, *the GreenTech Innovation Competition*, research funding for AI methods within the *Research Initiative for the Biodiversity Conservation (FEdA)* and the funding initiative *AI Lighthouse Projects for the Environment, Climate, Nature and Resources*. They not only offer perspectives on how digital solutions and AI can contribute to greater climate protection and sustainability, but also demonstrate ways in which these technologies themselves can become sustainable and more energy-efficient.

The Federal Government is fostering research, development, testing and capacity building on digital technologies and their practicality in crop production, animal husbandry and value chains. To this end, it is currently funding the set-up and networking of digital experimental test beds as part of the agricultural *Future Programme Digital Policy Agriculture* as well as research projects on the use of AI technologies in agricultural and food industry practice.

Two employees digitally plan and record the cultivation and harvesting of lettuce in a large greenhouse complex

In collaboration with the state of Saxony-Anhalt, the Federal Government is using funds from the *Coal Regions Investment Act* to support a model region for the *Digitalisation of the Plant-based Value Chain*. The goal is to build up a digitalised, climate-neutral and competitive bioeconomy in the region. The development and testing of digital bioeconomic approaches is at the core of the *Agricultural Systems of the Future* initiative. The insights gained make important contributions to the sustainable and resource-efficient transformation of our agri-food systems.

The Federal Government is driving technological developments in the field of breeding research as well, as also recommended in the EFI 2024 report. The *National Bioeconomy Strategy* therefore fosters innovative open-technology and open-method plant breeding research, for instance through the BMBF funding priority *'Modern Plant-breeding Research for Climate-ready and Site-specific Crops of Tomorrow'*.

3.3 Focus on healthcare: research and innovation for the medicine of tomorrow

An employee of the NMI Natural and Medical Sciences Institute at the University of Tübingen conducting research on biomarkers

Health research is constantly creating new opportunities to maintain health, better understand and prevent diseases, develop therapies and improve medical care for people. For instance, the National Decade Against Cancer is pooling the strengths of a variety of stakeholders to enhance cancer research in Germany over the long term.

The critical importance of productive health research was underscored during the pandemic by the rapid advances that were able to be achieved in the prevention, diagnosis and treatment of COVID-19. Nevertheless, a great deal of effort is still required in health research to deal with its consequences, especially with its long-term post-acute sequelae – long COVID/post-COVID syndrome and ME/CFS (myalgic encephalomyelitis/chronic fatigue syndrome), which is a serious form of post-infectious syndrome similar to long COVID.

Since as early as 2021, the Federal Government has been funding research into the causes, diagnosis, treatments and care with regard to post-COVID syndrome/long COVID and ME/CFS and has meanwhile stepped up its efforts even further. The *National Clinical Study Group (NKSG)*, for example, has strengthened research into therapies and treatments for ME/CFS and post-COVID syndrome. The Federal Government will continue to systematically fund research on long COVID/post-COVID syndrome and ME/CFS, focusing on healthcare research, new data-driven approaches and research into the pathomechanisms of ME/CFS.

To prevent future pandemics, it is necessary to take a more holistic view of global health issues and the interrelationships and dependencies between people, livestock, pets and ecosystems. This is what the so-called One Health approach stands for, a holistic view of the health of humans, animals and the environment. The importance of this approach has been particularly highlighted by the COVID-19 pandemic and the suspected origin of SARS-CoV-2 in an animal host.

The Federal Government-funded alliance of German university hospitals within the Network of University Medicine (NUM) plays a key role in strengthening pandemic preparedness and our capacity to deal with future health crises. The ongoing support of the inter-

national vaccine initiative *CEPI (Coalition for Epidemic Preparedness Innovations)*, which is co-funded by Germany as one of the world's largest donors, also contributes to this goal. The prevention of pandemics and global health crises is also a key focus of increased efforts in One Health research. The aim is to improve the understanding of the interdependencies between human, animal and environmental health and to conduct interdisciplinary and transdisciplinary work on prevention approaches, for instance, through improved surveillance. The aim of the *One Health Platform* is to create better networks and bundle existing national and international research capacities and funding initiatives. In addition, the Federal Government is also focused on the fight against the so-called 'silent pandemic' of antimicrobial resistance and is funding nationally and internationally relevant research projects and initiatives.

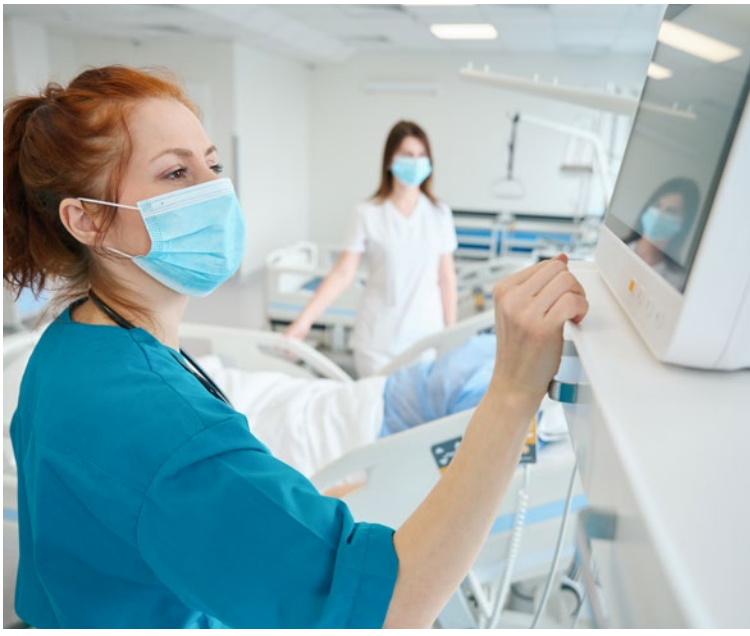
The *Funding of Public Health Research* also broadens the perspective of individuals and expands the health of individual population groups and the population as a whole. The key factors in this process are the fostering of physical, mental and social health, the prevention of disease, health literacy and people's health-related behaviour. At a time when we are experiencing multiple crises, aligning public health research with currently emerging challenges is essential in order to achieve a lasting improvement in the German research landscape in terms of healthcare and public health crisis preparedness and response. In 2023, in collaboration with the Länder, the Federal Government launched the new funding phase of the *German National Cohort Study (NAKO)*. The large-scale longitudinal survey aims to obtain answers to questions related to the emergence of widespread chronic diseases such as cardiovascular disease. In addition, projects to research and improve scientific procedures in the *Public Health Service (ÖGD)* also specifically promote the further development of public health practice on the ground.

Cancer still remains the most feared disease. This is why the National Decade Against Cancer was conceived. The aim of the initiative is to specifically advance cancer research in Germany and accelerate translation so that innovative treatments and therapies reach all patients as quickly as possible. At the same time, a significant priority of the Decade is the prevention and early detection of cancer.

Due to demographic change, the number of people suffering from dementia in the population is increasing – this figure is currently at around 1.7 million. Therefore, research is essential to improve the quality of life of those affected and to find better prevention and therapy options. The National Dementia Strategy aims to improve the living situation and quality of life of people with dementia in the long term.

The research and development of digital technologies, the application of AI, and the use of digital health data across locations, disciplines, healthcare areas and national borders present considerable opportunities for medical research and for an efficient and effective healthcare system. That is why the Federal Government is driving digitalisation in medical research and healthcare. In this process, it attaches central importance to the use of AI and access to health data for provision of care and for research. This is also evident, for example, in the *Digitalisation Strategy for Health and Care*. AI in data-based biomedical research enables the rapid and intelligent analysis of, in as far as possible, representative data, and its application to medically relevant research topics. The use of AI can therefore leverage enormous innovation potential for medicine of the future.

The Federal Government is making a decisive contribution to the development of a decentralised research data infrastructure for health data through the



European Health Data Space (EHDS) and the *Health Data Use Act*, and with its funding of the *Medical Informatics Initiative (MII)*, the NUM and the *Digital Hub: Advances in Research and Health Care*. For example, since 2023, the *MII's German Portal for Medical Research Data (FDPG)* has served as a hub for making applications to access patient data and biosamples held by the university medical centres for medical research purposes. Current priorities of R&D funding also include the use of AI-based assistance systems in hospitals and the promotion of computational life sciences – methodological approaches in bioinformatics, modelling and simulation, and AI.

In 2024, as part of the *National Strategy for Genomic Medicine (genomDE)*, the Federal Government plans to launch the *Pilot Project Genome Sequencing* for the nationally standardised diagnosis and treatment of rare diseases and cancer using genome sequencing. The consent-based use of the data is also intended to advance research.

The Research Data Centre (FDZ) at the Federal Institute for Drugs and Medical Devices (BfArM) will also be collecting health data (under the rubric: Health) for research and innovation from approx. 70 million people insured in the statutory health insurance system. From mid-2025 this will include data from the Electronic Health Record System (elektronische Patientenakte – ePA). A huge step forward in the digitalisation of healthcare was achieved in the mandatory use of e-prescriptions, which has been in place since the beginning of 2024. This also opens up the prospect of making comprehensive research data available in the future.

↗ Further links can be found in the ***Link-Portal R&I Policy*** (in German only).

3.4 Technological sovereignty: co-designing key enabling technologies on an equal footing

Project at the German Research Center for Artificial Intelligence on digitalisation of construction services and processes with Industry 4.0 technologies

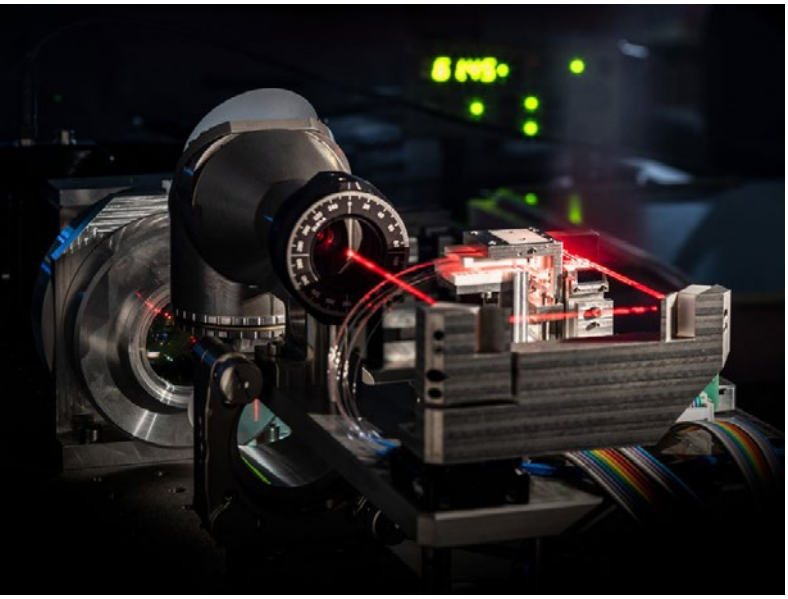
In order to boost digital and technological sovereignty, the Federal Government is committed to systematically funding key enabling technologies (KETs). International competition in the field of technology has become much more intense, posing challenges for Germany and its European partners in terms of Europe's technological sovereignty. This sovereignty is essential for the future-readiness, security, freedom and prosperity of both Germany and Europe. The development of modern technologies and their self-determined application enables innovation, secures competitiveness and employment and makes an important contribution to meeting global challenges. In addition to quantum technologies, cloud and edge computing, distributed data spaces, microelectronics, materials technologies, interactive technologies and robotics, it is above all the responsible, human-centred development and application of AI as a KET for the common good that opens up far-reaching opportunities to improve the lives of many people, increasing their safety and security, advancing environmental and climate protection and stimulating economic growth.

Data is increasingly proving to be the key resource for the acquisition of scientific knowledge, for innovative technologies, for circular value creation and data-driven business models, and for use in public administration. It is the foundation for the development of AI. For this reason, it is crucial to have technical infrastructures available that ensure the accessibility, portability and interoperability of research data while guaranteeing data compliance and transfer.

The Federal Government has defined strategic R&I policy guidelines for the digitalisation of data and its effective collection, sovereign and innovative use, and management in its *Digital Strategy* (2022) and the new, expanded *Data Strategy* (2023). These activities form one of the pillars for the development of a specifically German and European style of artificial intelligence, which the Federal Government is pursuing through the *Artificial Intelligence Strategy of the German Federal Government*, along with the *AI Action Plan* as the relevant implementation plan under the remit of the BMBF. The *AI Action Plan* aims to further strengthen and network excellent AI research in Germany so that the use of AI leads to visible and

measurable economic successes that yield concrete, tangible benefits for society. This also entails greater European solidarity and advocacy for the innovation-friendly and risk-based design and implementation of the *EU Artificial Intelligence Act (AI Act)*. The goal is to establish 'AI made in Germany' as a seal of excellence that unites the new technologies with the strengths of Germany as a research location and embodies a solid European canon of values. Of particular note in the existing AI ecosystem are the six German Centres of Excellence for AI Research, which conduct cutting-edge research in the field of AI, as well as the four AI service centres that offer companies access to computing infrastructure and AI expertise, thus fostering the transfer of knowledge and technology into real-world practice. These are flanked by further recruitment activities by a number of federal ministries to attract specialists and supplemented by topic-specific funding measures.

The EU is boosting technological sovereignty in microelectronics through the *EU Chips Act* – in particular through significant investments in research and innovation. The Federal Government is involved in the relevant initiatives, including the establishment of pilot lines to ramp up the transfer from 'lab to fab'. In addition to microelectronics, it is also looking towards the development of quantum chips.



Laser-based addressing optics for an optical quantum computer from the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) in Jena

In order to create secure and robust systems for a cyber-resilient society, the Federal Government is expanding its funding for cybersecurity research on the basis of the *Cyber Security Strategy*. The R&I policy framework is provided by the *Research Framework Programme on IT Security 'Digital.Secure.Sovereign'* and the *Cyber Security Research Agenda*, as well as being underpinned by specific measures.

Through the National Coordination Centre for Cybersecurity, the Federal Government is strengthening national and European coordination on research, development and innovation in cybersecurity and fostering the establishment of a national cybersecurity community.

While the expansion of the 5G mobile communications standard is forging ahead on a broad scale, research and development is already focusing on the emerging technology of 6G. This is supported by Federal Government funding initiatives such as the *Hyperconnectivity Flagship Initiative* and the *6G Research Initiative*. An important part of the structural measures is the establishment of four hubs for research into 6G technology and the broad-based funding of industry-led joint research projects.

The ultimate goal of research funding for cybersecurity and communication technologies is to ensure that Germany participates in shaping the hyperconnected digital world of tomorrow according to liberal democratic values and to achieve greater technological sovereignty, security, resilience and sustainability through fundamental and disruptive innovations.

Quantum technologies constitute another emerging area with disruptive potential for business and society. With its outstanding research landscape and excellent research infrastructures, Germany has the opportunity to position itself as a global leader.

The Federal Government's 2023 *Quantum Technologies Conceptual Framework Programme* has created the strategic framework for forging ahead with the independent development of quantum computers, quantum sensor technologies, quantum-based imaging and fundamental quantum technologies. One focus is on quantum computing demonstration devices for early-stage applications in the fields of simulation, optimisation, machine learning and AI.

As quantum technologies are still in the early stages of development, there is the potential to play a key role in shaping future fields of application and markets. With this in mind, new initiatives were launched in 2023 for the development of hardware and software for quantum computers, materials and processes for quantum technologies and photonics, and for the early-stage applications of these future technologies for environmental sustainability.

Through the Research Fab Microelectronics Germany, the Federal Government is promoting the development of a module for quantum and neuromorphic computing in order to accelerate research and technological development and facilitate the transfer to industrial applications.

Robotics, and in particular AI robotics, offers an enormous range of application and consequently holds huge potential for innovation. For this reason, the Federal Government has strategically aligned robotics research with application-oriented research and is strengthening the national robotics ecosystem in the areas of research and skilled professionals with the *Robotics Research Action Plan*, presented at the end of 2023. In terms of the structural framework, the Federal Government will build the *Robotics Institute Germany* to strategically strengthen the networking of top research in Germany and the fostering of talent at leading robotics sites.

3.5 Boosting space travel, exploring and making sustainable use of space and oceans

International Satellite Station Facility of the Earth Observation Centre at the German Aerospace Center (DLR) in Inuvik, Canada

The exploration of the universe provides fundamental insights into the origin and development of the cosmos and our planet. Basic scientific research and its relevant infrastructures form the foundation for future technologies and function as a catalyst for innovation. Thanks to new technological possibilities, the operational use of outer space, in particular for Earth and climate observation, navigation and communication, is becoming a key strategic focus for securing the sovereignty of Germany and Europe as a whole. In addition, space travel is becoming increasingly dominated by a privately operated space industry (New Space) involving a growing number of commercial satellites and players. This opens up new market opportunities, especially for start-ups and SMEs. At the same time, the need for a sustainable, regulated utilisation of outer space is also growing in relevance.

In 2023, the Federal Government adopted a new *Space Strategy* as the basis for Germany's space activities over the next decade. This takes account of the increased relevance of space travel for science, for state capacity and for technological sovereignty, as well as recognising space travel as an economic growth market. In order to advance the development of commercial and cost-effective access to outer space and the viable business models associated with this, the German government is supporting two start-ups in developing a launch system for small payloads such as minisatellites as part of the *Microlauncher Competition*. In addition, investments are primarily planned in the areas of Earth observation, satellite communications, space security, space infrastructures and space exploration.

In 2024, the Federal Government will complete the Square Kilometre Array Observatory (SKAO) enrolment process. This will enable German radio astronomy to take a big step forward on its path to decoding dark matter. At the same time, fundamental research will be structurally strengthened and expanded through the establishment of the *German Center for Astrophysics (DZA)*, initiated in 2023 by the Federal Government in collaboration with the Free State of Saxony. The aim is to bundle technology development, data expertise and astrophysics research in one research centre.

In the interests of further research into the universe and its fundamental forces, the Federal Government will continue to strategically expand research infra-

structures for basic scientific research both nationally and internationally and will intensify its involvement. The strategic basis for this is provided by the *Exploration of Universe and Matter (ErUM)* framework programme. The action plans *ErUM-Pro (Project Funding for the Networking of Universities, Research Infrastructures and Society)*, *ErUM-Data (From Big Data to Smart Data)* and *ErUM-Transfer (Innovations from Fundamental Research)* are designed to develop specific measures to achieve the goals of the framework programme.

The Federal Government will also continue to advance the development of forward-thinking space technologies as key instruments for state capacity and for the technological sovereignty of Germany and Europe. These include the ability to launch satellites into space, safeguard satellite communication and obtain an up-to-date space situational overview. To this end, Germany will cooperate even more closely in Europe and internationally, while ensuring its capacity to contribute and engage in partnerships through national activities. In addition, the Federal Government will focus on the development of private-sector space applications and the long-term use of space.

Oceans and seas cover more than two-thirds of the Earth's surface. As the largest contiguous ecosystem on earth, they offer unique biodiversity, as well as being crucial for the global carbon budget and the climate. They are also of immense socio-economic importance for fishing, for resource and energy production and as a transport route for maritime shipping. However, overfishing, environmental pollution and destruction, and climate change are placing a major strain on our oceans and seas. That is why the European Union has set itself the task of researching, protecting and revitalising them by 2030, as set out in the mission 'Healthy Oceans, Seas, Coastal and Inland Waters'. Marine research in particular contributes to gaining a better understanding of ecological relationships in marine ecosystems. It allows us to better assess the consequences of human activities and to identify innovative solutions for the protection and sustainable use of the oceans.

The Federal Government is taking a cross-sectoral approach to ensuring the protection of the oceans with its appointment of a marine commissioner in 2022 and the development of a marine strategy by 2025. Important contributions to this are research into the effectiveness of measures and the transfer of knowledge gained from research to society and politics.

Remotely operated underwater vehicle

In order to strengthen German coastal, marine and polar research, the Federal Government and the Länder of Bremen, Hamburg, Mecklenburg-West Pomerania, Lower Saxony and Schleswig-Holstein have joined forces in the *German Marine Research Alliance (DAM)*. *DAM* focuses on long-term, high-impact, application-oriented research missions in its approach. In addition to two *DAM* research missions on the protection and sustainable use of the oceans and on their function as carbon sinks, which have been running since 2021 and will continue in 2024, a third research mission on risk management for extreme marine events and natural hazards was launched at the beginning of 2024. The research missions contribute to the implementation of the Federal Government's research programme *MARE:N – Coastal, Marine and Polar Research for Sustainability.*

In the interest of positioning marine and polar research for the future, the German government is planning the prospective modernisation of the German research vessel fleet. The 'Meteor IV', the successor ship for the research vessels *'RV Poseidon'* and *'RV Meteor'*, is currently under construction. A call for tender for the construction of a successor ship for the icebreaker *'RV Polarstern'* has been put out across Europe.

↗ A detailed description of the R&I policy of the Länder and statistical data at Länder level can be found in the ***Online Tools*** of the report.

Working on sediment cores aboard the research vessel 'Maria S. Merian'

3.6 Fostering social resilience, diversity and cohesion

Mounting socio-political crises, intensifying systemic competition, and socially divisive and anti-democratic tendencies pose challenges to the liberal democratic order and social peace. R&I can contribute to equitable living conditions in all regions of Germany to reduce existing disparities and achieve resilient regions, good development and fair participation opportunities regardless of where people live. It can also strengthen social cohesion and ensure freedom and security for all people – this is all underpinned by the *Future Research and Innovation Strategy*.

The Federal Government is pursuing an approach based on a broad understanding of innovation, which includes technological and social innovations in equal measure. Social innovations have the potential to provide answers to important topical issues of our time and to strengthen social cohesion and participation. After all, new social practices and organisational models open up a wide range of opportunities for participation. They have the potential to make the transformations that are needed more socially equitable. The EFI has repeatedly highlighted this in its reports. In 2024 it devoted particular attention to social innovations as a core topic, not without pointing out that the impact measurement necessary for an evidence-based R&I policy, including for social innovations, poses significant challenges.

To address this, the Federal Government adopted a *National Strategy for Social Innovations and Social Enterprises* in 2023 in order to remove structural roadblocks, improve general conditions and appropriately align innovation funding. This is geared towards societal needs and aims to reinforce diversity, participation and sustainability.

The funding programme *REACT with Impact – Promoting Social Entrepreneurship* was conceived, for instance, to support the stabilisation and professionalisation of social SMEs and grow the attractiveness of social start-ups for investors. Its successor programme is due to start in the summer of 2024. In addition, the *Platform for Social Innovations*, launched in 2023, is designed to promote networking, provide information and strengthen social innovation capacity. On top of this, the cross-departmental initiative *Civic Coding – Innovation Network AI for the Common Good* aims to create structures that promote the emergence of social innovations from mainstream society and the widespread societal uptake of AI.

In order to drive the implementation of the *National Strategy for Social Innovations and Social Enterprises*, the Federal Government will strengthen cross-sectoral exchange with civil society, science, the private sector and the capital market. The strategy engages relevant stakeholders and bundles capacities and expertise. In addition, the progress and success of the strategy are recorded and monitored using a comprehensive set of indicators.

The Federal Government is providing knowledge for orientation, decision-making and action, creating scope for unconventional research questions, and establishing research data infrastructures. These focus areas reinforce the humanities and the cultural and social sciences in making important contributions to a liveable society that is capable of transformation and innovation. The Federal Government is also expanding funding for research into racism, right-wing extremism, anti-Semitism and antiziganism in response to incidents and crimes of the past related to these areas. To ensure that research, development and innovation are guided by their benefit for all people – regardless of gender, age or other dimensions of diversity – the Federal Government is committed to driving the structural integration of gender perspectives and excellent research in all disciplines through the *Gender Aspects in Focus*.

Science communication and the active exchange of ideas with wider society enrich evidence-based civic discourse. The participation of society also contributes to the development of practical and socially viable solutions and thus to increasing the impact of science. Insights from science and research are important to enable policymakers and civic society to make good decisions.

In order to intensify the dialogue between science and society so that scientific findings can effectively contribute to tackling societal challenges, the Federal Government has set itself the priority of fostering science communication, and to this end it established the participatory discourse platform *#FactoryWisskomm*, a think tank on prospects for action in science communication. This creates a solid framework for effective and responsible science communication. In addition, the think tank platform has served as a tool to develop recommendations for action and identify new topics.

As part of the *Science Year 2024 – Freedom*, the Federal Government is highlighting science and research on the topic of freedom. The general public is invited to engage in discussion and constructive debate on the topic. A wide range of formats, events and individual initiatives focus on issues relating to the resilience of our democracy in the light of the many crises we are currently facing and on the preservation of freedom for future generations.

To ensure that people in Germany are even better prepared for the crises of tomorrow, the Federal Government is continuing its commitment to security research in the new framework programme *Research for Civil Security – Working Together for a Safe Life Within a Resilient Society*, which was launched in January 2024 and will run from 2024 to 2029. The focus is on the targeted transfer of innovative solutions for civil protection during crises and disasters, detecting and managing hybrid threats, ensuring population supply with an emphasis on self-sufficiency, and identifying, understanding and combating crime and radicalisation phenomena. An innovation laboratory for security research is to be created for this purpose.

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