



# *Federal Report on Research and Innovation 2022*



Federal Ministry  
of Education  
and Research

Short version

# Foreword

Dear Readers,

The Federal Government's leitmotif is 'Dare more progress'. We want to enable more technological and social innovation and transfer ideas from research into practice more quickly in order to meet the challenges of our time with new courage.

What we achieved during the COVID-19 outbreak, for instance in developing a virus detection method and vaccines in record time, must also work for other challenges. We need to be able to swiftly find good answers to pressing questions and resolutely put them into practice.

A myriad of complex tasks have taken on a new dimension with the Russian attack on Ukraine. The European Union must recalibrate international relations with its partners by reducing its foreign dependencies. At the same time, it must strengthen its own position in international competition, also with a view to domestic security. From cybersecurity to civil security, we will make our contribution through research.

We are striving for a sustainable and climate-neutral economy and society. That is why we are focusing on research in new energy technologies, green hydrogen, biotechnology and climate-neutral industrial processes. By the same token, we want to shape the digital transformation based on our European values by advancing quantum technologies and making better use of the opportunities offered by artificial intelligence. We will improve access to big data, for example in health research.



Our research and innovation policy determines how well we prepare the ground for emerging fields of development. In a joint effort with the Länder and with industry, the Federal Government is therefore vigorously pursuing the goal of investing 3.5% of GDP in research and development from 2025 onwards. The 2030 Agenda and the Paris Agreement provide an additional global framework for our actions, which will consistently keep the well-being of future generations in mind as well.

In this Federal Report on Research and Innovation 2022, I am pleased to provide you with an impression of this work. The report describes the political commitment at federal and state level and addresses key statements made in the report delivered by the Commission of Experts for Research and Innovation. In addition, it provides an outlook on the agenda for the coming years and highlights the recent adjustments and focal efforts undertaken by the current Federal Government. As such, it serves as a reliable overview. I wish you all a pleasant read.

A handwritten signature in white ink that reads "B. Stark-Watzinger".

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

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# 1 Launching a new decade of transformation

**Education, science, research and innovation set the foundation for social and technological progress and sustainable development. They contribute to prosperity, quality of life, social cohesion and the preservation of the natural life-support systems. Having a good regulatory and business environment strengthens Germany's position as a science location in international competition. This also helps us generate innovations from ideas that will contribute to meeting the major societal challenges of the coming decades.**

The challenges are many. Geopolitical and security policy changes have created new conditions for society, the economy and science. In view of the Russian war of aggression against Ukraine, the European Union and its partners are faced with the task of recalibrating international relations, reducing foreign dependencies and strengthening Germany's and Europe's position in international competition. Against this backdrop, there is a high priority to secure and continuously expand technological and digital sovereignty and to increase research activities and investments in the field of rapidly developing key enabling technologies. This is of particular importance both for the energy sector, where the transformation towards renewable energies is of high

urgency for both climate and security policy reasons, and for civil, military and cybersecurity as key areas of national security.

The transformation towards a climate-friendly and sustainable economy that is in harmony with the natural life-support systems requires profound economic and social changes. As the Commission of Experts for Research and Innovation (EFI) also points out, this requires both new and disruptive ideas. To achieve this, a globally coordinated system of goals that includes the well-being of future generations is found in the Sustainable Development Goals in the 2030 *Agenda*, the climate goals in the *Paris Agreement* and the global goals for the conservation of biodiversity.

At the same time, we still need to address the COVID-19 pandemic and its social and economic implications. The COVID-19 pandemic has shown the potential in mobilising research, science, business and civil society in Germany to quickly develop effective solutions to pressing problems. Basic and applied research teams collaborated with industry to make important contributions to the pandemic response. With its long-term prioritisation of R&I policy, the Federal Government has laid the foundation for Germany's research strength.

The digitalisation push triggered in the pandemic situation has also been reflected in research activities. Companies in the information and communication technology sector increased their turnover in this generally difficult situation and boosted their R&D expenditure by 5.2%, compared to the previous year. Accordingly, the Federal Government also sees the pandemic-related challenges as an opportunity to accelerate urgent transformation processes towards a sustainable economy, public administration and society. The goal remains to achieve an investment of 3.5% of GDP in research and development by 2025 in a joint effort with the Länder and the private sector.

After reaching a new high in 2019, total expenditure on R&D fell in the following year due to the pandemic. The full-time equivalent of R&D personnel nevertheless remained almost constant at 735,000 in 2020 compared to the previous year. To counteract the negative consequences of the COVID-19 pandemic, the government increased funding for R&D in 2020. The Federal Government alone increased its R&D spending by 1.9 billion euros, for instance through the *Economic Stimulus and Future Development Package*. According to preliminary calculations, R&D expenditure by the government, private sector and universities totalled 105.9 billion euros. This corresponds to preliminary R&D expenditure of 3.14%.

Germany offers researchers in science and industry a unique space to develop and explore new ideas. The strength of its innovation lies in its excellent science system, which has its roots in internationally renowned universities and non-university and ministerial research institutions, at which basic and applied research is closely dovetailed with transfer into policy and society. This system is also sustained by a strong, crisis-resistant economy that makes

diverse contributions to R&I, and by a high level of institutional stability that guarantees scientific freedom in an openly competitive landscape. The Federal Government will build on this and launch a new decade of transformation.

The Federal Government will present a future research and innovation strategy that consolidates the targets and activities of its R&I policy whilst setting priorities and milestones horizontally across its ministries. The future research and innovation strategy is intended to meet the new demands on government, policy and public administration entailed by the current crises and the necessary transformation processes. In key emerging fields of development, the Federal Government will engage with tougher global competition in technology and accelerate sustainable development. In the future, it will also increasingly foster social innovations in order to accelerate transformation processes. In its R&I policy, the Federal Government takes the entire innovation chain into account, from basic research as the launching pad for potential new solutions through to the development of marketable and societal innovations. In its Annual Report 2022, the EFI additionally emphasises that public administration and government must also undergo a comprehensive modernisation process and that European and international cooperation in R&I must be strengthened. This will ensure that insights become innovations, data potential is leveraged, talent is fostered, and new players are attracted into the R&I system. People should be encouraged to become involved and boldly try something new – to launch into a successful decade of transformation.

Those measures mentioned in this report that have financial implications for the federal budget and/or social security schemes are subject to financing and can therefore only be implemented as long as they are directly, fully and permanently counter-financed in the respective individual budget or policy area. The inclusion of measures in this report is without prejudice to current or future budget negotiations.



## 2 Actively shaping transformation processes and reaping the benefits of emerging fields of development

Changes in the global political situation must also be taken into account in the area of research and innovation (R&I) policy. To safeguard peace and freedom, the Federal Government is therefore directing its R&I policy more clearly towards strengthening Germany's and Europe's technological sovereignty and avoiding unilateral dependencies. To this end, aside from developing key enabling technologies, it will resolutely advance sovereign digital design. The energy transition and the phase-out of fossil energy sources must also be further accelerated in view of the Russian war of aggression against Ukraine. At the same time, Germany must continue to play its part in meeting the global challenges. To this end, the Sustainable Development Goals of the 2030 Agenda must be achieved and resilience must be strengthened in all areas of society. The Federal Government will address key fields of future development in the form of missions applied horizontally across the ministries and will closely link its R&I policy measures with those of other policy fields.

## 2.1 Securing the sovereignty of Germany and Europe

Research and innovation (R&I) make crucial contributions to securing Germany's and Europe's technological sovereignty. In this context, the EFI points to the importance of key enabling technologies. Their availability and our ability to master them are an important prerequisite for avoiding unilateral dependencies. Key enabling technologies play a pivotal role in Germany's technological and economic development. They are drivers of technological change and are essential for advancing the development of many other technologies. Accordingly, the Federal Government is increasingly gearing its R&I policy towards securing Germany's and Europe's technological sovereignty. This includes positioning Germany and Europe in strategically important areas such as aerospace research and exploration.

### Future field of development: Securing the technological sovereignty of Germany and Europe

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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. Key enabling technologies are particularly relevant for the preservation and expansion of technological and digital sovereignty, as they form the basis for advancing the innovative development and application of many other technologies. They are therefore essential for the future viability, security, freedom and prosperity of Germany and Europe. As the EFI notes, international competitiveness in the field of technology has greatly intensified. Therefore, strengthening our ability to shape technological development processes on an equal footing with international partners – while avoiding unilateral dependencies and maintaining harmony with European values and the Global Sustainability Goals – is a matter of concern to the Federal Government.

The Federal Government has specifically driven forward development of key enabling technologies through its funding. On the basis of the *Roadmap for Quantum Computing* and the *2030 Research Agenda for Quantum Systems*, the necessary steps for implementing the *Economic Stimulus and Future Development Package* were taken at the beginning of 2021, particularly those in the direction of designing internationally competitive quantum computers. Since June 2021, a pioneering universal quantum computer – IBM Quantum System One – has been available for use in Germany. The European Partnership for High-Performance Computing (HPC) and the new *RTD Framework Programmes for Microelectronics and for Quantum Technologies* are instruments for the Federal Government to increase its investment in the funding of key enabling technologies. The Federal Government has updated its *Artificial Intelligence Strategy* and envisages a variety of measures to make Germany and Europe into leading AI locations. Furthermore, in 2021 the Council for Technological Sovereignty shouldered its task of supporting the Federal Government in the strategic design of its funding policy with regard to technological sovereignty. In addition, the Federal Government promoted the expansion of pioneering work in key enabling technologies at the European level within the framework of *Important Projects of Common European Interest (IPCEI)*.

The Federal Government has set itself the goal of making Germany a strong technology location that builds on European values and attracts talent, while ensuring Germany's future viability and its sustainable development, along with its competitiveness and security. To this end, it is investing in particular in AI, quantum technologies, robotics, sensor technology, cloud technology, microelectronics, IT, cybersecurity, communications and networking systems such as 5G and 6G, hydrogen and other emerging technologies. Funding will also be granted in a targeted manner, through *IPCEIs*, to innovative technology fields such as microelectronics, cloud technologies, battery cell production, hydrogen technologies and communications technologies.



## Future field of development: The exploration and sustainable use of outer space

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Exploration of the universe provides answers to questions about the formation and origin of our planet and our solar system. Findings in this area not only expand our knowledge of the laws of physics and the fundamentals of particles and matter, but also provide the basis for future technologies and are thus drivers of innovation. Basic research, in combination with the necessary research infrastructure in Germany, makes important contributions to this. Due to new technical possibilities, the operational use of outer space, for instance for earth and climate observation, navigation, and communication, is an important strategic focus for securing the sovereignty of Germany and Europe as a whole. The increasing number of commercial satellites and actors in this domain heightens the relevance of ensuring the sustainable, rule-based use of outer space.

The research programme *Exploration of Universe and Matter (ErUM)* provides the strategic approach for basic scientific research conducted using large-scale facilities such as particle accelerators, telescopes and observatories in Germany and worldwide. In particular, the exploration of the universe is being greatly advanced by providing funding for universities and research centres in developing the instruments and

methodologies for these large-scale facilities. Space missions such as Solar Orbiter and ExoMars, as well as Germany's involvement in the James Webb Space Telescope in the framework of the European Space Agency ESA, continue to drive forward the exploration of our solar system and outer space and the development of this research. The first all-German hyperspectral satellite, EnMAP, makes it possible to observe the Earth and its surface and environmental changes in unprecedented resolution.

For the Federal Government, space is a key field of innovation that is fostered on both a national and a European level, particularly through the European Space Agency (ESA). In order to meet pressing societal, economic and security challenges, untapped space potential is to be exploited, especially within the framework of European cooperation. In the future, private activities in space (NewSpace) will also increase, and in turn, issues of avoiding and recovering space debris will also need to be addressed. The Federal Government will develop a new space strategy in keeping with these developments. In addition, through *Science Year 2023 – Our Universe*, it will sharpen the focus of science and society on space travel, as well as on basic scientific research and the large-scale facility landscape for exploring the universe.

## 2.2 Increasing digitalisation dynamics, creating secure and powerful infrastructures, and leveraging data potentials

The digital transformation is fundamentally changing the worlds of business, work and life. Digitalisation holds great potential to drive the transformation towards a sustainable and climate-neutral way of life and economic activity. On the one hand, it makes important contributions such as improving the quality of and access to education and healthcare, developing sustainable, automated and connected mobility, increasing the efficiency of administrative processes and the competitiveness of our economy, and finally, strengthening security and defence. On the other hand, political and military conflicts are increasingly taking place in digital spaces – for example, through cyber-attacks – whilst the threat of cybercrime is also intensifying. Therefore, the focus is shifting more towards the security of critical and digital infrastructures.

### Future field of development: Exploiting the potential of digitalisation

To prepare Germany for a digital future in the best way possible, it is crucial to be involved in the digital transformation and to reinforce Germany's and Europe's digital sovereignty. In this context, the opportunities and innovative power of digitalisation must be used in a way that provides new value creation potentials and business models, whilst also revolutionising communication, mobility and healthcare. At the same time, the transformation process must focus on people's opportunities for growth to ensure prosperity, freedom, security, social participation and sustainable development. Digital literacy is a key prerequisite for actively and inclusively shaping the digital transformation. We must tap into the potential offered by data – as a resource both for a digital society and for public administration, business and research. To achieve this, research activities will be given better and legally secure access to data. Data infrastructures are a key prerequisite for the efficient use of data in this process.

The Federal Government has presented the implementation strategy *Shaping Digitalisation* as an interministerial framework for action that pools the financing mechanisms for steering the digital transformation. One of the priorities set by the Federal Government is the digital transformation of the economy, especially of small and medium-sized enterprises (SMEs). New digital processes, business models and markets, as well as IT security, were the focal points of programmes and funding priorities such as *Mittelstand Digital*

(SMEs Digital) *go-digital*, *Digital Jetzt* (Digital Now) and the initiative *IT Security in Industry*. Federal Government measures such as *Digital Now* and the establishment of the Federal Digital Academy in the Federal Academy of Public Administration (BAkÖV) aim to promote the development of digital skills in education and training both for companies and for administrations. The Federal Government aims to improve data provision, access and use, whilst also building up national and European data infrastructures. To this end, in 2021 it presented its *Data Strategy* and *Open Data Strategy* and introduced the *Act Governing the Use of Public Sector Data (DNG)* together with an amendment to Section 12a of the *E-Government Act (EGovG)*.

The Federal Government has laid the foundation for a networked, open data infrastructure that is based on European values. This will improve access to data and enhance the innovation potential of data, especially in the context of reusing research data. The basis for this is provided by the National Research Data Infrastructure (NFDI) and its EU level counterpart, the European Open Science Cloud (EOSC), as well as Gaia-X. Crucial advances were also made in the use of health data for medical research. As the most data-intensive field of science and the first adopter of new technologies and methods, the *Exploration of Universe and Matter (ErUM)* at large research infrastructures acts as a driver for digital innovation and data services. The implementation of the action plan *ErUM-Data* will advance the expansion of data literacy, the development of software and algorithms, and the transfer of innovative methods and technologies.

The Federal Government is enabling the digital transformation and leveraging data potentials by using data to create the necessary knowledge and harnessing it to foster innovation. To this end, it supports the development of data infrastructures and strives to establish open standards and better access to data, for instance in the environmental, transport and agricultural sectors. The establishment of data trust models is intended to facilitate the exchange of data between industry, science and civil society and to promote innovation. One of the aims of this move is to enable new innovative business models and social innovation in digitalisation for start-ups and SMEs. To this end, the Federal Government is expanding its *Data Strategy* and establishing a data institute. Data access for research purposes is to be comprehensively improved. To achieve this, the Federal Government is examining all available instruments such as sector-specific research clauses, a research data law and voluntary agreements. The aim is for Germany to become the leading light for innovative and secure data use and sharing in Europe. This is because data assets – structuring, using and linking them – are key resources for the economy and society.

## Future field of development: Designing digital security

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The success of digitalisation is largely dependent on people, organisations and companies being able to trust digital solutions and use them on a broad scale in a secure and self-determined way. The necessary trust in digital solutions can only be ensured where the level of IT security is sufficient to meet the risk exposure and where data security and data protection are guaranteed. However, cyberattacks on businesses, individuals, public institutions and critical infrastructure are consistently rising. To ensure our digital future and to be able to continue transacting security-relevant private, economic and governmental tasks, there is a need for R&I that develops demonstrably secure, constantly reliable, resilient and user-friendly ICT solutions and IT infrastructure.

In the Federal Government's research framework programme on IT security *Digital.Secure.Sovereign*, research funding focuses not only on technology-based innovation but also on questions of privacy, data protection and autonomy. The programme is firmly based on European standards and values such as freedom, democracy, the rule of law and informational autonomy, setting the foundation for people-centred digitalisation. In addition to the applied research of key enabling technologies such as quantum technologies or AI in the area of IT security, the focus was particularly on sustainably improving expertise and value creation in the field of IT security. Apart from the establishment of centres for IT security research, we also saw the launch of the *Agency for Innovation in Cybersecurity GmbH (Cybersecurity Agency)*.

The Federal Government will drive forward the development of secure, resilient and trustworthy communications systems and, with Gaia-X, it will create the conditions for secure and sovereign data exchange in industry and society. Furthermore, the aim is to establish shared data spaces and a comprehensive data infrastructure ecosystem for science and industry. IT security research will be further expanded.

## 2.3 Protecting the climate and the environment, resource-conscious management and accelerating the energy transition

**Achieving the global sustainable development goals, the goals of the Paris Agreement on climate protection and the global goals for the conservation of biodiversity will only be possible through a profound transformation in the economy and society. Research, innovation and transfer into practice make crucial contributions to this. Apart from achieving the global sustainable development and climate goals, current changes in the geopolitical and security landscape clearly demonstrate that Germany must quickly become independent of fossil energy sources and ensure the sustainable and crisis-proof production and supply of food. Therefore, the energy transition must also be accelerated through additional R&D activities.**

### Future field of development: A resource-efficient economy, renewable energies and sustainable mobility

The establishment of a competitive, net-zero, resource-efficient economy represents a crucial building block on the path to realising the sustainable development and climate goals of the Federal Government. The transformation required for this also presents itself as an enormous opportunity for innovative companies to develop solutions for this changed mode of economic activity. Up to now, the global economy has been 91% linear in the sense of take–make–dispose. At the same time, industry is responsible for a significant proportion of greenhouse gas emissions in Germany, at a level of almost 24% of total emissions. Therefore, it is of crucial importance to raise resource efficiency and conservation, whilst expanding the substitution of primary raw materials by secondary raw materials in combination with the creation of circular economies.

Other important areas where greenhouse gas neutrality and resource efficiency and conservation can be tackled are urban development and construction. Until now, these areas have also been resource-intensive and responsible for greenhouse gas emissions. Particularly the transport sector is facing the major challenge of significantly reducing emissions, whilst simultaneously enabling affordable mobility that meets demand. In addition to technological innovations (such as alternative drive systems and fuels, battery cells, lightweight solutions, and autonomous and connected driving),

there is a need for integrated sustainable mobility concepts and innovative, attractive mobility options. The Federal Government's goal is to use the 2020s to effect a radical shift in mobility policy. It aims to create sustainable and affordable mobility solutions for all, to push environmental and climate protection, to design a resilient transport system and to embed a new mobility culture for a mobile, digitally connected society and economy. This also includes continuing to leverage the potential of digitalisation and stepping up integrated mobility in passenger and freight transport. Measures must be expanded for adapting to climate change and for ensuring safety and security (road safety and cybersecurity).

Measures such as the *research concept for Resource-efficient Recycling Management*, the *German Resource Efficiency Programme (ProgRes)*, the *National Bio-economy Strategy* and the *National Hydrogen Strategy* will exploit the potential for sustainable and economical use of biogenic and abiotic resources and advance the decarbonisation of industry and transport. Biotechnological processes are of great importance for achieving this.

The Federal Government is driving sustainable and future-oriented urban development across all ministries through measures such as the *Strategic Research and Innovation Agenda City of the Future*, the *Future Building Innovation Programme* and *Resource-efficient Urban Districts (RES:Z)*, as well as through investment funding programmes. A range of interministerial measures have been launched to fund battery-electric and hydrogen-based technologies and lightweight

construction as the keys to a climate-neutral and sustainable transformation of the mobility sector. This also includes the digitalisation and networking of mobility. In addition, the Federal Government has placed its focus on sustainable urban mobility, integrated mobility services, public transport, and walking and cycling, as well as on new business models – especially at the municipal level.

The Federal Government will continue its efforts to establish a circular economy and a successful energy and mobility transition. To this end, research on the use of sustainable fuels in the transport sector, including aviation, will be further expanded. Technological changes are being sought to achieve the decarbonisation of industry – for instance, in the steel, chemical and cement industries. Electrification and the use of hydrogen, for instance in steel production, play a key role in this process. In addition, the Federal Government will present a new Energy Research Programme.

Measures for establishing a circular economy are pooled in the *Circular Economy Roadmap for Germany*. The Federal Government's *Lightweighting Strategy* will also support the creation of lead markets for green innovations. Additionally, through the continuation of the *National Hydrogen Strategy*, the Federal Government is pursuing the goal of even more intensively driving the establishment and rapid market ramp-up of an efficient hydrogen industry based on renewable energies and anchoring it at the European level. In order to develop another non-fossil fuel-based energy source in the long term, the German government is also funding fusion research.

The Federal Government will promote R&I in the area of energy-efficient construction and building refurbishment and is therefore expanding on the development of the research programme *Future Building*. It is also focusing on new, sustainable building materials as well as on measures that upscale the generation and supply of renewable energies at the building and district level. Social innovations for net-zero, affordable construction and housing and sustainable neighbourhood development are also expected to make an important contribution here.

For future-ready, sustainable mobility in our cities and regions, the Federal Government is promoting the development and transfer of intermodal and digital

solutions and ensuring the nationwide transfer of knowledge between the Federal Government, the Länder and local authorities. This is done by strengthening the National Competency Network for Sustainable Mobility (NaKoMo). In order to establish an integrated approach to mobility planning, the Federal Government is supporting the prerequisites for implementing sustainable urban mobility plans (SUMP) and investigating the baseline data required to apply sustainable mobility indicators.

The aim of digital networking and automation is to ensure that there is greater safety, more efficiency and less negative impact on the environment through rail, road and waterway transport. For this reason, the Federal Government will develop a long-term strategy for autonomous and connected driving which will incorporate its main areas of action into the development of a mobility system across all modes of transport.

### Future field of development: Climate protection and biodiversity conservation, adaptation strategies

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As a result of the large-scale changes to nature made by humans, natural ecosystems are under massive pressure. Climate change, loss of biodiversity and land degradation are already having significant negative impacts on people, the environment and society. Protection of the climate, adaptation to climate change, preservation of biodiversity, and sustainable, climate-resilient land use – especially through sustainable agriculture and forestry and sustainable food systems – are therefore important prerequisites for the preservation of the natural life-support systems. R&I can develop new solutions in this context.

The *Climate Action Programme 2030* addresses research needs across and within all sectors of the *Climate Action Programme*. In 2021, the Federal Government tightened climate protection legislation through an amendment to the *Climate Change Act*. The aim is that by 2030, we will have reduced greenhouse gas emissions by 65% compared to 1990 levels, and that by 2045, we will achieve net-zero emissions. The *National Sustainable Development Strategy* is consistently evolving and working towards implementation of the United Nations' *2030 Agenda* with its 17 Sustainable Develop-

ment Goals, which are of crucial importance for all future fields of development. In this context, the Federal Government is also increasing its focus on Education for Sustainable Development (ESD) and is continuing the ESD process of structurally embedding ESD in all areas of education as part of the new UNESCO roadmap *ESD for 2030*. The *Research for Sustainability (FONA)* strategy places research funding for greater climate protection and sustainability in alignment with the *2030 Agenda* and sets the focus on the Global Sustainability Goals. The *National Biodiversity Strategy (NBS)* is Germany's key instrument for implementing the obligations of the *UN Convention on Biological Diversity (CBD)* and the *EU Biodiversity Strategy*. The European Biodiversity Partnership *BiodivERSa+*, launched in October 2021, is intended to make an important contribution to this.

The *Climate Action Programme 2030* will be implemented consistently over the next few years. In order to protect the Earth system and preserve the natural life-support systems, the Federal Government will continue to raise awareness of climate and environmental issues. The development of agriculture will continue to be improved in harmony with nature and the environment, and the digitalisation of this field will be advanced under these same objectives. Innovation potentials for a sustainable agricultural and food system are leveraged via a European agricultural data space.

The proposed Federal Climate Adaptation Act, a new precautionary climate adaptation strategy with measurable targets, the Natural Climate Action Programme and the expansion of biodiversity monitoring are intended to make a substantial contribution to achieving the Federal Government's goals for climate protection. These efforts are geared towards protecting biodiversity and taking precautions against the consequences of the climate crisis. R&I plays a crucial role in the implementation of these goals. Model regions and pilots for adaptation to climate change are being developed through other research initiatives.

## Future field of development: Exploring and sustainably managing the oceans

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Oceans form the largest interconnected ecosystem on earth. Among other things, they are the habitat for more than two million species and play a crucial role in maintaining the global CO<sub>2</sub> balance and planetary air circulation. In the period from 1994 to 2007, the world's oceans absorbed an average of 31% of the CO<sub>2</sub> released by humans. The maritime economy, fishing and shipping are important economic sectors. At the same time, overfishing, climate change, and environmental pollution and degradation are placing severe stresses on the oceans. Marine research plays an important role in understanding ecological relationships, assessing the impacts of human activities and developing new solutions for the protection and sustainable management of the oceans.

The UN Decade of Ocean Science for Sustainable Development (2021–2030), launched in 2021, will boost our knowledge of the oceans and raise public awareness of their key role in the Earth system and in our lives. The extensive international collaboration within the MOSAiC 2019/2020 polar research expedition also provided important scientific insights into the role of the Arctic and the ocean in relation to climate change. In 2021, as part of the German Marine Research Alliance (DAM), the Federal Government joined with the north German federal states to launch two research missions on the protection and sustainable management of the oceans and to research their function as carbon sinks.

The Federal Government aims to reconcile the protection, safety and sustainable use of the oceans and will continue to support top-tier marine research to achieve this. For instance, the aim is to make greater use of automated methods to expand ocean observation, which is indispensable for providing baseline data, and to achieve better usability of the measurement data collected by research vessels. This will increase knowledge of both the deep sea and the polar regions, for example to better assess the ecological impacts of potential deep-sea mining, the capacity of the oceans as carbon sinks, and their vulnerability to climate change. For instance, in order to protect marine ecosystems and promote the use of renewable energies and sustainable shipping, the Federal Government is funding research into alternative propulsion systems and is also looking at hydrogen solutions for shipping.

## 2.4 Fostering resilience in all areas of society

**Global crises, their concomitant impacts and the measures undertaken in response have a profound effect on social and economic systems and infrastructures. The Russian war of aggression against Ukraine and its far-reaching consequences are currently shaking the bedrock of security and certainty we take for granted in Germany; the COVID-19 pandemic and the long-term impacts of climate change are causing uncertainty in many parts of society. The speed of transformation and the experience of crisis are changing people's everyday lives, potentially endangering their prosperity and putting social cohesion to the test. Having a certain degree of robustness in dealing with crises along with resilience, i.e. the ability to adapt to changing conditions in all areas of society, is therefore of great importance. Ideally, resilience does not mean returning to the original state of being, but rather undergoing a transformative development. For example, lessons can be learned from the COVID-19 pandemic to achieve a health system that is more resilient and at the same time more efficient in the future.**

### Future field of development: Fostering social resilience, diversity and cohesion

Social and economic participation, critical and respectful discourse, and the recognition of diversity are considered basic prerequisites for the functionality of liberal democratic societies, for their cohesion and resilience. A lively exchange between the areas of politics, science and society is of great importance for democracy and the legitimisation of political action. This is particularly true in crisis situations, when we need to anticipate changes, identify problems and develop solutions. Therefore, it is important to support the involvement of societal actors in order to align scientific knowledge with societal needs and to benefit from the expertise and perspective of citizens.

The ability of societies to drive transformation processes on the basis of innovation and in alignment with common goals is also becoming increasingly important. A comprehensive examination of current social, cultural and political developments creates knowledge for reflection, orientation and action that contributes to enhancing the cohesion of societies and their democratic institutions.

The promotion of structurally weak regions in particular plays an important role in terms of creating equivalent living conditions throughout Germany.

Through the establishment of the Institute for Social Cohesion (FGZ) and the framework programme *Understanding Society – Shaping the Future*, the Fed-

eral Government is directing research in the social sciences and humanities towards the development of a sustainable and resilient society. This is, for example, guided by questions of post-pandemic renewal and resilience, as well as combating extremism, racism and anti-Semitism.

The *Federal Funding System for Structural Development Regions* pools the relevant federal funding mechanisms and also aims to help provide people in all regions of Germany with the opportunity for a decent life, decent basic services, a decent education and decent work, thus also strengthening social cohesion.

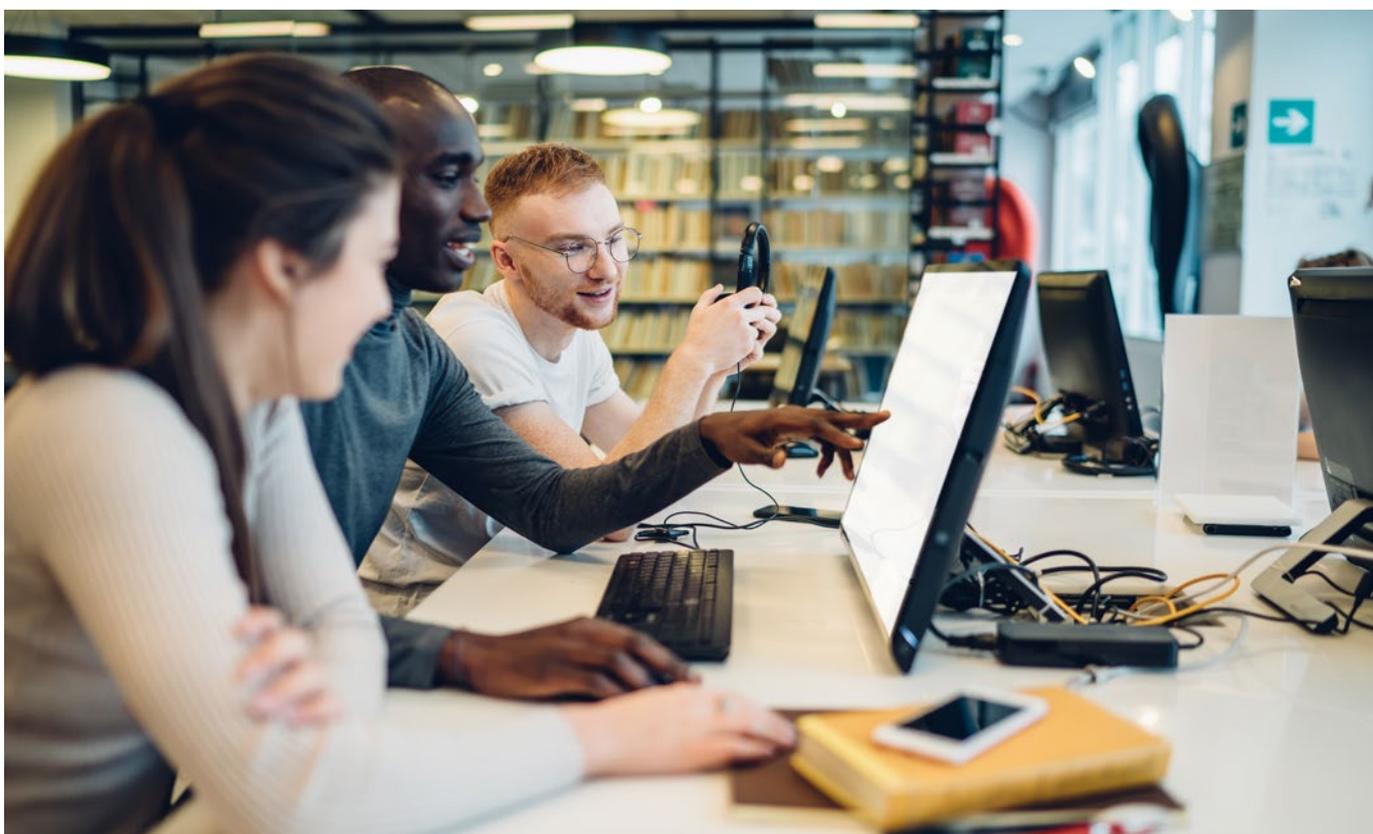
In response to the COVID-19 pandemic and the flood events of July 2021 in North Rhine-Westphalia and Rhineland-Palatinate, funding was made available through the Federal Government's framework programme *Research for Civil Security 2018–2023* for applied research projects to be conducted in collaboration with industry partners on data availability, pooling and use for crisis preparedness and management, as well as on issues of crisis governance and crisis communication. Based on these findings, potential for improvement in the prevention, preparation, management and follow-up of crisis and disaster situations can be identified and implemented in a targeted manner.

To improve the general conditions for knowledge flow between society, science and politics, the Federal Government has initiated the multi-stakeholder process dubbed #FactoryWisskomm. Implementation of the

resulting recommendations for action is intended to achieve a lasting improvement in science communication in Germany. At the same time, in Science Year 2022 – Participate!, the Federal Government has expanded dialogue with and about science and research, along with social participation in it through formats such as the Citizens’ Assembly on Research and ‘IdeenLauf’, an initiative inviting citizens to input their questions and ideas for research.

The Federal Government will further boost research on cohesion, resilience and the transformation capacity of societies. Further, it will expand the participation of civil society actors in R&I and promote diversity and gender equality in research. In particular, this will be set in the perspective of the life situations, participation opportunities and future prospects of children and young adults. Civil security research is being intensified to step up the crisis response and crisis management capabilities of the government and the economy, but also of the general populace. Innovative security solutions will contribute to the optimisation of civil protection and the protection of critical infrastructures.

The Federal Government’s goal is to contribute to achieving equivalent living conditions in urban and rural areas and to having a locally engaged civil society. It therefore intends to further develop the *national funding system* in the current legislative period with macroeconomic and societal challenges also in view, to support local transformation processes and to increasingly focus on sustainability and innovation. It also aims to learn from the experiences of social transformation, for example in the context of German reunification. Science communication and participation will continue to be promoted as an integral part of science and research so as to increase broad societal knowledge and the acceptance of innovative methods and technologies, to enable science to access the knowledge of the many, and to inform the knowledge exchange between science, politics and society in a way that is geared towards the common good.



## Future field of development: Improving healthcare for all

Environmental and societal changes on a global level, such as climate change and demographic trends, are creating new challenges for individual and public health. The COVID-19 pandemic has strikingly demonstrated this. Research will continue to be vital for combating COVID-19 and containing the consequences of the pandemic, as well as for preventing future pandemics. Further, cancer, cardiovascular diseases and other particularly widespread diseases or disease fields with a high mortality or morbidity burden are on the rise. Efficient health research helps us to better understand and prevent diseases, improve medical care and reduce health inequalities. At the same time, the health system is also undergoing a transformation process towards climate-neutral and resource-efficient care, which is being prepared for and supported by research. Significant opportunities are offered by the rapid developments in the life sciences – a number of technologies with significant disruptive potential are on the verge of breakthrough. At the same time, digital transformation in the healthcare sector, especially through better, GDPR-compliant networking of the enormous amounts of data from research and healthcare, as well as through digital applications and analytical processes, holds considerable potential for developing innovations and improving care. This will enable more people to lead healthy and self-determined lives in the future.

In response to the outbreak of the COVID-19 pandemic, in the summer of 2020 the German government rapidly launched the *Special Programme to Accelerate Research and Development of Urgently Needed Vaccines against SARS-CoV-2*, funding three vaccine development projects to the tune of approximately €590 million. The approval of BioNTech's vaccine at the end of 2020 meant that the target – to make safe and effective vaccines available as early as possible – was achieved within a record time of just around 300 days. Emerging from the *biotechnology start-up initiative GO-Bio* and also as one of the partners in a leading-edge cluster, the award-winning company BioNTech has become a global leader as a result of the development of its vaccine against the SARS-CoV-2 coronavirus. The rapid decoding of the novel coronavirus SARS-CoV-2 impressively demonstrates

how it ultimately pays off to invest in excellent basic research, applied research and its transfer into application.

The Federal Government has specifically advanced the digital networking of health research and healthcare, for instance as part of the Network of University Medicine (NUM) and the *Medical Informatics Initiative (MII)*. To do this, it launched the 'Data for Health' innovation initiative. It also expanded the MII and supplemented it with Digital Hubs for Health – pilot projects for the cross-sectoral and research-compatible networking of health data at the regional care level. Mechanisms to fund cancer research in Germany are being pooled and more firmly reinforced by the Federal Government through the *National Decade against Cancer*. The German Centres for Health Research are forging ahead with the pooling of competences to combat widespread diseases. On an international level, the Federal Government is participating in the funding of preventive strategies, such as the initiative for pandemic prevention within the *Multi-Partner Trust Fund on 'Nature for Health'*. The initiative will make an important contribution to addressing biodiversity and climate change as key factors for human and animal health.

An innovative and efficient health system is the basis for medical progress and fosters employment and prosperity. To ensure that more innovations are generated from cutting-edge medical research in Germany, the Federal Government is continuing with its forward-looking development of structures for health research and for the funding of biotechnology. As recommended by the EFI, it will use the potentials of digitalisation to achieve better quality of care as well as to enable more personalised diagnostics and therapy. The establishment of a European Health Data Space will create the basis in Europe for the use and exchange of health data for the purposes of health research. Innovation should also be geared towards improving pandemic prevention. In this context, the leveraging of efficiency potential should not stand in conflict with the attainment of a resilient and crisis-resistant health system.



### 3 Working together effectively – paving the way for modernisation

The transformative change we need to address societal challenges can only be implemented with significant, often radical, technological breakthroughs, social innovations and structural changes. Therefore, the best possible framework for research and innovation (R&I) must be created in European and international collaboration. The Federal Government will introduce measures for transforming new knowledge into innovation and leveraging data potential. There will also be measures to strengthen European and international cooperation, attract new actors to innovation and boost participation in innovation, as well as inspiring talent and supporting qualification. According to the EFI, public administration and the government must also undergo a comprehensive modernisation process. In this vein, it is necessary to design an agile political style and to rethink government and administration.

## 3.1 Making research and innovation go hand in hand – translating new findings into innovations

Excellent research results are the hallmark of the German research and innovation system. They create a broad knowledge base, but oftentimes lack widespread application and are still too slow to find their way into application. As a result, the economic and social utilisation of ideas, their implementation into new business models and their integration in the start-up culture in Germany are lagging behind their potential, as is also noted by the EFI.

In order to be able to use this knowledge as a basis for sustainable action, innovation systems must be considered in their entirety. This concerns both basic and applied research as well as the efficient research infrastructures that support the successful interaction of the various participants in the innovation process. Social innovations are also of great importance in this context. The expansion and consolidation of the transfer and start-up culture are key concerns of the Federal Government, so that new findings can become innovations and transformative change in society can succeed. These goals are pursued through the breadth of innovation-oriented research funding and through specific funding instruments.

With the establishment of the *Federal Agency for Disruptive Innovation, SPRIND GmbH* in December 2019, the Federal Government crucially paved the way for creating new scope and funding opportunities for disruptive innovations. *SPRIND* is designed to help radical technological innovations with game-changing potential to achieve a breakthrough and thus disruptively change markets.

The establishment of a 'Zukunftsfonds' (future technologies fund) significantly improved the general financial conditions for young, innovative companies. Ten billion euros have been earmarked as additional federal funding to finance start-ups over the next ten years. In this way, the Federal Government is boosting the German venture capital market and mobilising private-sector venture capital.

Generating innovation and transfer and boosting start-up activity are among the key tasks of R&D policy in this legislative period. An important instrument for this is the establishment of the *German Agency for Transfer and Innovation (DATI)*. Through *DATI*, the Federal Government aims to provide new impetus for the targeted funding of evidence-based innovations, especially technological and social innovations, and their use in the economy and society.

The Federal Government will step up future funding for social innovations. Social innovation includes developing new social practices and organisational models aimed at finding sustainable solutions to the challenges facing our society. To achieve this, the Federal Government will develop a national strategy and improve the financing situation for social innovations and social enterprises that are geared towards the common good. In addition, it will open up appropriate new sources of financing, such as the use of dormant accounts.

In order to make technological developments on large-scale equipment usable as cutting-edge technologies for broad fields of application, the Federal Government intends to intensify the pooling of funding structures through the Action Plan *ErUM-Transfer*, at the same time simplifying them and increasing their flexibility. The Federal Government will also substantially improve the general legal and financial environment for *SPRIND*, the *Federal Agency for Disruptive Innovation*, so that it has greater freedom for action and investment.

## 3.2 Strengthening European and international cooperation

The grand challenges facing society can only be tackled on the basis of European and international cooperation in science and research. The COVID-19 pandemic has made this abundantly clear. At the same time, it is important to strengthen the position of both Germany and Europe in international competition against the backdrop of rapid technological development. Securing the technological and digital sovereignty of Germany and Europe is also a high priority. The Russian war of aggression against Ukraine has demonstrated the importance of reducing unilateral foreign dependencies. Especially against the backdrop of the new geopolitical situation, Germany, together with other partners sharing the same values, is facing intensified system competition with autocratic states in dynamic regions such as Africa and the Middle East. Informing and expanding European and international cooperation in line with European values and principles and the global Sustainable Development Goals will therefore remain one of the key tasks in the coming years.

The EU's key funding programme for research and innovation, *Horizon Europe*, replaced its predecessor *Horizon 2020* at the beginning of 2021, with closing negotiations taking place under Germany's EU Council Presidency. This programme pools all the EU funding measures relevant to R&I for the years 2021 to 2027. With a funding volume of around 95.5 billion euros, it is the world's largest public research funding programme.

During its EU Council Presidency in 2020, Germany advocated for a new positioning of the European Research Area (ERA) in order to further improve the general conditions for R&I. The goal of expanding and deepening the ERA was successfully completed with the adoption of the *Pact for Research and Innovation in Europe* during the trio presidency formed by Germany with Portugal and Slovenia in 2020 until the end of 2021.

The Federal Government will continue to promote the internationalisation of the German science and research system in future and will also scale up education and science diplomacy to this end. In this context, the expansion of strong – and bilateral – R&I partnerships will be accelerated, especially in the area of key enabling technologies, on the basis of shared values. In strategically important regions such as Africa and the Middle East, new potential and opportunities are being developed for Germany as a science location. The Federal Government advocates improving the protection of the freedom, integrity and security of science and research at national, European and international levels. Because of the Russian war of aggression against Ukraine, in February 2022 all ongoing and planned R&I measures of the Federal Government with state agencies in Russia were frozen and/or critically reviewed. In Europe, the ERA remains the strategic framework for European cooperation in R&I. Germany will strengthen the ERA and help inform it at the European level. It will also proactively implement the *Pact for Research and Innovation in Europe* and the *Policy Agenda* of the ERA at national level.

### 3.3 Attracting new actors to innovation activities and boosting participation in innovation

The German innovation system is supported by a broad base of actors. More than half of all companies introduced product or process innovations even during the COVID-19 pandemic. Although innovation expenditure in 2020 declined somewhat compared to the previous year, the number of companies active in innovation increased. This positive development shows that companies are taking up innovation activities to adapt their product offerings or internal processes despite or even because of the changed situation due to the COVID-19 pandemic.

In order to manage and utilise the transformation processes taking place in society and the economy, it is important to advance the transfer of knowledge from science to the economy and broader society even further. Germany's regions play a significant role in its innovative strength, because many new ideas are created 'locally' where innovative work is done on the solutions of the future. In order to increase innovation participation, a clear focus must be placed on strengthening and networking important actors from business and science.

The Federal Government, in conjunction with the Länder, has resolved to intensify collaboration between universities of applied sciences and businesses. The extension and expansion of the funding programme for *Research at Universities of Applied Sciences* is promoting cooperation between universities of applied sciences and private-sector companies. The *FH-Impuls* programme line initiates and funds topic-oriented strategic partnerships between higher education institutions and their high-research environments.

The Federal Government has implemented a key requirement of the EFI by introducing *tax incentives for R&D*. Since 2020, companies, especially SMEs, have had the opportunity to apply for research allowances for relevant R&D projects. This created additional innovation incentives for industry and boosted Germany's international competitiveness as a research location.

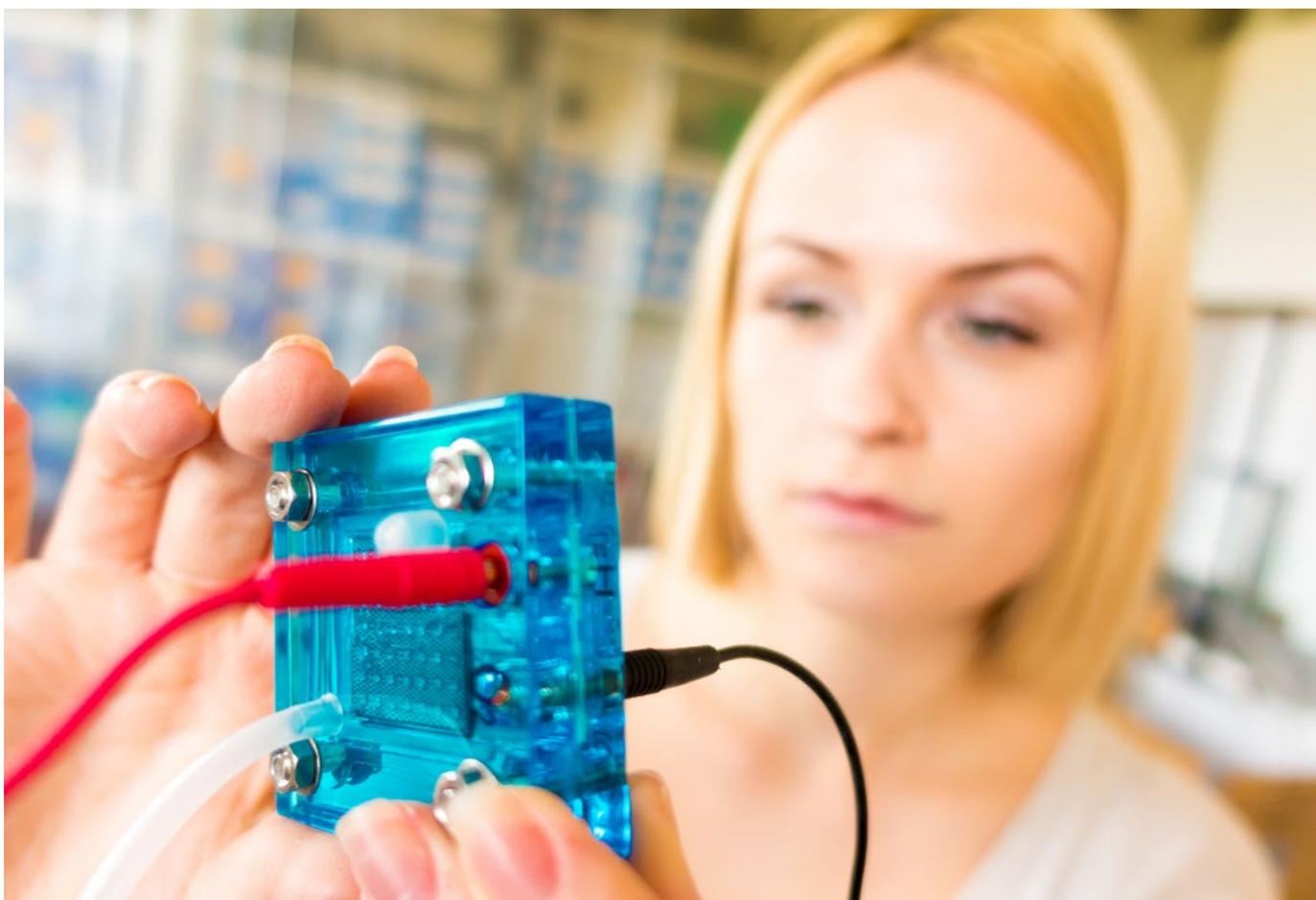
The #WirVsVirus (#UsVsVirus) hackathon has shown that the innovative capacity of civil society can be tapped to quickly develop solutions in exceptional situations which can then be utilised by civil society, authorities and companies to manage crisis situations.

As also recommended by the EFI, the Federal Government will implement a package of measures to increase innovation participation and broaden the innovation base. To this end, support is being provided to knowledge-based start-ups in particular and university locations are being developed into innovation hubs. Tax incentives for R&D will be evaluated in 2025 and reviewed against the background of the evaluation results. Low-threshold funding formats, including those for social innovations, will attract new actors to the R&I system.

## 3.4 Attracting talent and promoting qualification

The transformation in the economy and the world of work brings with it new demands on the qualifications of employees. Professionally and academically well-qualified people increase the innovative capacity of research institutions and companies and secure their need for skilled workers, thus contributing to economic prosperity and Germany's future viability. Structural change must not lead to structural disruptions. It is therefore important to guide the transformation in a future-proof and socially acceptable way so that prospects open up both for companies and for all people of working age. Accordingly, education, training and further education systems must be geared towards the future – especially towards digital transformation and socioecological transformation for a sustainable economy and society.

In order to attract top talent in international competition and to recruit and retain skilled workers from abroad, it is necessary to continue improving the conditions for researchers in science and industry and facilitate the immigration of qualified professionals. In this context, it is important to support not only skilled workers, but all groups of people who tend to participate less in continuing education. At the same time, it is important to attract the best minds for excellent and innovative research by improving gender equality and equal opportunities in science and research – especially by increasing the proportion of women in leadership positions. Scientific freedom and free competition of ideas are the basic prerequisites for maintaining Germany's attractiveness as a research and innovation location.



With the launch of the *National Skills Strategy (NWS)*, the Federal Government aims to reform, systematise and boost continuing education policy against the backdrop of digital, ecological and demographic change. This strategy also pools relevant programmes for continuing vocational training and lifelong learning. The aim is to empower all people for tomorrow's world of work. In order to meet increasing demand, the Federal Government has expanded funding for continuing education and training (CET), established CET networks and significantly expanded its offers of digital guidance and online platforms on education and CET.

The establishment of the *National Education Platform* was commenced as part of the Digital Education Initiative. This digital networking infrastructure is intended to provide users with sovereign, interdisciplinary educational access to learning opportunities and a continuous learner journey. The goal is to achieve a data-sovereign, interoperable platform ecosystem. The national online CET platform NOW! aims to provide greater transparency in the variety of actors, offers and funding opportunities available in the field of continuing vocational education and training. These initiatives strengthen IT skills development in education and work-related CET, which was also a requirement of the EFI.

For example, the joint initiative of the Federal Government and the Länder for *AI in Higher Education* and the *InnoVET* competition fund education and qualification programmes in fields such as AI and nanotechnology. The many projects in the *MINT Action Plan* serve to strengthen STEM education along the education chain and to inspire young people of all genders to pursue vocational or academic careers in STEM

disciplines. As at February 2022, 1,000 tenure-track professorships had been advertised as part of the joint programme between the Federal Government and the Länder for the *Promotion of Emerging Researchers*, and around 620 of these positions had been filled. Under the *Programme for Women Professors*, more than 800 new professorships were created by the end of 2021 and gender equality structures in German higher education were improved.

To ensure that the demand for qualified professionals can be filled, the Federal Government will update its Skilled Labour Strategy and adapt it to the current challenges, and also boost the data skills of the populace. Key fields of action include the topics of qualification measures and continuing education and training. It is necessary in particular to facilitate access to qualification programmes for all persons. By introducing such measures as the *Excellence Initiative for Vocational Education* and incentives such as (part-time) study leave, the Federal Government will expand the offers and attractiveness of initial, further and continuing education, as well as vocational reorientation. It will also increase the participation of women in the labour force and modernise immigration law.

In the science sector, it will improve working conditions and career prospects, as well as firmly embedding gender equality and diversity. Therefore, it will scale up the *Programme for Women Professors* to further increase the proportion of women in professorships at universities. In view of increasing restrictions on academic freedom, the safety of researchers in some parts of the world is at risk. Therefore, awareness of research security among researchers will be raised in cooperation with research institutions, the relevant ministries and security agencies.

## 3.5 Establishing an agile R&I policy style – rethinking government and public administration

Having a modern state is the prerequisite for making the best possible use of the opportunities offered by the digital transformation – and for giving its citizens and businesses alike access to public services simply, quickly and from a single source. To achieve this, the EFI believes that the government and public administration must be modernised and join forces in inter-departmental cooperation to tackle the challenges facing society. This approach requires a continuous process of adaptation that allows experimentation, including in the political space.

The *Online Access Act (OZG)* created the legal basis for the comprehensive digitalisation of the administrative structures of the Federal Government and the Länder, including local governments and authorities. The Federal Government has also earmarked 3 billion euros to accelerate the implementation of digitalisation in government administration through funds from the *Economic Stimulus and Future Development Package*. To this end, the Federal Government's IT governance has been expanded to speed up decision-making processes, while the *GovTech Campus* initiative aims to develop and test technological solutions for everyday administration using an agile approach. The Federal Government has also begun to set up its own data labs in all federal ministries and the Federal Chancellery, which heads them, and to hire chief data scientists to boost data literacy in the ministries. A sum of 240 million euros has been earmarked for this purpose. The Federal Government has also established flexible and agile R&I funding

instruments by setting up *SPRIND, the Agency for Disruptive Innovations*, and the *Agency for Innovation in Cybersecurity*. An organisational unit that operates in an interdisciplinary and agile manner and is new to the ministries was established within the Federal Government in the form of the *Denkfabrik Digitale Arbeitsgesellschaft* (Digital Work Society Think Tank). As part of an ecosystem with the interministerial innovation network Civic Coding, it is also tasked with promoting the use of AI for the common good.

The targeted funding of innovations for digital administration will make government processes faster and more effective in the long term. The Federal Government is striving to overcome silo thinking and, to this end, has set up dedicated interministerial and interagency agile project teams and innovation units, as well as equipping them with specific responsibilities (GovLab.DE). Interministerial cooperation will be strengthened within the framework of a mission-oriented R&I policy. More weight will be given to the involvement of external actors to achieve the mission goals. In the spirit of an adaptive strategy, the future research and innovation strategy will integrate new scientific findings and societal input.

The Federal Government intends to effect a fundamental transformation towards becoming an adaptive digital government which works proactively for its citizens whilst promoting economic and social innovation processes in order to become faster, more effective and more efficient overall.

# Online tools

Federal Report on Research and Innovation



## Research institutions >

Database of German research institutions by topic and region



## Interactive diagrams >

Statistical time series data on R&D expenditure, personnel and results, plus international comparisons



## Research in the Länder >

Information on the R&D policy of the Länder, plus figures and data at Länder level



## Figures and tables (in German only) >

Overview of all figures and tables from the Federal Report on Research and Innovation 2022, incl. download options



## Link portal R&I policy (in German only) >

Database of further information on the Internet, such as specialist websites, R&I policy documents and information portals



## Actors in the German R&I system >

Interactive overview of the actors in the German R&I system, incl. further information

All online tools are available at  
[bundesbericht-forschung-innovation.de](https://bundesbericht-forschung-innovation.de)





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