



Federal Ministry
of Education
and Research

Federal Report on Research and Innovation 2018

Short version



Foreword

Only an innovative nation can offer its citizens quality of life and prosperity. That is why we are investing greater amounts in research and innovation than any other European country. That is why we are moving forward with key topics, such as *Industrie 4.0* or micro-electronics. Or why we are promoting state-of-the-art education and training. We are raising the profile of our science system in order to attract – and retain – the best minds.

These endeavours have elevated Germany's standing as a dynamic hotspot for research and a powerful innovation hub. More than one in ten products on the global markets that are the result of exceptional research was made in Germany, putting us on a par with the United States. Although Germany is at the top of the international league in this respect, China's success in knowledge-intensive sectors, such as electric mobility and artificial intelligence, ultimately reminds us that we must stay on the ball.

We provide funding for innovations to improve people's lives. Faster and faster access to more and more knowledge, data and information offers enormous opportunities for research, for new business models, and for new medical and industrial processes. We must

exploit these opportunities to greater advantage. To achieve this goal, we need more openness and transparency in science and industry, more participation, but also more determination in politics and society. We want to open up new creative forms of collaboration to spur the transfer of ideas into innovations and the implementation of research findings into applications.

The Federal Report on Research and Innovation presents the research and innovation activities of the Federal Government and the *Länder*, and it responds to the results of the current report by the Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation, EFI). It therefore offers a comprehensive overview of innovation politics in Germany and serves as a key decision-making tool for policymakers, science and society.

Federal Ministry of Education and Research

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Info boxes explain important terms, present projects and programmes or provide additional information.



For the full Federal Report on Research and Innovation and further information, please go to [bundesbericht-forschung-innovation.de](https://www.bundesbericht-forschung-innovation.de) (only available in German).





I The Federal Government’s objectives and priorities in the area of research and innovation policy



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1 Research, innovation, education and science for prosperity and quality of life

Just like the Federal Government's education and science policy, its research and innovation policy serves society, the economy and each and every individual. This policy aims to identify solutions to global challenges, to open up promising career prospects based on excellent qualifications, to increase our competitiveness and ensure future-proof jobs.

Research, innovation, education and science are sources of our prosperity. By introducing new ideas to the world, they pave the way for competitive products, processes and services. Our goal is to further enhance Germany's innovative strength. The Federal Government puts a high value on outstanding researchers and well-trained specialists to achieve this goal. We set great store by a modern education and science system that encourages analytical and creative ways of thinking. We need an economy that boosts employment and remains competitive in the international arena with future-oriented products and services. Furthermore, we want to join forces in shaping social and technological developments in a society that is open-minded and yet critically committed.

Germany is one of the leading innovation countries, both in Europe and around the world, as well as a

highly attractive location of science and research. Nonetheless, Germany's innovation policy environment has experienced marked changes in recent years. Compared to the traditional industrial nations of Europe, America and Asia, the emerging countries are making up ground in the global competition between business and innovation hubs. Emerging economies such as China, South Korea or Singapore have proved to be strong innovators. At the same time, a great many countries – particularly in Europe – are still labouring under the repercussions of the global economic crisis and strained budgets. According to the Organization for Economic Cooperation and Development (OECD), there has been a subsequent drop in public research and development (R&D) expenditure around the world. The changing competitive landscape is increasingly shifting the momentum of the established division of labour between the world's centres of innovation. This

development means that Germany is facing higher demands. Adapting dynamically to the changes on the global innovation stage is imperative to retain and expand our competitive edge.

This applies especially to the key role played by Germany in the European Union (EU). Germany's responsibility will continue to grow in the wake of Brexit. Moreover, globalisation and digitalisation are transforming and accelerating innovation processes. New, high-performing opponents are rushing headlong into the global markets, where they jockey for position with established market players. This leads to mounting pressure in the international competition. Added to which are the global challenges of demographic development, migration flows, the scarcity of numerous natural resources and climate change, which represent difficult tasks for us all.

Positioning Germany as a forward-looking centre of research, science and business is now more important than ever to enhance our competitiveness and come up with solutions to the global challenges. A strong science sector offers a fertile breeding ground for academic excellence, as well as ideas for new products and services with the 'Made in Germany' quality seal. It is therefore vital that we uphold the positive momentum of Germany's research and innovation policy, as highlighted by the Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation, EFI).

The Federal Government wants to open up future possibilities and identify solutions to the Grand Societal Challenges by means of research and innovation (R&I). When we invest in research, we strive to create the best possible framework conditions as these are a crucial pillar of the research and innovation system (R&I system), along with high-level science and research, an innovative, competitive economy and qualified specialists in every sector.

We can only maintain the present strength of Germany's innovation model if we succeed in keeping pace with technological advances and in taking advantage of the opportunities for new business models. At the same time, the Federal Government must structure the changes in such a way that they are conducive to sustainability and environmental protection, make

allowance for consumer and data protection, do not restrict competition and cultivate both social participation and gainful employment. Moreover, a prerequisite for more innovation is greater success in empowering those groups in the scientific, research and innovation communities that have been under-represented to date. The opportunities generated by diversity can thus be exploited to greater effect. This involves the commitment and participation of women, for example.

Among small and medium-sized enterprises (SMEs) in particular, the potential for creating new, good jobs in industry, as well as in knowledge-based services, can – and indeed must – be opened up. Germany's declining share of innovative firms – the proportion of companies that have introduced new products or processes within a certain period – points to a concentration of innovative activity as innovation expenditure continues to rise sharply. In some industry segments, fast-paced technological change and the growing importance of data may constitute market entry barriers, thereby hampering innovation. Technology companies whose business models are based on collecting and utilising large quantities of user or other data may become monopolies. In its 2018 expert report, the EFI stated that restricted access to the new resource of 'data' may hinder small, young enterprises from entering the market. In the years ahead, the Federal Government will focus on broadening the innovation basis and augmenting the share of innovative firms in an effort to increase the chance of revolutionary, innovative products and services.

The Federal Government enshrined in the coalition agreement its ambitious goal of investing 3.5% of the gross domestic product (GDP) in R&D by 2025 by acting in concert with the *Länder* and industry. This sends a clear signal to partners from academia and the business sector to follow the same path. There can be no question: an outstanding centre of science and innovation will continue to need exceptional commitment to R&D. Our priority must be to foster and acknowledge not just academic excellence, but also pioneering spirit and entrepreneurial courage, in order to transfer creative ideas into applications, developing them rapidly for the benefit of mankind. Establishing an open culture of innovation represents a major step forward in this respect.

The specified measures fall within the remit of the appropriate Federal Ministry, where they are financed under the budgetary and financial planning principles currently in force (including positions/permanent posts). As a general rule, provided that they have not yet been included in the implementation plan or

identified as a priority in the coalition agreement, these measures can only be carried out if there is additional financial leeway or where direct, complete and long-term reciprocal financing is guaranteed to this effect in the corresponding section of the budget.





2 The High-Tech Strategy: joining forces for greater competitiveness and quality of life

At the beginning of each legislative term, the *High-Tech Strategy (HTS)* pools research and innovation funding across governmental departments. The strategy focuses the Federal Government's research and innovation policy activities on priority task areas and key topics of relevance to society. Since 2006, it has been instrumental in securing Germany's foothold in the global competition and in creating an environment that encourages the transfer of ideas into marketable products and services.

The broad-based strategic approach of the *HTS* is recognised both nationally and internationally as a shining example, with framework programmes such as *Horizon 2020* adopting a similar approach. Moreover, the EFI has consistently acknowledged that the *HTS* represents an excellent governance model of a R&I system. As the achievements of recent years have shown, R&I investments pay dividends. Over the last ten years, the Federal Government has increased R&D spending by 68%, culminating in some 15.6 billion euros in 2016. Thus, in partnership with the business sector, the goal of the *Europe 2020* strategy – for 3% of GDP to be invested annually in R&D – is within reach. Education, science and research have been rigorously reinforced.

Today, as attested by the EFI, Germany is a hotspot for research and a highly attractive innovation hub. Numerous indicators bear out this positive development:

- In macroeconomic terms, a total of 92.2 billion euros was spent on R&D in 2016. Germany is one of the world's ten most research-intensive economies.
- At almost 3% of GDP in 2016, Germany's share of R&D expenditure outperformed the United States and exceeded the EU average by far. According to current estimates, the average R&D intensity of the EU-28 was 2.03% in 2016. Within the EU, only Sweden and Austria scored a higher R&D intensity than Germany.

- The number of R&D personnel has risen dramatically in recent years. In 2016, over 650,000 full-time equivalents (FTEs) were employed in R&D. In 2015, there were more than 43,000 foreign scientists at German universities.
- In 2016, German companies spent 158.8 billion euros on innovation, with the manufacturing industry accounting for over three quarters of this sum. In a year-on-year comparison, innovation expenditure rose overall by 2%. In terms of innovation spending, Germany is the European leader. The increase in innovation expenditure was not just driven by large corporations, but also by SMEs. In 2016, SMEs with fewer than 500 employees spent more than 36 billion euros on innovation.
- Germany's business sector recorded turnover of 719 billion euros with product innovations in 2016 – approximately 3% more than in the previous year.
- In recent years, the number of scientific publications originating in Germany has grown steadily. Furthermore, the OECD excellence rate – the percentage of a

country's highly cited papers in all scientific publications around the world – climbed from 11.2% to 12.2% between 2006 and 2016.

- In 2015, Germany filed 371 patents relevant to the world market per one million inhabitants. Consequently, Germany accounts for nearly twice as many patents with world market relevance per million citizens as the United States.

In accordance with a broad understanding of innovation, in its *HTS*, the Federal Government supports technological and non-technical innovations, i.e. social and societal innovations, as well as new business models and process innovations. Aside from social innovations, there is a strong emphasis on the participation of the general public in the continued development and implementation of the *HTS*. Digital technologies are creating new opportunities and setting new benchmarks in the sociopolitical dialogue. The Federal Government is continuing its tradition of dialogue in its research and innovation policies, systematically developing them with new participatory formats.



2.1 Finding solutions to the Grand Societal Challenges

With its *HTS*, the Federal Government has set thematic priorities in research and innovation, concentrating on six promising areas for growth, prosperity, quality of life and keeping Germany ahead of the international competition in innovative terms. The goal is not merely to generate technological innovations, but also to set processes of social change in motion, at the same time developing and spreading service innovations and social innovations, for example. The six priority tasks are the digital economy and society, the sustainable economy and energy, the innovative workplace, healthy living, intelligent mobility and civil security.

Digital economy and society

Digitalisation affects virtually every aspect of our lives – and all economic sectors. It offers huge potential for innovation that should be exploited to the full. The EFI also emphasises the opportunities of digitalisation in its current report.

It is vital for Germany's innovative strength to integrate digital technologies in the economy and in areas of society where new solutions are needed. From digital medical technology to autonomous driving and *Industrie 4.0*, remaining competitive in the future will depend on generating knowledge and value added from big data, establishing reliable, powerful communication systems or utilising learning systems in workflows and making them intuitive.

The Federal Government is proactive in shaping the digital transformation integratively and with foresight. At the same time, it is keeping a close eye on the challenges involved, e.g. with regard to consumer rights or data security, and on the question of whether and how the digital transformation is affecting the lives and work of men and women, possibly in varying degrees. We are looking for solutions that transform challenges into opportunities. In its latest report, the EFI stresses the importance of unrestricted access to data wherever possible in order to develop new business models, for example.

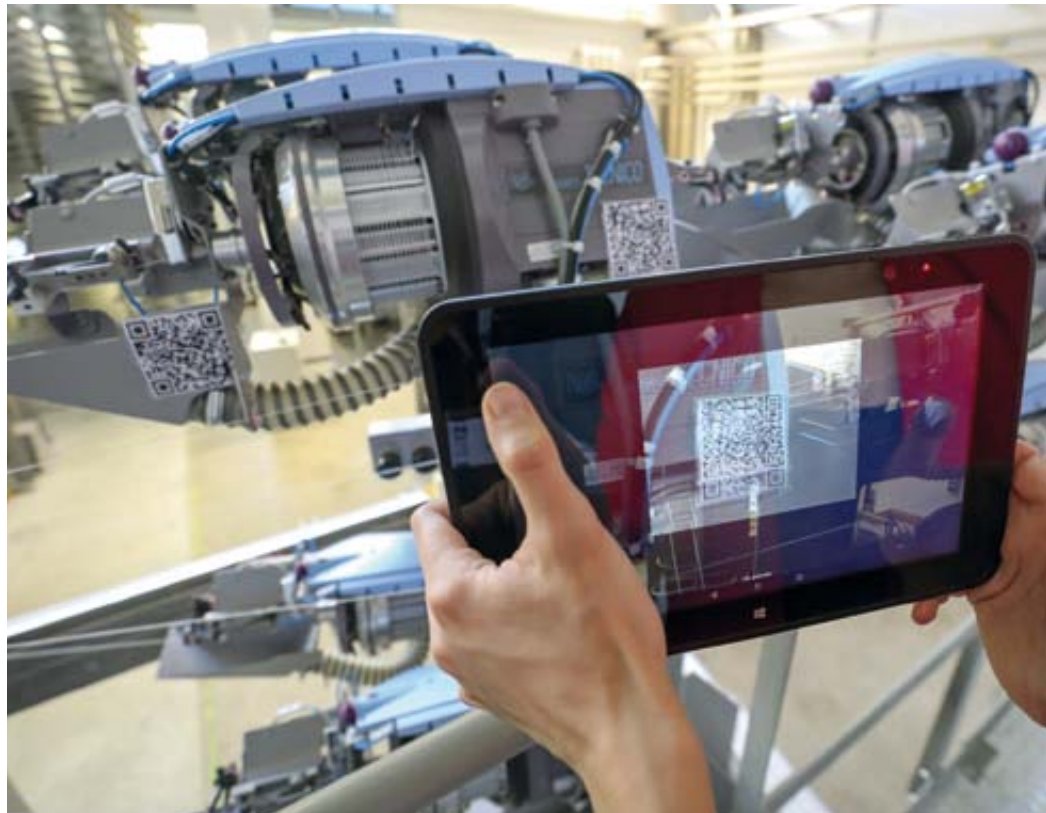
We are working with science, industry and society to explore ways of living, learning and working in the digital world. With its *Digital Agenda*, the Federal

Government provided invaluable impetus to developing the digital economy and shaping digital life worlds.

In order for Germany to lead the market for innovative digital products and services, the Federal Government is driving development in key fields:

- Groundbreaking technologies and business models: the Federal Government is underpinning the development of new analysis techniques for large amounts of data and the utilisation thereof as 'smart data', and promoting innovative information and communication technologies, as well as technologies for networked industrial production, including agile logistics, service robotics, 3D printing and 3D image processing. Connecting technologies across sectors – and the opportunities this represents – is a core element of the research funding. Moreover, one key aspect is the interconnection of products or production with sophisticated, knowledge-intensive services.
- Strong alliances between academia, industry, politics and society: the Federal Government's *Industrie 4.0* platform is also regarded as a successful approach in the international arena. Around 300 actors from over 160 organisations are working to harness the progressive digitalisation of value chains and to design new intelligent, knowledge-based production environments. The new *Lernende Systeme* platform seeks to advance the research, development and use of Artificial Intelligence (AI) in Germany in dialogue with the partners and the general public.

- Digitalisation of work and production processes in SMEs: the digital transformation offers SMEs and crafts businesses enormous potential in terms of improved workflows, manufacturing techniques and innovative digital business models. The Federal Government is mobilising SMEs for the digital economy by providing practical, application-oriented support, for example with the *Reference Architecture Model Industrie 4.0 (RAMI 4.0)*, the Fraunhofer-Gesellschaft's Industrial Data Space, the *Industrie 4.0 - Shopfloor Research, I4KMU*, the *Mittelstand-Digital* programme or with the national *go-digital* funding programme.



- If we succeed in transferring Germany's strengths in mechanical and plant engineering and industrial robotics to digital assistance systems, Germany may be able to blaze a trail in this market. The goal is for Germany to become a leading market for digitally assisted learning and working. Therefore, an application programme is being launched on *Assistenzsysteme für kleine und mittlere Unternehmen (Assistance systems for small and medium-sized enterprises)*.

Moreover, the Federal Government is addressing the new legal, ethical and social issues occurring in response to the digitalised world. The Weizenbaum Institute for the Networked Society, the German Internet Institute, is searching for answers to these questions. It conducts comprehensive, interdisciplinary research into the internet and digitalisation, thereby compiling important reference information and practical knowledge for politics, business and society. The Federal Government funds the Competence Center Public IT at the Fraunhofer Institute for Open Communication Systems FOKUS, which observes and analyses trends and technological developments, reviews current topics of relevance to digital policy and the social impact thereof from a cross-sectoral, application-oriented perspective, identifying courses of action for opinion leaders in politics and public administration.

The Federal Government's *Open Access Strategy* will help speed up the information flow in the scientific community and increase the visibility of research findings. Innovative Open Access projects funded by the Federal Government are already in place. By introducing the *National Action Plan on Open Data*, the Federal Government pledged to ensure the widespread publication of administration data. Using this data for digital innovations, thereby fostering digital entrepreneurship, is one of the key objectives of the *Modernity Fund*, which supports innovative, data-based projects. The Federal Government took a further step towards the greater transparency of administrative data with the First Amendment to the E-Government Act, which entered into force in July 2017.

Sustainable economy and energy

In its *HTS*, the Federal Government focuses on the vision of sustainable development. In our quest for innovations, we remain mindful of our responsibility

towards current and future generations. To this end, we are committed to improving the resource efficiency, environmental footprint, climate performance and social compatibility of our production methods and consumption patterns.

The Federal Government advocates an environmental and climate policy that effectively combines preserving the planet and systematically reducing greenhouse gas emissions with economic success and social responsibility. By pooling efforts with our partners in society, we aspire to design an efficient, technology-neutral environmental and climate policy that encourages innovation.

The scope of our international framework is defined by the United Nations' 17 Sustainable Development Goals for 2030 and the Paris Agreement of 2015. In its latest report, the EFI declares that innovations can – and indeed must – play a key part in achieving these sustainable development goals. We are therefore upholding our commitment to innovations in this area. The Federal Government's *Climate Action Plan 2050* proposes solutions and outlines a process for implementing international, European and German climate targets. It contains target ranges to cut greenhouse gas emissions in all sectors by 2030, compared to 1990 levels. The first programme of measures with a time horizon until 2030 is currently being drawn up. It also includes a technology-neutral research programme that is designed to give the German business sector new innovation momentum.

With the nuclear power phase-out and the general rejection of fossil fuels, Germany's *Energiewende* – or energy transition – is an extremely ambitious task, whose successful conclusion calls for the close cooperation of politics, industry, science and civil society. Above all, it is now up to the scientific and research community to quickly lay the foundations and make the technological breakthroughs that are necessary to assure Germany's energy supply in the long term. In August 2011, the Federal Government outlined the roadmap for this forward-looking project in its *6th Energy Research Programme*. It focuses on the R&D of innovative technologies and solutions based on energy efficiency and renewable energy to facilitate the restructuring of the energy system as an environmentally friendly, reliable and affordable supply in the fu-

ture. Preserving Germany's strength as a competitive industrial base is a cornerstone of the programme.

While updating its energy research funding, the Federal Government carried out a consultation process in 2017 to pave the way for a new energy research programme. Various research organisations, associations, companies, stakeholders and social actors were involved in the process. The *Länder* were also invited to formulate their specific regional research needs for the new energy research programme. Further impetus was obtained from the dialogue with national players from industry, politics and research on the energy transition's *Research and Innovation Platform* and the Energy Research Networks. The results are all documented at energieforschung.de (in German only).

The consultation process highlights in particular those topics that will impact decisively on the development of the energy sector in the years ahead: decarbonisation and thus climate protection by using renewable energy sources, energy efficiency, sector coupling and digitalisation. The growing number of participants on both the supply and the demand side of the energy system means that social science research regarding acceptance, for example, is a crucial aspect. The process provides food for thought concerning a stronger export orientation in reference to the global energy transition, as well as the increased involvement of start-ups and small companies in research funding. A significant departure in the energy research policy is the format of *Reallabore*, which complement applied research with theory-to-practice transfer. The laboratories are set up to test the systemic interaction of new technologies, procedures and business models, thereby removing technical and non-technical obstacles to the transfer of new energy technologies into practical application.

The advantages offered by digital technologies – in the agricultural sector or resource-efficient construction, for example – and modern biosciences are instrumental in achieving our goal of a more sustainable lifestyle and economic framework. The Federal Government is addressing key social tasks and political priorities in this field with three flagship initiatives – *Green Economy*, *City of the Future* and *Energiewende*. Research endeavours are being pooled for the trans-

ition to sustainability and for an environmentally friendly, reliable and affordable energy supply in the Federal Government's Raw Material Strategy, the energy research programme and the National Research Strategy *BioEconomy 2030 – our path towards a bio-based economy*. The *FONA³ framework programme* will serve to incorporate sustainability research more closely in the public forum, thereby increasing its relevance to sustainable development. The mission and broader goal of the Science Platform *Sustainability 2030* is to reflect on sustainability policy and provide new impetus for policymaking. The Platform fosters dialogue between science, politics, business and civil society in order to develop new solutions and identify the need for further research.

The transformation of production and consumption patterns constitutes a challenge for society as a whole, calling for a systemic perspective and the involvement of all relevant players. Therefore, the Federal Government is empowering platforms where representatives from science, industry, civil society and politics join forces to stimulate sustainable development: the *City of the Future* innovation platform, the *Green Economy* implementation platform, the National Platform on *Education for Sustainable Development*, the *Construction of the Future* research initiative, the *Energiewende* Research Forum, the Energy Transition *Research and Innovation* Platform and the Energy Research Networks. In its current report, the EFI recommends involving different social groups in this way. The Federal Government pools the resources of prime movers from the business sector, science and society in the *Kopernikus projects* with a long-term, ten-year perspective. The objective is to develop sustainable solutions and facilitate the restructuring of the energy supply.

We intend to promote the use of nature's principles and draw up an interdepartmental agenda called 'From Biology to Innovation' in collaboration with the business sector, science and civil society. Moreover, we want to encourage the development of new, intelligent and programmable materials. With regard to energy and climate research, we plan to join forces with the business sector and civil society organisations in investigating system solutions, particularly in connecting the sectors for electricity, mobility and heat. The same applies to earth-system research.

Future-oriented solutions must take account of change processes such as global warming, the demographic shift, social and cultural transformations and the resulting changed requirements. As infrastructures also have a significant impact on mankind's use of environmental resources, they should take centre stage in a green economy.

Innovative workplace

The way we work is changing at full speed. The working environment is undergoing a profound transformation, while the globalised economy is increasingly being marked by a strong service orientation and interactive value creation processes. Digitalisation is paving the way for new forms of working, different qualification profiles and changed job descriptions.

The Federal Government acknowledges its responsibility to remain actively involved in digitalisation, with input from social partners. The Federal Government's endeavours focus on the individual and the changing workplace. Well-trained specialists are absolutely vital for tomorrow's working world. To an increasing extent, digital skills are now a prerequisite for a successful education and career. According to the EFI, digital literacy should be enhanced and the skilled use of digital technologies encouraged on a wide scale. In particular, provision must be made for the participation of women and girls, who are still underrepresented in the digital workplace.

The Federal Government advocates digital literacy, the teaching of digital skills and learning with digital media. Furthermore, it supports the development of qualification measures and further training for a digitalised workplace, e.g. under the umbrella of the *Vocational Education and Training 4.0* initiative. Continuing professional development is a key factor, enabling the workforce to meet the challenges of the digital workplace and respond to rapidly changing qualification requirements. Together with all stakeholders, the Federal Government plans to draw up a 'Nationale Weiterbildungsstrategie' (National Vocational Training Strategy) for employees and job seekers that pools all professional development programmes initiated

by the Federal Government and the *Länder*, thereby establishing a new culture of vocational education and training.

Furthermore, the Federal Government is helping companies, particularly SMEs, to put their mark on tomorrow's working world. This is the goal of the *Future of Work* programme in the *Innovation for Tomorrow's Production, Services and Work* framework programme. Our *Future of Work* programme seeks answers to the question of how new technologies can be used to improve the working environment. To this end, we want to facilitate the exemplary development of new forms of work in regional competence centres for labour research. This includes developing leading-edge qualification concepts, as digital skills and the ability to adapt are becoming an increasingly essential resource for companies and employees alike. We aim to support SMEs in this endeavour in regional future centres. The Federal Government is funding the *Future Work Lab* in Stuttgart, an important centre that showcases the production work of the future. In the ESF-funded programme *unternehmensWert:Mensch plus*, we encourage process consulting in SMEs to develop customised solutions for the digital transformation and enable them to try out innovative work concepts.

Moreover, attitudes are also changing along with the upheavals in the workplace. Many people wish to combine a career and a family, yearning for a good work-life balance. Digital technologies offer new ways of achieving this goal. The Federal Government is making every effort to ensure that these possibilities are exploited to the full in order that families can spend more time together. We plan to develop models that ultimately allow greater freedom for family time. Digitalisation may increase employees' time sovereignty by opening the door for mobile working, for example. Therefore, as part of its endeavour to promote and facilitate remote working, the Federal Government proposes to create a legal framework.

The *Science Year 2018* revolves around the 'Working Life of the Future'. Together with innumerable partners and in a wide range of formats, the goal is to show the impact of technical and social advances on future employment – and how they are not just changing the typical working day, but also setting new benchmarks

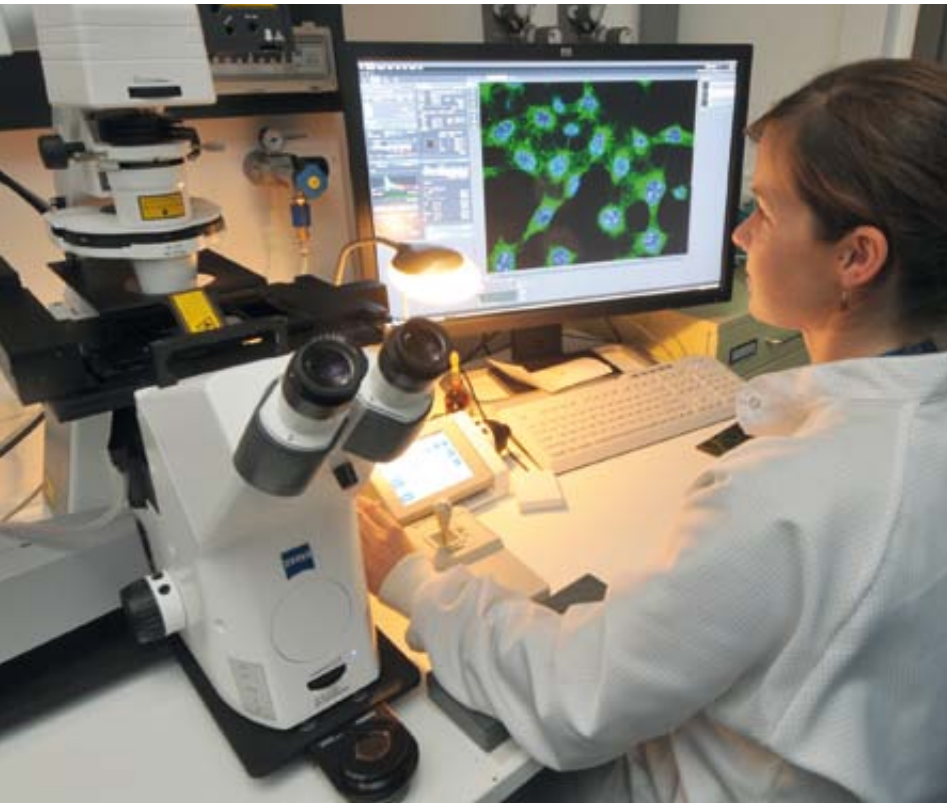
in the dialogue on social policy. The *Science Year 2018* deliberately explores the diverse 'Working Life of the Future'. This approach creates space for a shift in perspective, from the various points of view of research and education, companies, employees, organisations and each individual, plus with regard to working time and location. 'Experience. Learn. Shape.' This is the motto of the *Science Year 2018*, inviting members of the public to get involved by asking new questions – for example on the many different ideas and opportunities offered by successful human-machine interaction, human relationships, flexible working, tradition and future or intelligent offices – and helping find solutions together.

In order to empower the research infrastructure for social policy and legislation, which studies profound changes on the labour market over the long term, the Federal Government is planning to expand the *Fördernetzwerk Interdisziplinäre Sozialpolitikforschung (FIS)*, *Funding Network of Interdisciplinary Social Policy Research*. We are determined to follow up and build upon the achievements of the research funding mechanisms in the funding lines for chairs, projects and junior research groups.

Healthy living

Health is our most precious asset and the principal factor for the well-being of the individual and society. Life expectancy and the level of prosperity in Germany are high. Nonetheless, increased life expectancy also poses an enormous challenge for the healthcare system due to a rise in common diseases and multimorbidity in the population.

But the inherent challenges of climate change, such as the colonisation of hitherto non-native pathogens and their vectors, as well as allergens, must also be overcome. For example, this includes establishing suitable monitoring mechanisms and introducing alternative diagnostics and therapies. At the same time, the growing demand for health services and innovative medical applications offers a wealth of opportunities for Germany's healthcare industry, on both the national and international sales markets.



The Federal Government's *Health Research Framework Programme* pools its activities to promote research into a healthy, active and self-determined lifestyle. The main emphasis of the programme is the fight against widespread diseases such as cancer, cardiovascular, metabolic, pulmonary and neurodegenerative diseases, infectious illnesses and rare diseases. Intensive efforts are being made to pursue prevention, early detection and access to medical care and drugs as vital components for a long and healthy life.

The trend towards personalised medicine and digital networking are key drivers of progress in patient care. The digitalisation of healthcare is one of the greatest challenges facing the health sector in the years ahead. The Federal Government has laid the crucial groundwork for these developments. The *Personalised Medicine – Action Plan* seeks to harness the potential for innovative, customised therapies and diagnostics. One of the measures to foster the networking of the life sciences and information technology is the *Medical Informatics Funding Scheme*: clearly, the opportunities – as well as the risks and challenges – of digitalisation in healthcare are enormous. Strategic goals

for the future include studying and developing the responsible use of e-health and big data in the healthcare sector, up to and including the electronic research file.

Germany is expected to lead the way in adopting digital innovations in its healthcare system. The Federal Government is drawing up a road map for the development and implementation of innovative e-health solutions.

The Federal Government plans to extend the telematics infrastructure and introduce an electronic health record for all insured patients during this legislative term. We want to create new regulatory methods of approving digital applications that establish interoperability and enhance digital

security in the healthcare sector. We are determined to subject the restrictive regulations of telemedicine to rigorous scrutiny. We mean to update nursing care using the new options furnished by digitalisation, thereby allowing both nursing staff and those in need of care to make more efficient use of information and communication technologies or new technical applications. This will improve the working conditions of the nursing staff, the vast majority of whom are women. Technical assistance systems may also be instrumental in reconciling care and work. This calls for nursing care to be integrated in the telematics infrastructure. The use of telemedicine – and the regulations governing payment of such services – are to be developed further. Steps are being taken to ensure that data is stored in accordance with stringent data protection requirements. The stored data belongs to the patients.

The faster deployment of new knowledge and innovative products that enhance patients' well-being continues to be a strategic goal for the Federal Government. To this end, outstanding scientists from university and non-university research facilities col-

laborate with departmental research institutions on an interdisciplinary basis in the six German Centres for Health Research (Deutsche Zentren der Gesundheitsforschung, DZG). Translating research findings from basic research into clinical application is also the purpose of the Berlin Institute of Health. The innovation offices of the Paul-Ehrlich-Institut or the Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte) also contribute significantly to the transfer of health research. New forms of care provision and health services research are gaining further ground thanks to the *Innovation Fund* that has been set up at the Federal Joint Committee. With a strong focus on healthcare needs, the specialised programme on medical technology *Fachprogramm Medizintechnik* helps the highly SME-based sector press ahead with developing viable innovations for the benefit of patients.

Intelligent mobility

As a prerequisite for economic prosperity and social participation, mobility is a significant factor in enhancing citizens' quality of life. The Federal Government is therefore pursuing its goal of developing sustainable mobility models that reduce emissions, protect the environment and are accessible to all, yet reinforce Germany's competitive edge at the same time.

Above all, alternative drives – electromobility in particular – represent major technological contributions to the climate-friendly transformation of our transport system. Accordingly, with its *German National Platform for Electric Mobility*, the Federal Government is encouraging strategic dialogue between industry, science, politics, trade unions and trade associations. It is to be transformed into a *National Platform for the Future of Mobility* that explores the ongoing development of the automotive industry, for example. In order to maximise the energy efficiency and cruising range of electric vehicles, the Federal Government has set funding priorities in battery research, the charging infrastructure, grid integration and the development of holistic, energy-efficient vehicle concepts. Moreover, we propose to improve efficiency by optimising the interfaces between the individual transport operators, for example, by promoting an almost

seamless travel chain, with door-to-door passenger information and ticketing services, and by funding groundbreaking projects at the interface where the public transport network, car-sharing schemes and the bicycle converge. Furthermore, vehicle automation and networking play a pivotal role in developing intelligent mobility systems. This is the goal of the *Strategy for Automated and Connected Driving*, the *New Vehicle and System Technologies* programme and other specialised Federal Government programmes.

Germany is an innovation leader for safe, sustainable mobility solutions. Connecting modes of transport and vehicles and ensuring they are environmentally friendly, developing new vehicles and drive systems, along with sustainable fuels for the various modes of transport are all imperative for tomorrow's mobility. The objective must be to transform mobility into an intelligent system. State-of-the-art information and communication technologies, technical solutions that enable the real-time networking of vehicles, but also IT security and data protection issues will play a key role in this process. The Federal Government's *Space Moves!* initiative is also helping develop satellite-based navigation and communication applications for the mobility of the future.

Germany has every intention of using the great opportunities offered by digital innovations such as automated and connected driving. Quite apart from huge investments in traffic engineering, the digitalisation of the transport system calls for the ongoing development of information and communications technology. We plan to launch a mobility research programme that also investigates autonomous mobility. Experimental and exemption clauses will be set up to allow autonomous vehicles to be tested and deployed in public areas in compliance with the law. We will create the statutory requirements for fully autonomous vehicles (Level 5) on appropriate infrastructures by the end of the legislative term. We intend to review the liability regulations governing the use of autonomous systems (e.g. self-driving cars, robots). The aim is to close any accountability gaps. We hope to continue the successful 'Digital Motorway Test Bed' and pave the way for digital test beds on roads (particularly in urban areas), railways and inland waterways. We want to identify an effective political

framework that will enable autonomous driving to reach its full potential for sustainable urban development.

Research for civil security, IT and cyber security

Safeguarding security and freedom is of the utmost importance for our society. For critical infrastructures such as the energy supply, information and communications technology or transport and traffic networks, technical safety and the seamless interaction of complex systems and infrastructures are increasingly important in everyday life. Even minor disruptions may lead to supply shortfalls and cause considerable economic damage. Other risk factors include natural disasters, the global spread of terrorism and organised crime.

In its *Research for Civil Security Framework Programme*, the Federal Government promotes comprehensive security solutions that protect the freedom of Germany's citizens. Furthermore, the Federal Government stresses the tremendous importance of a high-performing, competitive civil security industry in Germany with a strategy designed to reinforce this sector.

With the advance of the digital transformation, the demands placed on the security, integrity and reliability of digital infrastructures and services increase accordingly. Although the exponential growth of vast quantities of data engenders an enormous increase in knowledge, it also entails new risks, especially in terms of the right to informational self-determination.

The Federal Government regards IT and cyber security as a crucial element for innovation and growth in Germany and Europe. This is borne out by the research framework programme *Safe, secure and empowered in the digital world 2015 – 2020*, an interdepartmental package of measures aimed at developing secure, innovative IT solutions, and the *Cyber Security Strategy for Germany* to safeguard civil security. Furthermore, a close collaboration is envisaged with France in the field of industry-driven IT and cyber security research under a joint memorandum of understanding that was signed in June 2018.

Navigating the digital world safely and with self-determination calls for strategies and efficient tools. Science and research can make vital contributions in this respect. Located in Darmstadt, Karlsruhe and Saarbrücken, three high-powered IT security competence centres operate with a thematic and organisational focus on the greatest challenges in the field of IT security. For example, the centres not only investigate encryption methods for making online payments or sending messages on the internet, but also follow up on secure cloud computing and end-to-end security solutions for large systems. As part of our commitment to perpetuating and expanding these competence centres, we are therefore transforming the CISPA Center in Saarbrücken into a Helmholtz Center. We intend to raise the visibility of the competence centres for IT security research, establishing them as research and consultancy centres in the international arena, not least for technology-oriented start-ups. The expectation is for science, industry, security agencies and task forces to pool their efforts. We are launching a new framework programme for civil security research to improve safety and order in the networked world.

2.2 Disseminating innovations

Innovation in Germany is marked by a lively cooperation and networking culture. The close collaboration between science, industry and – to an ever-increasing extent – society is one of the core strengths of Germany's innovation system. In its HTS, the Federal Government encourages multi-focus, interdisciplinary networking and the transfer of ideas, knowledge and technology along the entire innovation chain. New, open forms of cooperation are emerging that complement classic transfer structures. One of the mainstays of our R&I system, we are determined to strengthen the transfer and substantially enhance it over the long term.

Boosting networking

Building on the progress made so far, the Federal Government has set itself the target of combining the existing strengths of science and the business sector even more effectively to unlock new potential. We place great emphasis on cultivating clusters and networks in which SMEs are particularly active. Accordingly, the links between the scientific and business communities have strengthened considerably in recent years. The Leading-Edge Clusters of the *Leading-Edge Cluster Competition*, the *Research Campuses*, the *SME-NetC* consortia, the *Innovation Forums Mid-Size Sector*, the innovation clusters from the *go-cluster* programme, cross-sector initiatives such as *INNOspace* and the countless SME-based networks of the *Central Innovation Programme for SMEs (Zentrales Innovationsprogramm Mittelstand, ZIM)* represent the numerous dynamic regional partnerships. Consortia in the *Industrial Collective Research (Industrielle Gemeinschaftsforschung, IGF)* also generate synergy effects, thereby guaranteeing successful, industry-related research, particularly for SMEs. Competence networks for machine learning or the *Future Work Lab* aim to reinforce the ties between science and industry, especially SMEs, with both sides learning from each other in the process.

Strengthening universities' potential for cooperation with the business sector and society

The joint Federal Government/*Länder* initiative *Innovative Hochschule* supports third mission activities at German institutions of higher education – alongside

research and teaching – to boost knowledge transfer and innovation. The Federal Government and the *Länder* provide up to 550 million euros in funding for two selection rounds of five years each. The funds are made available in a ratio of 90:10 by the Federal Government and the respective *Land* in which the institution is located. The initiative is an ongoing programme based on a Federal-*Länder* agreement under Art. 91b of German Basic Law (*Grundgesetz, GG*). The Federal Ministry of Education and Research (BMBF) bears all direct programme expenditure, while the *Länder* finance the basic research equipment at the universities of applied sciences. It is directed mainly at small and mid-size universities as well as universities of applied sciences. Funding is currently granted to 48 universities in 19 individual projects and 10 consortia, of which, 35 are universities of applied sciences, one a college of art and music, plus 12 universities and colleges of education. The aim is to enable universities to strengthen their strategic role in the regional innovation system. Thus, the *Innovative Hochschule* incorporates recommendations from numerous sources – such as the EFI – to drive the cultural change in universities towards a better exploitation of findings and draw up transfer strategies for systematic implementation.

Under the funding stream of *Research at Universities of Applied Sciences and Companies (Forschung an FH mit Unternehmen, FHprofUnt)*, the BMBF supports R&D projects that are carried out in cooperation by a university of applied sciences and companies in the commercial sector. These are designed to result in long-term research consortia involving science and industry, enabling the partners to pool efforts in developing and implementing innovative solutions. At the same time, the research environments at the universities of



applied sciences are optimised. As the collaborating companies are obliged to share the project costs, they thereby demonstrate their firm commitment to the R&D projects in question.

In future, the Federal Government will focus its direct research funding more closely on the transfer of ideas, knowledge and technology to the business sector. It plans to set powerful incentives for research and science institutions to partner with industry in selected fields of research.

Closing innovation gaps and accelerating diffusion

Validating research findings at an early stage may be crucial in translating good scientific ideas more quickly into innovative products, services and innovations for society. Promoting such validation is thus

of central importance for the Federal Government. The Federal Government's VIP+ funding programme, *Validation of the technological and social innovation potential of scientific research*, addresses precisely this concern. The Federal Government thus effectively bridges the gap between research in all scientific disciplines and its commercial utilisation and application in society. It is based on an extended concept of innovation that encompasses both technological and social innovations.

The Federal Government's measure, *WIPANO – Knowledge and technology transfer via patents and standards*, helps public sector research institutions and companies to patent and exploit new, market-relevant technologies and promotes innovative R&D projects on standardisation, thereby accelerating their diffusion on the market. *WIPANO* also offers the option of refining technologies that are patented but not yet competitive on the market, for example by making prototypes or functional models.

Accelerating the dynamic pace of innovation through internationalisation

European and international R&D alliances offer enormous value creation potential. The Federal Government is therefore intensifying cooperation between universities, research institutes, companies and international partners.

National funding programmes that foster networking with international partners, thereby helping German SMEs to step up their activities overseas, are already available: the *Internationalisation of Leading-Edge Clusters*, *Forward-Looking Projects* and *Comparable Networks* measure is aimed particularly at giving SMEs the opportunity to become involved in international alliances. With partner regions all over the world, the first international R&I projects have begun their work. The development of the *Central Innovation Programme for SMEs* provided additional incentives for German SMEs to engage in international cooperation. Under the umbrella of *SME international*, the Federal Government grants SMEs access to the value creation potential that lies in European and international partnerships and economic relations.

Establishing an open innovation culture

We want to create an innovation culture that encourages creative ideas and their rapid implementation. We want to cultivate Open Innovation strategies, social innovations and inter- and transdisciplinary approaches. In addition, we want to set up experimental spaces to test innovative technical systems and new business models. Therefore, the Federal Government will press ahead with the transfer of basic research into applications and continues to facilitate the opening of innovation processes. The EFI also advocates consolidating basic research as a key source of innovation and focusing on the transfer of ideas, knowledge and technology. Demonstration projects and innovation labs allow companies to become more receptive to external expertise and involve new participants in the innovation processes.

To this end, a future cluster initiative that builds on the *Leading-Edge Cluster Competition* is to be developed, the *Research Campuses* are to be extended and new collaborative models encouraged between research institutes, companies and start-ups, such as Open Innovation campuses; all measures are to be consolidated into one highly visible brand.

In order to remain at the cutting edge of international competition, the Federal Government plans to fund the development of breakthrough innovations in Germany. New instruments that complement the Federal Government's successful funding mechanisms are to be created for this purpose. This will enable excellent research findings with a high potential for groundbreaking products, services and business ideas to be translated into applications and value creation for the benefit of society. The EFI welcomes the proposal to set up an agency for breakthrough innovations; the Federal Government's plans for its implementation are currently at an advanced stage.

2.3 Enhancing innovation dynamism in the business sector

Companies are the key players in the innovation process, which is why they take centre stage in the HTS. By international standards, Germany's business sector is characterised by a high focus on innovation. In the HTS, the Federal Government pursues its goal of consolidating this strength, continuing to support German companies as they face the growing challenges of globalisation and the digital transformation.

Increasing SMEs' innovative drive and unlocking the potential of key technologies

Particular emphasis should be placed on SMEs. With a range of issues spanning digitalisation, changes in classic value chains and globalisation, SMEs face considerable challenges today and in the future. Due to global competition and the new international division of labour, large companies have upped their innovation expenditure substantially. The innovation expenditure of Germany's business sector, which includes purchasing equipment and software, plus the costs of construction, design, training and market launch, in addition to R&D expenditure, rose by 2% in 2016. Large companies raised their innovation expenditure by an average of 2.1% in 2016, while SMEs only reported an increase of 1.6%. At the same time, the share of innovative firms – the percentage share of companies that have introduced new products or processes within a certain period – has been dwindling for years. Even though it recovered slightly in 2016, rising to 36.1%, this development is cause for concern. Companies are under mounting pressure to adapt to new technologies, business models and manufacturing bases.

To prepare SMEs for the escalating international competition and induce more SMEs to make their mark on the innovation landscape, the Federal Government is scaling up its R&I funding for SMEs on an ongoing basis. Moreover, it continues to refine its innovation policy instruments for SMEs.

The Federal Government guides companies through each stage of the innovation cycle from the idea to the

successful market launch with its concept *Von der Idee bis zum Markterfolg*. Customised instruments cater for the companies' varying needs and different development stages. Four programme families promote innovative start-ups, innovation expertise in the companies, pre-competitive research and market-driven R&D of innovative products and processes. The programmes have no specific thematic or technological focus, thereby allowing the companies to decide which technology they wish to invest in.

In addition to challenging standalone projects, *ZIM* supports collaborative efforts and network projects that bring SMEs and research institutes together. The broad-based, technology-neutral funding is aimed at market-oriented R&D projects carried out by SMEs. Following the increase in eligible costs, the relaxed entitlement that includes larger SMEs and the increase in the funding rate of up to 10% for international projects, *ZIM* now has a larger budget at its disposal.

This is supplemented by the ten-point *Priority for SMEs* programme, which boosts the innovative strength of SMEs, based on four fields of action. It aims to encourage greater SME participation in the specialised programmes of the research funding, to boost networking with strong partners such as other companies, universities and research institutes, to safeguard the supply of skilled labour and meet qualification requirements, to improve the framework conditions and streamline funding processes. The emphasis is on the dissemination and widespread utilisation of research findings and standard solutions among SMEs: apart from developing tried-and-tested instruments, such as the *SME innovative* funding initiative, new funding schemes without thematic restrictions such as the *Innovation Forums Mid-Size*

Sector and the *SME-NetC* help boost SMEs' flagging innovation focus.

The Federal Government is encouraging SMEs to make large-scale use of key technologies for new products and services. The *SME innovative* funding initiative gives them customised access to the special thematic programmes, appealing to SMEs with cutting-edge research in particular. An entry-level module helps those SMEs with little or no previous experience in setting up R&D projects in specialist programmes. The *SME innovative* funding initiative represents approximately one quarter of the BMBF's SME funding.

The EFI recommends introducing tax incentives for research funding to intensify R&D activities, particularly among SMEs. The coalition agreement includes plans for the introduction of R&D tax incentives.

The Federal Government is currently considering how to implement these measures expressly for SMEs. In addition, the Federal Government continues to rely on established technology-specific and technology-neutral project funding.

Unlocking the innovation potential of structurally weak regions

With its innovation-policy instruments, the Federal Government is helping to develop the hidden innovation potential in structurally disadvantaged regions, thereby opening up new prospects for the innovation-driven structural transformation.

Under the umbrella of the *Entrepreneurial Regions*, the Federal Government promotes the creation and expansion of exceptional technological, scientific and economic expertise in the new German *Länder* with five measures that single out different stages of the innovation process. The measures make allowance for the unique structure of the research landscape in East Germany. The *Twenty20 - Partnership for Innovation* funding programme encourages the development of newly networked innovation structures in East Germany and further afield. Up to 45 million euros have been earmarked until 2021 for each of ten selected interdisciplinary consortia to implement their strategies; these consortia are open to new partners from all over Germany.



Following up on the positive effects of the *Entrepreneurial Regions*, the Federal Government is developing the new *Innovation and structural transformation* funding concept, which targets structurally weak regions in East and West Germany. *WIR! – Wandel durch Innovation in der Region (WIR! – Transformation through innovation in the region)* is the first funding measure to be implemented under this umbrella. Funding is granted to broad-based regional alliances that develop and implement innovative strategic concepts for their region. Some 150 million euros have been earmarked for this programme, the pilot scheme of which is restricted to East Germany for the time being.

Furthermore, the R&D funding of non-profit, external industrial research institutes – *Innovationskompetenz (INNO-KOM, Innovation expertise)* – is open to structurally disadvantaged regions throughout Germany. This is aimed at industrial research institutes that make their research findings available to SMEs.

Nurturing start-ups

Business start-ups are a major driving force in kick-starting the innovation system. Young companies challenge successful established models and rapidly transfer innovative technologies into flourishing business models. Meanwhile, German metropolises such as Berlin and Munich attract start-up entrepreneurs from all over the world. Nonetheless, the start-up dynamism in Germany is still inadequate, particularly among women. Therefore, the Federal Government is embarking on a crucial process of realignment in terms of start-up funding. The *HTS* intensifies the support available for start-ups in scientific fields considerably.

In addition, the *EXIST Business Start-up Grant* and *EXIST Transfer of Research* have been extended. Moreover, a new national *Digital Innovations – Competition for Business Start-ups* has been launched. Between 200 and 250 new *EXIST* start-up projects are added every year. Non-university research organisations also cultivate the start-up culture with a range of measures at their facilities. The *German Accelerator* acts as a gateway for German tech start-ups seeking a foothold on the US market, and the Southeast Asian markets since March

2018, incorporating start-up ideas from the life sciences. The *ESA Business Incubation Centres* offer successful accelerators for space technology start-ups.

The Federal Government is enhancing its start-up funding in areas in which promising start-up projects from the science and research communities have not been explored to date or there has been a lack of key support, for example, in its concept *More opportunities for entrepreneurship – Five points for a new entrepreneurial age*. The R&I funding mechanisms under the umbrella of the *HTS* ensure the innovation pipelines are filled, while establishing sustainable research networks. Meanwhile, application-oriented infrastructures are being firmly anchored in the research landscape.

The priority now is to use this solid basis to spur innovation. The first new measure of the five-point concept, *Young Entrepreneurs in Science* pools efforts with cooperation partners from academia and industry to raise awareness for business start-ups among doctoral students. *Young Entrepreneurs in Science* is designed to harness the start-up potential among the new generation of academics at German universities more effectively. A pilot phase is scheduled to start at selected universities in 2018.

2.4 Laying the foundation for creativity and innovative strength

Our priority tasks include offering scientists opportunities for development and securing the skilled labour base. Furthermore, in order to foster the development of creative ideas and the transfer of social or technological innovations, we need favourable conditions that ensure a sound productive environment for business innovation and value creation.

Reinforcing science and research as the basis for Germany's innovative strength

Outstanding scientists, state-of-the-art facilities and the freedom for creative research are the hallmarks of a high-performing science system, offering a fertile breeding ground for innovations. The Federal Government aims to further enhance Germany's higher education sector and research institutes as centres of excellence in the international arena. Furthermore, we are determined to create the best possible conditions for training specialists and young scientists, at the same time particularly promoting the participation of women. We are making great strides in this respect. The enormous appeal of the German science system for both national and international students and scientists confirms that our efforts are bearing fruit in the right places.

Tapping the potential of specialised personnel

Qualified specialists and progressive thinkers are key to our success and prosperity. This is particularly true in an ageing society. Above all, however, the increasingly digitalised world is placing new demands on companies and employees alike. During recent years, the Federal Government's skilled workers concept has secured and supplemented the base of qualified personnel in Germany. We place great emphasis on stimulating labour market participation, for example, by improving the work-life balance. Similarly, our goal is to raise the qualification level of the (work-

ing) population. Young people can only express their individual talents and contribute their skills to the fullest extent if they have a decent education and good qualifications.

The digital transformation and the demographic shift will accelerate changes in both the supply and the demand for specialised personnel. By monitoring the skilled labour situation, we intend to take a closer look at both sides, synchronising them even more effectively for a successful transformation. One of the key challenges involves continually adjusting the skills and qualifications of the workforce to meet the variation in demand. Solid further training and the opportunity for – and willingness to engage in – lifelong learning are vital. Our National Vocational Training Strategy will ensure that the workforce keeps pace with digitalisation and that companies continue to find the skilled staff they need.

Other important elements in safeguarding the supply of skilled personnel are increasing the number of gainfully employed women and integrating workers with migrant backgrounds in the labour market. We have made significant progress here in recent years, for example in recognising international qualifications and offering job-related German language courses. Attracting specialists from abroad is crucial in securing the skilled labour base. According to the OECD, Germany currently has some of the most liberal immigration regulations for academic professionals. Among well-qualified international specialists, Germany is thus already highly sought-after as a place to live and work.

Extending funding for innovations

Access to adequate financing is another prerequisite for innovation activity. Nowadays, funding gaps affect dynamic start-ups in particular. However, they play a pivotal role in securing Germany's position as a business location. Therefore, in the *HTS*, the Federal Government takes important steps to open up the venture capital market for start-up entrepreneurs.

The *INVEST – Venture Capital Grant* measure offers business angels specific incentives to make capital available to young, innovative companies. The *High-Tech Gründerfonds* supports technology-based start-ups. The co-investment fund *coparion* and its predecessor, *ERP Start-up Fund*, invest in research-intensive technology companies during the start-up and expansion phase. *coparion* finances young, innovative technology companies with private investors who commit at least the same sums to the financing rounds, on the same terms and conditions. Furthermore, the *ERP/EIF fund of funds* participates in venture capital funds that invest in fledgling technology companies, most of which are active in Germany. We plan to continue and refine the existing financing instruments that assist the foundation and growth of start-ups. Wherever appropriate, we also want to open them to non-academics and add complementary instruments, such as the *Tech Growth Fund*. The *Tech Growth Fund* seeks to supplement state funding instruments in the growth phase by extending loans as venture debt. At the same time, we are considering the introduction of tax incentives to mobilise private venture capital beyond the scope of previous measures. In the years ahead, we will endeavour to double the volume of venture capital in Germany compared to 2016 by the concerted efforts of the private sector, the Federal Government, KfW Development Bank and the participation of European partners. This will enable us to close the gaps in the previous funding schemes for start-up entrepreneurs.

Refining the legal framework

Owing to its high volume of over 350 billion euros per year, public procurement can provide powerful incentives for more innovation in the business sector.

Against this backdrop, one of the goals of the *HTS* is to exploit the leverage of innovation-oriented public procurement to greater effect, thereby giving innovative companies crucial impetus for successful market penetration. To this end, important structures have been established in recent years: the *KOINNO Competence Center for Innovative Procurement* advises contracting authorities on demanding more innovation on the market, thereby creating innovation incentives for the economy. Procurement law gives the public sector the option of emphasising strategic – and thus also innovative – aspects in the procurement process. In its latest report, the EFI stresses the importance of innovation-oriented public procurement as the instrument of a strategic R&I policy.

A strong centre of R&I calls for a regulatory framework that is conducive to innovation, striking a balance between avoiding risks and fostering innovation. This is the starting point of the innovation principle, which stipulates that, when drafting laws and regulations, their impact on Germany's innovative capacity is to be assessed. This adds to the proven precautionary principle. Therefore, one objective must be to formulate regulations for the protection of mankind and the environment in such a way that they do not impede innovations or even prevent them. The Federal Government will reflect on how the innovation principle can be enshrined in Germany in addition to the precautionary principle.

2.5 Shaping change together

A modern, effective research and innovation policy must include as much expertise and as many perspectives as possible. Increasing numbers of citizens are already actively involved in the innovation process. Digitalisation is opening up further opportunities for participation. The Federal Government encourages this development, remaining resolutely committed to its tradition of dialogue and adding new participatory formats. The expertise of eminent Federal Government advisory bodies offers valuable guidance in implementing and refining the *HTS*.

Stepping up civil dialogue and public research

The Federal Government fosters a society that is open to new ideas and full of enthusiasm for future technologies and innovations. With a range of new initiatives, it offers interested citizens the opportunity to take an active part in shaping innovation and research policy.

The civil dialogue series *Future Forums* systematically stimulated debate among stakeholders from academia, politics and society. Together, the participants explored

central questions relating to the four forward-looking topics of 'Rethinking health', 'Exchanging, sharing, DIY', 'Teaching, learning and living in the digital world' and 'Generating knowledge – thinking and working in tomorrow's world'. The *Future Forums* are to be expanded as a tried-and-tested dialogue format. The *Futurium* will serve as a platform for dialogue on the future of technology, business and society.

Moreover, we are strengthening citizen science. This involved launching an internet platform that brings citizens and scientists together to undertake joint projects. The Federal Government has set up a new



'Pepper' the robot presents the large collages in the exhibition room to visitors in the new *Futurium* building in Berlin.

funding mechanism to support citizen science: the BMBF is financing 13 projects with a lifespan of up to three years. First and foremost, we want to bring about a more effective degree of cooperation between citizens and scientists, while methodically advancing citizen science. The funding has resulted in a high level of mobilisation in the community.

Moreover, we do our utmost to enlist multiple stakeholders to help identify research priorities. Agenda processes and platforms, such as the National Platform for the *City of the Future* or the National Platform on *Education for Sustainable Development*, exemplify this participation.

Intensifying scientific communication

The Science Years turn the spotlight onto current topics such as ‘The Digital Society’ (2014), ‘City of the Future’ (2015), ‘Seas and Oceans’ (2016*17) or the latest ‘Working Life of the Future’ (2018) by stimulating discussion and encouraging participation in science and research. In future, the Federal Government aims to bring education, science and research more into the public arena and to facilitate dialogue on forward-looking topics among the scientific, social and political communities. This has led to the further development of science communication activities and experiments with new forms of citizen participation.

Adopting a more future-oriented approach

The Federal Government intends to fine-tune its strategic foresight. The *Foresight Process* identifies future technological and social developments with a long timescale in order to provide guidance to the Federal Government for early agenda setting and prioritisation in education, research and innovation policy. *Foresight* may help to design strategic processes, future research programmes and projects. The BMBF plans to launch a new *Foresight Process* on future issues in industry, academia and society.

The *innovation and technology analysis (ITA)* studies and evaluates the challenges, opportunities and risks posed by new interdisciplinary topics of societal relevance. The analysis looks at the various dimensions of future developments: what are the environmental and economic consequences of a future trend? What societal and ethical debates must be conducted? What framework conditions must be created and what obstacles overcome in minimising the risks? Providing analyses in the area of conflict between technological possibilities, social values and commercial requirements, the ITA is an essential component of the Strategic Foresight.

Achievements must be measurable; to this end, a pilot project developed new methods for an expertise monitoring mechanism. These methods make it possible to identify future technologies and innovation fields that are particularly relevant for the competitive position of Germany’s economy, enabling the necessary expertise to be anticipated and strategically cultivated. This gives industry, science and politics a tool to facilitate the breakthrough of new fields of added value and to leverage the untapped potential for prosperity and competitiveness.

Evaluation and consulting for an effective research and innovation policy

The *HTS* is implemented in an effective, coordinated and proactive manner. In so doing, the Federal Government calls on the expertise of external advisory bodies. In addition, all major *HTS* funding measures are evaluated prior to, during and on conclusion of the initiative. Evaluations help configure efficient funding programmes, instruments and processes for R&I. Continued enhancement of the evaluation practice is the prerequisite for evidence-based policy advice that boasts high-quality academic input in the field of R&I.

Evaluations are thus a logical instrument of R&I policy that has increasingly come to the fore in recent years. Public expectations grow apace with the rise in tasks and resources to ensure that the Federal Government’s funding measures actually meet the stated goals.

Given the increasing momentum of scientific and technological progress, the demand for orientation, discussion and active participation continues to grow. To meet this demand, it is imperative to identify and analyse technological innovation potential and society's need for innovation, while studying the correlation between them. To this end, the Federal Government consults with panels of leading experts.

Instituted by the Federal Government, the EFI pools interdisciplinary discourse relating to innovation research from the fields of economics and social sciences, education economics, engineering, natural sciences and technology foresight. The EFI advises the Federal Government by comparing and analysing the German R&I system over time and according to international standards, by reviewing priority issues and recommending courses of action for the continued development of the German R&I system. The Commission publishes its main results in its annual reports on research, innovation and Germany's technological performance.

The High-Tech Forum provided key substantive and strategic assistance in implementing and further developing the *HTS*. At the same time, the Federal Government's planned Research and Innovation Strategy (R&I Strategy) drew on the interdisciplinary expertise of partners from science, industry and society. The High-Tech Forum highlighted a number of topics that are central to Germany's future viability as a centre of R&I: autonomous systems, digitalisation and healthcare, the effectiveness of the innovation system and SME innovativeness, the challenges and success factors of cooperation and transfer, innovative working environments, internationalisation, the sustainable economy, participation and transparency. The High-Tech Forum provided implementation impetus and developed scenarios for these topics. Extensive consultation processes underpinned the development of the recommendations. In May 2017, the High-Tech Forum presented its package of recommendations for raising the profile of R&I in Germany. The proposals are being included in the *HTS*.

In the Innovation Dialogue, the Federal Chancellor invites high-ranking representatives from science and industry to discuss the strategic direction of innovation policy. To date, eleven innovation dialogues have taken

place, focusing on subjects such as STEM education; digital networking and the future of value creation; the innovation potential of human-machine interaction; modern forms of knowledge, technology and information transfer; the innovation potential of biotechnology; Germany's role in European innovation policy and incentives for radical innovations.

2.6 Developing the High-Tech Strategy further as an inter-ministerial research and innovation strategy

Germany is one of the largest exporting nations and ranks among the world's innovation leaders. Our strength is due to consistently pursuing our policy of making research and innovation a high priority for over a decade, under the umbrella of the HTS.

The future still calls for an all-embracing R&I policy that fosters academic excellence, pioneering spirit and entrepreneurial courage. Our task is to forge closer strategic links between research and innovation, science and industry over the long term, to support innovative ideas that are 'Made in Germany' until they are ready for application and, lastly, to encourage entrepreneurship in universities and research institutes.

The Federal Government plans to further develop the HTS as an inter-ministerial R&I Strategy. It is designed to underpin Germany's target of investing 3.5% of GDP in R&D by 2025. The coalition agreement includes plans for the introduction of R&D tax incentives. The Federal Government is currently exploring the options of implementing these measures expressly for SMEs. From school to vocational training, right through to obtaining academic qualifications, education is to be



aligned with the growing demand. The aim is to lay the foundation for a dynamic innovation system as regards financing and personnel resources.

The *HTS* focuses on the Grand Societal Challenges of digitalisation, health, climate change, the transition of energy and mobility, security, social innovations and the future of work. The Federal Government means to develop new instruments to accelerate breakthrough innovations and knowledge transfer to the business sector. The new R&I Strategy is intended to help establish an open culture of innovation in Germany that offers space for creative ideas and fosters both technical and social innovations. The Federal Government will push ahead with transferring basic research into useful applications for industry and society. Research funding that does not favour any specific technology is of fundamental importance in our research policy.

Germany is not only expected to keep pace with technological advances, but to lead and define these developments. The Federal Government seeks to enhance expertise in forward-looking technologies, including key digitalisation technologies such as microelectronics, communication technologies, artificial intelligence, data science, IT security, blockchain technology and quantum technologies. Biological resources, principles and procedures should be integrated to a greater extent in various aspects of modern life and business activities.

The priority today is to strengthen data science in all fields, but particularly in the higher education sector. To this end, the management of data must be recognised as a separate area of science and a discipline in its own right. We need a training initiative and a research campaign in all aspects of digitalisation. We consider digital sovereignty and interdisciplinarity particularly important in this regard. One of the ways in which we are guiding the digital transformation as a process of overall social development and policy-making is with the work of the Weizenbaum Institute for the Networked Society and the Competence Center Public IT at the Fraunhofer Institute for Open Communication Systems FOKUS.

The aim is to enhance Germany's start-up culture and support SMEs every step of the way towards a modern, digital-based economic framework. Lastly, this serves

to step up European and international cooperation in R&I. We have resolved to build on our international R&I partnerships, more specifically to intensify international cooperation with African countries in terms of education, science and research, by studying poverty-related diseases, for example.

In implementing the R&I Strategy, the Federal Government will reinforce inter-ministerial coordination and encourage dialogue between science, industry and society, with a stronger focus on scientific communication and participation.



3 Driving progress through internationalisation

Global challenges can only be overcome in partnership. Thanks to its global network, Germany benefits from open markets, international knowledge exchange, free trade and a European Union without barriers. One of our priority tasks is to preserve and reinforce the openness of the German and European R&I system, while sustaining free flows of knowledge and mobility.

As one of the world's leading innovation hubs, Germany has both the potential and the responsibility to help shape future issues in the international arena. We are fully aware of our duty to contribute to finding groundbreaking solutions to the major challenges facing our societies and economies. Moreover, we realise that solutions must primarily be found in international collaboration.

Challenges such as climate change, global health and security cannot be overcome in a purely national context: although the impact of pollution can be seen locally to some extent, even remote regions within the Earth system are also affected. By the same token, this applies to healthcare in our interconnected and globalised world. The prevention of disease can never be confined to a national framework, as shown by the spread of Ebola. The same goes for security. Physical

safety and protection against cyber attacks can only be guaranteed as a combination of national action and international cooperation.

With this in mind, the Federal Government dedicates its energy and resources to developing the cooperation in R&D activities and finding solutions to pressing societal challenges. The international networking of all German stakeholders from science and research – and their integration in transnational knowledge flows – can make a vital contribution in this regard.

As this international network guarantees the competitiveness and achievement potential of German science and industry, the Federal Government makes every effort to nurture these relations. Europe continues to be the unshakeable central pillar of Germany's international commitment.

In the course of globalisation and the growing interdependence of international interests, education, research and innovation are in a constant state of flux. In view of the progressively transnational processes of knowledge generation and utilisation, it is more important than ever before to reaffirm Germany's position as a powerful innovation hub. Numerous indicators place Germany at the top of the international league and show how it benefits from globalisation:

- With an overall market share of approximately 12% in research-intensive goods in 2015, Germany has maintained its outstanding competitive position in the global marketplace behind China and ahead of the United States.
- At 371, the number of patents relevant to the world market in Germany per million inhabitants is well above the EU average of 156.
- In 2016, 58% of the scientific papers published in Germany were the result of cooperation between researchers from several countries. Therefore, the degree of networking in Germany's science sector is far above average.
- According to the EU Industrial R&D Investment Scoreboard, five of Europe's top ten corporate R&D investors are based in Germany.
- The European Commission's Innovation Union Scoreboard 2017 ranks Germany in sixth place out of 28 countries, making it one of the European Innovation Leaders.
- Regarded as a hotspot for research and an attractive academic location, Germany is one of the five most popular destinations for international students from OECD countries.

Exploiting the potential of international cooperation

The Federal Government aims to further leverage the potential and opportunities that international cooperation offers Germany. International cooperation gives Germany's role greater definition and empowers

its science and research presence in the converging arenas of industry, research and urban centres. The instruments launched by the Federal Government range from the exploration and initiation of opportunities for collaboration, the implementation of specific research, innovation and education projects, right through to developing joint funding programmes and establishing joint research infrastructures.

With Brexit looming large, we want to join forces in the world and hold our own in economic terms. The Federal Government is therefore actively pursuing the integration of its endeavours in the European framework. The creation of the European Research Area (ERA) has elevated Europe, making it a decisive factor in the alignment of international research policy. Joint, concerted action on the part of leading EU Member States enhances Europe's visibility, lending it added weight vis-à-vis the world's other major innovation regions. *Horizon 2020*, which runs from 2014 to 2020, was designed to complement national research programmes; with a total funding volume of 77 billion euros, it is the world's largest self-contained programme. The Federal Government will play an active role in shaping the 9th EU Framework Programme for Research.

Moreover, Germany is underpinning its bilateral cooperation with important partner countries around the world, developing creative potential for the common benefit of all parties. This applies first and foremost to countries with dynamic growth and significant emerging markets; it is also of strategic importance in terms of access to excellent science and technology resources.

The root causes of migration and flight must be combated where they arise. It is therefore the Federal Government's avowed goal to strengthen the research and innovative capacity of the source regions of flight and migration. We want to help ensure decent living conditions for the local population, this includes providing access to adequate health services and protection against the risk of disease.

Boasting a wealth of international contacts, the Federal Government's departmental research institutes perform specific tasks at the interface of politics, science and practical application. In so doing, they play a cru-

cial role in the development and international harmonisation of methods, standards, norms and regulations or the regulatory approval of innovative products. Thus, they create conditions that are conducive to the success and effectiveness of innovation processes and international collaboration in tackling global social challenges, such as the Ebola epidemic or the fight against antimicrobial resistances.

The G7 and G20 are important instruments for achieving concerted action and transnational cooperation. Germany is a significant force in this regard. In 2017, during its G20 presidency, Germany hosted the Digital Ministers' Meeting in Düsseldorf. The main result was the 'Roadmap for Digitalisation: Policies for a Digital Future', which outlines the future digital policy agenda to support the digital transformation. The core objectives include access to the internet, extending the infrastructure, promoting new business models, ensuring fair competition in the digital world, supporting SMEs, the ongoing development of *Industrie 4.0*, digital education, enhancing

trust in the digital world, online consumer protection, measuring the impact of the digital economy and overcoming the gender-based digital divide. The priorities set out in the roadmap will be pursued further under the Argentine presidency. The meeting of the G20 Digital Ministers took place in Argentina in summer 2018.

At the G7 Science Ministers meeting in Germany in 2015, it was agreed to meet regularly at senior officials' level to review progress in these topics over the long term. The main issues of the G7 Science Ministers meeting in Germany were poverty-related infectious diseases, the future of the seas and oceans, and clean energy. These topics were re-addressed at the meeting in Japan in 2016. Italy continued the series of G7 Science Ministers meetings in September 2017. The agenda included attracting excellent researchers, financing mechanisms and policy approaches for inclusive science, research and innovation, global research infrastructures and Open Science. Under Canada's G7 Presidency, the G7 Ministers



Global research endeavours focus on the future of the seas and oceans. At work on the seabed: the ROV KIEL 6000 system was designed specifically for deep-sea scientific operations.

of Employment and Innovation convened in 2018 to discuss artificial intelligence and innovation. Canada is following in the footsteps of Italy and Japan's previous G7 presidencies, with the science working groups continuing their collaboration.

In addition to Germany's active involvement in multilateral initiatives and institutions such as the OECD and the United Nations Educational, Scientific and Cultural Organization (UNESCO), its partnership with international bodies such as the World Health Organization (WHO) and the World Organisation for Animal Health (OIE) is conceived as a long-term investment in the future. Firstly, these multilateral initiatives and institutions serve as a forum for identifying common research topics at the global level and developing the framework conditions thereof. Secondly, by providing selective data processing and analyses, these international organisations ameliorate the basis for national and international policy decision-making. Examples include the Intergovernmental Panel on Climate Change (IPCC) or the cooperation of German research institutes with international health organisations and international funding bodies in handling global health crises, such as the Ebola and Zika epidemics.

Extending the European Research Area

Europe upholds common values, which also apply to scientific exchange and innovation cooperation. The ERA ensures an open labour market for researchers and facilitates the exchange and transfer of scientific findings. In the spirit of 'Open Science', digital infrastructures and the digital availability of publications and research data are coming increasingly to the fore.

Within the EU, the Federal Government advocates measures to strengthen the strategic research policy, the ability to innovate and the ERA. In order to maximise Europe's potential as a centre of knowledge, the European Commission and the EU Member States are harmonising their science, research and innovation policies. Germany is particularly eager for the countries of Central, Eastern and South-Eastern Europe to

be more closely integrated in the ERA. As national research budgets account for the lion's share of research funding in Europe, the coordination of research objectives and funding mechanisms is a central pillar of the ERA. This allows for an effective response to the Grand Societal Challenges, such as climate change, the energy supply and the fight against widespread diseases.

The goal is to enhance Europe's excellent research, to pool efforts in advancing research topics with European added value and to increase the cohesion, competitiveness and willingness to reform in European systems of R&I. Excellence and subsidiarity must continue to be the fundamental principles of European research funding. In close consultation with the European Commission and the Member States, it is imperative to identify the challenges for Europe that can only be overcome by joining forces. It is also essential to set the specific R&I objectives that can only be achieved as a concerted effort. The Federal Government proposes to incorporate its national research goals in European partnerships and to help expedite the formation of a European Innovation Council (EIC). The EFI recommends that the tasks and structures of an EIC be clarified in the near future.

A top priority: accelerating internationalisation

Over 90% of the world's knowledge is generated outside Germany. International collaboration in science and research is absolutely vital in enabling Germany to tap into this wealth of knowledge and in maintaining Germany's competitive edge as a centre of science and industry. With this in mind, the Federal Government is pursuing its *Strategy for the Internationalisation of Education, Science and Research*. It follows up on the Federal Government's previous Internationalisation Strategy in response to the new trends and challenges that are having a significant impact on international collaboration in education, science and research. These trends and challenges include increasing globalisation, digitalisation, the further development of the ERA and the emergence of new global centres of innovation outside established science hubs.

Under the Internationalisation Strategy's guiding principle of 'International cooperation: networked and innovative', the Federal Government directs international collaboration effectively and efficiently, with a focus on achieving strategic goals:

- Strengthening excellence through global cooperation
- Enhancing Germany's innovative dynamism on the international stage
- Developing the international aspects of vocational training and qualifications
- Working with emerging and developing countries to shape the global knowledge community
- Overcoming global challenges together.

The strategy leverages synergies between the various activities of the participants from science, the business sector and politics to make the greatest possible impact.

The Federal Government deploys a broad range of instruments in working towards the objectives. These include stepping up the networking of international activities carried out by German science and research organisations or companies, making excellent research infrastructures available for research coopera-

tion at the international level, supporting the international programmes of the United Nations (UN), the success of which depends on R&D, such as the *Global Framework for Climate Services* (GFCS) and the *Sendai Framework for Disaster Risk Reduction*, sponsoring foreign students and scientists, and the internationalisation of the *HTS* instruments. The Federal Government thereby lays the foundations for exploiting the opportunities of internationalising R&D. A cornerstone of the Federal Government's *Strategy for the Internationalisation of Education, Science and Research*, the round table brings together Federal Ministries and key German stakeholders for discussion of strategic issues relating to international cooperation in education, science and research. The core objective of the round table is to identify where future action is required and set up cross-departmental synergy projects to address this need.

A further target is to boost Germany's international standing as an attractive location for science, research and innovation. Research marketing, the German Houses of Research and Innovation and strengthening the culture of welcome for foreign researchers all play a crucial role in this respect.



4 Empowering science and cutting-edge research

A strong, broad-based science system that produces cutting-edge research is essential for an innovation hub like Germany. In cooperation with the *Länder*, the Federal Government's *Higher Education Pact*, *Excellence Strategy*, *Pact for Research and Innovation*, *Tenure Track Programme*, *Teaching Quality Pact* and *Teacher Training Quality Campaign* have all helped to empower the science, research and innovation landscape in Germany. The goal is to maintain this strength and improve Germany's position in the global competition. To achieve this, the Federal Government is raising the visibility of the country's science system, while increasing the focus on excellence.

As a leading centre of science, research and innovation, Germany has a powerful attraction for national and international students and researchers.

- With 1,367 scientific publications per million inhabitants in 2016, Germany boasts a higher publication intensity than either the United States or Japan.
- According to current estimates, the number of researchers in Germany reached a record level of over 400,000 in 2016, approximately 160,000 of whom work in the higher education sector and the government sector. In recent years, the percentage of female researchers has risen sharply to more than 36% in the higher education sector and around 32% in the research institutes. We will do still more to promote this positive development.
- More and more students of a given age cohort are completing their education with a university degree. The graduation rate rose from 19.9% in 2005 to 31.8% in 2016. During this period, there was a marked increase in the number of graduates according to subject groups, in engineering as well as in mathematics and natural sciences.
- Both students and established scientists regard Germany as an attractive host country. Between 2008 and 2017, the number of foreign students in Germany shot up by 54% from approximately 234,000 to 360,000.

- In 2016, more than 88,000 (non-tenured) scientists from abroad were registered in Germany. Foreign researchers already account for 11% of the entire scientific staff in Germany.
- Approximately one quarter of German university graduates complete part of their studies abroad, with the majority spending at least three months overseas.

Facilitating outstanding research

With the *Excellence Strategy* following on the heels of the *Initiative for Excellence*, the Federal Government joins forces with the *Länder* to boost the competitiveness of the German science system. Together, the *Excellence Strategy*, the ongoing pacts – *Higher Education Pact*, *Teaching Quality Pact*, *Pact for Research and Innovation* – and the joint Federal Government/*Länder* initiative *Innovative Hochschule*, which promotes research-based transfer, form an overall strategy to enhance the excellence and achievement potential of the science system.

In terms of prize money, the *Excellence Strategy* is one of the world's most prestigious competitive processes for cutting-edge research at universities, comprising the cluster of excellence and universities of excellence funding mechanisms. The Federal Government and the *Länder* take advantage of the constitutional scope provided for in the new Article 91b GG (Basic Law). This basis ensures the permanent funding of the universities of excellence. Every year, the Federal Government and the *Länder* earmark some 533 million euros for the *Excellence Strategy*, three quarters of which is borne by the Federal Government. The *Excellence Strategy* increases the competitive edge of German universities on the international stage. This also benefits Germany across the board as a centre of tertiary education and research; needless to say, flagship research projects showcase the entire higher education sector.

Thanks to the *Pact for Research and Innovation*, the science organisations (the German Research Foundation (DFG), Fraunhofer-Gesellschaft, the Helmholtz Association (HGF), Max Planck Society (MPG) and the Leibniz Association) can rely on a steadily growing

source of funds. In return, the science organisations commit to undertake certain research policy objectives, with autonomous control over the implementation thereof. Not only do they make inroads into forward-looking fields, expand their national and international networks, and enshrine the transfer of ideas, knowledge and technology in their strategic mission, they encourage the promotion of women and early career scientists. The Federal Government is ring-fencing an additional 3.9 billion euros for this purpose between 2016 and 2020. The pact's combination of research policy goals and financial planning security has reaped tangible rewards: the Federal Government therefore plans to continue the *Pact for Research and Innovation* as of 2021, based on the approved Federal Government/*Länder* funding rates, with an annual increase of at least 3%. We intend to fine-tune the goals and instruments of the *Pact for Research and Innovation* and publish annual progress reports.

By means of the *DFG's programme-overhead financing*, we are stepping up research at universities, with in excess of 2 billion euros in total from 2016 to 2020. We will extend the *programme-overhead financing* beyond 2020.

Seizing the opportunities of digitalisation for the science system

Digitalisation offers tremendous opportunities for our tertiary education institutions. We want to help universities take full advantage of these opportunities to improve the quality of their degree courses, teaching, research and administration, as well as academic exchange. We will be launching a competition to encourage digitally innovative universities or higher education associations. In particular, we mean to facilitate inter-university, networked concepts, e.g. teaching and learning platforms.

However, digitalisation is also posing enormous challenges for science as a whole. Universities and other research institutions need to manage their research data in a meaningful way in order to make the vast quantities of accumulating data available for science throughout their life cycle, from data collection to processing and protection, right through to their reuse.

The National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur (NFDI)) may provide a basis for this by systematising scientific data repositories and making them permanently accessible. Together with the *Länder*, we are also considering launching a long-term national strategy for high performance computing (Strategie für Nationales Hochleistungsrechnen) with joint funding.

Providing sustained support to universities and maintaining the quality of teaching

Higher education institutions not only form the core of the science system, they are also key places of learning. The number of prospective school leavers who aspire to study at university is almost 60% of an age cohort and will remain high in the future. In the third phase of the *Higher Education Pact*, the Federal Government and the *Länder* have pledged to provide university places for up to 760,033 additional first-year students by 2020, compared to 2005. Over the entire term from 2007 to 2023, the Federal Government is providing in excess of 20 billion euros to strengthen the universities. The goal is for all those who wish to study, and who meet the requirements, to be granted access to higher education, the more so as demand for university graduates remains high. At the same time, the principle of equivalence between academic and vocational training still applies.

The universities depend on the Federal Government funding for additional first-year students under the *Higher Education Pact*. Given the persistently high demand for tertiary education, we have resolved to perpetuate the federal funds on the basis of the new Art. 91b GG to ensure a high level of teaching. The

specific funding criteria may be negotiated periodically with the *Länder* and the universities every seven years. In so doing, continuity and reliability are key criteria in the interest of good work and are to be combined with both quality and quantity in higher education. The effective use of federal funds is verified on a regular basis. The focus of this measure is two-fold: the quality of research and teaching and students' career prospects (graduate surveys).

In the *Teaching Quality Pact*, the Federal Government and the *Länder* seek to encourage the universities in their endeavours to improve studying conditions and teaching quality. The Federal Government has earmarked up to 2 billion euros for the pact from 2011 to 2020. This allows the sponsored universities to adopt customised measures, whether that be higher staffing levels or incentives for innovative teaching formats. We plan to extend the *Teaching Quality Pact*, fine-tuning it according to the recommendations of the German Council of Science and Humanities. Furthermore, we intend to cultivate the competitiveness of innovative academic teaching, the interaction between different universities and the transfer of successful concepts. We also want to strengthen the universities of applied sciences by launching a broad-based initiative with the *Länder* that allows graduates to actively plan their



careers up to professorship level and supports the recruiting process at universities of applied sciences. Moreover, we aim to systematically support the internationalisation strategies of the universities of applied sciences.

Enhancing Germany's standing as a centre of science through internationalisation and mobility

International exchange in science and cutting-edge research is an important safeguard of open-mindedness and international understanding. At the same time, it is a basic attribute of our science landscape. Germany's largest intermediary organisations, the German Academic Exchange Service (Deutsche Akademische Austauschdienst (DAAD)) and the Alexander von Humboldt Foundation (AvH), are of extraordinary relevance in this regard. The scholarship programmes of the DAAD include measures for undergraduates, doctoral students and experienced, established scientists from Germany and abroad. The AvH offers various sponsorship programmes for foreign postdoctoral scholars, who have demonstrated scientific excellence, funding their stay in Germany for a research fellowship.

In addition, the Federal Government funds structural measures that promote the internationalisation of German universities within the scope of international university cooperation agreements for the strategic networking of teaching and research. We seek to break new ground in this respect by wholeheartedly supporting the initiative launched by President Macron of France to establish European university networks. The Bologna Process was developed to improve the general conditions governing international academic mobility.

We aim to foster the global competitiveness of our science system and intensify international networking, based on the Federal Government's

Strategy for the Internationalisation of Education, Science and Research. We are forging ahead with the process of internationalising the universities and encouraging the successful programmes of our intermediary organisations, AvH and DAAD. We want to continue their sponsorship programmes for students with refugee status and endangered researchers at German universities and research institutes. Our goal is to recruit – and retain – talented foreign university graduates, young scientists and outstanding researchers with even greater success than hitherto by advertising the wealth of opportunities for research in Germany. We are stepping up European and international mobility in schools, vocational training and higher education. The extended *Erasmus+* programme is instrumental in this regard. In addition, we are creating incentives to study or teach outside Europe.

Ensuring the effective promotion of early career researchers and scientists

Germany's science system must be able to attract brilliant minds and creative thinkers. Therefore, the Federal Government is committed to establishing working conditions and career prospects in the scientific community that are internationally competit-



ive. The *Tenure Track Programme* promotes young scientists by making careers in the academic world easier to plan and enhancing the transparency of the various steps. For the first time, the Federal/*Länder* programme will establish tenure track professorships at German universities nationwide. Following a successful trial phase, the *Tenure Track Programme* facilitates the direct transition to a tenured professorship. The Federal Government is ring-fencing up to 1 billion euros for 1,000 additional tenure track professorships. The programme is scheduled to run until 2032. Some 468 professorships are being funded in the first allocation round.

The reform of the Academic Fixed-Term Contract Act (*Wissenschaftszeitvertragsgesetz*) improved the management of fixed-term regulations in an academic context and was directed at improper short-term contracts in particular. The duration of fixed-term contracts for scientific personnel must be commensurate with the intended qualification; where the limitation is due to third-party funding, it should be based on the approved project duration. The reform therefore countered the undesirable developments in the practice of issuing fixed-term contracts, without prejudicing the essential flexibility and dynamism of the research sector; moreover, it extends the scope of universities and research institutes' activities, thereby improving the conditions of employment for young scientists.

Fostering departmental research

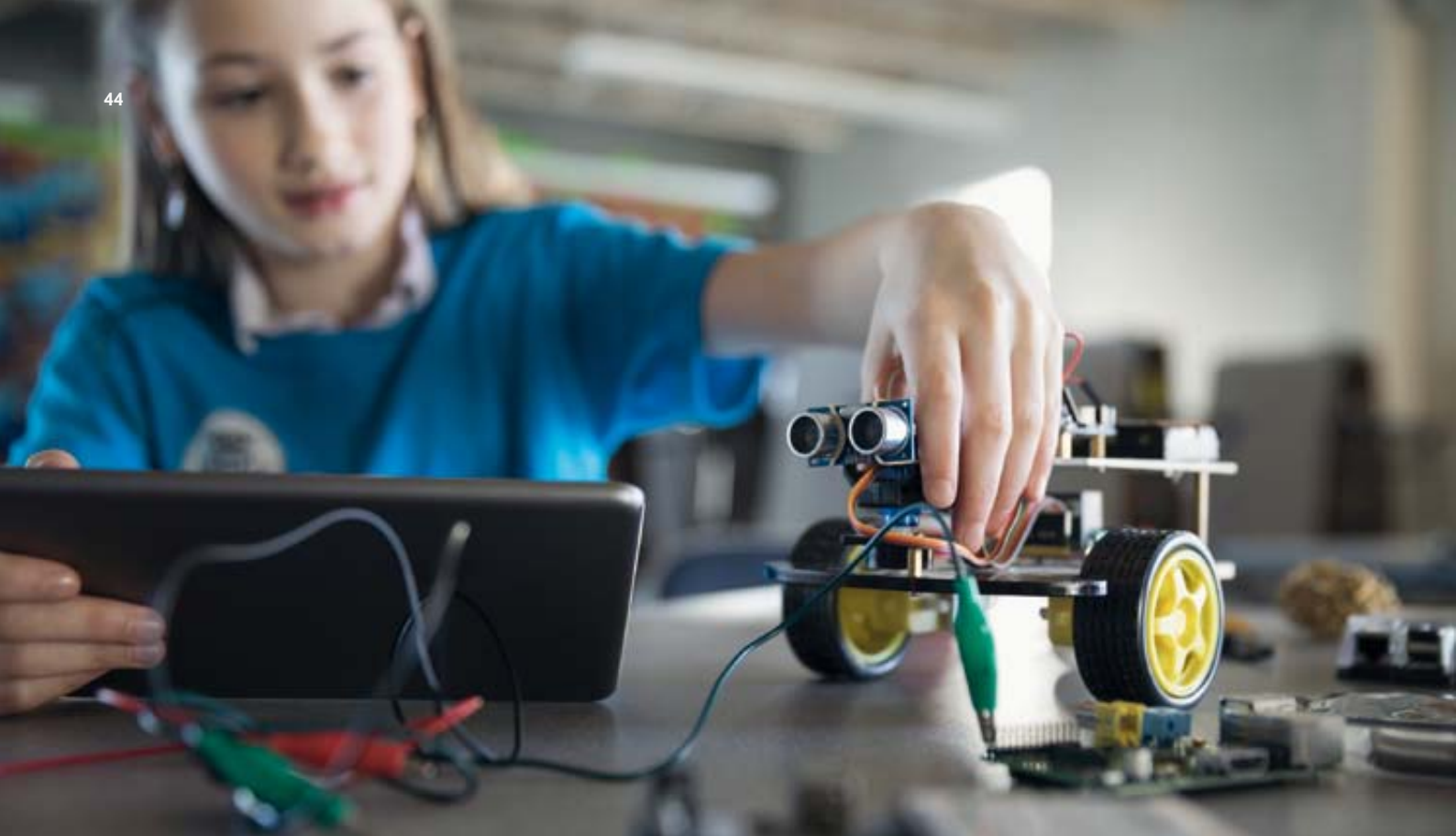
The departmental research conducted by the Federal Government at the interface of science, society and politics is a crucial component of Germany's science system. Associated with the performance of each ministry's statutory and specialist tasks, departmental research covers a broad spectrum of responsibilities. Its remit includes scientific research on legislative tasks; scientific and technical services such as permits and approvals; maintaining databases, operating expert systems and monitoring networks; collaboration in developing and updating legislation and standards at national, European and international level; knowledge and technology transfer; research and social reporting or studies on current sociopolitical issues.

Departmental research plays a pivotal role at European and international level on account of its direct involvement in the advisory and decision-making structures of the European Union and of international organisations with an emphasis on R&D activities.

Departmental research is carried out by R&D-performing federal institutes, non-university R&D facilities working within a regulated framework of continuous collaboration or by awarding research contracts to external researchers. The departmental research institutes maintain a wealth of scientific expertise that is available at short notice to support the Federal Government's actions and provide science-based advisory services to aid the political decision-making process. To this end, they address current, ongoing problems affecting society, science and industry, and develop various options for government measures with a sound scientific basis. They conduct research into relevant policy issues within their individual areas of responsibility and undertake initial research with a long-term perspective in preparation for future societal challenges.

The Federal Government aims to optimise the conditions for departmental research and to guarantee that it continues to produce high-quality results. It is important to ensure that departmental research institutes are perfectly capable of performing their tasks, firstly as intermediaries between policymakers and the expectations of an innovative society, and secondly, as scientific competence centres with the ability to adopt a continuous, research-based approach to studying short-term and long-term issues.

We are working to strengthen departmental research, while ensuring that the departmental research institutes continue to profit from the Freedom of Science Act.



5 Opening up greater prospects through education and integration

Excellent qualifications are a precondition for excellent opportunities, social participation and the innovative capacity of our country. They are the key to integration and advancement through education. The foundation of a competitive R&I system is an education system that teaches knowledge and skills as comprehensively as possible over the course of a lifetime – from early childhood education to school, vocational training and higher education, through to lifelong learning and upskilling. This calls for an education system that is permeable and compatible, that encourages individuals to develop their talents, regardless of their background or level of resources. We are committed to greater equity in education. This is the joint responsibility of the Federal Government, the *Länder*, local authorities and society.

Over the last few years, Germany has made good progress towards becoming the Republic of Education:

- The results of PISA 2015 (Programme for International Student Assessment) show that the performance of Germany's schoolchildren has improved since the first PISA surveys in 2000 and is significantly above the OECD average in the core subjects of mathematics, science and reading skills. However, the science results have remained static since PISA 2006, when this indicator was first tested. The onus is on the *Länder* to take countermeasures. Nonetheless, pupils from socially disadvantaged families were able to improve their academic performance. The percentage of resilient students achieving a solid level of competence, despite their low socio-economic status, has risen considerably since PISA 2000. Scarcely any other OECD country has outperformed Germany in increasing the share of resilient students.
- At the same time, there was a reduction in the number of early school leavers. Whereas, in 2006, 75,900 young people left school without a *Hauptschulabschluss* (certificate of secondary education), this figure fell to approximately 49,200 in 2016.
- Following a sharp drop in the number of young people entering the transition system designed to

foster the maturity required for successful vocational training between 2005 (417,649) and 2014 (252,670), the number of new admissions to the transition area rose in 2015 and 2016. In 2017 again, there were fewer young people in the transition system than in 2016, namely 291,924.

- At a mere 7.1% (2016), youth unemployment in Germany remains the lowest in the EU, where the average is 18.7%.

Overall, the planned spending on education by the Federal Government, *Länder* and local authorities for 2017 comes to approximately 134.8 billion euros, an increase of around 48 billion euros compared to 2005. Accordingly, if public sector education expenditure is viewed in relation to the total government budget, almost one in five euros was invested in education. The Federal Government has steadily increased its commitment to education: in each of the last two years alone, investments in education rose by 1 billion euros to 11.1 billion euros in 2017, an increase of almost 160%, compared to 2005.

Establishing the concept of lifelong learning

Numerous Federal Government initiatives are conducive to lifelong learning:

- The *Little Scientists' House* programme systematically introduces children between the ages of three and ten to science, mathematics, technology and education for sustainable development.
- While conducting independent experiments in the student labs set up in non-university research facilities, children find it easier to understand scientific theories and are encouraged to explore them. Student labs complement the formal education system and create an interface between school and vocational training. Educators and teachers can also take part in the wide range of training courses.
- In the *Culture Empowers You. Alliances for Education* programme, the Federal Government supports extra-curricular activities aimed at the cultural education of disenfranchised children and adolescents, while promoting active citizenship. *Culture Empowers You* is being continued in 2018 with extra budgetary resources.
- The ESF federal programme *Parent's Opportunity II* aims to enhance the competence of family education specialists and professionals from early childhood educational institutions and childcare facilities. They then work with parents regarding early childhood development and advise families on their children's education, day-to-day educational options and educational transitions. The experts are offered modular vocational training as parental advisors with recognised certification.
- In the *Leistung macht Schule (Performance sets a precedent)* programme, the Federal Government and the *Länder* together promote exceptionally talented students. Over a period of ten years, they are making equal contributions to the total of some 125 million euros in funding. The *Länder* are responsible for overseeing schools and offering further teacher training. The BMBF plans to provide practical guidance to the initiative in the form of research and evaluation.
- The *Educational Chains* initiative coordinates and systematises the measures of the Federal Government, the Federal Employment Agency and the *Länder* for the transition from school to employment. The initiative also includes the *Vocational Orientation Programme*, which helps make pupils at secondary schools aware of their vocational training options and assists them in choosing the right career. As required, these endeavours also mentor school leavers as they pursue their training goals.
- In the *Klischeefrei – Nationale Kooperationen zur Berufs- und Studienwahl (Cliché free)* initiative, the Federal Government supports career advisors in encouraging students to choose an occupation or study course without regard for gender-specific stereotypes, by focusing on their own interests and abilities, not on outdated role models and gender clichés.
- The Federal Government is supporting the initiative for the *Qualification-Related Validation of Skills*

Acquired Non-Formally and Informally (ValiKom) that seeks to integrate people without formal qualifications in the education system and the labour market. *ValiKom* aims to develop a standardised procedure for evaluating and documenting professional skills, thereby laying the foundation for a future validation policy in Germany.

- With a funding volume of over 3 billion euros for all jurisdictions in 2018, the higher education support programmes of employment agencies and job centres play a key part in meeting individual needs for adjustment in terms of qualifications. This applies particularly to the subsequent vocational qualification of young adults, to which the *Zukunftstarter* initiative is making a significant contribution.
- Sponsored jointly by the Federal Government and the *Länder*, the *Advancement through Education: Open Universities competition* aims to give professionals and people with vocational qualifications better access to higher education.
- Upgrading scholarships and training fellowships are available for talented, motivated professionals who wish to take advantage of specific training opportunities or enrol on a degree course.
- Under the *Decade for Literacy*, the project funding is promoting new learning options and access opportunities for functionally illiterate adults.
- The federal *Continuing Education Grant* programme encourages people on a low income to take part in continuing professional development. The 13 federal-funded organisations for the promotion of talent and the *Scholarship Germany* programme support gifted, committed undergraduates and doctoral students. *Scholarship Germany*, which is funded on a 50:50 basis by the Federal Government and private sponsors, is instrumental in establishing a new culture of donation, attracting highly qualified experts and linking the universities with local enterprises.
- Teacher training has a key function in the education system. Therefore, the Federal Government and the



Länder have launched a *Quality Pact for Teaching* to support the use of innovative concepts in teacher training programmes. We have resolved to continue the *Quality Pact for Teaching* and add the core areas of digitalisation and teacher training for vocational schools.

- In the funding priority on *Vocational education and training for sustainable development (Berufsbildung für nachhaltige Entwicklung (BBNE))*, the Federal Government promotes the development of sustainability-oriented skills for training practitioners and trainees in business, logistics, forwarding and the (craft-based) food industry; it supports the implementation thereof by means of appropriate organisational and personnel development concepts to establish sustainable training environments. In accordance with the holistic approach, the Federal Government has undertaken to develop further measures in the *BBNE*.
- We want to step up vocational education and training for sustainable development. Within the framework of the *European Social Fund (ESF)* projects are funded that seek to raise awareness for new production processes, workflows and skills on the way to achieving green core competencies and climate-friendly, resource-efficient business management.
- The *National Platform of Education for Sustainable Development* is committed to making key sustainable development issues an integral part of teaching and learning in general.

The Federal Government's second report on gender equality notes that a higher percentage of men take part in continuing vocational training than women and that women are less likely to have this participation financed by their employer. Therefore, on the one hand, suitable training and further training courses throughout their careers are one of the prerequisites for the equal opportunities of men and women; on the other hand, these measures must take the specific needs of men and women into account in order to open up individual opportunities more effectively, facilitate participation and integration in society and forestall the growing shortage of qualified specialists.

Enhancing digital literacy

Digital literacy is a crucial topic for the future. By virtue of their individualised solutions, digital media offer enormous opportunities for overcoming the major challenges facing the education system as they are able to accommodate the growing heterogeneity of training participants. Both higher and lower achievers can thus be supported in a more targeted way. Digital media make it possible to respond more promptly to complex and rapidly evolving qualification requirements.

In order to take full advantage of the opportunities presented by digital education and prevent a digital divide in society, the teaching staff and the participants must both be media literate and have a heightened awareness of the various circumstances and needs of different target groups, e.g. girls and young people with migrant backgrounds. Endorsing media literacy will thus be a top priority in the years ahead. In its latest report, the EFI emphasises that digital skills are prerequisites for innovation and productivity growth. The Commission therefore recommends that the Federal Government and *Länder* promote digital education. In its *Educational Campaign for the Digital Knowledge Society*, the Federal Government is driving the digital transformation in schools, institutions of vocational and advanced training, and the higher education sector.

The draft law amending the Basic Law (Articles 104c, 104d, 125c and 143e GG) lays the necessary constitutional foundations to implement the Federal Government's financial support measures for *Länder* tasks, as enshrined in the coalition agreement. The abolishment of the restrictions placed on the Federal Government's granting financial aid to municipalities with limited budgets only in co-funding investments, as defined in Art. 104c of the Basic Law (GG), extended the Federal Government's scope for sponsoring the investments of the *Länder* and municipalities in the local education infrastructure, particularly all-day schools, childcare services, digitalisation and vocational schools, as outlined in the coalition agreement. The *Länder* retain sole responsibility for initial and further teacher training and for operating digital infrastructures.

As part of the *Digital Pact for Schools*, the implementation of which is also recommended by the EFI, the



Federal Government intends to help schools expand their digital infrastructure. With the assistance of the BMBF, the Hasso Plattner Institute for Digital Engineering (HPI) is working with the MINT-EC association, a nationwide network of excellence comprising almost 300 schools, to develop a school cloud. This pilot project is designed to establish the technical basis that will enable teachers and pupils to use modern, digital teaching and learning content in every subject as easily and intuitively as apps on smartphones or tablets.

The Federal Government continues to advocate good digital work that has a positive impact on employability. Furthermore, it supports the development of qualification measures and further training for a digitalised workplace. To help channel the dynamic developments in digitalisation and automation, and control the impact thereof on advanced training, the Federal Government is consolidating ongoing and new measures under the umbrella of the *Vocational Education and Training 4.0* initiative. By studying selected job profiles from all sectors, the initiative

analyses the impact of digitalisation on qualification requirements and recommends certain courses of action. To ensure that training measures are high quality and up to date, a special digitalisation programme was launched in inter-company vocational training facilities and competence centres. Funding is available for purchasing digital equipment and to sponsor selected pilot projects, in which competence centres develop, test and support innovative training concepts.

Overall, the flexible and dynamic dual training system is well-positioned to cope with the changes associated with digitalisation. It offers a wealth of possibilities and plenty of scope for structuring vocational training and integrating new technologies, without training regulations having to be revised in every case. Nevertheless, the increasing relevance of digital literacy will affect the development of initial and continuing training regulations. This phenomenon will spawn new professions in some industry segments and for certain areas of work. Against this backdrop, the modernisation of the metal-working and elec-

trical industry sectors was recently concluded with regard to digital literacy requirements, for example in the areas of data protection and data security (the amending regulations entered into force on 1 August 2018), along with the first stage of modernising IT training occupations (which also entered into force on 1 August 2018). The second stage is to define all new requirements placed on IT professions, with the fully revised training regulations due to enter into force on 1 August 2020. The newly established apprenticeship as an 'e-commerce merchant', which focuses particularly on online trading and online shops, was introduced as of 1 August 2018.

The *Digital Media in Vocational Education and Training* programme promotes the use of digital media in vocational education and training, raising awareness thereof among multipliers; this includes the use of e-portfolios, open educational resources (OER) or augmented and virtual reality concepts. This reflects the changed requirements that the business sector is placing on vocational training due to *Industrie 4.0* and is instrumental in modernising and increasing the competitiveness of vocational education and training (VET). Moreover, to increase the widespread impact and raise awareness, the Federal Government has commissioned the Federal Institute for Vocational Education and Training (BIBB) to carry out the 'Digital media in everyday training' roadshow with user workshops for trainers in various German cities. Each workshop offers VET trainers from companies, inter-company vocational training centres, vocational schools, chambers and education institutions the opportunity to experience and try out new digital media in VET environments in three case studies. For example, the Skills Workshop is an online application that tests apprentices' personnel and specialist skills, while the Social Virtual Learning project enables participants to come together in a virtual space to learn and try out training contents by means of a VR3D headset.

The *Vocational Education and Training 4.0* initiative also includes strategies for guiding SMEs through the digitalisation transformation process to *Wirtschaft 4.0* (under the education and training structure programme *JOBSTARTER plus*) and for introducing technology-based assessment of skills and competencies in vocational training (*ASCOT+*).

Reinforcing vocational training

In recent years, the education system has become more efficient and more equitable. Nonetheless, social background still has a huge impact on academic success. Therefore, greater equity in education continues to be a primary objective for the Federal Government.

Germany's dual system of apprenticeships plays an important role in this context. The Alliance for Initial and Further Training has undertaken to reinforce the dual training system and motivate even more young people to sign up. The major advantage of the dual system is its close orientation to real-world employment. To ensure that as many young people as possible benefit from the system, the Federal Government has systematically expanded its promotion of individual counselling and orientation programmes and its support of lower achievers prior to and during training. In particular, assisted training is one tool that guides both young people and companies.

The measures of the *Educational Chains* initiative help young people cope with the transition from school to vocational training. The initiative is underpinned by Federal Government/*Länder* agreements to enshrine it in the regulatory systems over the long term. This paves the way for the partners' various measures and programmes to be dovetailed and extended. First and foremost, the initiative coordinates careers guidance and transition system measures, as well as consolidating measures that fall within the remit of the *Länder*. Job and study orientation programmes and coaching for pupils are being developed further in cooperation with the *Länder*. In the medium term, we plan to work with the *Länder* to extend careers guidance at *Gymnasien* (grammar schools) and to take a more concerted approach to dualising the measures of the transition system.

As part of the Federal Government's *ESF* programme on *Career entry support*, around 113,000 young people receive continuous, individual coaching from the penultimate year of school and for up to six months into the vocational training. Some 954 million euros have been earmarked for this purpose in the Federal Government's *ESF* programme. Moreover, the BMBF-funded *VerA* initiative, which aims to prevent young

people from dropping out of education and training, has been expanded. Over 10,000 apprentices have been mentored since the initiative was launched in 2008.

The education and training structure programme *JOBSTARTER plus* (2015–2020: 109 million euros) introduces initiatives to reinforce apprenticeships and on-the-job training, thereby combating the shortage of qualified personnel. The Coordinating Office for Vocational Training and Migration (KAUSA) promotes training in companies in the migrant economy and encourages young people with migrant backgrounds and refugees to participate in apprenticeships. The joint *Federal Government/Länder competition, Advancement through Education: Open Universities* offers attractive education prospects to those with vocational qualifications. The *JUGEND STÄRKEN* initiative focuses on disadvantaged young people who need special social and educational support to manage the transition from school into employment. Individual mentoring and targeted services facilitate their educational, vocational and social integration with the aim of helping them return to school, take up an apprenticeship or pursue some other form of education or training.

The Upgrading Training Assistance Act (AFBG, also known in Germany as the *Aufstiegs-BAföG*) provides financial support to participants who have enrolled in professional development training courses. They receive a non-means tested contribution towards the cost of their training; in addition, those attending full-time measures are eligible for a means-tested grant to help cover their living expenses. As a first step, the AFBG was successfully amended, modernised and improved in 2016. In so doing, the Federal Government upgraded its proven *Meister-BAföG* system of financial assistance to the modern *Aufstiegs-BAföG*, with higher allowances, subsidies and funding rates. At the same time, the funding was extended to include candidates who are accepted for further training examinations without an initial qualification and to graduates with Bachelor degrees who want to get ahead by means of further vocational training. Furthermore, since 1 August 2016, the AFBG application process has been simplified and requests may be submitted online within the deadline. With the planned fourth amendment of the AFBG, the Federal Government proposes to invest an additional

350 million euros during this legislative term to sponsor people seeking professional promotion to attract even more participants for vocational upgrading training measures. At the same time, the grants are to be raised significantly, thereby also increasing the family friendliness of the scheme. In addition, the expansion of the funding options of up to three stages of further training is designed to facilitate access to a career trajectory in vocational education.

Encouraging further training

The agreement on a *Nationale Weiterbildungsstrategie* reflects the increasing relevance of lifelong learning and continuing professional development as part of vocational education and training. The establishment of a new vocational training culture as a culture of lifelong learning will take centre stage in the strategy. Formal and non-formal continuing education and training, and informal learning all have a role to play here; furthermore, an institutional, organisational framework and funding mechanisms are prerequisites in achieving this objective. The best way of meeting the diverse and rapidly evolving requirements of vocational education and training is by establishing a structure that is characterised by plurality and competition among educational institutions and their programmes. The guiding principle for participation in further training must be that it is optional.

Jobs, business models and organisational structures are evolving in a working environment that increasingly revolves around digitalisation. Digital literacy is essential for a successful career. The focus of initial and continuing vocational education and training must be on systematically teaching these skills. Further scientific training will also be reinforced. It contributes substantially to ensuring the skills base for knowledge-intensive innovations and is thus the bedrock of Germany's innovative capacity and international competitiveness.

Both the German education system and the business sector set great store by recognised certificates. However, around two million people in Germany do not have a formal vocational qualification. Many of them have acquired skills over the course of their professional



lives, the potential and applicability of which should be established by a generally accepted validation system. The National Decade for Literacy and Basic Skills is being extended to improve basic education for adults.

Providing needs-based *BAföG* support

With the 25th *BAföG* amending law, the Federal Government assumed the full cost of financing benefits, thereby granting the *Länder* additional scope for investing in education in the long term, particularly in the higher education sector. The *Länder* are thus relieved of the burden of financing the *BAföG* alone to the tune of approximately 1.17 billion euros per year. Moreover, the Federal Training Assistance Act has been adjusted further in line with the actual training situation: with effect from the beginning of the 2016/2017 school year and the 2016/2017 winter semester, income deductions and entitlements have both been increased

by 7%, with supplementary housing costs for non-local students rising by over 10%. Raising the childcare allowance to a standard 130 euros for each child means extra support for young parents, while the flat-rate calculation of the health insurance premium greatly reduces bureaucracy. Furthermore, since 1 August 2016, *BAföG* applications can be submitted online quickly and conveniently from all over Germany. The Federal Government is determined to expand the German Federal Training Assistance Act, significantly increasing benefits yet again.

Integration through education

Germany has 18.6 million inhabitants with a migrant background, in other words, almost a quarter of the population. Consequently, this offers enormous potential for industry and society. Sound education and training is therefore crucial. On average, children, adolescents and young adults with a migrant

background still perform below their peers without a migrant background, in terms of participating in education, or achieve lower levels of academic success. Nevertheless, growing investments and the continued development of the education system's approach to heterogeneity are helping young people with a migrant background to catch up. The Federal Government's targeted funding measures support this trend and are instrumental in granting migrants access to education and apprenticeships. In particular, the over 450 youth migration service centres offer advice and guidance to young people with migrant backgrounds and refugees aged between 12 and 27 on their education, training and career choices.

It is imperative to pursue these successful approaches and exploit them to integrate refugees. With the assistance of the *ESF*, the Federal Government fosters the integration of persons seeking protection in Germany with extensive measures in education. Objectives include German language courses, recognising skills and potential, and integration in training and employment. Education remains key to successful integration.

The Alliance for Initial and Further Training agreed on specific measures to facilitate the integration of displaced persons in education and work (e.g. coaching refugees to cope with the daily routine of training and work, ensuring long-term residency for apprenticeships and initial employment).

The Recognition Act is proving to be an effective instrument in assuring the availability of skilled personnel by enabling foreign specialists to find employment suited to their qualifications, thereby easing their integration. From April 2012, when the law entered into force, to the end of 2016, over 86,000 applications for recognition in federal professions were submitted. Most foreign credentials were certified as fully equivalent to a German qualification; in 2016, this applied to 66% of all rulings, while a mere 3% of applications had to be rejected altogether. The other applications were granted partial equivalence; additional measures may be taken to compensate. Under the *Integration through Qualification (IQ)* support programme, if there are major differences between the foreign credentials and the German reference profession, the necessary knowledge and skills can be



acquired as a bridge qualification to compensate for these differences. This compensation is a precondition for full professional recognition. With the new recognition grant, the Federal Government has reduced the financing obstacles on the path to recognition. Together with partners in the business sector, entrepreneurial engagement in the field of recognition is being honoured, for example by the company prize 'Wir für Anerkennung' (We for Recognition), awarded in cooperation with the Association of German Chambers of Commerce and Industry (DIHK) and the German Confederation of Skilled Crafts (ZDH).

Internationalisation in education

Germany is a member of various multilateral institutions in the education sector. UNESCO, the United Nations Educational, Scientific and Cultural Organization, regards education as a key instrument for bringing about individual and societal development. UNESCO facilitates international cooperation in higher education, vocational education and training, education research and counselling. As a forum for the international exchange of strategic information and experience, the OECD develops universally recognised indicators and sets global standards.

Under Argentina's Presidency 2018, education is one of the priorities on the agenda for the Group of Twenty (G20) of the world's major economies, both developed and emerging: for the first time, this year's G20 Education Ministerial Meeting will focus on the skills needed for the future and the financing of education.

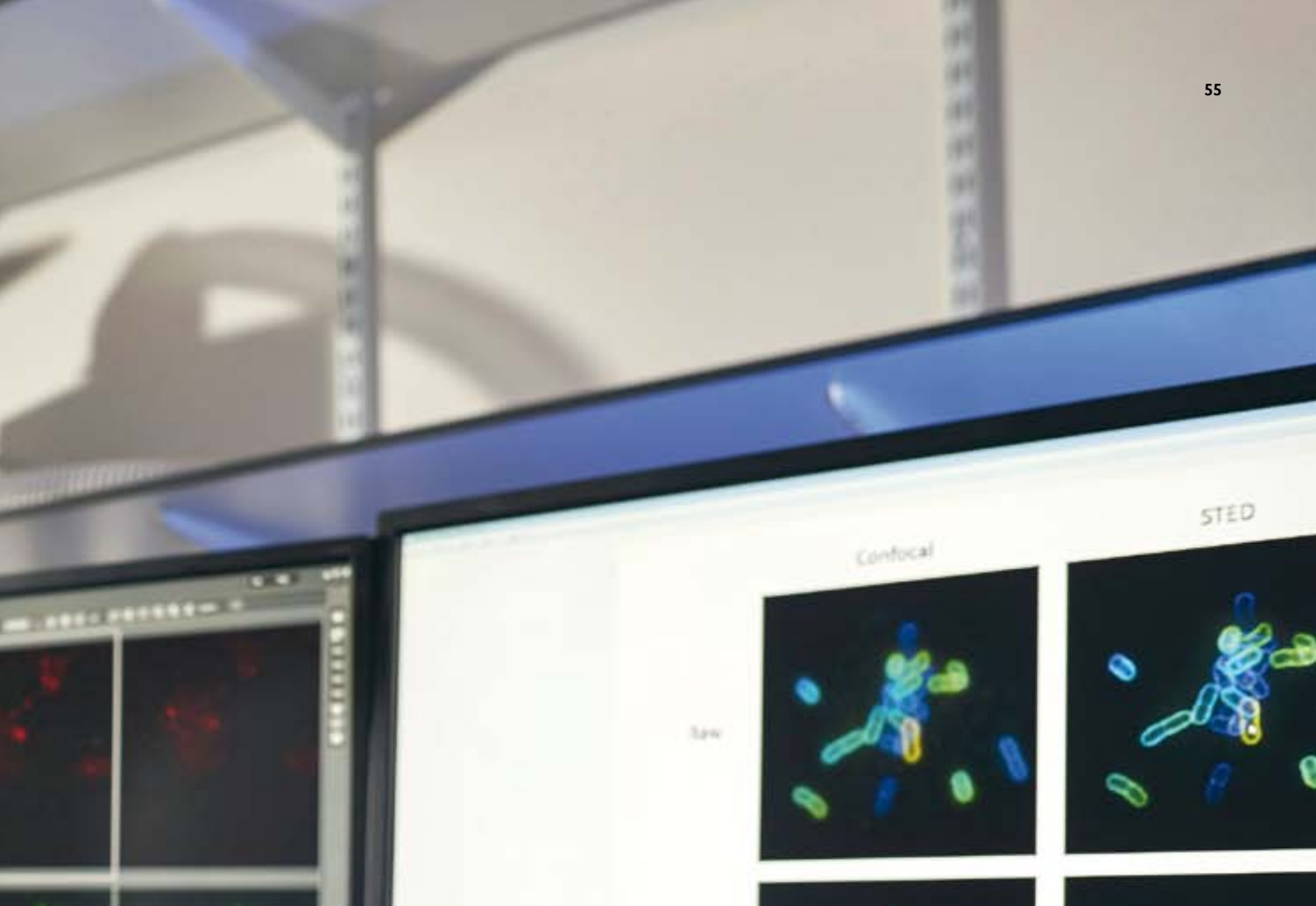
As regards vocational education and training, the Federal Government cooperates with many partner countries in the European Union, the OECD and a number of other industrialised, emerging and developing countries. In recent years, countless countries have shown an even keener interest in Germany's dual system of vocational training because it has proven to be highly effective in the needs-based qualification of skilled personnel and a key factor in assuring employability and social participation. In addition, by ensuring that German companies abroad have an adequate supply of suitably trained, skilled workers, the dual system of vocational training is of vital importance. Therefore,

the Federal Government has significantly increased the international exchange of information and stepped up the corresponding advisory services at the Federal Institute for Vocational Education and Training.

Thanks to its excellent transition into apprenticeships and employment – combined with the pledge made by the social partners in the Alliance for Initial and Further Training to improve the situation – the dual system of vocational training serves as a role model for European countries with high levels of youth unemployment. In 2013, the European Commission initiated the European Alliance for Apprenticeships (EAfA) with the goal of ensuring a greater degree of employability in young adults in the Member States by means of company-based training and work-based learning. The EAfA promotes youth employment and supports the aims of the Youth Guarantee, while reducing the disparity between the supply of skills and the demand on the labour market. Although managed by the Commission, the success of EAfA lies in the joint commitment of politics, industry and social partners to modernise the training systems. The self-imposed obligation of companies to provide apprenticeships plays a vital role in this respect.

The Federal Government is proactive in shaping the OECD's education programme to aid the evaluation and development of the vocational training systems, even at international level. Moreover, to foster international VET cooperation, the Federal Government promotes the UNESCO-UNEVOC International Centre for Technical and Vocational Education and Training in Bonn.





II The German research and innovation system

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AT A GLANCE

Germany is one of the world's most research-intensive and innovative economies. This presupposes a high-performing R&I system that combines basic research, applied research and experimental development, and entails the collaboration of a wide variety of disciplines.

By international standards, the German R&I system excels by virtue of its high degree of continuity and division of labour. By interacting on all levels, the various stakeholders create framework conditions that are conducive to translating high-grade innovations from R&D in enterprises into marketable products and services. The Federal Government regards research, innovation and education policies as primary fields of action. Over the long term, its targeted measures add to Germany's performance and competitiveness as a hotspot for R&I.

The first chapter of this Part II describes the structure of the German R&I system. It presents a summary of the public and private institutions that perform, fund or finance R&D in Germany and outlines the state R&I funding mechanisms. A more detailed account of the R&D performers and R&D funding bodies follows in Chapter 2. The report first considers the funding made available for science, research and development by the Federal Government and the *Länder*. It goes on to show how the business enterprise sector, higher education institutions, non-university and state research institutions operate in the German R&I system, along with other R&D funding organisations. Chapter 3 focuses on research, development and innovation results, and on ranking Germany's performance, compared to international benchmarks.



1 Overview of the German research and innovation system

The success of the German R&I system follows from the complex interaction of very different parameters and factors. The architecture of the German R&I system is determined by the country's federal structure, the size and focus of its economy, and by the diversity of its many players. Today's social and global challenges call for a multifaceted research and corporate landscape that is underpinned by a variety of institutions and stakeholders.

State R&I funding is based on a multi-pillar system. Germany's Basic Law (GG) constitutes the legal framework. The Federal Government, the *Länder* and the European Union work hand in hand. The *Pact for Research and Innovation* and the funding of research facilities and large-scale equipment at German universities exemplify the commitment of the Federal Government in this respect. Three types of instruments provide for targeted funding mechanisms: project funding, institutional funding and the financing of departmental research. R&D is carried out by a wide range of public and private institutions. For the statistics, R&D expenditure is either recorded in the financing institutions (survey of funding sectors) or the research institutions (survey of performing sectors) (see also II 2 Funding and performance of research and development).



Further information is available online:

Federal Report on Research and Innovation:
bundesbericht-forschung-und-innovation.de

BMBF's Data Portal:
datenportal.bmbf.de/portal/en/index.html

Federal Statistical Office:
destatis.de/EN/Homepage.html

Stifterverband für die Deutsche Wissenschaft:
stifterverband.org/english

1.1 Structure and stakeholders

Germany has a highly diverse R&I system, partly as a result of the country’s federal structure and long tradition of science. It has a rich variety of research fields and facilitates a high degree of specialisation in core areas. There is a fundamental distinction between R&D funding and performing sectors.

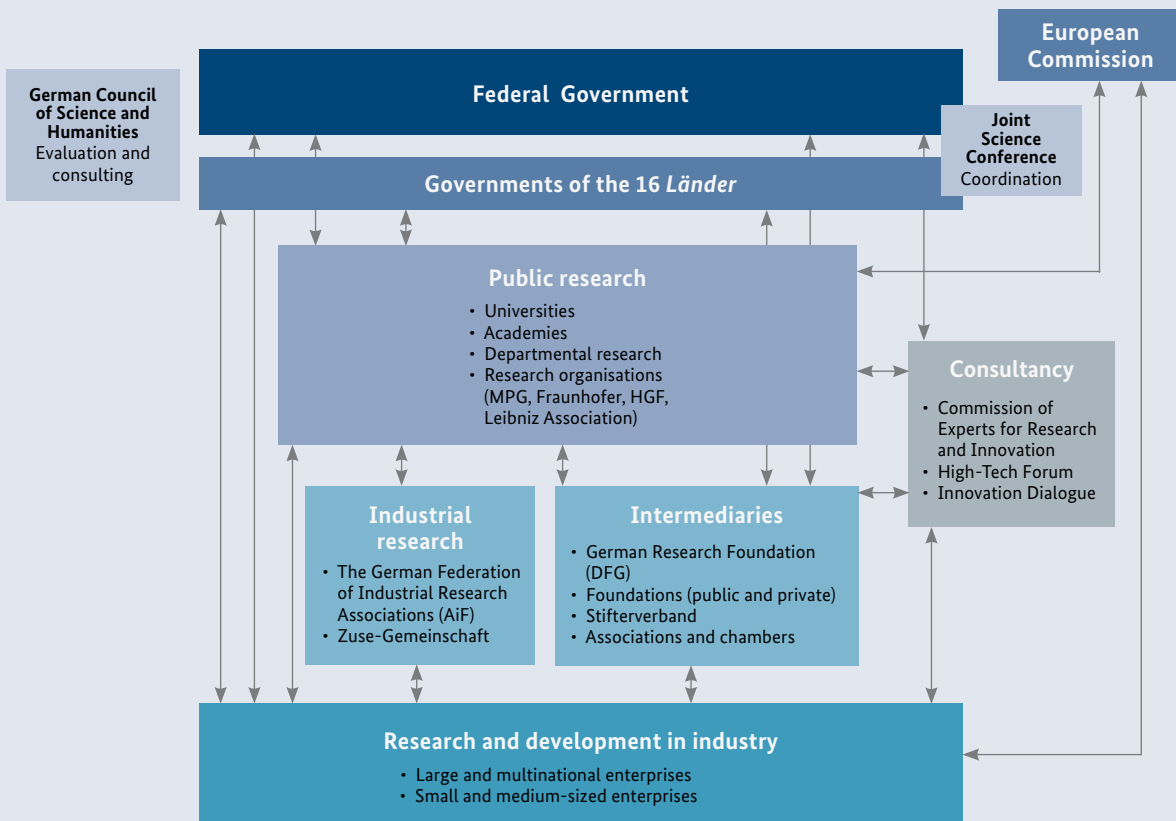
R&D is often carried out in public and private institutions. Figure II-1 shows the stakeholders in the R&I system and their interrelationships.

The Federal Government and Länder as funding stakeholders

The Federal Government and the Länder are major players in funding research and development. The Basic Law (GG) and the state constitutions of the

individual Länder together form the legal foundation for the government funding of science, research and teaching. Moreover, important framework conditions are set forth in the Federal Budget Code and the corresponding Länder provisions. A variety of funding instruments facilitate outcomes-based research funding: acting jointly, the Federal Government and the Länder provide institutional funding in a medium to long-term framework, the purpose of which is to safeguard the entire spectrum from basic research through to application-oriented research, the research infrastructure and the strategic orientation of the

Fig. II-1: Stakeholders of the German research and innovation system



Source: BMBF

German research landscape. The Federal Government/*Länder* project funding mechanisms provide resources for research, technology and innovation projects with a limited lifespan. Project funding is principally directed at application-oriented research. The Federal Government and the *Länder* ring-fence approximately one third of all gross domestic expenditure for R&D (see also II 1.2 State funding instruments).

A number of coordinating and advisory bodies are on hand, namely the German Council of Science and Humanities (*Wissenschaftsrat*, WR) and the Joint Science Conference (*Gemeinsame Wissenschaftskonferenz*, GWK). The Commission of Experts for Research and Innovation (EFI), the High-Tech Forum and the Innovation Dialogue between the Federal Government, industry and science also act in an advisory capacity.

Implementation of public sector research

A key player in the public research infrastructure is the higher education sector (universities and universities of applied science), which falls within the remit of the *Länder* (see also II 2.4 The higher education sector). Besides the research conducted at universities, a vast array of non-university research projects are carried out for the most part by institutions that are jointly supported by the Federal Government and the *Länder* (see also II 2.5 Non-university research institutions). These mainly include the research institutions of the four major research organisations: the Fraunhofer-Gesellschaft (Fraunhofer), the Helmholtz Association (HGF), the Leibniz Association and the Max Planck Society (MPG). In a broader sense, the non-university research organisations also comprise the eight Academies of Science of the *Länder*, the National Academy of Science and Engineering (acatech), and the Leopoldina – the German National Academy of Sciences.

Departmental research serves to prepare, support and implement political and administrative decision-making. To this end, the Federal Government maintains departmental research institutions that study current, application-oriented issues on a permanent basis, operate state-owned monitoring networks and

continually supply data, on which additional R&D facilities and other public-sector users depend. Departmental research is thus the backbone of the R&I system. It is linked to the fulfilment of the relevant department's legal assignments and special tasks. This spectrum of assignments is performed by federal institutions with R&D tasks, either independently, in cooperation with other research facilities or by awarding research contracts to external researchers (extramural research). Other *Länder* and municipal research facilities are financed by the *Länder* and, to some extent, by third-party funding (see also II 2.6 State research institutions).

The business enterprise sector

The private sector finances around two thirds of annual R&D expenditure in Germany. These funds include both expenditure for companies' own R&D activities and expenditure for joint R&D projects with partners from industry and science (see also II 2.3 Research and development in the business enterprise sector).

The R&D performed in the business enterprise sector is oriented strongly to applications: its overarching objective is to obtain results that can be directly commercialised. By contrast, basic research plays a subordinate role in the private sector. The huge variation in the regional distribution of R&D activities is determined for the most part by large companies. Nevertheless, despite their more modest share, SMEs and start-ups also contribute significantly to the innovation performance of Germany's business enterprise sector, with this dynamic group blazing a trail in groundbreaking innovations. Another structural feature of private industry is the high concentration of R&D capacities in high-level technology, compared to other countries.

Intermediaries

The intermediary organisations in the German R&I system are essentially those stakeholders who support R&D activities with their own funding programmes

and/or represent the interests of the R&I stakeholders (see also II 2.7 Other R&D funding organisations). They include the German Research Foundation (*Deutsche Forschungsgemeinschaft*, DFG) and the *Stifterverband für die Deutsche Wissenschaft* (Donors' Association for the Promotion of Sciences and Humanities in Germany).

Industrial research for companies

The research associations of the German Federation of Industrial Research Associations (*Arbeitsgemeinschaft industrieller Forschungsvereinigungen*, AiF) and the external research institutions that are organised via the *Deutsche Industrieforschungsgemeinschaft Konrad Zuse* (Zuse-Gemeinschaft) also act as an important interface in pre-competitive research between academia and an economy dominated by SMEs.

European Commission

Launched on 1 January 2014, *Horizon 2020* (2014–2020), the EU Framework Programme for Research and Innovation is instrumental in developing the ERA. At the same time, it places the European research landscape firmly on the global map. Adopted by the Council of the European Union and the European Parliament, and administered by the European Commission, the world's largest R&I programme has a funding volume of approximately 77 billion euros. It bundles the research funding programmes at European level and places an even greater emphasis on cooperation between science, research and industry, and on innovation, than previous programmes.

1.2 State funding instruments

Within the given statutory framework, the Federal Government and the *Länder* may join forces for the purpose of providing government science and research funding. They have several instruments at their disposal, which facilitate targeted financing: project funding, institutional funding and the financing of departmental research. A further mechanism is the funding of research facilities and large-scale equipment at German universities.

Funding R&D is the shared responsibility of the state and society. In order for research to be internationally competitive, and for the scientific and research communities to be able to operate freely as set forth in Art. 5(3) Basic Law (GG), an appropriate financial framework must be in place. For the most part, research funding is carried out jointly by the Federal Government and the *Länder* on the basis of Article 91b GG.

With regard to state research funding, the Federal Government and the *Länder* act in concert within the scope of their respective constitutional options. The GWK is the ministerial body that decides on shared funding mechanisms and serves as a platform for mutual exchange. The Federal Government and the *Länder* are represented with an equal share of the vote. The Conference deals with all questions relating to the promotion of science, research and teaching, science and research policy strategies and the science system that jointly affect the Federal Government and the *Länder*. In particular, the GWK rules on joint science funding according to Article 91b GG in cases of supra-regional importance (e.g. in connection with the *Excellence Strategy* and the *Higher Education Pact*).

The WR advises the Federal Government and the *Länder* governments regarding the development – in terms of both structure and focus – of the higher education, science and research sectors.

The Union's framework for state subsidies to support research, development and innovation, and Section 4 of the EU's General Block Exemption Regulation is also relevant in this regard. The national framework conditions are primarily set forth in the Federal Budget Code and the Federal Budget Act.

Institutional funding

Institutional funding refers to the operations and investments of research and science institutions that are chiefly funded by the Federal Government and the *Länder*, acting in concert, over an extended period of time. This safeguards the expertise and strategic orientation of the German research landscape in the long term. Important examples of institutional funding include the allocations that the Federal Government and the *Länder* provide in the context of joint research funding pursuant to Art. 91b Basic Law, for example, basic funding for the research organisations Fraunhofer, HGF, the Leibniz Association and the MPG (see also II 2.5 Non-university research institutions).

Institutional funding accounts for more than one third of all government subsidies. Apart from the four research organisations listed above, institutional funds are also allocated to the German Research Foundation, whose core task is to identify and finance the best research projects submitted by scientists. The institutional funding provided to the Max Weber Foundation – German Humanities Institutes Abroad is administered by the Federal Government alone (see also II 2.6 State research institutions and II 2.7 Other R&D funding organisations).

Project funding

Federal project funding is normally provided in the framework of general or specialised funding programmes, on the basis of applications for fixed-term projects. Both individual projects and collaborative research projects involving several partners are eligible for such funding. Federal Government project

funding is provided within the scope of the legal and political framework, which is set up at European and national levels. It is necessary to distinguish between direct and indirect project funding: direct project funding refers to a specific field of research in each case. One purpose of this funding is to help achieve and uphold high international standards of performance in selected areas of research and development. Indirect project support reduces general innovation risks and offers financial incentives to companies that are receptive to innovation, primarily SMEs. For example, it aims to support the development and enhancement of research infrastructure, research cooperation, technology and innovation projects, innovative networks and the exchange of personnel between research institutions and industry. As a key aspect of project funding, the utilisation of results has been given a greater innovation-focused and practice-oriented orientation since 2017. In so doing, the BMBF's eligibility regulations, which apply to R&D project funding across governmental departments, were duly revised.

The departments' project funding activities receive extensive support from project management agencies, who have qualified in the course of a competitive process. For the most part, project management agencies are organisational units at suitably qualified research institutions or private companies, who perform scientific, technical and administrative management tasks on behalf of Federal Ministries. These include, most

importantly, technical and administrative advisory services for applicants, preparation for funding decisions, project support and monitoring of project success. In addition, the project management agencies provide consultancy and support services. Collaboration may be on a contractual basis or be delegated by way of appointment (see also the info box [Information on the Federal Government's funding options](#)).

Contract research

In the framework of departmental research, federal institutions with R&D tasks conduct their own research and research contracts are awarded to third parties. In principle, R&D projects are assigned on the basis of a competition, either independently by the departments or by federal institutions with R&D tasks; contracts are awarded or grants authorised in accordance with the regulations for public procurement and the allocation of public funds.

Contractors and grantees may be any persons and institutions working in the knowledge-based sector, including non-profit and industrial research institutions. R&D projects are awarded on the basis of plans that have the flexibility to meet the current requirements for departmental research, while facilitating the lines of research over several years. R&D findings are generally published.



Information on the Federal Government's funding options

The Federal Government's Funding Advisory Service on Research and Innovation is instrumental in increasing the transparency of federal funding schemes. Thus, the Federal Government has subsumed its research and innovation funding advisory services to complement the specific consulting provided by the respective programme coordinators or project management agencies. The service is the central point of contact for information concerning research and innovation funding. Interested parties find fast-track, customised advice on details of federal funding schemes and helpful introductory information on *Länder* and EU funding. The Federal Government's Funding Advisory Service on Research and Innovation is aimed at universities, research institutions and companies, particularly SMEs, and those with little or no previous experience with public-sector R&D funding schemes. By providing a clear overview, it saves time, especially for innovative companies.

It also includes a Corporate Guidance Service that is specifically geared towards the needs of SMEs. The Federal Government's Funding Advisory Service

- Identifies suitable funding programmes and outlines the conditions
- Advises on the Federal, *Länder* and EU research and funding landscape
- Provides information on the procedures for obtaining funding
- Assists with the classification of project ideas
- Recommends specialist and regional partners.

The Advisory Service's electronic newsletter provides the latest announcements of Federal funding, special information for SMEs and information on EU calls for tender. Interested companies with project ideas can request an individual consultation. The advisory services are free of charge.

Free hotlines:

- 0800 262-3008 (For all aspects of research and innovation funding)
- 0800 262-3009 (Corporate Guidance Service)
- Email: beratung@foerderinfo.bund.de



Further information available online:

- Federal Funding Advisory Service on Research and Innovation: foerderinfo.bund.de/en/index.php
- Federal Funding Advisory Service on Research and Innovation – Guide to Research and Innovation Funding: bmbf.de/pub/Federal_Funding_Advisory_Service.pdf
- Funding catalogue of the Federal Government (only available in German): foerderportal.bund.de/foekat



2 Funding and performance of research and development

Both the business enterprise sector and the state support, finance and conduct R&D in Germany. R&D expenditure has risen steadily since the 1990s. In 2016, Germany invested over 92 billion euros in R&D, equivalent to 2.93% of its economic output. It is one of the ten most research-intensive OECD countries.

R&D is carried out in a wide range of public and private institutions. The diversity of the German R&I system is reflected in the different sources of funding: R&D projects at mainstream-funded public sector institutions also receive third-party funding, while some private research in companies is also publicly funded (see also II 2.1 Research and development expenditure and personnel).

Germany is making a significant contribution to achieving the 3% target outlined in the *Europe 2020* strategy. Germany's share of R&D expenditure exceeds the EU average and outperforms the United States. According to current estimates, the average R&D intensity of the EU-28 was 2.03% in 2016. Within the EU, only Sweden and Austria score a higher R&D intensity than Germany.

According to the latest figures published by the Federal Statistical Office, the state and industry together spent approximately 92.2 billion euros on R&D in 2016. Germany is one of the world's ten most research-intensive economies. The number of R&D personnel has risen sharply in recent years. In 2016, over 650,000 FTEs were employed in R&D in Germany. In 2015, more than 43,000 foreign scientists were working at German universities (see also Fig. II-2).

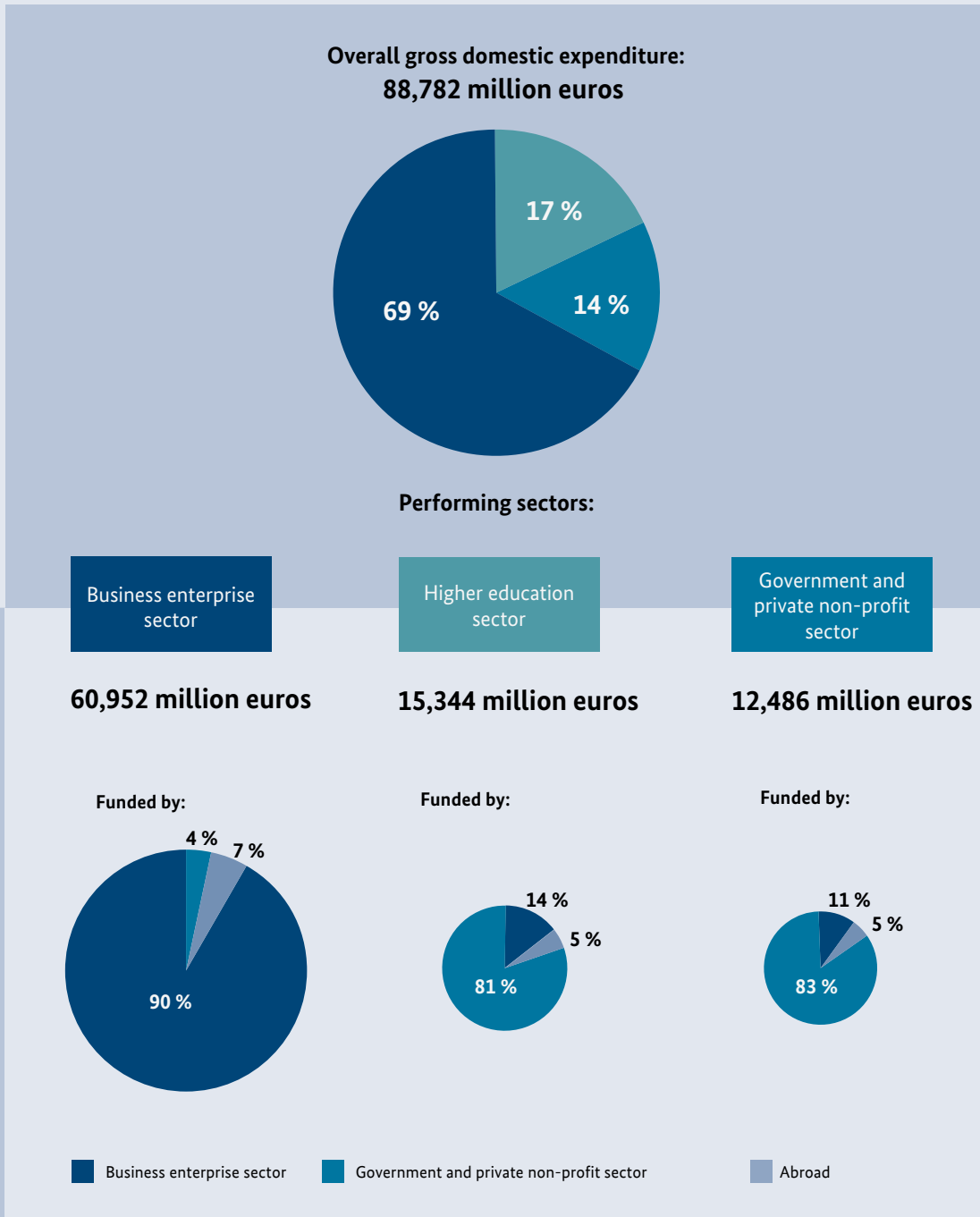
2.1 Research and development expenditure and personnel

The business enterprise sector and the state allocate substantial resources to R&D activities in higher education institutions, non-university research institutions and private R&D facilities. Alongside R&D expenditure, the number of people working in R&D in Germany has increased steadily in recent years.

Fig. II-2: Core indicators of the German R&I system

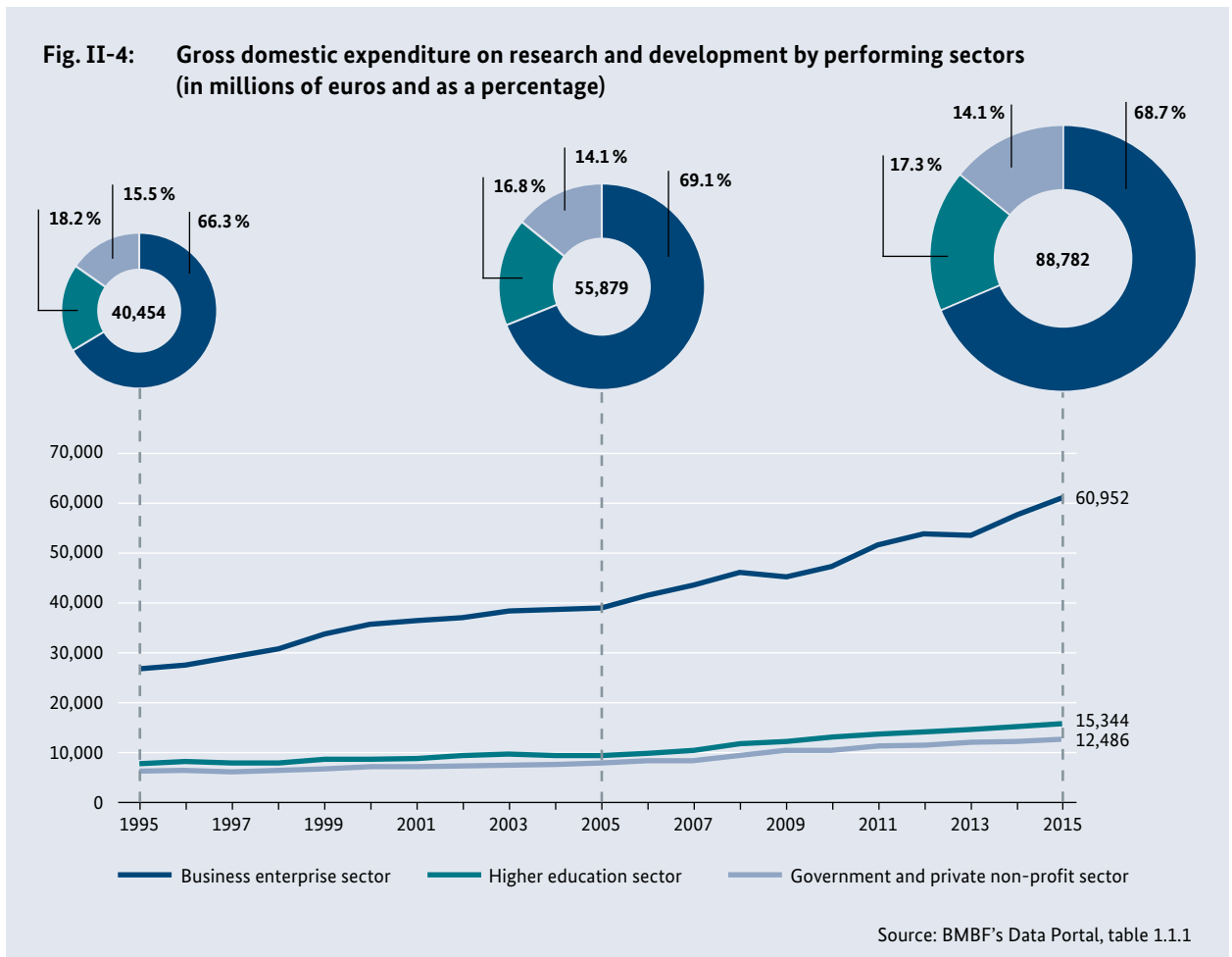


Fig. II-3: Gross domestic expenditure on research and development in Germany in 2015 (survey of performing sectors)



Rounding differences

Source: BMBF's Data Portal, table 1.1.1



Overall, R&D expenditure came to 88.8 billion euros in 2015¹. The expenditure of the R&D performers is financed by domestic industry, the government, private non-profit institutions and funding sources abroad. In 2015, the business enterprise sector financed approx. 58.2 billion euros or just on two thirds of all gross domestic expenditure on research and development (GERD). Compared to other countries, this figure is extremely high and is regarded as a characteristic feature of the German R&I system. Approximately 25.1 billion euros were earmarked by the Federal Government, the *Länder* and private non-profit institutions. The remaining 5.5 billion euros came from sources abroad.

At almost 61 billion euros in 2015, some two thirds of GERD are used in the private sector. By far the largest share is financed by the business enterprise sector itself (almost 90%). The higher education sector utilises approximately 15.3 billion euros. The federal, *Länder* and municipal research institutions and the private non-profit institutions show R&D expenditure in the amount of 12.5 billion euros. The majority of research activities at universities, non-university and government institutions receive state funding (see also Fig. II-3).

In recent years, gross domestic expenditure on R&D has continued to rise, culminating in some 88.8 billion euros in 2015. Therefore, gross domestic expenditure on R&D has increased by 59%, compared with 2005. However, its distribution across the business enterprise sector, the higher education sector, the govern-

¹ According to the latest figures published by the Federal Statistical Office, the state and industry together spent approximately 92.2 billion euros on R&D in 2016. As a rule, the Federal Report on Research and Innovation 2018 works with the final figures. With regard to R&D expenditure and R&D personnel, all data are available for the reference year 2015. Provisional estimates are indicated as such.

Fig. II-5: Development of R&D personnel in Germany (in full-time equivalents)



Source: BMBF's Data Portal, table 1.7.2

ment and private non-profit sector only fluctuates marginally (see also Fig. II-4).

In total, approximately 658,000 FTEs were employed in R&D in 2016. Thus, the total number of R&D personnel has increased by more than one third (38%), compared with 2005. Approximately 175,000 women were employed in R&D in 2015 (27%). In comparison with 2005, when 122,000 women were employed in R&D, this is a

rise of over 40%. Despite the appreciable improvement over the last decade, women are still underrepresented in R&D (see also Fig. II-5). There are striking differences between the sectors. In 2015, the proportion of women in the higher education sector was as much as 43%, with 40% in non-university research facilities and governmental research institutions. By contrast, just 19% of the total R&D personnel in the business enterprise sector were women.

2.2 Federal Government and *Länder* funding of research and development

When financing R&D activity in industry, universities and non-university research institutions, the Federal Government and the *Länder* liaise closely on projects of national importance. Furthermore, the German federal system offers both the Federal Government and the *Länder* scope for internal R&I funding within their respective spheres of responsibility.

Publicly funded research is a high priority in Germany. In 2015, the joint R&D expenditure of the Federal Government and the *Länder* came to around 26.4 billion euros. The bulk of Federal Government spending on R&D is allocated by the BMBF and the Federal Ministry for Economic Affairs and Energy (BMWi). Public research funding is directed at both basic and applied research.

The Federal Government's R&D expenditure

Federal Government expenditure totalled 17.1 billion euros in 2017 (target). In the last few years, the growth in Federal Government R&D spending has been considerably more dynamic than in the 1990s and the early 2000s. The BMBF accounts for approximately 60% of Federal Government R&D expenditure, the BMWi for about 20% and the Federal Ministry of Defence (BMVg) for about 7% (see also Fig. II-6). In February 2018, the Federal Government and the *Länder* confirmed the increase in R&D expenditure as a share of GDP as an intermediate objective of the *Europe 2020* strategy.²

Federal Government R&D expenditure is largely earmarked for project funding, departmental research and institutional funding. In total, spending on project funding and departmental research comes to some 8.3 billion euros (2017 target). The corresponding expenditure for institutional funding amounts to

approximately 7.7 billion euros (2017 target). Federal Government R&D expenditure as part of direct project funding and departmental research has continued to rise in recent years, totalling 7.4 billion euros in 2017 (target). Of which, the BMBF alone finances some 3.9 billion euros. The BMBF, the BMWi and the BMVg together account for more than 80% of direct project funding and departmental research (see also Fig. II-7).

Federal Government R&D spending in indirect research and innovation funding equalled approximately 944 million euros in 2017 (target).

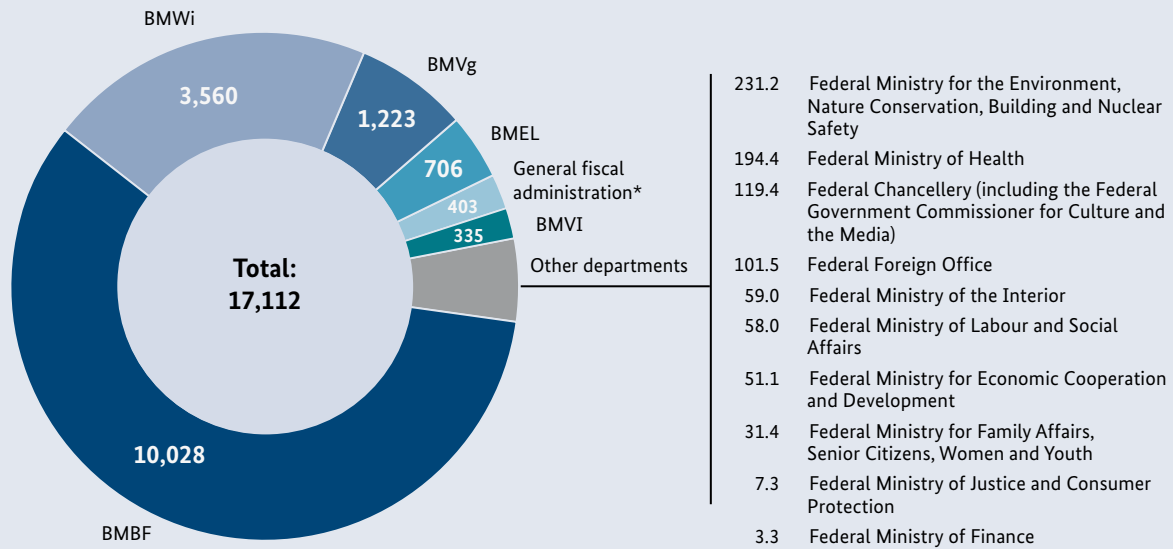
Joint funding of research and science by the Federal Government and the *Länder*

The Federal Government and the *Länder* join forces in supporting scientific research institutions and projects of national importance. The Federal Government/*Länder* agreements determine the specific configuration of this joint research funding.

The joint funding arrangement, which includes both research spending and science expenditure, has a total budget of around 15.3 billion euros (2017 target). Two thirds of these costs are assumed by the Federal Government and one third by the *Länder*. With roughly 4.9 billion euros, the *Higher Education Pact 2020* accounts for the largest portion of Federal Government/*Länder* funds in the breakdown of the planned total 2017 budget by funding areas. Approximately 4.5 billion euros are being ring-fenced for the first pillar of the *Higher Education Pact 2020*. The funding allocated to the research and science organisations involved in the *Pact*

² GWK (2018): Increase in R&D expenditure as a share of gross domestic product (GDP) as an intermediate objective of the *Europe 2020* strategy. Assessment report on the three-percent target for R&D. Report to the heads of the Federal and *Länder* governments.

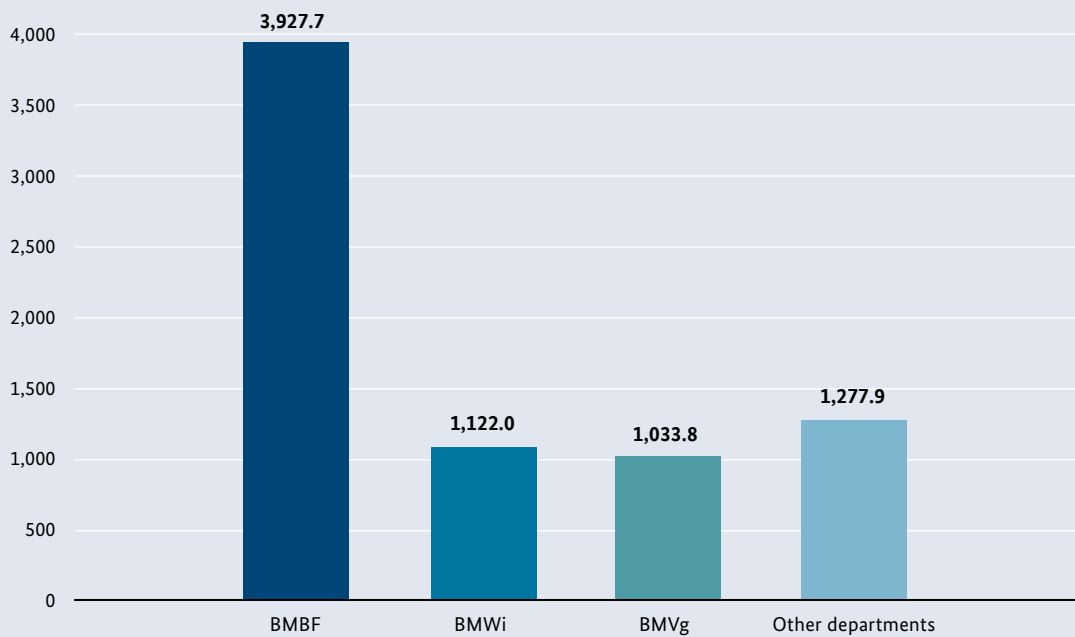
Fig. II-6: Federal Government expenditure on research and development in 2017 by department (target in millions of euros)



* Expenditure that cannot be attributed to an individual department or relates to the entire Federal Government.

Source: BMBF's Data Portal, table 1.1.4

Fig. II-7: Federal Government expenditure on research and development as part of direct project funding and departmental research in 2017, by department (target in millions of euros)



Source: BMBF's Data Portal, table 1.1.7

for Research and Innovation (DFG, Fraunhofer, HGF, Leibniz Association and MPG) was in the region of 8.9 billion euros (see also Fig. II-8).

The *Pact for Research and Innovation* is part of the institutional research funding of 9.9 billion euros made available by the Federal Government and the *Länder* (2017 target). Of which, some 7.1 billion euros were provided by the Federal Government and 2.7 billion by the *Länder*.

Major investments in research facilities and large-scale equipment aim to improve the national and international competitiveness of the higher education sector. In detail, the research facilities refer to properties and new buildings, conversions and extensions that are of significance in budgetary terms, along with basic equipment, including large-scale apparatus. Pursuant to Art. 91b (1) GG, the financing is carried out as a joint task by the Federal Government and the *Land* in which the subsidised institution is located. Large-scale investments at universities pave the way for scientific excellence and help elevate Germany’s international standing as a centre of research. Moreover, they are conducive to improving the competitive playing field in research.

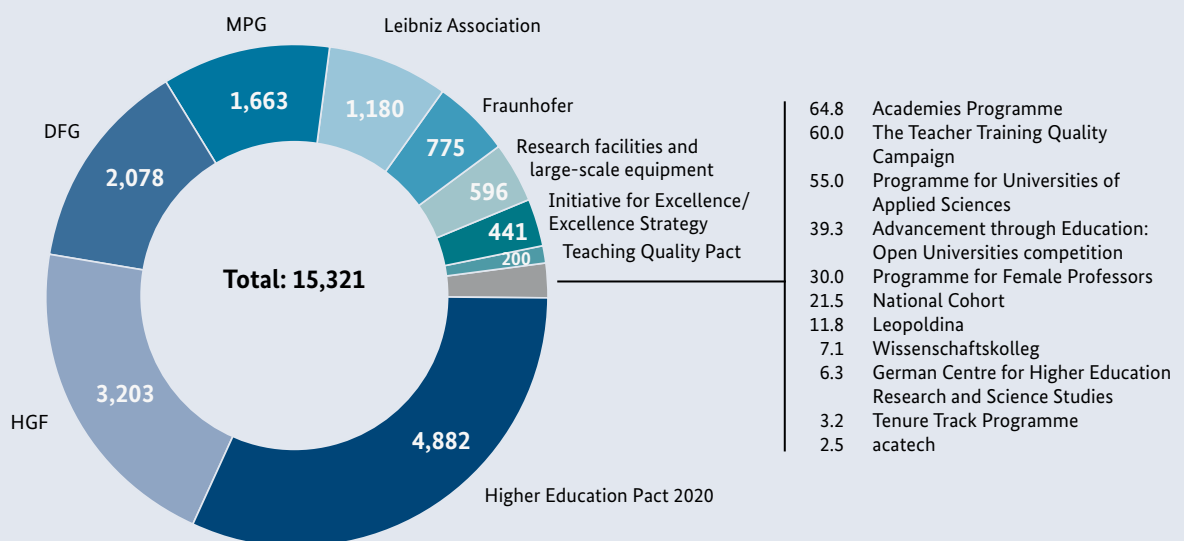
National roadmap for research infrastructures

An essential component of every science and research system, research infrastructures are supremely important in remaining a national hotspot for research. Research infrastructures consist of large-scale equipment, such as particle accelerators, satellites, telescope arrays and research vessels, along with data infrastructures or longitudinal studies and collections in social science and medicine. Research infrastructures may be stationary or virtual, centralised or dispersed, terrestrial or in orbit; their useful life must be at least ten years.

Given the multi-year construction period, their long service life, the structural effects and the exorbitant investment costs, the set-up and extension of new research infrastructures calls for strategic planning.

Based on the experience gained in a pilot project, the *National Roadmap Process for Research Infrastructures* was established in 2015 as a strategic instrument for prioritising future investments in Germany’s research policy. The primary objective is to follow a standardised, fair and transparent procedure when evaluat-

Fig. II-8: Joint research funding of the Federal Government and the *Länder* in 2017 (target in millions of euros)



Source: Joint Science Conference (GWK), BMBF’s Data Portal, table 1.2.6

ing new concepts. In early 2016, representatives of the German scientific community were given the opportunity to contribute their ideas to the process regarding new, complex research infrastructures, with Germany's share of the investment amounting to at least 50 million euros (the German contribution in the humanities and social sciences was 20 million euros). The concepts submitted undergo a rigorous review process. The benchmarks include a high degree of scientific quality, economically viable planning and major significance for society. With the prioritised concepts, the new *National Roadmap For Research Infrastructures* is scheduled for publication. It should lead to greater planning security and to an enhanced strategic focus of research and research funding. Moreover, this realignment is expected to prepare the way for other agreements and networks with national and international partners.



Further information is available online:

The National Roadmap Process for Research Infrastructures: bmbf.de/pub/The_National_Roadmap_Process_for_Research_Infrastructures.pdf

European Strategy Forum on Research Infrastructures (ESFRI): esfri.eu

R&D expenditure of the *Länder*

Besides the activities of the Federal Government and the joint Federal Government/*Länder* endeavours, the *Länder* carry out *Land*-specific research, technology and innovation policy funding measures, including basic funding for tertiary education institutions. The potential of the individual regions is taken into consideration, along with any existing spatial structures and special features. These regional differences are a vital asset in strengthening the German R&I system as a whole. In 2015, the R&D expenditure of the *Länder* (not including the municipalities) came to around 11.3 billion euros.

Public funding of R&D in the business enterprise sector

In Germany, the public funding of R&D in industry employs the instrument of project funding and primarily addresses projects in pre-competitive, application-oriented research. Specialised funding programmes have been set up for basic technologies that advance developments in key fields of application, thereby acting as growth drivers in many sectors. The *HTS* focuses on issues related to climate, energy, work, health, nutrition, mobility, security and communication. Not to forget the special technology-neutral funding programmes – chiefly directed at or benefitting SMEs – that encourage dialogue and accelerate the transfer between science, industry and society in the long term.

The latest surveys carried out by the *Stifterverband* found that approximately 45% of all government R&D funding in the business enterprise sector is allocated to SMEs with fewer than 250 employees. This category finances around 17% of its R&D expenditure from public funds. This shows that state R&D funding in Germany benefits SMEs at a disproportionate rate. In the case of companies with at least 500 employees, public funding accounts for a mere 1.9% of R&D expenditure.

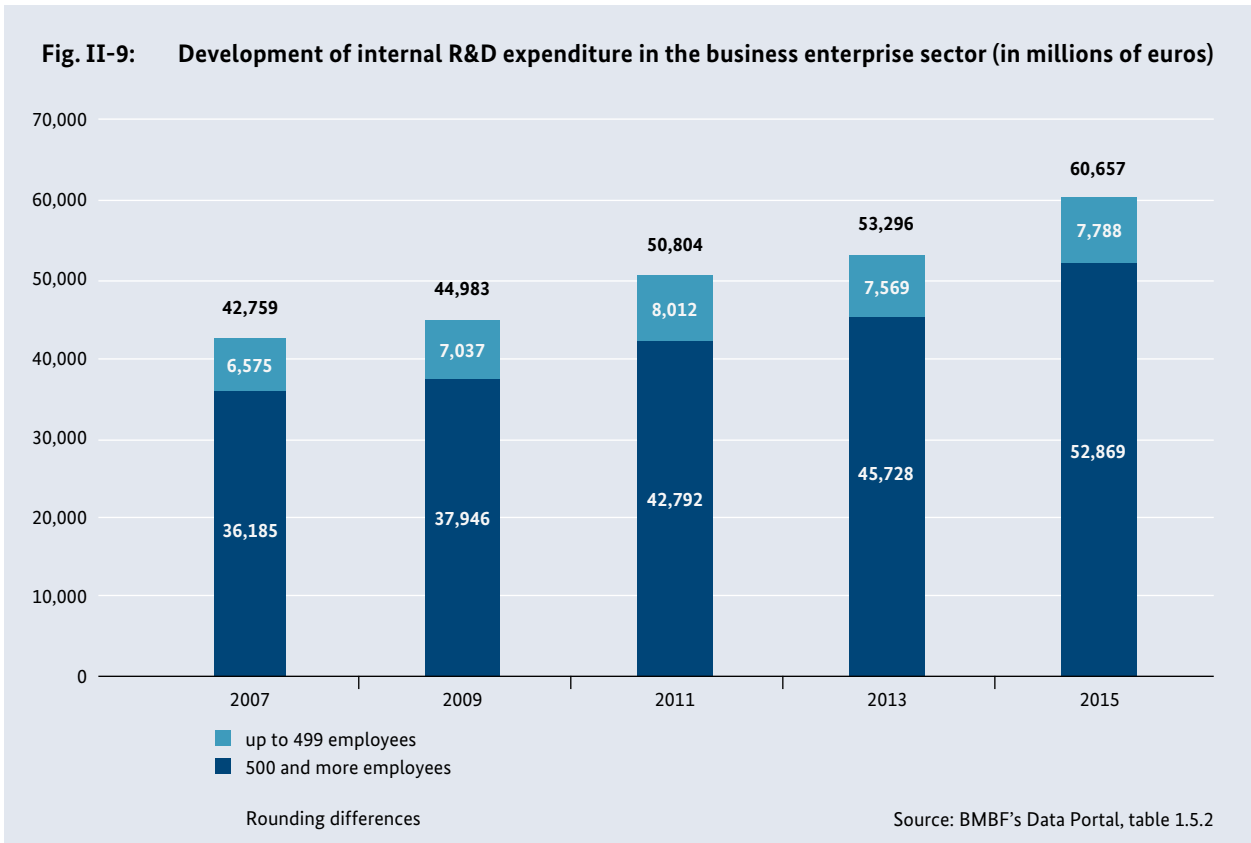
This is in line with the Federal Government's goal of promoting SMEs in particular. Accordingly, Federal Government R&D funding to and in support of SMEs has also been stepped up significantly in recent years. Funding has doubled from 783 million euros in 2007 to 1,550 million euros in 2017.

2.3 Research and development in the business enterprise sector

Corporate R&D activities are drivers of prosperity and employment. The R&D activities of the business enterprise sector give rise to new, improved products, processes and services. A good two-thirds of Germany’s R&D is carried out in companies and largely financed by industry itself. A significant portion is spent by large international companies with in-house research departments. Nonetheless, research-intensive SMEs are key initiators of regional innovation.

Industry-financed R&D activities totalled almost 61 billion euros in 2015. This represents approximately 2% of the GDP. By far the largest share of this expenditure (54.7 billion euros in 2015) is borne by the business enterprise sector itself, thereby achieving a high self-funding percentage of nigh on 90%. In addition, German industry co-finances the R&D activities of the public sector. In 2015, the private sector’s funding contribution to R&D activities at universities and non-university institutions was 14% and 11% respectively.

In addition to industry’s strong R&D commitment, intensive cooperation is a crucial factor in the innovative success of German enterprises. These alliances pave the way for the transfer of research findings into innovative products and services. One indicator that clearly shows this involvement in research consortia is the ratio of internal to external R&D. Internal R&D expenditure of the business enterprise sector refers to funding for R&D activities that are carried out by the companies’ own research personnel. Research contracts awarded to other companies, universities and



research institutions are subsumed under external R&D expenditure. Internal R&D expenditure added up to almost 61 billion euros in 2015, with around 17 billion euros being invested in external R&D. Approximately 12% of these resources were awarded to universities and research institutions by the private sector.

For the most part, R&D in Germany's business enterprise sector is financed and performed by large corporations. Companies with more than 500 employees account for roughly 87% of internal R&D expenditure in Germany (see also Fig. II-9). SMEs with fewer than 250 employees only make up about 9% of internal R&D expenditure. The internal R&D expenditure of SMEs (up to 250 employees) amounted to approximately 5.3 billion euros in 2015.

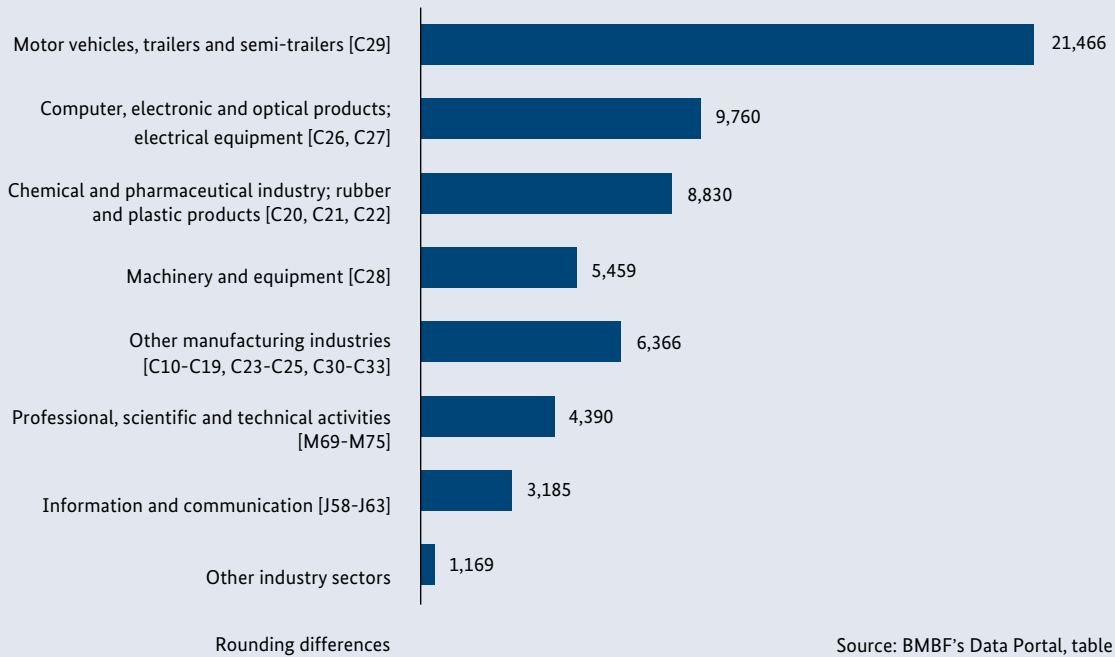
At the same time, SMEs spent some 827 million euros on external R&D contracts. The bulk of SMEs' external R&D expenditure remained in the business enterprise sector (around 45%). Compared to large companies, SMEs in Germany award more external R&D contracts

to universities and non-university research institutions (approximately 27%). The corresponding figure for large companies was around 7%.

A characteristic feature of the R&D structure of Germany's business enterprise sector is its high concentration on research-intensive industries, which were responsible for three quarters of corporate R&D expenditure in 2015. Research-intensive sectors include mechanical engineering and vehicle manufacturing, the chemical and pharmaceutical industries, and the electrical industry. Research-intensive industry sectors that are considered high-level technology play a particularly important role as they account for over half (about 53%) of internal R&D expenditure. The automotive industry enjoys an outstanding position in this respect. By international standards, with just under one quarter (around 22%) of internal R&D expenditure, leading-edge technology sectors play a subordinate role. The same applies to research-intensive services, which together account for approximately 12% of internal R&D expenditure in Germany.



Fig. II-10: Internal R&D expenditure in the business enterprise sector in 2015, by industry sector (in millions of euros)



Source: BMBF's Data Portal, table 1.5.2

A good third (more or less 35%) of all internal R&D expenditure benefits the automotive industry (see also Fig. II-10).

In 2015, the business enterprise sector employed roughly 405,000 FTEs, the majority of the R&D workforce (around 63%) in Germany. Women accounted for 19% (approximately 75,400 FTEs). As in university and non-university research, a significant increase in the number of R&D personnel has been apparent for some years now. A similar trend can be observed in the number of researchers compared to the total R&D workforce, which was 57% in 2015. Most researchers were employed in the automotive sector (roughly 68,500 FTEs), the electrical industry (roughly 53,000 FTEs) and mechanical engineering (roughly 22,000 FTEs).



Further information is available online:

Stifterverband für die Deutsche Wissenschaft:
stifterverband.org/english

2.4 Higher education

The universities play a major role in performing research and development; they combine general education with cutting-edge research and train the next generation of scientists. By collaborating closely with SMEs at the regional level, they do much to nurture the innovative capacity of German industry. The spectrum of research at institutions of higher education ranges from basic research to application-oriented R&D for the business enterprise sector.

Universities traditionally form one of the main pillars of the German R&I system. In 2015, they carried out R&D activities amounting to approximately 15.3 billion euros, or 17% of the overall R&D. Their prominence is based on their highly diversified research endeavours in terms of content, discipline and methodology, and the advancement of early career scientists, particularly at universities.

In Germany, the higher education sector comprises all state and state-accredited private and church-sponsored universities and universities of applied science. They act as the interface between research, the research-oriented qualification of students and the promotion of young scientists. As a result, they contribute substantially to the success of Germany's R&I system. Diverse forms of cooperation are found within the universities and universities of applied science, between them and with non-university research institutions. These include research consortia or collaborative research centres sponsored by the German Research Foundation. Some universities also house associated institutes (*An-Institute*). Although these exist as legally autonomous institutions with close organisational, staff and spatial links to the relevant universities, they are not an integral part. Their task is to research industry- and application-oriented fields in the dynamic space where applied research and market-relevant product development meet.

Universities of applied science play an ever more prominent role in application-based research and development. Owing to their practical orientation and regional embeddedness, they are important links between academia and industry; moreover, they are optimally positioned as partners, particularly for the SMEs in the region that do not have their own R&D departments.

According to the Federal Statistical Office, Germany currently has 428 institutions of higher education, including 106 universities, 6 teacher training colleges, 16 theological colleges, 53 academies of art, 217 universities of applied science and 30 colleges of public administration.

2.5 Non-university research institutions

Another cornerstone of public sector research in Germany are the non-university research facilities that receive joint funding from the Federal Government and the *Länder*. Their tasks cover the entire spectrum from basic research to infrastructures, some of which are unparalleled worldwide, through to industry-related, application-oriented research.

Non-university research facilities include the four research organisations of Fraunhofer, HGF, Leibniz Association and MPG (see also Fig. II-11). The research organisations also comprise the Academies of Science, which are organised in the Union of the German Academies of Sciences and Humanities. Other institutions are also financed by public funds, such as the Max Weber Foundation, the Wissenschaftskolleg zu Berlin, the German Centre for Higher Education Research and Science Studies, the caesar foundation, which is closely associated with the Max Planck Society, the Berlin Institute of Health

and the Futurium (see also II 2.6 State research institutions).

The R&D expenditure of the research institutions that are jointly funded by the Federal Government and the *Länder* rose from 5.1 billion to 9.9 billion euros between 2005 and 2017 (target). This may be attributed first and foremost to the *Pact for Research and Innovation* and the greater procurement of third-party funds, representing an increase of about 94%. Figure II-12 shows the geographical distribution of the institutions and academies belonging to the four research organisa-

Fig. II-11: Non-university research organisations in Germany

Fraunhofer-Gesellschaft

- Application-oriented research
- Health and Environment, Security and Protection, Mobility and Transport, Energy and Resources, Production and Supply of Services, and Communication and Knowledge
- Driver of innovation in Europe for society and the economy

Helmholtz Association

- Strategic, programmatically oriented, top-level research
- Energy; Earth and Environment; Aeronautics, Space and Transport; Matter; Health and Key Technologies
- Identifies and explores the major challenges facing society, science and the economy over the long term

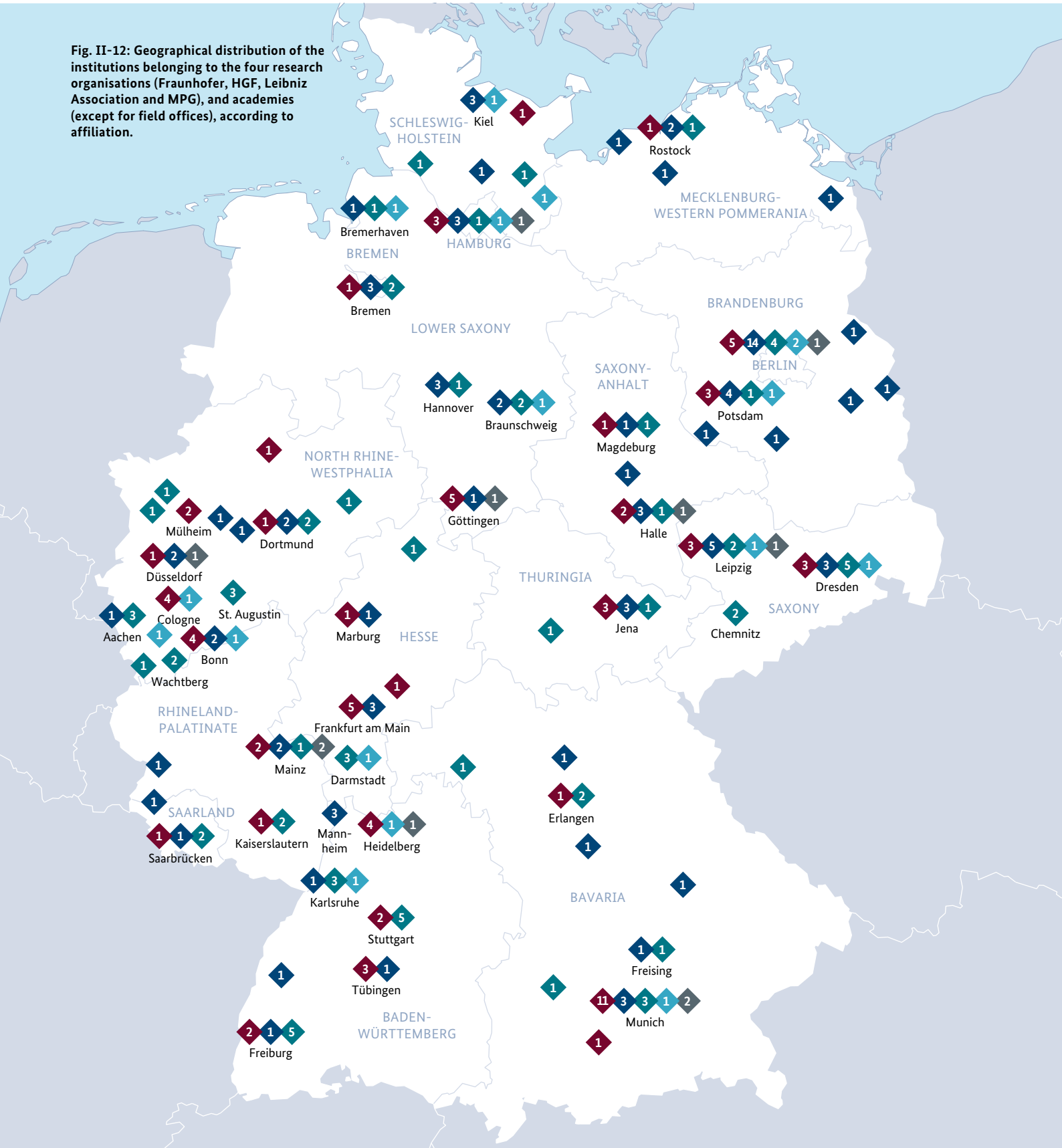
Leibniz Association

- Knowledge-driven and applied basic research
- Issues of social, economic and ecological relevance
- Maintains scientific infrastructures, provides research-based services and is dedicated to the transfer of knowledge to society

Max Planck Society

- Knowledge-oriented basic research
- Natural sciences, life sciences, the humanities and social sciences
- Outstanding scientists select their own research topics and recruit their staff autonomously

Fig. II-12: Geographical distribution of the institutions belonging to the four research organisations (Fraunhofer, HGF, Leibniz Association and MPG), and academies (except for field offices), according to affiliation.



Non-university research institutes

- ◆ Max Planck Society
- ◆ Leibniz Association
- ◆ Fraunhofer-Gesellschaft
- ◆ Helmholtz Association
- ◆ Scientific academies

The figure shows only the main sites of the organisations, locations with more than one institute are labelled.

Source: Federal Report on Research and Innovation 2018, Organisationenband, information provided by the organisations and the Länder. Geodata: © EuroGeographics for the administrative boundaries. Location coordinates: © GeoBasis-DE/Geobasis NRW (2016), Deutsche Post Direkt GmbH, Federal Statistical Office, Wiesbaden (2016). © BMBF, cartographic presentation: RISO, DLR Project Management Agency 2018.

tions (Fraunhofer, HGF, Leibniz Association and MPG), according to affiliation.

Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft (Fraunhofer) is the largest research organisation for applied research in Europe. The fields of research fall into the following categories: Health and Environment, Security and Protection, Mobility and Transport, Energy and Resources, Production and Supply of Services, and Communication and Knowledge.

Fraunhofer currently operates 72 institutes and research units located throughout Germany, as well as subsidiaries in Europe, North and South America, the Fraunhofer Representative Offices and Fraunhofer Senior Advisors. The network facilitates worldwide access to the regions of greatest importance to present and future scientific progress and economic development.

Fraunhofer employs in excess of 25,000 staff, who generated a research volume of approximately 2.3 billion euros in 2017. Roughly 2 billion euros may be attributed to contract research, around 70% of which consists of commissions from industrial clients and publicly financed research projects (as of January 2018). Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: the R&D activities of the Fraunhofer Institutes are crucial in reinforcing the competitive strength of the local region. They promote innovation, strengthen technological capabilities, improve the acceptance of modern technology and ensure the much needed practical training of the next generation of scientists and technicians.

Another important task for Fraunhofer is strategic research. The institutional funding provided by the Federal Government and the *Länder* enables research projects to be realised that help bring about innovations in both society and key technologies. These include research in fields like information and communications technology, life sciences, microelectronics, light & surfaces, production, materials and components, as well as defence and security research.

Fraunhofer maintains close ties with universities, thereby supplementing its own basic research resources and recruiting the young scientists it requires. By the same token, the universities benefit from their cooperation with Fraunhofer in the form of practical training and the joint approach to practice-oriented research topics. Common features of this collaboration are joint appointments to chairs and the management boards of Fraunhofer Institutes.



Further information is available online:

Fraunhofer-Gesellschaft: fraunhofer.de/en.html

Helmholtz Association

The Helmholtz Association (HGF) is dedicated to pursuing the long-term research goals of state and society, and to maintaining and improving the livelihoods of the population. Strategic, programmatically oriented cutting-edge research is conducted in the following six research fields: Energy; Earth and Environment; Aeronautics, Space and Transport; Matter; Health and Key Technologies. In cooperation with national and international partners, the HGF contributes to unravelling complex systems by means of large-scale facilities and infrastructures. It combines research and technology development with perspectives for innovative applications and provisions for tomorrow's world.

The HGF brings together 18 scientific-technical and medical-biological research centres. Its research centres have an annual budget of 4.5 billion euros (2017), making the HGF Germany's largest scientific organisation. A good two thirds of this funding comes from public sponsors. The Helmholtz Centres themselves attract around 30% on average in the form of third-party funding from public and private sector sponsors, with some raising considerably more. As of July 2017, the Association's research centres employed 38,733 staff, of which 14,452 were scientists, 8,054 supervised doctoral candidates and 1,561 were in vocational training. The HGF cooperates with diverse international partners

to conduct competitive, cutting-edge research that produces results of worldwide significance. To this end, the Association creates strategic international alliances and consortia, networking with national and international partners from science and research, especially from universities and industry. The HGF excels at promoting early career researchers, also at international level. Each year, several thousand visiting scientists and researchers come to the Helmholtz Centres, not least to work with their large-scale scientific facilities; in some cases, this equipment is the only one of its kind in the world. In 2016, some 10,176 foreign scientists made use of the infrastructures in the HGF centres. The HGF has international offices in Brussels, Peking and Moscow, along with Israel in future, in addition to the foreign representations of the research centres. For example, the German Aerospace Center (DLR) has its own offices in Brussels, Paris, Tokyo and Washington.



Further information is available online:

Helmholtz Association: helmholtz.de/en

Leibniz Association

The Leibniz Association addresses issues of social, economic and ecological relevance. It conducts knowledge-driven and applied basic research, maintains scientific infrastructures and research museums, and provides research-based services. Moreover, the Leibniz Association identifies focus areas for knowledge transfer to policy-makers, academia, business and the public.

Comprising 93 institutions, the Leibniz Association is funded jointly by the Federal Government and the *Länder*. The research spectrum of the institutions spans the natural sciences, engineering and environmental research to economics, spatial research and the social sciences, right through to the humanities. In 2016, the institutions of the Leibniz Association had a total budget of approximately 1.8 billion euros, almost 1.1 billion euros of which was provided by institutional funding.

Third-party funding from the public and private sectors represents a further substantial factor, with some 384 million euros being raised in 2016.

In 2016, the research infrastructures in the Leibniz Association employed a total staff of 18,668, including 9,485 scientists, 3,791 supervised doctoral candidates and 383 individuals in vocational training. Gender equality in science is one of the Leibniz Association's core objectives. Women made up a good 47% of doctoral students, at least 44% of academic staff and almost 35% of scientific leadership positions.

Alliances with higher education institutions are of considerable strategic importance for the Leibniz Association: in 2016, there were 348 joint professorial appointments of leading scientists from Leibniz institutes in conjunction with universities. The Leibniz ScienceCampi, of which 19 have been established as of 2018, is the Leibniz Association's effective model of cooperation between university and non-university research. A ScienceCampus promotes collaboration on an equal footing between universities and Leibniz institutions in the form of thematically focused, complementary regional partnerships. In 2018, a total of 12 Leibniz research alliances are exploring current issues of great scientific and societal relevance. Leibniz Institutes from all areas of expertise act in concert, bundling their complementary skills in inter- and transdisciplinary approaches.



Further information is available online:

Leibniz-Gemeinschaft: leibniz-gemeinschaft.de/en

Max Planck Society

The Max Planck Society (MPG) is the umbrella organisation of the 84 Max Planck Institutes (as of January 2017), which mainly conduct basic research in the natural sciences, life sciences, social sciences and the humanities. The Max Planck Society is essentially financed by public funds from the Federal Govern-

ment and the *Länder*, to the tune of approximately 1.8 billion euros in 2017. The research focuses on topics with a high degree of interdisciplinarity that are especially demanding in terms of funding or time requirements. Since MPG's inception in 1948, no fewer than 18 Nobel laureates have emerged from the ranks of its scientists. The MPG currently employs 22,995 staff, including 6,488 scientists, and supervises 2,355 doctoral candidates with a grant contract. Women account for roughly 44% of the total staff, around 39% of the doctoral students and about 31% of the scientific personnel (figures as of 31 December 2016).

The MPG Institutes offer outstanding research conditions and are thus one of Germany's greatest magnets for the world's scientific elite. Overall, a good third of the institute directors (35%), 47% of the researchers and more than half of the junior and visiting scientists (around 54%) do not hold a German passport. Among the academic fellows, the figure is even higher, at approximately 83%. Shining examples of the MPG's strong international focus include the intensive scientific exchange, the science-driven cooperation of its institutes and the International Max Planck Research Schools that foster the development of young scientists. Max Planck Institutes are involved in more than 4,500 cooperation projects with around 5,400 partners in 118 countries.

Special mention must be made of their particularly close ties with the German higher education sector. Over 300 of the MPG scientists are affiliated with German universities through honorary or extraordinary professorships. Moreover, a total of 43 professors working at Max Planck Institutes have been appointed in conjunction with a university. MPG Institutes are represented in almost one third of the Collaborative Research Centres run by the DFG.



Further information is available online:

Max Planck Society: mpg.de/en

German Academies of Sciences and Humanities

The Academies are mandated with coordinating long-term basic research projects and cultivating interdisciplinary dialogue. In addition, they contribute to the science-based consulting of the public and policymakers. The Academies carry out symposia and public events, thereby stimulating intensive dialogue between science, society and industry. The basic budget of the Academies of Sciences and Humanities is provided by the *Land* in which the respective academy is located. The Academies in Berlin, Düsseldorf, Göttingen, Hamburg, Heidelberg, Leipzig, Mainz and Munich have banded together in the Union of the German Academies of Sciences and Humanities, with the aim of coordinating their basic research and presenting themselves more effectively to other science organisations in Germany and abroad. In total, the member academies comprise over 1,900 scholars of diverse subjects, all of whom are outstanding in their research fields, both nationally and internationally. The Union coordinates the *Academies' Programme*, currently the most comprehensive humanities and cultural sciences research programme in Germany. Financed in equal parts by the Federal Government and the *Länder*, it has a total budget of approximately 65 million euros (2017 target).

Furthermore, the National Academy of Science and Engineering (acatech) in Munich and the German National Academy of Sciences Leopoldina in Halle (Saale) also operate under the umbrella of the Union of German Academies. A working academy, acatech currently numbers some 500 ad personam members from science and business (as of 2017). Firstly, experts from science, business, politics and society develop sound concepts as input for the public and political debate; secondly, the Academy consults autonomously and independently on technology-related issues that are relevant to Germany's future as a business and innovation location. acatech's funding comes from the Federal Government and the *Länder*. Additional funding is drawn from donations and project-specific third-party sources.

Also entrusted with this task as the German National Academy of Sciences, Leopoldina is financed by the

Federal Government (BMBF) and the *Land* Saxony-Anhalt at a ratio of 80:20. With some 1,500 members, the Leopoldina brings together outstanding scientists, mostly from Germany, but also from Austria, Switzerland and other countries. As the National Academy, representing the German scientific community on international academy committees also falls within its remit. In addition, it is tasked with providing science-based advice to society and policymakers in association with acatech and the Union of the German Academies of Sciences and Humanities.

The Leopoldina has adopted two junior academies under its auspices: founded in 2000 and permanently institutionalised in 2011, the *Junge Akademie* specifically helps young scientists make themselves heard in Germany, offering them the opportunity to develop freely. The Global Young Academy (GYA), which has been anchored at the Leopoldina in Halle since 2017, was established with substantial German support. The Federal Government underpins the GYA office. The

current 200 members and over 100 alumni come from around 70 countries. The Global Young Academy aims to become the voice of young scientists around the world. With the Leopoldina as host academy in Germany over the long term, this fosters the networking of young German scientists with their international peers.



Further information is available online:

Union of the German Academies of Sciences and Humanities: akademienunion.de/en

acatech: en.acatech.de

Leopoldina: leopoldina.org/en

Global Young Academy: globalyoungacademy.net

2.6 State research institutions

Apart from the universities and the institutions for science, research and development that are jointly funded by the Federal Government and the *Länder*, other public sector entities also carry out direct R&D assignments. They perform statutory tasks like authorisation, auditing and establishing regulations, as well as providing science-based advisory services for political decision-making processes. These include both Federal Government and *Länder* institutions with R&D tasks (departmental research institutions of the Federal Government and the *Länder*).

State research institutions are the backbone of the German R&I system; their function is to provide scientific advice to policymakers and take up research issues at short notice. To do so, they must be aware of the application and effect of modern technologies; they require knowledge about health and nutrition, mobility and urban development, the environment, energy and climate protection, about the changes in working and living conditions and the challenges of our globalised economy. Only then can the state take appropriate action and uphold security. The federal institutions perform their tasks under the remit of the responsible department. In addition, the federal institutions with R&D tasks nurture early career scientists.

It is becoming increasingly important for these organisations to take an active part in European and international committees governing standardisation and preparing legislative processes.

The funds earmarked by the Federal Government for R&D activities in federal institutions with R&D tasks have increased in recent years. For example, R&D expenditure rose from 960 million euros in 2013 to roughly 1.1 billion euros in 2016.

Each federal ministry is responsible for departmental research within its own portfolio (departmental principle). Departmental research is either conducted directly by the federal ministries or commissioned by

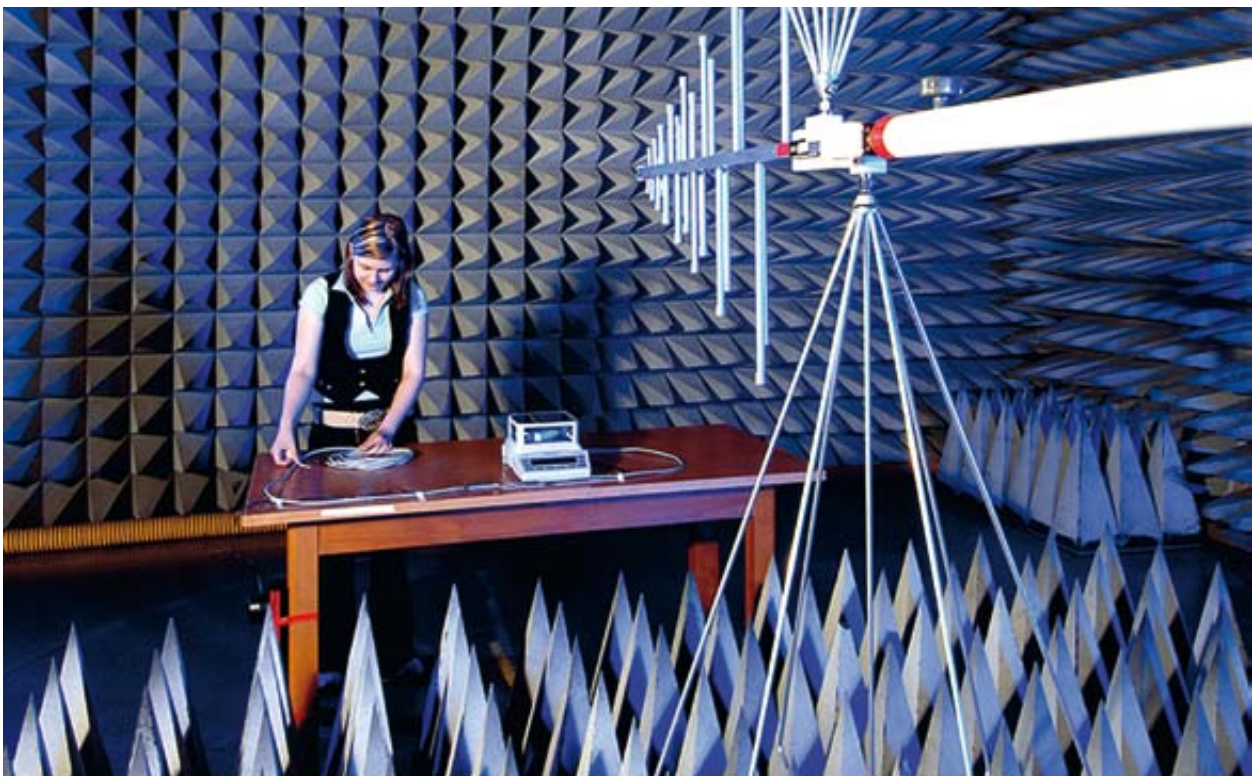
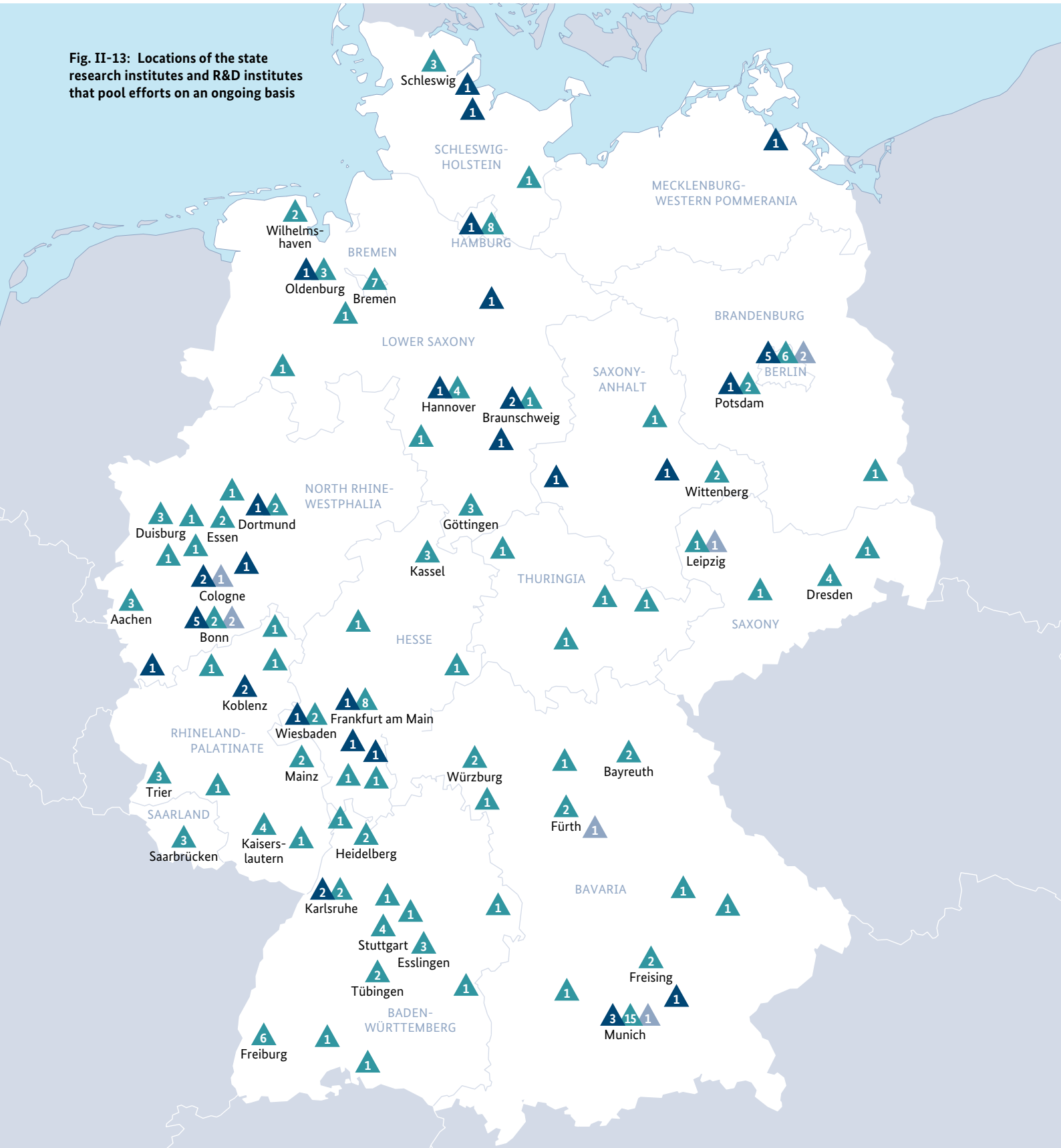


Fig. II-13: Locations of the state research institutes and R&D institutes that pool efforts on an ongoing basis



Federal Government and Länder institutes with R&D tasks

- ▲ Federal institutes
- ▲ Institutes that pool efforts on an ongoing basis
- ▲ Länder institutes

Only the main sites of the organisations are shown. Locations with more than one institute are labelled.

Source: Federal Report on Research and Innovation 2018, Organisationenband, information provided by the organisations and the Länder. Geodata: © EuroGeographics for the administrative boundaries. Location coordinates: © GeoBasis-DE/Geobasis NRW (2016), Deutsche Post Direkt GmbH, Federal Statistical Office, Wiesbaden (2016). © BMBF, cartographic presentation: RISO, DLR Project Management Agency 2018

the federal institutions with R&D tasks, of which there are currently 37. Moreover, with regard to departmental research, the departments liaise with other R&D institutions on an ongoing basis. The spectrum of this continuous collaboration ranges from regular exchanges of information through to cooperation and institutional funding according to the provisions of funding legislation.

The federal institutions with R&D tasks have outstanding research infrastructures, which are also made available to external research groups as a rule. Thus, they facilitate networking among the stakeholders of the German R&I system. A number of federal institutions with R&D tasks maintain internal scientific information facilities and central specialised libraries, whose services are required to perform departmental tasks or are placed at the disposal of interested experts.

The *Länder* and municipal institutions with R&D tasks are financed institutionally with funds provided by the *Länder* and, in some cases, by third parties. Internal R&D expenditure of the municipal and *Länder* institutions with R&D tasks (except for Leibniz Association) increased from approximately 201 million euros in 2014 to around 209 million euros in 2016. The previous figure shows the locations of the state research institutions and R&D facilities that pool efforts on an ongoing basis. It also includes the *Länder* research institutions that receive at least 50% of their basic funding from the respective *Land* (see also Fig. II-13).³



Further information is available online:

Federal governmental research institutes (only available in German): [bundesregierung.de/Webs/Breg/DE/Themen/Forschung/ressort/_node.html](https://www.bundesregierung.de/Webs/Breg/DE/Themen/Forschung/ressort/_node.html)

Departmental research (only available in German): [bmbf.de/de/ressortforschung-540.html](https://www.bmbf.de/de/ressortforschung-540.html)

³ As a rule, the Academies of Sciences and Humanities also form part of these institutions. On account of their special orientation and partial financing from the Academies' Programme, they are listed separately in the report under non-university research institutions. The report disregards archives, libraries, museums and similar facilities that are not included in the Leibniz Association.

2.7 Other R&D funding organisations

The DFG is the largest self-governing organisation of science and research in Germany. It is tasked with providing financial support to science-based research endeavours that are largely concentrated on higher education institutions. In addition, various foundations and funding bodies that are organised as associations are instrumental in financing science and research. The European Commission's framework for state aid measures to support research, development and innovation is also crucial for Germany's R&I system.

German Research Foundation

The DFG is the self-governing organisation of science and research in Germany. The main task of the DFG is to select and sponsor the best projects by researchers at universities and research institutions on a competitive basis; for the most part, funding is awarded to scientists at institutions of higher education. The statutory tasks of the DFG include facilitating national and international collaboration among researchers, fostering the advancement and training of early career researchers and advising parliaments and public interest institutions on scientific matters.

The DFG is a registered association under civil law. The 96 member organisations are made up of higher education institutions, non-university research institutions, academies and scientific associations. The Federal Government and the *Länder* have been funding the DFG institutionally since 2002 according to a standardised funding formula under which the Federal Government provides 58% of funding and the *Länder* 42% (Skeleton Agreement on Research Promotion in the version of 11 April 2001 and Agreement on the execution of joint funding of the DFG). A total of approximately

3.1 billion euros were allocated to the DFG (including the DFG's programme-overhead financing for indirect project costs) in both 2016 and 2017.

Foundations and funding bodies

Scores of non-profit foundations and other funding bodies that are organised as associations make a valuable contribution to financing science and research in Germany.

The foundations complement public research funding. Moreover, they are outlets for private financial commitment. The benefactors thereby set an example of responsible action in a democratic state. Examples of important foundations that fund research in Germany include the Volkswagen Foundation, the Robert Bosch Stiftung, the Klaus Tschira Stiftung and the Stiftung Mercator, which fund projects and institutions in a variety of scientific fields. One joint initiative started by companies to promote science and research in Germany is the *Stifterverband für die deutsche Wissenschaft e. V.* (Donors' Association for the Promotion of Sciences and Humanities in Germany), under whose umbrella over 650 foundations were managed in 2017, with total assets in excess of 2.9 billion euros.

These should be differentiated from the foundations and associations, whose annual funding budget is provided mainly or exclusively by public sources or where the Federal Government subsidised their start-up financing. Apart from the DFG, these include the Alexander von Humboldt Foundation, the German Federal Environmental Foundation, the German Foundation for Peace Research, the organisations for



Further information is available online:

DFG – Research funding: [dfg.de/en/research_funding/index.html](https://www.dfg.de/en/research_funding/index.html)

DFG – Annual report: [dfg.de/en/dfg_profile/annual_report/index.html](https://www.dfg.de/en/dfg_profile/annual_report/index.html)

the promotion of young talent in the higher education sector – most of which are associations – and the German Academic Exchange Service.



Further information is available online:

Stifterverband für die deutsche Wissenschaft:
stifterverband.org/english

Alexander von Humboldt Foundation:
humboldt-foundation.de/web/home.html

German Federal Environmental Foundation:
dbu.de/2535.html

German Foundation for Peace Research:
bundesstiftung-friedensforschung.de

Scholarships for outstanding students:
stipendiumplus.de/en/dein-plus/stipendiumplus-who-we-are.html

German Academic Exchange Service: daad.de/en

The programme is flanked by two intergovernmental initiatives or networks, with which European countries and/or the European Union endorse cooperation between research institutions and companies in Europe: *COST* (European Cooperation in Science and Technology) and *EUREKA* (Initiative for intensified technological cooperation in Europe). Driven largely by the interests of science and industry, these cooperation systems serve as an excellent complement to the European framework programmes.

European Union

The European Union is also an important financing and supporting agency in the German R&I system, with *Horizon 2020* (2014–2020), the EU Framework Programme for Research and Innovation, as its central instrument. The total approved funding amounts to approximately 77 billion euros, making *Horizon 2020* the world's largest self-contained R&I funding programme. The European Union is thus pursuing its goal of creating sustainable growth and future-proof jobs in Europe, thereby increasing Europe's competitive edge. *Horizon 2020* is aimed at higher education institutions, research institutions, companies (particularly SMEs) and other stakeholders involved in the development of innovations. All phases of the R&I process receive funding, from basic research projects right through to preparing marketable products and services.



3 Results of research, development and innovation

The role played by research and innovation in the development of knowledge-based economies can scarcely be overestimated. R&D output and the innovative performance of national R&I systems help secure entrepreneurial competitiveness and employment in the long term. Compared to other industrialised countries and emerging economies, Germany succeeded in maintaining and improving its position in the key parameters for R&I activities. This positive development is also corroborated by the relevant innovation indices.

By both European and international standards, the performance of the German R&I system is considered extremely high. Indicators that quantify the individual dimensions of R&D output and innovative success include scientific publications, patents relevant to the world market, cooperation with the business enterprise sector, spin-offs, product and process innovations or the share of world trade in research-intensive goods.

In recent years, the number of scientific publications originating in Germany has grown steadily. Germany's excellence rate, the percentage of publications from Germany that feature in the most cited papers worldwide, also went up. In 2016, German industry posted turnover of approximately 719 billion euros with product innovations. With regard to its share of world trade in research-intensive goods, Germany is a European leader (see also Fig. II-14).

The advantage of juxtaposing individual output indicators is that it enables straightforward, transparent comparison. Selective analysis of these indicators fails to do justice to the complex nature of the R&I system as they only reflect certain aspects. In order to show the complete picture, the following part also includes indicator systems that summarise selected individual indicators as an overall index.

R&D output

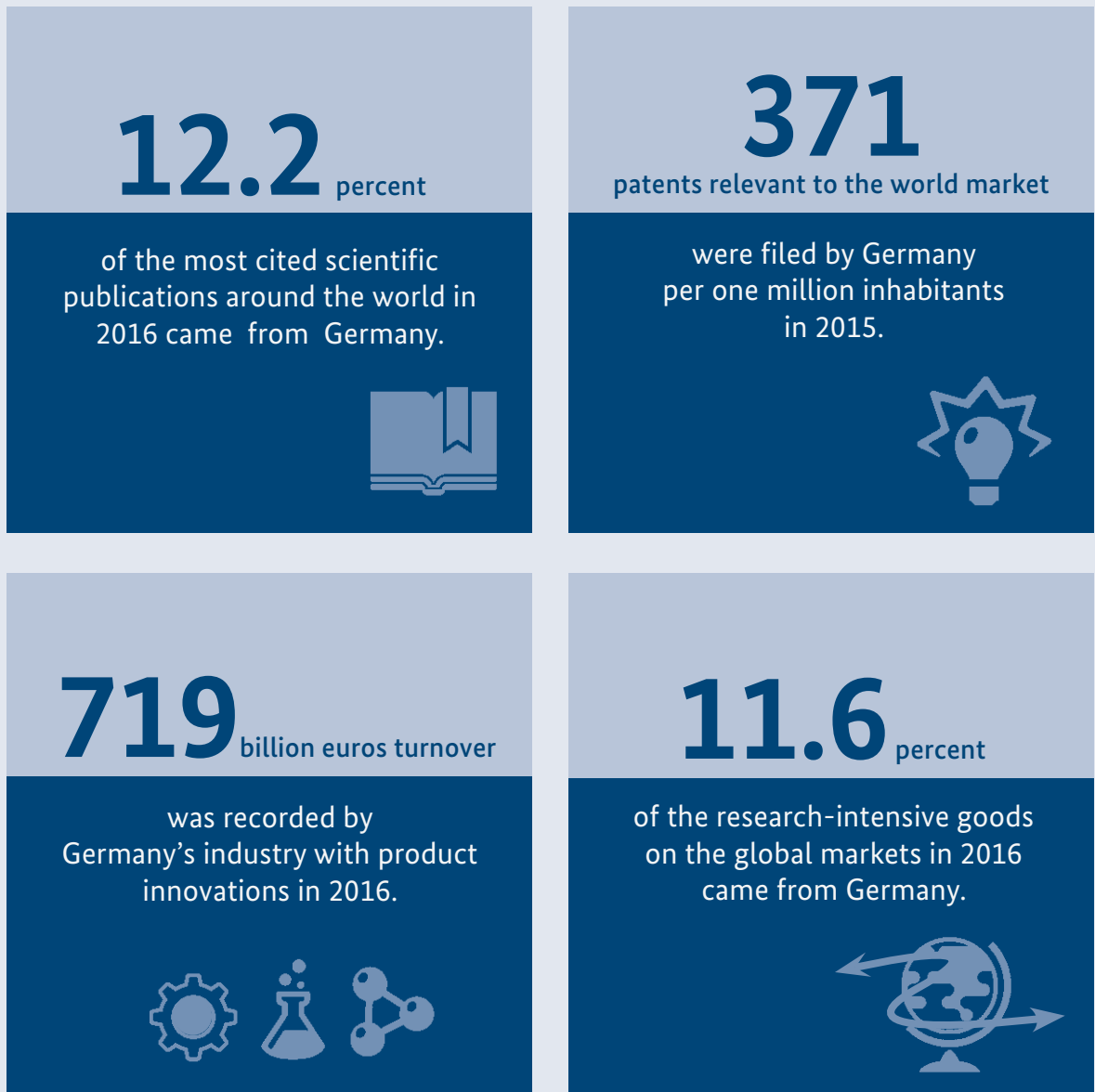
Successful R&D activities lead to new findings, which find expression in scientific publications, for example. Publications are an essential scientific output. Bibliometric methods can be used to analyse the scientific

performance of entire economies and individual disciplines. Nonetheless, it must be remembered that quantitative comparisons of publication indicators presuppose the prudent collection and interpretation of the data. Scientific disciplines may differ considerably in terms of their typical publication patterns. Over the last twenty years, the number of scientific publications originating in Germany has grown steadily, peaking at 1,367 publications per million inhabitants in 2016.

Thus, Germany boasts a higher publication intensity than either the United States or Japan.

One method of evaluating the significance of a publication is how often the results are cited by other scientists, measured by a country's excellence rate. It shows what proportion of its published research results are among the 10% most cited in all scientific publications around the world in the respective disciplines. Germany has

Fig. II-14: Core indicators of R&D output and innovation performance



improved its excellence rate in recent years. In 2016, the excellence rate of Germany’s total scientific publications was 12.2%. Overall, the German science system is increasingly publishing results at the forefront of the various disciplines (see also Fig. II-15).

Patents are an important basis for the commercialisation of research results. They are a key indicator for the technological performance of a national economy. The patent intensity reflects the number of patents with world market potential per million inhabitants. Patents relevant to the world market are inventions that were filed with the European Patent Office (EPO) or the World Intellectual Property Organization (WIPO). In 2015, Germany filed 371 patents relevant to the world market per million citizens. Consequently, Germany accounts for nearly twice as many patents relevant to the world market per million citizens as the United States (see also Fig. II-16).

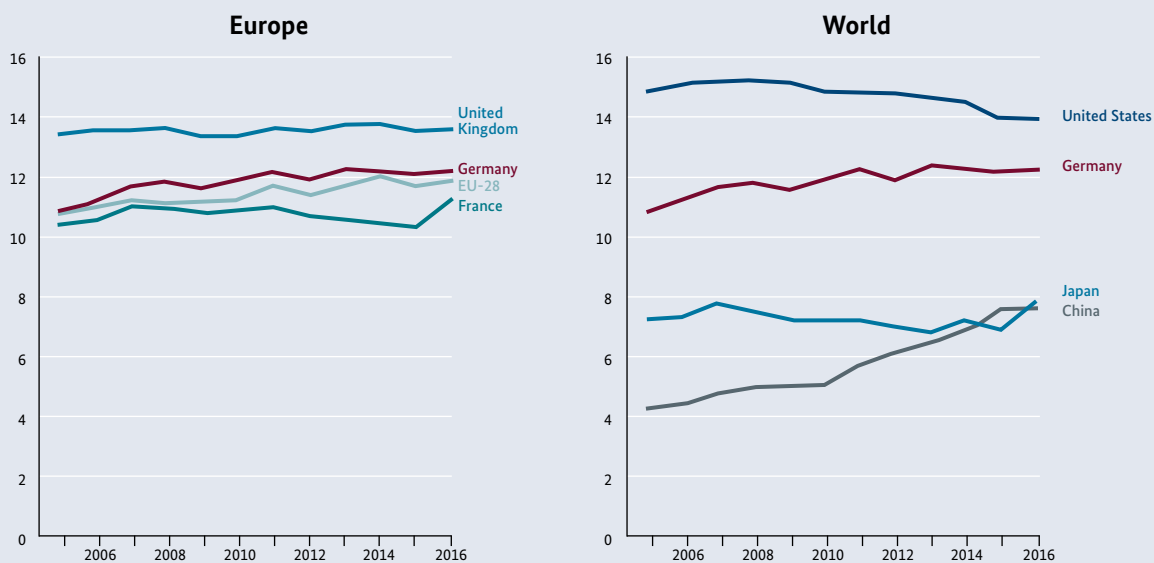
Besides Germany, other European countries with a high patent intensity are Switzerland, Sweden and Finland. Japan and South Korea have substantially expanded their patent activities over the past decade. With regard to this indicator, China performs at a low

level. Particular importance is accorded to patents filed in research-intensive industries. Sweden, the United States, Japan, South Korea and China lead the way here. In research-intensive industry, Germany is particularly well positioned in high-level technologies (e.g. automotive engineering, the chemical industry and mechanical engineering).

Innovation performance

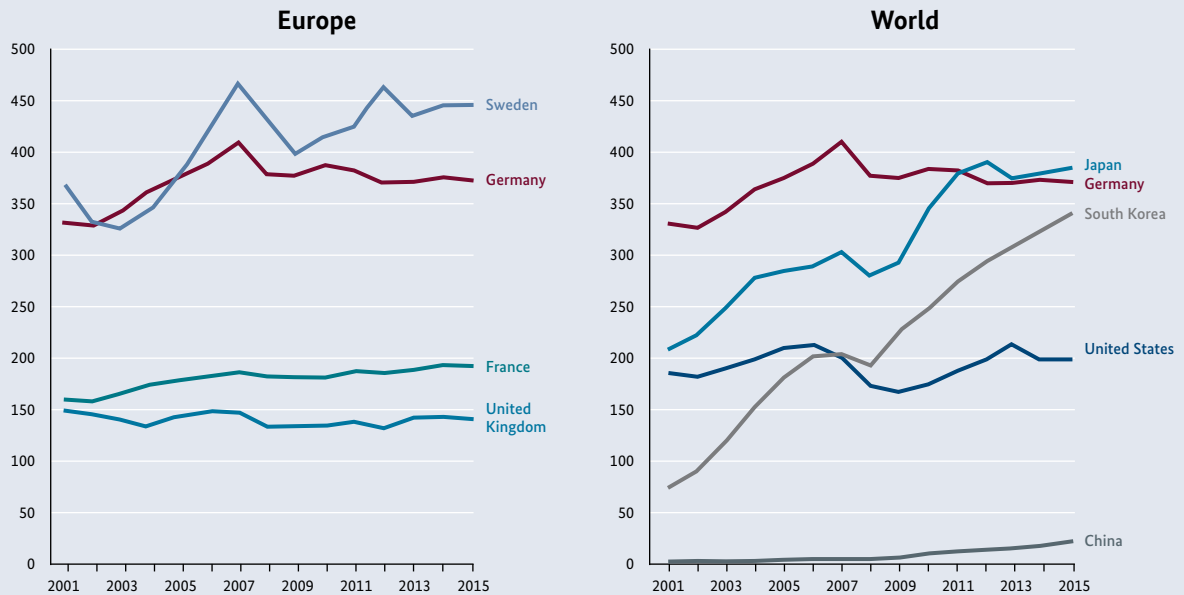
Investments in R&D by both the private sector and the science sector are translated into economic benefits when companies implement R&D results to introduce new or improved products and services or realise productivity increases: in short, they yield innovations. In Germany, an annual study of the innovation behaviour of the German economy is carried out by the Centre for European Economic Research (ZEW). The key indicators are the innovation expenditure, innovation intensity, the share of innovative firms and innovation success of Germany’s economy. The 2016 innovation performance of the German economy improved in a number of key indicators.

Fig. II-15: Excellence rate (in percent): Germany by international comparison



Source: OECD Science, Technology and Industry Scoreboard 2017

Fig. II-16: Patents relevant to the world market (per million inhabitants): Germany by international comparison



Source: BMBF's Data Portal, table 1.8.4

In 2016, German companies spent 158.8 billion euros on innovation, with the manufacturing industry accounting for over three quarters of this sum. In a year-on-year comparison, innovation expenditure rose by 2%. In terms of innovation spending, Germany is still the European leader. The increase in innovation expenditure in 2016 was not just driven by large corporations, but also by SMEs. In 2016, SMEs with fewer than 250 employees spent in excess of 26 billion euros on innovation.

The innovation intensity expresses innovation expenditure in the German business sector as a fraction of revenue. As in the previous year, this was 3% in 2016. However, in terms of innovation intensity, the gap has been increasing between large corporations and SMEs since the late 1990s. While large corporations earmark 3.8% of turnover to finance their innovation activity, SMEs invest a mere 1.4%.

The share of innovative firms expresses the percentage share of companies that have introduced at least one new product or process innovation within the previous three-year period. Overall, approximately

36% of companies were regarded as innovators in 2016, following 35% in 2015. The decline in the share of innovative firms observed in recent years was therefore halted for the time being. The long-term downward trend is also in evidence in most of the other EU Member States. Electronics, measuring technology, optics, the chemical, pharmaceutical and automotive industries are the sectors with the highest share of innovative firms. Germany continues to outperform many other European countries in this indicator.

Innovation success refers to the percentage of revenue that companies generate with product innovations. Germany's business enterprise sector recorded turnover of 719 billion euros with product innovations in 2016 – approximately 3% more than in the previous year. In 2016, the ratio of turnover with new products to overall turnover was virtually unchanged year-on-year at 13.6%. An above average percentage of revenue is generated with product innovations in the R&D-intensive sectors (vehicle manufacturing, the electrical industry and mechanical engineering).

Market innovations represent a higher degree of innovation that was not previously available on the market. Over 8% of all German companies were the first suppliers to launch certain market innovations, generating turnover to the tune of 154 billion euros. The 2016 share of market innovations to total turnover was approximately 3%.

The international competitiveness of knowledge-based economies is reflected in the world trade in research-intensive goods. In 2016, research-intensive products accounted for 46.0% of all industrial global exports, of which, 16.4% were leading-edge technology and 29.6% high-level technology. The share of research-intensive products in all trade in industrial goods has been picking up again since 2013. The previous years had seen a considerable decline, due to the greater participation of the major emerging economies in world trade flows and the resulting relative increase in the percentage of non-R&D-intensive goods in global trade. In 2016, Germany's share of the worldwide trade in research-intensive goods amounted to 11.6%. Thus, Germany leads the way in Europe in this respect. With a global share of 14.6%, China is now the largest exporter of research-intensive products.

International positioning

Germany is one of the world's most innovative economies. This is reflected in the rankings of three international innovation indices: the European Innovation Scoreboard (EIS), the Global Innovation Index (GII) and the Global Competitiveness Index (GCI).

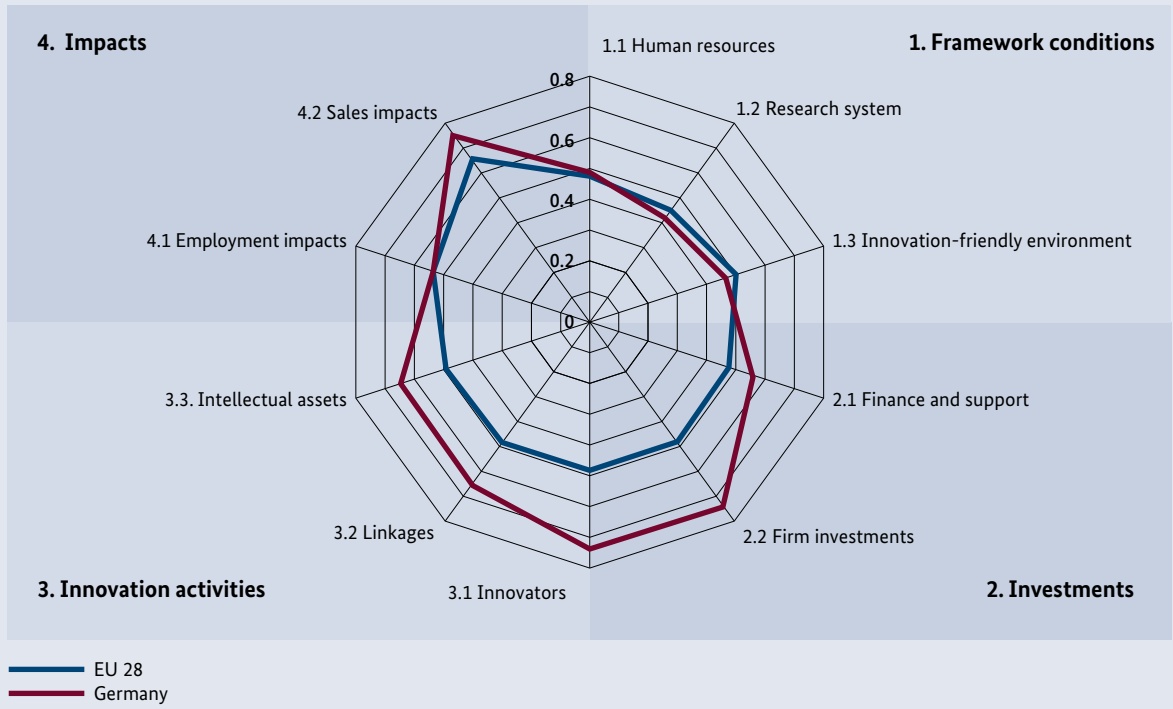
A tool developed by the European Commission, the EIS records and evaluates the progress made towards achieving the objectives of the *Europe 2020* strategy. Introduced in 2001, the EIS distinguishes between four main indicator categories (Framework conditions, Investments, Innovation activities and Impacts). The EIS 2017 classifies Germany in the group of countries that are Innovation Leaders, ranking Germany in sixth place of all EU-28 countries. Germany has maintained its good position for several years. The EIS underlines the attractiveness and high performance of Germany's R&I landscape. The relative strengths of

the German innovation system lie in the output dimensions of Firm investments, Innovators and Linkages, along with Intellectual assets and Sales impacts (see also Fig. II-17).

The GII has been co-published since 2007 by Johnson Cornell University in the United States, INSEAD in France and the World Intellectual Property Organization (WIPO). The GII 2017 ranks Germany in ninth place. Moreover, Germany has achieved rising index scores since 2012. Switzerland, Sweden and the Netherlands are the top three countries in the overall index. The Innovation Output Sub-Index puts Germany in seventh place out of 127 national economies. This attests to the German R&I system's capacity to transfer research findings into marketable innovations. It highlights the business enterprise sector's high share of R&D expenditure and the patenting activities as Germany's particular strengths. Lastly, the work of clusters in the R&D process is rated favourably.

The World Economic Forum's GCI has tracked the overall performance of close to 140 countries since 2004. The results are published in the Global Competitiveness Report. In the GCI 2017, the indicators of general competitiveness are assigned to twelve policy domains (referred to as pillars). Based on its general ability to compete, Germany ranks fifth in the overall index. One of the GCI's sub-pillars explicitly addresses innovations; Germany is in the global vanguard in this respect, also ranking fifth in the sub-indicator of Innovation. Switzerland tops the innovation league. Germany is on a par with developed economies such as the United States, Japan and Sweden, yet ahead of China and South Korea. Unlike most of the aforementioned comparative countries, Germany's scorecard in the field of innovation has shown positive development since 2009.

Fig. II-17: Innovation dimensions of the Innovation Union Scoreboard 2017



Characteristics of the innovation dimensions:
normalised scores between 0 and 1

Source: European Commission: European Innovation Scoreboard 2017





III The Federal Government’s research and innovation policy

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AT A GLANCE

The Federal Government's R&I policy is directed by means of the HTS. Since 2006, the Federal Government has been focussing its R&I activities across governmental departments in the strategy.

The HTS takes a systematic view of the entire innovation chain, from the creative idea to its implementation in the shape of new products and services, thereby combining all aspects and stakeholders involved in the innovation process that are particularly relevant for society: the main priority tasks are the digital economy and society, the sustainable economy and energy, the innovative workplace, healthy living, intelligent mobility and civil security. To this end, the HTS is even more firmly committed to citizen participation in shaping innovations. At the same time, it utilises new instruments to accelerate the transfer into applications and gives rise to a dynamic, innovative industry, thereby creating an environment that is conducive to innovation. The spotlight here is firmly on SMEs.

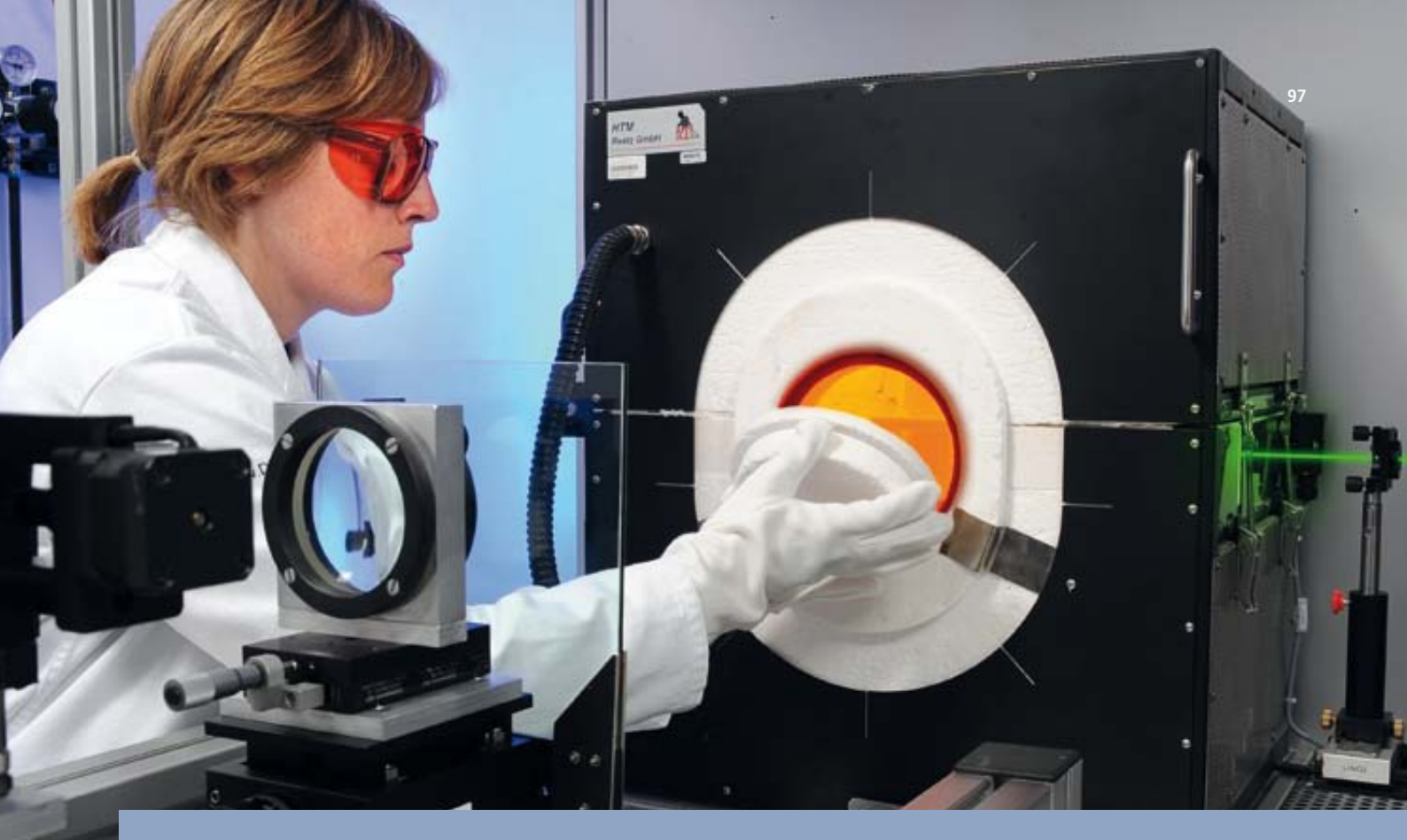
In recent years, the HTS has helped significantly improve Germany's position in the global competition. Greater sums have been invested in R&I. While the HTS was originally directed first and foremost at the market potential of specific technology fields, from 2010 onwards, it took particular account of society's demand for forward-thinking solutions and putting them into practice. Since 2014, the Federal Government has interwoven these different strands, considering the central aspects of an all-embracing R&I policy in a holistic context. The result was an optimal environment for ideas, their implementation in marketable products and services, for more value creation and new employment potential.

It is flanked by other strategic elements, such as the *Pact for Research and Innovation* and the *Excellence Strategy* or the Federal Government's *Strategy for the Internationalisation of Education, Science and Research*, which was launched in 2017.



Further information is available online:

The High-Tech Strategy 2025: hightech-strategie.de



1 Research priorities

The German research and science landscape enjoys an excellent reputation all over the world. Cutting-edge research ensures sustainable growth today, paving the way for solutions to the global challenges of tomorrow. The determination to strike out in new directions, discover the unknown and improve the status quo is the incentive that drives Germany's researchers.

With its *HTS*, the Federal Government is setting thematic priorities in R&I. One core element is its focus on priority tasks; propelled by an impressive innovative momentum, these tasks will continue to provide valuable impetus, thereby boosting economic growth and prosperity. The goal of the *HTS* is to break new ground in these fields, finding solutions to global challenges and offering satisfactory answers to the pressing questions of the 21st century. This means boosting the innovative strength and growth potential of the business enterprise sector, while guaranteeing qualified, future-proof jobs.

The Federal Government's R&I policy advocates the advancement of key technologies and basic scientific research, together with the development of important cross-cutting issues in the fields of education and society, such as demographic change and integration through education. It spans a wide range of topics from digitalisation, key technologies, sustainability, climate and energy, the world of work, production

and service to health and nutrition, mobility, security, basic scientific research, the universe and matter, right through to society and education.



2 Networking and transfer

The intensity of companies' business cooperation is steadily becoming synonymous with their competitive advantage. The Federal Government aims to encourage the mutual transfer of ideas, knowledge and technology between enterprises, universities, non-university research institutions and other social stakeholders. The nurturing of networks and clusters is a crucial basis for collaboration. The opening of innovation processes is gradually coming to the fore.

The *Leading-Edge Cluster Competition*, the *Internationalisation of Leading-Edge Clusters*, *Forward-Looking Projects and Comparable Networks* funding measure, the *go-cluster* programme and the *Research Campus* initiative all foster theme-oriented, results-based strategic cooperation between academia, companies and society. In order to fully utilise the innovation potential of universities of applied sciences, the BMBF launched the *Research at Universities of Applied Sciences* programme, thereby supporting application-oriented R&D alliances between these universities and companies and encouraging the qualification of early career scientists. The Federal Government and the *Länder* signed an agreement to extend the *Pact for Research and Innovation* until 2020, thereby scaling up the networking and transfer activities of science and research organisations. Moreover, the joint Federal Government/*Länder* initiative *Innovative Hochschule* seeks to cultivate the regional roots of higher education institutions on a sustained basis, thereby strengthening their strategic role as drivers of innovation on their own doorsteps.

The goal is to streamline and accelerate the transfer of research findings onto the market or into applications that benefit society. Closing the innovation gap between preliminary research findings and possible applications is a top priority in this regard. The BMBF's VIP+ funding programme, *Validation of the technological and social innovation potential of scientific research*, assists researchers in validating the innovation potential of their research findings at an early stage and in developing relevant economic or social applications. In early 2016, the BMWi pooled its patenting and standardisation activities in the *Knowledge and technology transfer via patents and standards (WIPANO)* measure in order to step up commercialisation and technology transfer.



3 The dynamics of innovation in industry

Government R&I funding specifically aims to strengthen the backbone of innovative, high-growth, SMEs. The high performance and creativity of German enterprises vitalise the innovative dynamism of the country's economy. The priority is to leverage innovation potential first and foremost in the *Mittelstand*, the skilled trade sector and technology-based spin-offs, as well as in structurally weak regions.

German companies, particularly SMEs, receive backing through an effective system of R&I funding. This is carried out by the BMWi, which bundles four programmes for each stage of the innovation cycle under the maxim of *Von der Idee bis zum Markterfolg* and by the BMBF in its ten-point *Priority for SMEs* programme. Furthermore, technology-specific programmes place particular emphasis on the involvement of SMEs.

Business start-ups have an enormous impact on an economy's innovative momentum. Although start-ups in research and knowledge-intensive sectors contribute disproportionately to growth and employment, they often have inadequate funding at the outset. Programmes like *EXIST*, *INVEST*, *GO-Bio*, the *Digital Innovations – Competition for Business Start-ups*, the *High-Tech Start-Up Fund* and *coparion* stimulate the growth of a new scale-up dynamism, especially in the early stages of new technological developments, thereby strengthening Germany's position as a competitive location for venture capital. Adopted in 2017, the BMBF programme *More opportunities for entrepren-*

eurship – Five points for a new entrepreneurial age aims to gradually extend its start-up funding.

Unlocking the innovation potential of structurally weak regions enhances their innovative strength, economic growth and employment level. The 'Progress Report of the Federal Government on the further development of a funding system for structurally weak regions from 2020', endorsed by the Federal Cabinet in September 2017, designates innovation funding as a key component of the new funding mechanisms. With several successful programme formats, *Entrepreneurial Regions – the Innovation Initiative for the New German Länder* promotes the formation of internationally competitive centres of excellence with highly dynamic innovation capabilities. The funding approach is being honed in the *Innovation and structural transformation* framework, due to be rolled out nationally by 2020 at the latest. The regional grants awarded under the *Joint Scheme for the Improvement of Regional Economic Structures* aid structurally disadvantaged regions in both East and West to reach technology and investment policy goals.



4 Favourable conditions for innovation

The Federal Government is committed to establishing an environment that is conducive to innovation. This includes securing the skilled labour base, guaranteeing adequate financing options, while maintaining fair competitive conditions and innovation-friendly regulations. This allows bright ideas to take root and become economic successes.

Securing the supply of skilled labour is one of Germany's priority tasks. Along with politics and society, companies and social partners now have to take action. The Federal Government pursues a comprehensive, systematic approach, with various interdepartmental initiatives aimed at securing the skill base.

As a location for venture capital investment, Germany needs to compete on an international scale. With a range of measures, the Federal Government has created incentives for investing in innovative companies and ideas. Standardisation and effective legal metrology are integral elements of economic and innovation policy. The elimination of non-tariff trade barriers and the international harmonisation of standards and norms are the subject of ongoing multi- and bilateral negotiations.

Owing to its high volume of over 300 billion euros per year, public procurement has enormous power to stimulate innovations in the business enterprise sector. Therefore, a competence centre funded by the BMWi

advises public procurers on encouraging innovation on the market via the contract award process.

The dissemination of knowledge is the driving force behind R&I. In its *Digital Agenda 2014–2017*, the Federal Government pledged to facilitate the unrestricted flow of information within the scientific sector and thus the dissemination of knowledge among the scientific community and the transfer of knowledge to the business enterprise sector. In 2016, the BMBF presented its *Open Access Strategy*, fostering the development with a set of measures that seek to make open access standard in the area of scholarly publishing. Aimed at SMEs in particular, modern open access and open innovation concepts offer scope for knowledge-based approaches and new market opportunities.



5 Transparency and participation

Firstly, boosting Germany's innovative drive presupposes greater investments in research – from both federal and entrepreneurial sources. Secondly, all participants must help guide the innovation processes. In its HTS, the Federal Government therefore advocates the greater involvement of all stakeholders – from academia to industry, right down to the citizens – in shaping innovation processes.

The substantiated processing of information is essential in directing the progress of new technologies and developments, and for initiating open dialogue at an early stage. With a focus on the next five years, the *innovation and technology analysis* (ITA) analyses the opportunities and risks of new technological and societal developments. The results of the *Foresight Process*, an integral part of the *Strategic Foresight*, illustrate the changes society could undergo in the long term.

Scientific communication must present research results and innovation processes in a readily comprehensible form. Dialogue formats play a key role in this respect and are increasingly dominating the *Science Years*. The *Science Year 2016*17 – Seas and Oceans* demonstrates how science and research contribute to protecting and using the seas and oceans sustainably. The Science Year 2018 revolves around the 'Working Life of the Future'.

By engaging in civil dialogue and encouraging trans-disciplinary research, the Federal Government seeks to entrench innovations in the very heart of society. As a platform to guide the prospective focus of research and development, the *Future Forums* enable citizens to contribute the wealth of their experience to policy-making. Sponsoring *Citizen Science* projects encourages society's active participation in research. Agenda processes ensure that R&I programmes cater to actual requirements. Together, the scientific, business and social communities help identify priorities, increase the acceptance and raise awareness of the funding programmes, stimulating innovative capabilities in turn.





IV International cooperation in research and innovation



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AT A GLANCE

A successful R&I system must have a strong international focus in order to benefit from knowledge bases around the world. The success of the German R&I system depends on its ability to establish a framework for international action that is conducive to science and innovation, thereby facilitating the exploitation of global resources. In this respect, the Federal Government has revised its strategic guidelines in recent years, all the while strengthening its foreign science and scientific development policy measures and scaling up alliances with partner countries around the world.

Released in 2017, the Federal Government's *Strategy for the Internationalisation of Education, Science and Research* creates the framework for Germany's international collaboration in the fields of education, science, research and innovation. It builds on the Federal Government's *Strategy for the Internationalisation of Science and Research* of 2008, in conjunction with the Federal Government's *HTS*.

The Federal Government places enormous emphasis on European integration. The joint, concerted action of the EU Member States in the ERA enhances Europe's visibility, lending it added weight vis-à-vis the world's other major innovative regions. *Horizon 2020*, the European Framework Programme for Research and Innovation, was designed to complement national research programmes; with a total funding volume of 77 billion euros, it is the world's largest funding programme for R&I. Apart from *Horizon 2020*, the EU cohesion policy's *European Structural & Investment Funds* are the major sources of EU investment in research, technological development and innovation.

Germany is boosting its bilateral cooperation with important partner countries around the world. This applies especially to countries with dynamic growth and significant emerging markets. Germany's active involvement in multilateral initiatives and institutions, and in informal forums, is conceived as a long-term investment in the future. Shining examples are its participation in the OECD, the UNESCO and its membership of the G7 and G20 economic forums.



Further information is available online:

The Federal Government's Strategy for the Internationalisation of Education, Science and Research:
bmbf.de/en/internationalization-strategy-2209.html



1 Objectives and priorities of the internationalisation of research and innovation

Since February 2017, the Federal Government's *Strategy for the Internationalisation of Education, Science and Research* has established the framework for Germany's international collaboration in these fields. It defines objectives and priorities in reference to the burgeoning globalisation and digitalisation of education, science and research, the further evolution of the European Research Area and the emergence of new global centres of innovation outside established science hubs.

The Federal Government first defined its strategic goals for cross-border cooperation in science, research and innovation in 2008. In 2014, the BMBF reviewed the internationalisation track record in its *International Cooperation action plan*, establishing vital modifications for the further implementation and enhancement of the Internationalisation Strategy. Thus, new challenges have arisen and others have escalated over the past ten years. These include integration in knowledge flows all over the world, the organisation of increasingly complex, cross-border value chains and the large-scale expansion of digital processes and methods.

The 2017 Internationalisation Strategy defines five targets in research excellence, innovation, education and training, collaboration with developing and emerging countries, and global challenges. As an important departure from its 2008 Internationalisation Strategy, the Federal Government included the additional objective of 'Developing the international aspects of vocational training and qualifications'. It

thus reflects the growing importance of vocational education and training in Germany's cooperation with its international partners.

The guiding principle of the Federal Government's current strategy is 'International cooperation: networked and innovative'. It pursues the primary aim of intermeshing the various levels of action more closely and forging stronger ties between the different stakeholders from science, business and politics. With this in mind, the Federal Government has instituted a round table of eminent experts for the Internationalisation of Education, Science and Research. The core objective of the round table is to identify where action is currently required in international cooperation in education, science and research and to create synergies, for example by intensifying cross-departmental collaboration (synergy projects).



2 Germany's role in Europe

The scientific excellence, commercial success and international competitiveness of the European research landscape are all based on the cooperation between Member States, their research institutions and enterprises. As a political concept, the ERA creates a unified framework in which scientific knowledge and researchers circulate freely. Germany places enormous emphasis on the expansion of the ERA. A central management tool and funding instrument in this regard is the EU Framework Programme for Research and Innovation, in which German research institutions and companies play a significant role.

With effect as of December 2009, the Treaty of Lisbon enshrines the goal of establishing the ERA in the primary legislation of the EU. The ERA will guarantee a number of privileges similar to the fundamental freedoms of the internal market – freedom of movement for researchers and innovators, plus the free exchange of scientific findings, technologies and innovations. The ERA is more than the sum of the activities carried out by Member States. The Member States, the EU institutions and the research organisations have joined forces to improve the framework conditions and facilitate a R&I landscape that works smoothly across European borders. To this end, the *Strategy of the Federal Government on the European Research Area* was adopted in July 2014, which is committed to the six priorities of ERA.

Horizon 2020, the EU Framework Programme for Research and Innovation, is the world's largest funding programme for R&I. German stakeholders are heavily involved in the funding measures of *Horizon 2020*, along with the European initiatives *EUREKA*, *Eurostars* and *COST*.

Apart from *Horizon 2020*, the EU cohesion policy's *European Structural & Investment Funds* are the major sources of EU investment in research, technological development and innovation. The joint EU *Erasmus+* programme for education, training, youth and sport has been in place since 2014. Moreover, Germany has stepped up its bilateral and multilateral cooperation with selected partner countries in Europe.



3 Worldwide cooperation

Traditionally, Germany's research landscape and its stakeholders boast an outstanding global network. German scientists have always been and continue to be mobile, while researchers from other countries are regularly hosted in Germany. This international exchange is rapidly moving to the next level. Its many forms of cooperation elevate Germany's standing, making it a key player in a globalised world.

Germany has created a reliable framework for collaboration with numerous international partners. Collaboration takes place at government level, among administrative bodies and intermediary organisations, as well as at the level of research organisations and universities. It is imperative that each individual alliance be tailored to the respective partner countries and Germany's interests. The most important basis for bilateral alliances are agreements on Science & Technology Cooperation (STC) or on collaboration in vocational training.

Germany's R&I policy aims to maintain a strong presence in countries whose science and technology resources are of strategic importance. This applies to both industrial nations and emerging markets, with a special focus on the five BRICS countries of Brazil, Russia, India, China and South Africa. Cooperation will be increasingly relevant with those countries that improve their development status rapidly and dynamically.

In its research and educational cooperation with regions like MENA and regional organisations in the world, such as ASEAN, African Union or MERCOSUR, Germany places greater emphasis on regional approaches and specially tailored measures. Furthermore, by bringing its expertise to bear in international organisations and forums (e.g. OECD, G7 or the UN), Germany acknowledges its share of global responsibility. For example, one of the main issues on the G7 agenda under Germany's Presidency in 2015, the future of the seas and oceans, was kept at the forefront during the subsequent meetings of the G7 Science Ministers in 2016 and 2017.





V The cooperation between the Federal Government and the *Länder*

AT A GLANCE

The task of promoting science and research is shared by the state, industry and society, with the Federal Government and the *Länder* working hand in hand. The amendment to Art. 91b GG proposed by the Federal Government entered into force on 1 January 2015, opening up greater opportunities for cooperation between the Federal Government and the *Länder* in the scientific sector. The Federal Government and the *Länder* can now set joint priorities and hone their profiles even more effectively, thereby enhancing the performance and excellence of the German science landscape at both the general level and the cutting edge.

In Germany's federal system, the responsibility for promoting science and research only falls into the exclusive remit of the Federal Government in a few cases. For example, the Federal Government is invested with legislative powers in the regulation of educational and training grants and the promotion of research (Art. 74 (1) 13 GG); by contrast, the higher education sector is predominantly the responsibility of the *Länder* (Art. 30 and 70 GG).

Nevertheless, as a result of consensus on the promotion of science, research and teaching pursuant to Art. 91b (1) GG, the Federal Government and the *Länder* may cooperate in cases of supra-regional importance.

The Federal Government/*Länder* agreements aim to underpin the joint emphases and profile development in the science system, thereby continuing to increase the potential of the German science landscape. Against this backdrop, the Federal Government and the *Länder* together launched the *Initiative for Excellence*, the *Pact for Research and Innovation* and the *Higher Education Pact* in the mid-noughties. Thanks to their major impetus, these science pacts have tangibly enhanced the performance and capabilities of the German science system. In December 2014, therefore, the Federal Government and the *Länder* agreed to extend the pacts.

To strengthen Germany's future viability, an extended package of measures for higher education institutions was approved in 2016, including the *Excellence Strategy*, the *Tenure Track Programme* and the joint Federal Government/*Länder* initiative *Innovative Hochschule*.

Excellence Strategy

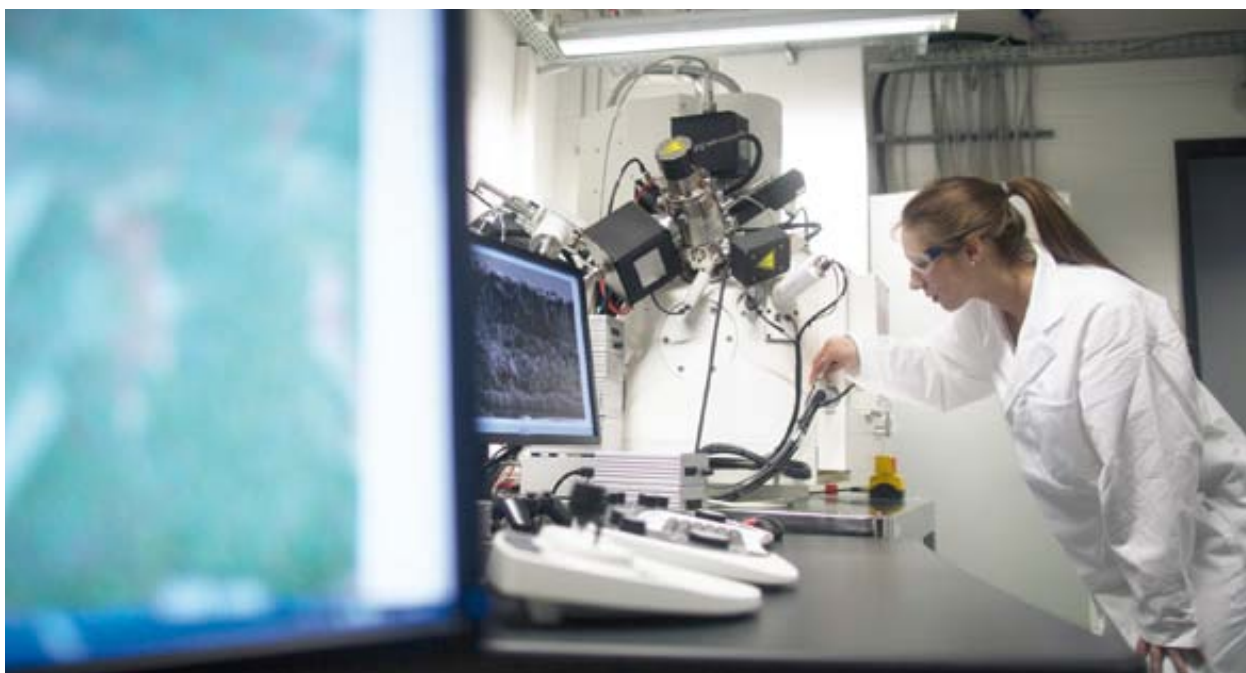
As of 2018, based on the agreement between the Federal Government and the *Länder*, the *Excellence Strategy* is funding cutting-edge research at German universities. For the first time, it is capitalising on the new possibilities offered by Article 91b GG. With the *Excellence Strategy*, the Federal Government and *Länder* aim to improve the position of German universities in the international arena and ensure scientific excellence. Unlike its precursor, the Initiative for Excellence, it is not limited in time but has been concluded for an unspecified period.

In 2005, the Federal Government and the *Länder* launched the *Initiative for Excellence* to promote early career scientists, cutting-edge research and academic research in the higher education sector. This measure further increased the attractiveness of universities for both students and scientists. Until October 2017, the *Initiative for Excellence* funded outstanding projects and institutes at universities in two periods with a total volume of 4.6 billion euros. Interim financing for a maximum of 24 months is currently in place. An independent evaluation carried out by an international commission of experts (the Imboden Commission) in 2016 acknowledged the profile-enhancing effect of the *Initiative for Excellence* on the funded universities

and the positive impact on Germany's entire science system.

Within the scope of budgetary constraints, the *Excellence Strategy* earmarks 533 million euros per year for universities. The funds are provided in a ratio of 75:25 by the Federal Government and the respective *Land* in which the institution is located. The joint funding in the *Excellence Strategy* covers the science-related activities of the universities and their cooperation partners in projects of national importance in the two funding lines, Clusters of Excellence and Universities of Excellence.

The Clusters of Excellence promote research fields at universities or in consortia of universities that are internationally competitive, on a project-by-project basis. The clusters are announced every seven years on a regular basis. As a general rule, relevant funding is granted for two periods of seven years; it is also possible to reapply. Universities with Clusters of Excellence may apply for a university allowance as a strategy grant to strengthen their strategic governance and focus. Annual funding of approximately 385 million euros (including the programme and university allowance) has been earmarked for Clusters of Excellence. Every year, between 3 and 10 million euros per Cluster of Excellence were appropriated for 45 to 50 eligible projects. In February 2018, 88 proposals were submitted for Clus-



ters of Excellence. The funding decision on applications for Clusters of Excellence was taken in September 2018, with funding starting in January 2019.

The Universities of Excellence funding scheme is directed towards strengthening the universities or consortia thereof as institutions and consolidating their leading position in the international research system, based on their successful Clusters of Excellence. Universities of Excellence receive long-term funding. Recognition as a University of Excellence is subject to the approval of at least two Clusters of Excellence at the same university, or at least three Clusters of Excellence in the case of consortia. Eleven Universities of Excellence or university consortia will be selected in the first round of proposals. Approximately 148 million euros are ring-fenced each year to support Universities of Excellence. The funding decision on applications for Universities of Excellence will be taken in July 2019, with funding starting in November 2019. The call for four new applications will follow for the second round of funding, which is due to commence in 2026.



Further information is available online:

General information on the Excellence Strategy:
bmbf.de/en/excellence-strategy-5425.html

Tenure Track Programme

The *Tenure Track Programme* is intended to make careers in the academic world easier to plan and enhance the transparency of the various steps. It is aimed at young scientists at universities and higher education institutions of equivalent status. For the first time, based on the recommendations issued by the WR on 11 July 2014, regarding career goals and paths at universities, the Federal/*Länder* programme is establishing tenure track professorships as an independent career path at German universities nationwide, in addition to the conventional appointment

process for a chair. The objective is to enable young researchers to choose to remain permanently in the science system at an earlier stage than is now the case. Following a successful trial phase, the tenure track programme therefore facilitates their direct transition to a tenured professorship.

Over the entire term from 2017 to 2032 and subject to budgetary constraints, the Federal Government plans to provide up to 1 billion euros to facilitate 1,000 additional tenure track professorships. In establishing tenure track professorships as an internationally renowned and accepted career path, the programme seeks to enhance the attractiveness of the German science system in the international arena and to underpin the endeavours of the universities to recruit – and retain – the best young scientists in Germany and abroad for as long as possible. Thus, the *Tenure Track Programme* represents a structural reform project for Germany as a prime location for innovation.

The universities' proposals are reviewed in a science-driven selection procedure in two allocation rounds (scheduled for 2017 and 2019). The selection committee is composed of experts from the scientific community and university management, together with representatives from the new generation of academics and delegates of the Federal Government and the *Länder*. Some 468 tenure track professorships are being funded at 34 universities in the first allocation round.



Further information is available online:

General information on the Tenure Track Programme: tenuretrack.de/en

Innovative Hochschule

The joint Federal Government/*Länder* initiative *Innovative Hochschule* helps raise the profile of the research-based transfer of ideas, knowledge and



technology at universities. It is directed particularly at small and mid-sized universities and universities of applied sciences that have already put in place a coherent strategy of interaction with the business sector and society, and that have the necessary structures for and experience in the transfer of ideas, knowledge and technology. The funding measure supports third mission activities to boost transfer and innovation at universities, alongside teaching and research.

Technological and social innovations from universities are drivers of prosperity and quality of life. In 2016, the Federal Government and the *Länder* approved the *Innovative Hochschule* initiative to encourage the research-based transfer of ideas, knowledge and technology and make the process of converting research results from all branches of science into creative solutions for the most pressing challenges in the economy and society even more efficient.

Moreover, the joint Federal Government/*Länder* initiative is conducive to strategically building and intensifying synergies with the business sector and other

stakeholders in society, thereby reinforcing universities' strategic role in the regional innovation system.

Funding under the measure provides the universities with resources to

- Continue the strategic development and implementation of their idea, knowledge and technology transfer profile across the university as a whole or in selected subject areas
- Optimise their transfer structures
- Step up their networking with regional partners
- Strategically align established transfer instruments
- Create and develop innovative forms of collaboration with industry, the arts and society.

Endowed with up to 550 million euros, subject to budgetary constraints, the *Innovative Hochschule* is set to run until 2027. The funds are made available in a ratio of 90:10 by the Federal Government and the respective *Land* in which the institution is located.



Further information is available online:

General information on the Innovative Hochschule:
bmbf.de/en/innovative-hochschule-3367.html

Pact for Research and Innovation

The *Pact for Research and Innovation* is a central agreement between the Federal Government and the *Länder* to strengthen the major science organisations that are funded jointly. Thanks to a combination of shared research policy goals, financial planning certainty and improved framework conditions, the Pact elevates Germany's standing as a centre of science and industry and enhances its international competitiveness.

The *Pact for Research and Innovation* was adopted by the Federal Government and the *Länder* in 2005 and extended over the following years. It was recently continued for the period 2016 to 2020. The Pact creates financial planning security for Fraunhofer, HGF, MPG and the Leibniz Association, along with the DFG as a funding organisation, by means of agreed regular increases in basic funding. In return, these organisations commit to specific research policy goals, with autonomous control over the implementation thereof. The financial certainty gives them the flexibility to elaborate their strategic measures, refine existing tools and create new ones. The *Pact for Research and Innovation* pursues the following research policy goals:

- To develop the science system dynamically
- To encourage networking in the science system
- To intensify international and European collaboration
- To strengthen the exchange between academia, industry and society
- To attract top-tier academics for the German science system
- To guarantee equal opportunity and family-friendly structures and processes.

Subject to the annual budgetary negotiations with the institutions and provided the legislative bodies allocate sufficient resources, the Federal Government and the *Länder* aim to raise institutional funding for the individual science organisations by 3% a year. From 2016 to 2020, only the Federal Government contributes to the increase. Overall, within the scope of budgetary constraints, an additional total of around 3.9 billion euros is earmarked for research during this period.

Every year, the GWK monitors and evaluates the progress of the measures, based on the annual reports of the science organisations.



Further information is available online:

General information on the Pact for Research and Innovation: research-in-germany.org/en/research-landscape/r-and-d-policy-framework/pact-for-research-and-innovation.html

Higher Education Pact 2020

With the *Higher Education Pact 2020*, launched in summer 2007, and its continuation, approved by the heads of government on 11 December 2014, the Federal Government and the *Länder* laid the foundations for a range of adequate, needs-based study options. Together with other Federal Government/*Länder* activities, the Higher Education Pact makes a significant contribution to ensuring the qualification of specialists in Germany over the long term. The *Higher Education Pact 2020* is based on three pillars:

- *The programme to provide additional university places for first-year students*
- *The DFG's programme-overhead financing*
- *The Teaching Quality Pact.*

The *programme to provide additional university places for first-year students* ensures that, despite the rising numbers of freshmen, all those interested in higher

education are able to enrol at university. The *Teaching Quality Pact* helps improve studying conditions and teaching quality. While the *programme to provide additional university places for first-year students* and the Higher Education Pact's *Teaching Quality Pact* concentrate on studying and teaching, the DFG's programme-overhead financing focuses on strengthening research at universities. Since 2007, the programme-overhead financing amounting to 20% of the project funding has been earmarked for indirect, additional and variable expenditure in DFG research projects. Until 2015, the Federal Government placed approximately 2.3 billion euros of special funding at the DFG's disposal. For all projects approved on or after 1 January 2016, the programme-overhead financing represents 22% of the direct project funds approved and disbursed by the DFG. The additional requirement is borne by the *Länder* according to the Königstein distribution formula.

Within the scope of budgetary constraints, the Federal Government is providing a total of 20.2 billion euros and the *Länder* 18.3 billion euros over the entire term of the *Higher Education Pact 2020* from 2007 to 2023.



Further information is available online:

General information on the Higher Education Pact 2020: research-in-germany.org/en/research-landscape/r-and-d-policy-framework/higher-education-pact-2020.html

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Guide to Research and Innovation Funding

**Planning an ambitious research or development project?
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