



Federal Ministry
of Education
and Research

Report of the Federal Government on Research 2004

Abridged Version



RESEARCH

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Edited by

Dr. Wolfgang Mönikes, Ulrich Schöpke

Translation

Eric Allen

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The information about German research organisations presented in this report is also provided, and regularly updated, at the Website www.forschungsportal.net. The site's integrated search engine supports fast searches for specific research areas and the research organisations working in them.



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Preamble on research policy

1	Basic principles	II
1.1	Reasons why the state supports research	III
1.2	Instruments of research funding	V
1.2.1	Institutional funding	V
1.2.2	Project funding at the interface between science and industry	VI
1.2.3	Centres and networks of excellence	VI
1.2.4	Indirect support	VII
1.3	Thinking about tomorrow – today	VII
2	Current political aims and measures	VIII
2.1	The task: increasing investments in the future	IX
2.2	Promoting and challenging human resources	X
2.2.1	Begin in the schools	X
2.2.2	Increasing the percentages of pupils who go on to higher education	X
2.2.3	Top-class universities can attract the best minds to Germany	X
2.2.4	Strengthening support for young scientists	XI
2.2.5	A brain-gain instead of a brain-drain	XI
2.2.6	Promoting personnel mobility	XI
2.3	Modernising the research landscape's structures	XII
2.3.1	Restructuring the division of competencies between the Federal Government and the Länder	XII
2.3.2	Intensifying networking among research organisations	XII
2.3.3	Increasing use of competition in awarding of research funding	XII
2.3.4	Being willing to take risks via new funding procedures	XIII
2.3.5	Ensuring that research is of high quality	XIII
2.3.6	Evaluating departmental research	XIII
2.3.7	Meeting the need for large-scale research facilities	XIII
2.4	Promoting technologies for new markets	XIV
2.4.1	Stimulating research and development in the business enterprise sector	XIV
2.4.2	Intensifying co-operation between science and industry	XIV
2.4.3	Providing special support for SMEs	XV
2.5	Research for people and the environment	XVI
2.5.1	Applying findings from life sciences to medicine	XVI
2.5.2	Expanding research aimed at sustainable development	XVI
2.5.3	Research for the workplace of tomorrow	XVI
2.5.4	Safeguarding mobility – minimising the impacts of transports	XVI
2.6	Promoting women in the research sector	XVII
2.7	Strengthening research in eastern Germany	XVII
2.8	Intensifying internationalisation	XVIII
2.9	Conducting a dialogue on research	XIX

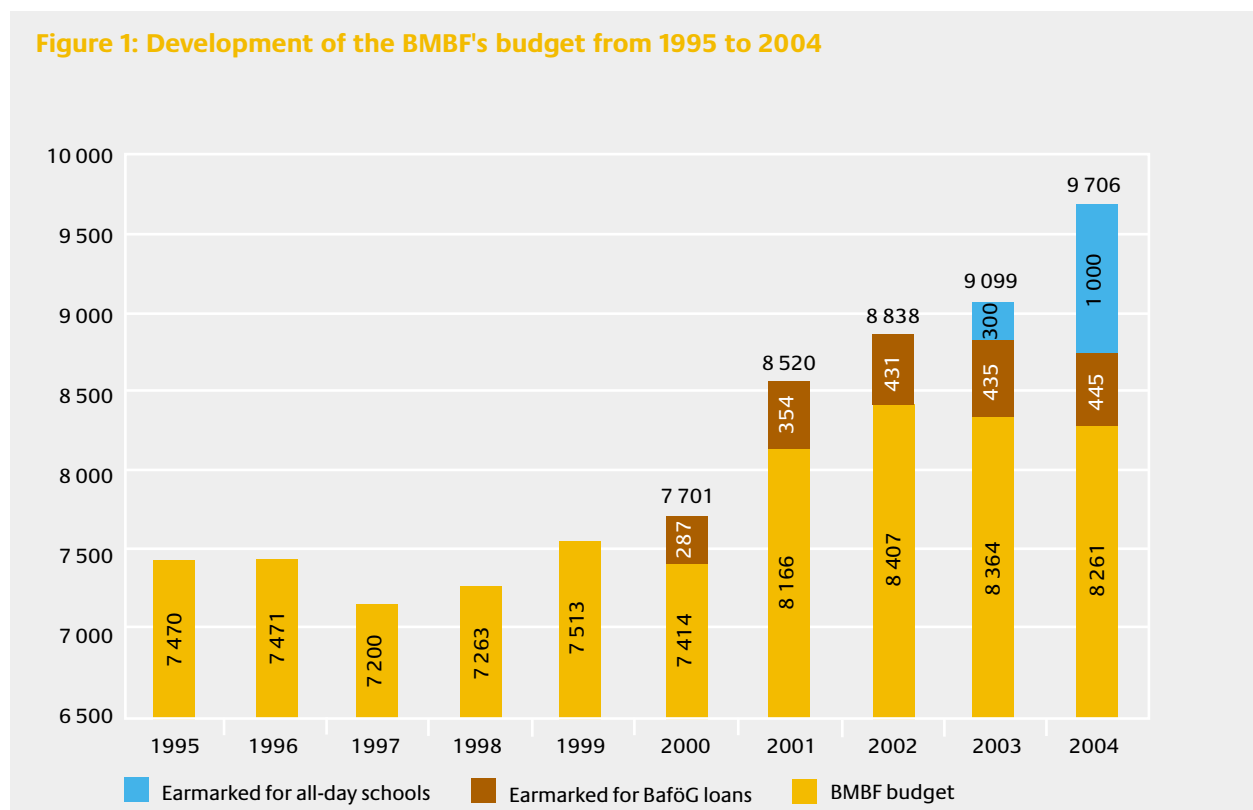
1 Basic principles

Research creates knowledge. Knowledge that expands our awareness and changes our perception of ourselves. Knowledge that shapes our thinking and gives us orientation. Knowledge with which we create economic growth, secure jobs and prosperity. Knowledge that helps us to improve our lives and workplaces.

Today's research opens up new possibilities for our lives of tomorrow. Many of the things that enhance our lives would never have been possible without the curiosity of researchers. Things such as communications satellites, cell phones, medications against dangerous diseases and laser scalpels, to mention just a few examples.

Today, we face the challenge of moving ahead toward the knowledge society and shaping a common European research and innovation area. Research-intensive industries, knowledge-intensive services and close links between products and services are growing in economic importance. Europe is aiming to become the world's most dynamic knowledge-based economic region by the year 2010. The German Federal Government has taken an active role in setting this goal, and it fully intends to help make this goal a reality.

Figure 1: Development of the BMBF's budget from 1995 to 2004



Since 1998, research and education have again been receiving priority. In just one example, the funds available to the Federal Ministry of Education and Research (BMBF) have grown by 34 percent from 1998 to 2004 – to over € 9.7 billion. Important reforms, such as introduction of programme-

oriented funding at the Helmholtz Association, and reform of service law (Dienstrecht) at universities, are helping to enhance quality in science and research, promote more competition in this sector and intensify its international orientation. The key now is to stay the course.

1.1 Reasons why the state supports research

Science and research have become a driving force for technological development – and, thus, for economic development as well. Francis Bacon (1561–1626) envisioned that the natural sciences emerging during his lifetime would improve living conditions. In the 19th century, his prediction began to be fulfilled, as physics and chemistry brought useful new progress in electrical engineering and paint production. In the 20th century, information technology has changed our lives completely. Now the life sciences, another major area of knowledge, have entered the phase in which scientific and technological development interact intensively. Physics and chemistry have discovered new phenomena in the nanometre range and are developing many new nanotechnological applications.

Not all branches of science have such direct relationships to technological – and, thus, economic – development. They are indispensable to society nonetheless. Research has become an especially powerful "eye": Scientific observation shows us the world in a multitude of new facets. Without microscopes, we would know nothing about bacteria and viruses; without the work of historians, we would soon forget our historical roots. Scientific theories often provide the framework for formulating our aims and aspirations.

Science has yet another function: It trains the highly qualified workforce the knowledge society needs. Today's students are tomorrow's highly skilled employees. Only countries that train sufficient numbers of highly qualified persons, and that are attractive for foreign specialists, can succeed in the international competition for the best minds. In the knowledge society, it is more important than ever for Germany to make the best use of its most vital resource: The talents and skills of people.

Research is oriented to the unknown. Often, we have to look for tomorrow's solutions in places that don't fit with our current expectations. No one can precisely predict the results of research projects. This applies especially to basic research, which searches for unknown new phenomena and formulates theories to explain the phenomena that have already been observed. Research findings are published in open sources that are widely accessible. Scientific knowledge is a public asset. To be able to move beyond the limits of our current understanding, scientists need the freedom and the possibilities to follow their curiosity. For this reason, the state has a special responsibility to give scientists the tools and resources they need to apply their freedom to the benefit of us all.

Basic research also has a cultural aspect. The search for answers to questions about our origins, about the development of the universe or the handing down of old writings are part and parcel of our culture, like art and music. And top

scientific achievements contribute to Germany's image and prestige in the world.

Basic research also provides impetus for application-oriented branches of science and research. The state is especially interested in supporting research that is for the common good or that will benefit future generations. Examples of such "precautionary" research include security research, health-care research, environmental research and energy research.

The state finances some 1/3 of all expenditures on research and development (R&D). Development of new technologies that generate economic prosperity is primarily the task of industry, however. Consequently, industry finances some 2/3 of all R&D expenditures in Germany. This financing corresponds to € 35 billion, or 1.7 percent of the country's gross domestic product (data for 2002).

When a company pursues its own research, it often generates positive external effects – findings whose benefits are not limited to the company itself. On the other hand, research always entails the possibility of failure. For this reason, the state must work to reduce the economic risks for companies that carry out research. It is in the public interest to strengthen innovativeness of domestic companies, through creation of an innovation-friendly climate and state support for research and development. Only innovative companies can offer jobs that remain secure in a competitive business environment. At the same time, companies must be networked with research resources at universities and non-university research institutions. The Federal Government makes special efforts to support small and medium-sized companies, which are the backbone of Germany's economy. Such companies often lead the way in applying new R&D findings to new products, procedures and services.

Research stimulates economic growth. And yet progress from research to market success seldom runs in a straight line; in most cases, its path is more complicated, tracing a dynamic, interactive process. It is thus difficult to quantify the real effects of research support. Nonetheless, many examples show: Innovation has a positive net impact. An enormous range of instances can be cited in which public support has triggered positive effects.

In the 1980s, for example, Germany imported its laser equipment. The country's machine-tools sector recognised the laser's great potential as a tool of the future and then, through efficient research support, Germany developed into a leading provider of optic technologies. Today, Germany produces 40 percent of all lasers used in materials processing. Revenue of laser manufacturers has increased more than tenfold, to € 1 billion per year. Manufacturers of optical components and devices now employ 110,000 people in Germany. Over 50,000 additional jobs have been created in recent years

in this sector alone, and lasers also create jobs at laser-using companies and institutions. This is also due to effects in the machine-tools sector, since modern machines and robots are able to move their appendages with great precision only because they have optical systems for spatial orientation. Dental patients also profit from laser technology; optical systems, for example, make it possible to fit dental work such as bridges perfectly to patients' mouths and jaws. Use of optical technology in such applications eliminates the need for subsequent correction, thereby providing top quality at reduced production costs.

Today, Germany has one of the world's most modern IT sectors. According to the OECD, an average of 0.38 percentage points of Germany's annual economic growth rate can be attributed to use of information and communications technologies. Under the aegis of the Fraunhofer Society, the Federal Government has created Europe's largest IT research institution. Via its "IT Research 2006" programme, the Federal Government is providing a total of € 3 billion, with the aim of strengthening innovation in this sector for the long term. Europe's own "Silicon Valley" has been created in the Dresden region, with considerable support from the BMBF. All in all, this effort has mobilised € 6 billion of additional value creation, and directly created 11,000 new jobs. Additional secure jobs will be created as well in this area. In October 2003, an Advanced Mask Technology Centre (AMTC) for development of photomasks for chip production was opened. This project is also tied to the BMBF's research support.

The example of Dresden also shows how education and research complement each other: The arrival of semiconductor companies has created an impressive network of study programmes at universities in the Dresden area. Over the past few years, the Federal Government, working in co-operation with the "social partners" (employers' and employees' representatives), has established a number of initiatives aimed at meeting the IT sector's demand for qualified employees, including the "Green Card" programme, a system for further training in IT and a programme for work-process-oriented further training.

Also in recent years, working in the framework of its support for R&D in multimedia, the Federal Ministry of Economics and Labour (BMWA) has pursued a strategy, in co-operation with various market competitors, for accelerating development and testing of systems for electronic legal and business transactions. One relevant example is the MEDIA@Komm project, which is aimed both at modernising administrative structures and at developing "eGovernment" as a future-oriented economic sector with new potential for growth and employment. In the MEDIA@Komm framework, over 300 eGovernment solutions have been created at the

municipal level over the past three years, including some 200 with provisions for use of legally binding digital signatures. At the same time, standards for secure, legally binding data exchange have been created, standards that have also become accepted at the European level. In March 2004, a new measure, MEDIA@Komm-Transfer, was launched, with the aim of accelerating the spread of "best-practice" examples in eGovernment and of standardising additional, related specialised procedures. MEDIA@Komm-Transfer is also part of DeutschlandOnline, the overall strategy of the Federal Government, the Länder and municipalities for integrated eGovernment solutions in Germany.

Biotechnology is a key technology of the 21st century. Promoting biotechnology is thus a central priority of the Federal Government's research policy. Support for biotechnology has led directly to the emergence of 25 "bio-regions" in Germany, with some 600 young companies – 360 of which are in the biomedical sector. This effort has made Germany a European leader in this category. Many bio-regions, in addition to receiving public-sector funding, have been able to mobilise significant amounts of private capital for establishment of biotechnology companies.

The close links between biotechnology and medicine are lighting a path that points directly toward the future. Many of today's new medicines would never have become available without biotechnological procedures. The National Genome Research Network (Nationales Genomforschungsnetz), which the Federal Government has supported since 2001, is working to reveal the molecular causes of the most common serious diseases. To date, this effort has produced over 1400 publications, some 80 patent applications, 68 products and six start-up companies.

Germany has traditionally been a leader in medical technology. German companies are among global leaders in development of state-of-the-art imaging procedures such as CT and nuclear magnetic resonance tomography, as well as of related therapeutic applications and procedures. With some 100,000 employees – primarily in SMEs – medical technology is an important economic sector, with annual revenue of over € 10 billion. Half of this revenue is generated through exports. This industrial sector is highly dynamic, with growth of about 5 percent and very short innovation cycles: over half of its revenue is generated with products that have been on the market for less than two years.

Nanotechnology promises to provide the next great leap in innovation. Most German firms view nanotechnology as a decisive new competitive factor and as a sector with the potential to generate up to 38,000 new jobs in the coming years. Germany now ranks second in nanotechnology

research, behind the U.S. Since 1998, the BMBF has increased its support funding in this area by 220 percent. "Centres of excellence", which have received funding since 1998, have sparked the formation of networks linking German research with users of the new technology. As a result, an excellent basis for economic implementation of nanotechnology has been created. In February 2004, the BMBF launched a new phase of support with its framework concept "Nanotechnology conquers markets – German future-oriented campaign for nanotechnology" ("Nanotechnologie erobert Märkte – Deutsche Zukunftsoffensive für Nanotechnologie"). The new concept focuses relevant support for nanotechnological applications in areas such as automaking, lighting technology, pharmacy and medical technology and semiconductor production.

The market for sustainability-oriented products and services and for advanced environmental technology has been growing dynamically. Research in the interest of a sustainable economy promotes Germany's economic competitiveness and ecological viability – and it increases the demand for better qualifications and improves jobs themselves. Some 900,000 people in Germany are employed in environmentally oriented and sustainability-oriented jobs – about as many people as those working in road vehicle construction. Innovations developed with the BMBF's support tend to unfold benefits throughout many different economic sectors. Two examples that help conserve water resources and prevent pollution: Innovative glues and adhesives that release their hold under defined conditions, i.e. that can be "switched on and off" – and thus used in both assembly and recycling of a broad range of products –, and water-free dyeing and cleansing processes using super-critical liquids.

As such examples show, Germany's future lies within our knowledge and skills. To grow economically and create new jobs, Germany needs superbly qualified people, a top-quality research sector and development of new technologies.

1.2 Instruments of research funding

Different procedures are used for research funding, in keeping with the specific aims in each case. In recent years, the Federal Government has strengthened its competitive awarding procedures, in order to enhance the efficiency of support. Between 1998 and 2004, for example, the BMBF's project support was expanded by 32 percent. Project support fosters competition among researchers, thereby providing impetus for top performance. It brings science and industry together and has developed into a driving force for innovation in central areas. In addition, the Helmholtz Association's institutional funding has been placed on a competitive, programme-oriented basis.

1.2.1 Institutional funding

Basic research must be given a free rein to develop in accordance with its own needs. This is why the Federal Government and the Länder, in supporting organisations active in basic research, provide most of their funding on an institutional basis. In each case, the percentage of a research organisation's total budget that is provided as basic institutional financing depends on the organisation's profile.

Universities are the basis of Germany's research system. They train each new generation of young scientists, thereby maintaining close links between teaching and research. Increasingly, basic financing provided to higher education institutions – funding for which the Länder are responsible – is being tied to performance indicators. Along with basic financing, project funding from industry and from research sponsors – such as the BMBF or the EU Commission – has increasingly been promoting greater orientation to applications and fostering competition leading to more efficiency.

The Deutsche Forschungsgemeinschaft (DFG) plays an important role in support of knowledge-oriented research. The DFG awards its funding on a competitive basis, to winning project proposals – especially from universities and research institutes. This approach ensures that supported projects provide the necessary efficiency and quality.

Along with its higher education institutions, Germany has a traditionally rich, highly differentiated non-university research landscape.

Scientists of the Max Planck Society (MPG) primarily carry out knowledge-oriented basic research. This is why nearly 90 percent of the MPG's budget is provided as basic financing. Adolf von Harnack, the first president of today's Max Planck Society, once formulated the following maxim with regard to the best way to establish a research institute: "Take an outstanding scientist and then build an institute around him". This maxim reflects the conviction that pure research, exploring new frontiers, thrives best when the outstanding men and women who carry out such research are free to follow their own curiosity. The success of this approach is manifested in the large number of Nobel Prizes that MPG scientists have won.

The Helmholtz Association (HGF) is another important pillar of the German research landscape. Basic financing accounts for some 90 percent of the funding for its 15 centres, which conduct both basic research, with large experimental facilities, and long-term research projects in the public interest, in areas such as health care, aerospace, energy, transport and the environment.

On the other hand, basic financing accounts for only about 40 percent of the total budget for the Fraunhofer Society (FhG), which is highly application-oriented. Basic

financing for the FhG funds preparatory research that enables Fraunhofer institutes to develop their competences continually and to maintain their contacts to the academic world. Since the FhG's basic financing is linked to the third-party funding that the organisation is able to attract, the FhG has a high incentive to mobilise such outside funding, especially from the business sector.

The 80 institutions of the Leibniz Association (WGL) differ widely in their profiles. The WGL's spectrum ranges from scientific service organisations to institutes oriented to basic research. As a result, the various Leibniz institutes differ in the percentage amounts (with respect to their overall funding) of third-party funding that they raise.

In addition, the Federal Government and the Länder maintain their own departmental research organisations. These organisations are charged with developing the necessary scientific foundations for the ministries' decisions and tasks. In addition to advising policy-makers, the organisations carry out scientifically oriented, government-based tasks and conduct supportive, preparatory research. Their research activities, which are primarily application-oriented, also provide scientific findings that benefit the public at large.

1.2.2 Project funding at the interface between science and industry

In scientifically mature areas, findings and applications are often not far apart. In such areas, there is no obvious boundary between basic research and applied research. For industry to be able to absorb and act on the newest research findings, and for researchers to be able to answer users' questions, academic researchers and users must be able to maintain close ties and contacts. Project support of the Federal Government, the Länder and the EU thus especially promotes co-operation between research institutes and industry.

The Federal Government has established research-support programmes for economically attractive fields – such as biotechnology, nanotechnology and information and communications technologies. Applicants – normally, collaborations of researchers and companies – submit project-based applications for funding. Companies are reimbursed for only part of their research costs. Because they have to co-fund research projects with their own money, companies have decisive interest in defining project aims and in implementing research findings. The leverage exerted by state research support is more extensive than this: Studies show that every euro spent by the public sector on average mobilises one extra euro in addition to the compulsory co-funding by industry. Such investments thus strengthen industrial innovation effectively.

Support programmes run for several years. It is important that they be properly balanced: On the one hand, applications need a certain amount of time in order to reach maturity; on the other hand, they should not become permanently dependent on support. Numerous experts, from both the science sector and the practical spheres in which results are applied, advise the Federal Government in designing support programmes and monitoring their success.

In addition to collaborative-research projects bringing together partners from science and industry, promising individual projects are also supported. Concentration on key projects enhances the visibility of project support – and, thus, its effectiveness in sending out signals.

1.2.3 Centres and networks of excellence

Regional clusters are particularly effective frameworks for fostering ongoing co-operation, outlasting individual projects, between researchers and users of results. Innovation-research findings confirm: Regional concentration of excellence stimulates innovation-friendly climates. The most prominent example of this principle at work is Silicon Valley, a relatively small area that is home to large numbers of research institutions and IT companies. Such local concentration promotes exchange and interaction and creates a special social climate. Such an environment fosters close links between universities, research institutions, high-technology companies and venture-capital providers. Excellent research centres spin off high-technology companies that, in turn, attract new companies, with complementary strengths, to the region. Such centres function as magnets for complementarily positioned companies and institutions, thereby continually increasing their attractive power. Via such mechanisms, a regionally prominent centre can develop into an internationally prominent one.

Germany has a highly differentiated research landscape that has grown over time, a landscape in which non-university research institutions play a much larger role than they do in other countries. For this reason, the BMBF has for years stressed the importance of subject-area-oriented networking of science sectors at universities, non-university research institutes and companies that carry out research. Intensive networking – across the boundaries of institution membership – is an indispensable basis for formation of clusters with enough "critical mass" to attain international leadership.

Innovative companies, research institutes and good university departments are also found outside of such major centres, however. Especially in highly specialised and newly emerging fields, the relevant players are often located far

apart and are known to only small groups of experts. The totality of the country's existing resources is thus often overlooked – and its potential is not used to the fullest. For this reason, it is also important that national competence networks be formed. The Federal Government directly supports the establishment of such networks. Such support helps networks' strengths to become known outside of small, well-informed circles of experts. This is important, since, in international competition, Germany needs to publicise its strengths more intensively and become more obviously attractive as a location for research.

In recent years, support of regional centres of excellence and national competence networks has become a central instrument of support. In nearly all important technological areas, excellent centres and networks are being supported that were selected through a competitive process. In 1995, with the "BioRegio" competition, the BMBF began building German biotechnology centres. Additional competitions followed, in areas that included nanotechnology, optical technologies and medical technology. Specific measures for the new Länder include InnoRegio, a regions' competition that is not limited to specific subjects, Innovative Regional Growth Cores and Centres for Innovation Competence. Effective contributions are also being made by the programme "Support of innovation networks" (InnoNet), which is supporting research networks linking small and medium-sized companies and research institutions, and "Network Management East" (NEMO), a competition-based support programme of the Federal Ministry of Economics and Labour (BMWA).

The "kompetenznetze.de" Internet portal gives German competence networks and centres of excellence the opportunity to jointly present themselves, and their capabilities, to an international public. The portal is designed to serve as a guide for national and international target audiences. Today, over 100 selected networks, representing 20 different fields of innovation and 30 regional centres, are now presenting themselves at www.kompetenznetze.de.

1.2.4 Indirect support

Indirect support is aimed at small and medium-sized companies, across technological and sectoral boundaries. The Federal Ministry of Economics and Labour (BMWA) supports technology-oriented start-ups and provides incentives to mobilise investment capital for young, innovative companies. Via programmes open to a wide range of sectors and technologies, R&D co-operation and networking between companies and with research institutions is supported. Such efforts are aimed at intensifying co-operation and technology transfer between science and

industry, and at preparing the basis for innovative networks. The BMWA also supports technological advising and qualification for small and medium-sized companies and for innovative crafts companies. The aim of such efforts is to support small and medium-sized companies in using state-of-the-art technologies and to enhance such companies' research and innovation competence.

1.3 Thinking about tomorrow – today

The future is open. This especially applies to research. After all, research explores the things we do not yet know.

However, many of society's challenges – such as creating secure jobs and combating disease – would be impossible to master without research. Therefore, it is especially important for research policy to remember the following: We must think about tomorrow – today! As a result, we're always asking ourselves the following questions in our research policy:

- Are we focussing on the right future-oriented topics and priorities in research funding?
- Have we overlooked any important topics, thereby endangering our country's ability to innovate in international competition?
- Is our research support helping to solve the problems of our society and our world?

The BMBF considers such questions via the following two approaches: Firstly, it continually reviews existing subject-related research-support programmes for new, future-oriented topics. Over the past few years, the BMBF's research-support programmes have become dynamic, "learning" programmes able to react quickly to shorter and shorter innovation cycles. Secondly, this continuous screening is complemented by the FUTUR process, which is not limited to any single topic. This keeps interdisciplinary efforts, especially those that do not fit within the existing research-support structures, from falling through the search "grid". While subject-related research-support programmes are usually focussed on further development of existing lines of research and technology, FUTUR works from societal developments and changes and considers how research and technology policy can help solve societal issues.

FUTUR is a dialog-based process that involves experts from science, industry, associations and NGOs, including creative, innovative thinkers, irrespective of age. Some 1,500 people have participated in the FUTUR process to date – the

BMBF invites broad participation in identifying its research-support areas. The key results of the FUTUR process include "lead visions" for research policy. Such visions highlight the

directions in which society may be developing, along with the ways research and technology could contribute to such development.

2 Current political aims and measures

Europe is to become the world's most dynamic knowledge-based economic area. This goal was adopted by the EU Member States' heads of state and government at a meeting in Lisbon in 2000. In keeping with this aim, Member States' expenditures on research and development are to grow to 3 percent of gross domestic product (GDP) by 2010. Of these expenditures, industry is to contribute 2/3 and the state is to provide 1/3. In 2003, Germany's percentage in this category was 2.5 percent – up from less than 2.3 percent in 1995. Industry provided 2/3 of the expenditures, and the state provided 1/3. Additional efforts will have to be made if the 3% target is to be reached.

The 3% target is not an end in itself. A country's expenditures on research and development are an important measure of its support for innovation and of its innovation capability. In terms of R&D expenditure as a percentage of GDP, Germany ranks third within the EU, behind Sweden and Finland, and ahead of countries such as France and the UK. On the other hand, important international competitors such as Japan and the U.S. have shown greater commitment in this area than Germany has. Consequently, the only way to improve Germany's position in the long term is to intensify its investments in its future. Experience shows: Countries that place a high priority on education, research and innovation achieve the highest rates of economic growth. To remain successful in innovation, Germany must be strong in education and research.

Without a strong educational sector, we will face growing shortages of skilled people. Without research, we will lack ideas for innovation. Without innovation, we will lack secure jobs – which are the basis for sustained prosperity and social peace. This is why we must strengthen our most important resources: our human resources (the knowledge and skills of our people), our technological capabilities and our companies' ability to innovate.

Germany must intensify its focus on the real bases of its prosperity. Innovation is the ideal road that leads to the Federal Government's central goal – safeguarding and creating jobs. On the other hand, policy-makers cannot simply tell people and companies to be innovative.

This is why the Federal Government has reached an agreement with leading representatives of industry, the unions and the science sector calling for a "Partners for Innovation" initiative. The aim of this effort is to strengthen the German innovation system, on all levels. This will involve reducing and eliminating hindrances to innovation and awakening new confidence in our country's real capabilities. The "Partners for Innovation" are being supported by an "innovation bureau", located in Berlin.

The Federal Government has taken the following first steps in this initiative:

1. High-tech master plan

Innovative small and medium-sized companies are a key driving force for growth and employment. At the same time, the sluggish growth of the past few years has left its mark on innovation and start-up behavior. Consequently, one of the central challenges for a future-oriented policy is to eliminate hindrances to the growth of innovative companies, to provide a growth-friendly framework and to support start-ups. With its initiative "Innovation and future technologies in small and medium-sized companies – High-tech master plan", the Federal Government has presented a package of measures for supporting innovative small and medium-sized companies. This initiative stands on four pillars:

- Improving the framework for technology-oriented start-ups,
- Expanding and enhancing research and innovation strategies in small and medium-sized companies, via a newly designed, expanded range of research funding programmes,
- Promoting co-operation between public-sector research and small and medium-sized companies,
- Combating shortages of skilled people via energetic education and qualification policies.

2. "Information Society Germany 2006" master plan

In December 2003, the Federal Government presented a master plan for development in information and communications technologies, based on the insight that Germany cannot strengthen its growth and competitiveness unless it has a leading position in the global information society: its action programme "Information Society Germany 2006". Information and communications technologies accelerate innovation in industry, science and society. Over 80 percent of Germany's exports now depend on the use of modern information technologies and electronic systems. IT research is one of this programme's emphases.

3. Promotion of excellence through top-class universities and a network of excellence in the science sector

Germany has many good universities and research institutions. What it lacks, however, are top-class universities that have worldwide reputations and attract the best minds from around the world. For this reason, the Federal Government has proposed a competition that is open to all German universities. The Federal Government and the Länder have agreed to use competitive procedures to initiate a "spiral of performance" aimed both at developing elites and at enhancing quality throughout Germany's higher education and science sectors. Excellence is dynamic, rather than static, constantly redefining itself; therefore, the competition will be repeated.

4. Pact for research and innovation

To give research organisations planning security, the Federal Government intends to increase their funding in a predictable way. At the same time, it plans to eliminate bureaucratic hindrances. In return, the Federal Government expects this reliable financial basis to be applied toward measures to enhance efficiency and quality in research and science. The central objectives include:

- Promoting quality and performance through competition, both within and between research organisations,
- Promoting co-operation and networking,
- Promoting the development of young scientists, to provide a self-renewing intellectual basis,
- Providing extra funding for new, unconventional research approaches.

5. Strengthening support for research projects in selected emerging areas

The Federal Government plans to strengthen its application-oriented research and technology support especially in those emerging areas that will have strong leverage on growth and employment. Such areas include biotechnology and nanotechnology, which are dynamic new growth fields, and basic technologies such as information and communications technologies, which drive growth in many different industries and sectors. The BMBF plans to work with science and industry to define "lead innovations" that will strengthen outstanding existing resources along value-creation chains with major economic potential. It also plans to make its project support more mission-oriented in relevant areas in the future.

2.1 The task: increasing investments in the future

The further the boundaries of knowledge are pushed, the more expensive and complex research becomes. Research solves the simple problems first, before it turns to the more difficult ones. How relatively simple the laws of mechanics are in comparison to the human genomic code or the processes at work in the human brain! Researchers such as Galileo Galilei (1564–1642) were able to make revolutionary discoveries with simple tools and equipment. Today, we need space-based telescopes, enormous accelerators and super-computers to achieve similar breakthroughs.

The continued growth of knowledge will be assured only if the research sector's continually growing needs for resources can be met.

In 2003, Germany spent some € 53 billion on research and development. This figure works out to over € 600 per capita, or 2.5 percent of the country's gross domestic product (GDP). Since 1998, the Federal Government has made considerable efforts to increase its expenditures on research and development. Whereas from 1992 to 1998 R&D expenditures decreased by an amount equivalent to about € 670 million, between 1998 and 2003 they grew by over € 1 billion. And: Expenditures on education, research and development will continue to grow markedly in the future.

2.2 Promoting and challenging human resources

Research is carried out by people. For the Federal Government, this elementary insight translates into a need to link education and research policies closely. Well-educated people are the knowledge society's most important resource.

2.2.1 Begin in the schools

A good education is each person's best insurance policy against unemployment. For a country, education is the basis of economic prosperity. A country such as Germany, poor in natural resources, must make the best use of its people's talents and skills. For this reason, we need a culture of education that supports and challenges children at an early age. A child who gets excited about natural sciences is likely to become a scientist when he or she grows up.

A first step in this direction has been taken with the investment programme "Programme for the Future, Education and All-Day School" ("Zukunft Bildung und Betreuung"), via which the Federal Government is providing a total of € 4 billion for establishment and expansion of all-day schools from 2003 to 2007. All-day schools provide more time for fostering individual talents and for giving individual attention.

In addition, the BMBF, in co-operation with the Länder, is promoting efforts to strengthen mathematics and science skills. For example, the SINUS programme is enhancing efficiency in mathematics and science teaching. The first SINUS wave is reaching over 700 schools, in thirteen of the sixteen Länder.

The BMBF projects "Chemistry in Context", "Physics in Context" and "Learning Laboratory" are aimed in the same direction: Enabling children to learn science through play. For similar reasons, the BMBF also supports the Länder competitions designed to encourage and challenge gifted students, such as the "Jugend forscht" youth science project contest and the "National Computer Science Competition" ("Bundeswettbewerb Informatik").

2.2.2 Increasing the percentages of pupils who go on to higher education

The future of our economy and society depends decisively on the qualification level of our population. Growing requirements in the employment market call for intensified efforts to encourage young people to go on to higher education. By the year 2015, Germany will need to add about 1 million more highly qualified, university-educated people to its workforce.

For this reason, more young adults need to begin university studies – and complete them successfully. On the average for all OECD member countries, about 46 percent of the people in each age group enrol in higher education. In Germany, the corresponding figure has grown from 27.7 percent in 1998 to 35.7 percent for the 2003 academic year. The current aim is to increase this figure to at least 40 percent. At the same time, the average duration of studies, and the number of students who discontinue their studies, both need to be reduced.

By improving individual support of students, via reform, in 2001, of the Federal Training Assistance Act (BAföG), the Federal Government has taken measures to reduce obstacles to university studies. From 2000 to 2002, the number of students receiving support increased by 72,000. In addition, the educational loan programme introduced in 2001 has proven to be a flexible, non-bureaucratic instrument that can overcome temporary financing shortages, effectively and efficiently.

Young people justifiably expect our universities to offer them an education that is of high quality, has a practical orientation and includes an international perspective. To ensure that the German higher education system remains internationally competitive, the Federal Government is strongly supporting efforts to attain the objectives of the Bologna Process, which commenced in 1999 and calls for the creation, by 2010, of comparable higher education structures in all European countries – and, thus, of a standardised European higher education area.

The Federal Government is ready to take an active part in this process. It has offered to support and assist the Länder and the nation's universities in implementing the Bologna Process. The primary task in this regard is to introduce a system of consecutive bachelor's and master's degree programmes throughout the country. This effort will also include introduction of the European Credit Transfer System (ECTS) for academic achievement, along with the Diploma Supplement and quality assurance, in keeping with international standards, via accreditation and evaluation.

2.2.3 Top-class universities can attract the best minds to Germany

In addition to a solid base of universities offering high-quality programmes for large numbers of students, Germany also needs top-class universities with worldwide reputations that can attract students and leading academics and scientists from around the world. German universities must be enabled to compete, in both research and teaching, with world-renowned universities such as ETH Zurich, Stanford

University and Oxford University. In light of today's globalised knowledge markets, true excellence in teaching and research must be defined in a global – rather than regional or national – context. To be a top-class university, a higher education institution must show excellence and research performance in considerably more than one area of science. It needs a broad basis in order to be able to quickly absorb and be inspired by new research opportunities at the periphery of established subject areas and disciplines. And new ideas are of course most likely to emerge from environments of excellence.

By announcing its intention to promote the growth of top-class universities, the Federal Government has initiated development toward such excellence. The Federal Government and the Länder have reached agreement on providing extra funding for the following three areas: Structural growth and development of universities into top-class universities via an orientation to areas of science that are conducive to reputation-building; creation of centres of excellence and of clusters, designed to enhance co-operation between university and non-university research; and establishment of graduate schools for young scientists.

2.2.4 Strengthening support for young scientists

Germany will be able to maintain its position as a leading nation in science and industry only if a great many of its young people receive a high-quality academic education. Talented young scientists must thus be groomed, via targeted support, for later leadership in science, industry, culture and society. Germany needs top-quality people in all areas.

Supporting and promoting young scientists is the responsibility of universities, but it is also the responsibility of all other research institutions. Teams of young scientists play an especially important role in giving young scientists opportunities to carry out research of their own choosing. The Federal Government is thus aiming to at least double the country's numbers of groups and teams of young scientists by 2010 – especially in subject areas with shortages of young scientists.

The "Pact for research and innovation" thus includes plans for expansion of structured graduate-studies and doctoral programmes – in both universities and non-university research institutions. Trans-boundary co-operation programmes, such as those of the DFG's Research Training Groups and those of the International Max Planck Research Schools, which are operated jointly with the universities, are leading the way in intensifying internationalisation.

One of the key factors that young researchers take into consideration when deciding about an academic career

in Germany is whether they will be offered opportunities for independent work in research projects. To enhance Germany's attractiveness for excellent young scientists from Germany and abroad, the Federal Government has introduced "junior" professorships. With such professorships, young scientists receive the opportunity to research and teach under their own responsibility as soon as they turn 30 – or ten years earlier than before. The Federal Government is providing a total of € 180 million for the junior professorship programme.

The key now is to enhance perspectives for young scientists' long-term career planning. Excellent young scientists must be offered attractive career tracks in research and science. In this context, intensified use of the "tenure track" model is one way to enhance opportunities in the international competition for the best young researchers.

2.2.5 A brain-gain instead of a brain-drain

The research sector requires close links to international partners. The Federal Government is thus supporting the science and industry sectors' efforts to expand their research co-operation both in Europe and around the world.

At the same time, the Federal Government is aiming to make Germany one of the world's most attractive locations for young scientists from Germany and abroad. The initiative "Brain Gain instead of Brain Drain" has significantly enhanced German universities' attractiveness in this regard. The number of foreign students at Germany's universities increased by over 10 percent in the 2002/03 winter semester. This success was due in no small measure to Federal-Government-supported marketing campaigns promoting Germany's education and research sectors. German universities are again well-represented in the international education market. The Wolfgang Paul and Sofia Kovalevskaya prizes, which were awarded for the first time in 2001 and 2002, respectively, also played a role in attracting leading international scientists to Germany. The initiative "Export of German study programmes", financed from UMTS license proceeds, has enabled German universities to establish locations abroad. For example, the German University in Cairo opened in October 2003. The Federal Government plans to continue its support for the successfully launched marketing campaign for Germany's education and research sectors.

2.2.6 Promoting personnel mobility

Germany's universities and research institutions must offer attractive conditions that can succeed in the tough interna-

tional competition for the world's best minds and attract outstanding scientists to Germany. The Federal Government and the country's science and research organisations thus wish to respond to the realities in this highly dynamic employment sector by means of modern salary systems – including, for example, improved opportunities for variable, merit-oriented compensation and more flexible work-time arrangements. Merit-orientation compensation has already been introduced in the salary system for professors. Obstacles that currently keep researchers from moving between the worlds of science and industry need to be reduced and eliminated so that new ideas can be translated into applications more quickly. After all, knowledge is transferred most efficiently via people.

2.3 Modernising the research landscape's structures

Change is the only constant. This also applies to the research sector, which has to adapt to the constantly changing conditions of a knowledge society that is increasingly global. In the last legislative period, financing for HGF centres, which was previously oriented to individual centres, was converted into a programme-oriented, competitive support system using content-based criteria and requirements. As a result, the fundamental principles applying to Federal and host-Länder funding for HGF facilities include competition, transparency, quality and efficiency. At the same time, HGF institutions have been given greater responsibility and flexibility in designing and evaluating research. For the future, the Federal Government is working to achieve a "Pact for research and innovation", with German research organisations, that will link a financial planning security with reforms and structural innovations on the part of the research organisations. Other important efforts in this area include restructuring of the division of competencies between the Federal Government and the Länder, building of new large-scale research facilities and evaluation of departmental research.

2.3.1 Restructuring the division of competencies between the Federal Government and the Länder

On 16/17 October 2003, the Bundestag and Bundesrat (Germany's upper and lower houses of parliament) jointly installed a "Federalism Commission" for modernisation of the country's federalist system; among its tasks, this commission is reviewing division of competencies, and the financial relationships, between the Federal Government and the Länder,

especially the "joint tasks" (Gemeinschaftsaufgaben) and mixed financing arrangements. In the Federal Government's view, the Federal Government and the Länder should retain joint responsibility for the areas of educational planning and research support. On the other hand, at least partial elimination of mixed-financing arrangements would meet needs for a clearer division of tasks and efficient, transparent design of structures for decision-making. In light of the science sector's growing internationalisation, of increasing globalisation in private industry and of the importance of research and development to Germany's competitiveness, Germany's research and innovation system needs to upgrade its research policy, enhance its performance and heighten its transparency.

2.3.2 Intensifying networking among research organisations

Germany has a highly capable and highly differentiated research landscape. The various research organisations pursue aims that are different but not unrelated. In light of the research sector's growing funding needs, and of the tight constraints on public-sector budgets, research policy will have to give top priority to funding efficiency. For this reason, the Federal Government supports the Science Council's recommendation for intensified consultation and co-ordination between the various research organisations. This effort should be based on portfolio analyses for important research areas, designed to identify strengths and weaknesses in light of international comparisons. The Federal Government is also strongly urging that research organisations intensify their efforts in the area of inter-organisational, interdisciplinary research projects.

2.3.3 Increasing use of competition in awarding of research funding

In an international comparison, there is too little competition between and within Germany's research institutions. Research organisations need to intensify use of competition procedures in awarding funding. Competition is the best way to improve quality. One of the aims of the Federal Government's "Pact for research and innovation" is to strengthen emerging efforts to enhance basic funding flexibility via establishment of central funds, within individual science institutions, from which institutions can make funding awards in accordance with performance criteria, under their own responsibility.

2.3.4 Being willing to take risks via new funding procedures

"Quantum leaps in innovation" often take place outside of established fields. It is vitally important that young scientists who wish to enter new research fields have the opportunity to pursue original approaches with great innovative promise but without any guarantee of success. Existing funding procedures are too rigid for this. The Federal Government is therefore acting on the Science Council's recommendation and in co-operation with science and research organisations to establish highly simplified funding mechanisms that complement conventional procedures.

2.3.5 Ensuring that research is of high quality

"Excellence" must remain the main research policy objective for science and for research funding. Evaluation of research institutions and scientific organisations is, and remains, a central element of quality assurance.

Results of previous evaluations are being implemented on an ongoing basis. For example, in response to a system evaluation, the DFG's review procedures were modified, and a standardised financing key (58 percent from the Federal Government; 42 percent from the Länder) was introduced, with the aim of enhancing the DFG's flexibility in designing its programmes. Via its International Max Planck Research Schools, the Max Planck Society has expanded its support for young scientists and intensified its co-operation with universities.

In 2001, financing for Helmholtz centres was placed on a programme-oriented basis. To this end, the Helmholtz Association's activities were divided into six research areas: structure of matter, transport and space, key technologies, energy, health and earth and the environment. The centres' research plans are reviewed, at regular intervals, by international experts. Initial evaluations have already been carried out for four of the six research areas. The reviews are providing the basis for future financial priorities. A total of 20 percent of the HGF centres' funding is for the centres' own discretionary use, in a category separate from funding for the various programme areas. In addition, a President's "Impetus and Networking Fund" has been established to support co-operation between the centres and networking between HGF centres and the overall national and European research landscape.

2.3.6 Evaluating departmental research

Evaluations of the German research landscape carried out to date have initiated important reforms and contributed significantly to enhancing the efficiency and safeguarding the quality of German research. Along with the country's major research institutions, the Federal Government's departmental research institutions have also been undergoing evaluations. For example, in 2002, the Federal Ministry of Economics and Labour (BMWA) carried out an evaluation of the Federal Institute of Physics and Metrology (PTB), and this year it is evaluating the Federal Institute for Materials Research and Testing (BAM). Both evaluations have been conducted by commissions of international experts. The Science Council's recommendations of January 2004 regarding departmental research within the sphere of the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) are of significance with regard to the further development of the entire system of departmental research. In particular, the Federal Government agrees with the Science Council's recommendation that competition-based elements should also play a greater role in departmental research.

In spring 2004, the Federal Government requested the Science Council to review selected departmental research institutions in light of their special tasks and purposes, giving special attention to the need for such institutions to conduct independent scientific research and to the quality of their work.

2.3.7 Meeting the need for large-scale research facilities

Research excellence is not possible without a state-of-the-art research infrastructure. At the Federal Government's request, the Science Council has reviewed and evaluated nine proposals for new large-scale research facilities. On the basis of the Science Council's recommendations, the Federal Government has decided to support procurement of the HALO research aircraft; construction of the HLD magnetic field laboratory in Rossendorf, near Dresden; construction of the X-FEL free electron laser and conversion of the PETRA ring accelerator into a state-of-the-art synchrotron-radiation source, at the DESY facility in Hamburg; and expansion of the GSI facility in Darmstadt.

Construction and maintenance of large-scale research facilities create major challenges for a country's research resources and, thus, for its entire science and research system. This is why the Federal Government also has to rely on international investors for expansion of the DESY and GSI facilities. At the same time, it is necessary for the respective host Land,

and German science organisations, to participate in financing construction and maintenance of the new large-scale facilities.

2.4 Promoting technologies for new markets

Research produces ideas and concepts for new products, processes and services. Without innovation, we can neither protect existing jobs nor create new ones. As a wealth of examples shows, we can achieve the Federal Government's central aim – protecting and creating jobs in Germany – only if we mobilise new forces for growth via research, new technologies and innovation.

2.4.1 Stimulating research and development in the business enterprise sector

Companies that wish to survive and thrive in national and international markets must engage in research, development and innovation. Stimulating research and development in industry thus pays off in two ways: Research findings and new knowledge bring rewards to researchers and contribute to economic growth and employment. For years, companies' revenues abroad have been growing faster than their domestic revenues. This trend is especially pronounced in research-intensive industries. In 2002, such industries achieved some 55 percent of their revenue abroad. The Federal Government's research policy is thus aimed at helping industry protect and improve its technological capabilities and at supporting it in its efforts to enhance its image and presence in the global competition.

The Federal Government's research policy is aimed, firstly, at enhancing the research-relevant and innovation-relevant framework for young, innovative companies, for example, by encouraging the establishment of technology-based companies, since start-ups play a special role in economic use of new technological know-how. Young, researching technology-based companies absorb research findings, position themselves, armed with concepts and product ideas, in new markets and create future-oriented, internationally competitive jobs. The Federal Government is thus working to eliminate hindrances to the establishment and growth of new technology-based companies. Special attention is also being given to the resources available to young, growing technology companies in financing research and innovation projects. Issues of financing are among the most common barriers for innovation. In addition, the framework in this area needs to be improved through further reduction of bureaucracy and red tape in the areas of re-search and innovation.

Secondly, the Federal Government has introduced targeted measures for making full use of the potential of the country's innovation system. For example, research and innovation projects are increasingly being carried out in the framework of collaborations involving either multiple industrial partners or partnerships with organisations in both industry and science. The Federal Government's support for such co-operation includes establishment of professional structures for patent exploitation in public-sector research and intensified involvement of small and medium-sized companies in networks for cutting-edge research. Furthermore, the Federal Government is using specialised programmes and indirect support programmes to stimulate research and development in industry.

2.4.2 Intensifying co-operation between science and industry

Our economic future depends essentially on how effectively we make use of the opportunities in new technologies and promote their transfer into commercial uses. We need new technologies, products and services. And research and innovation policy plays a central role in meeting this need. Consequently, R&D support must be focussed primarily on technological developments and processes that exert especially strong leverage for growth and employment. This means:

- Strengthening key basic technologies such as materials technologies, chemical technologies and information and communications technologies,
- Developing new growth fields – such as those in biotechnology and nanotechnology.

In the interest of such aims, project support is being concentrated on research in strategic technology developments and processes identified in co-operation with industry and science – especially on research efforts that span different technologies. Close links with research institutions ensure that such support is integrated, both in substance and strategy, with basic institutional support. The following examples illustrate this approach:

Conventional light bulbs are terrible wasters of energy. The future belongs to more energy-efficient light sources. Progress in nanotechnology is now making it possible to increase the luminescence of white LEDs more than tenfold. This is making such LEDs a highly attractive lighting option for everyday use – and not just for niche applications such as cell phones and flashlights. With its "lead innovation"

NanoLux, the BMBF is supporting industry-led research projects for development of highly versatile white LEDs.

Nanotechnological innovations have great economic importance in the automotive sector as a result of that sector's status as a lead market and technology driver that influences other application areas. At the same time, their importance in this sector results from their potential for the sector's supply industry, which consists mostly of small and medium-sized companies. Support of automotive-sector projects that use nanotechnological know-how for new functionalities is aimed at optimising sustainability, safety and convenience.

Software systems are now commonly integrated into many different types of technical systems and devices that must meet the highest standards of security and reliability. This category includes critical applications in which software errors can cause malfunctions of entire facilities and installations, with disastrous consequences for people, property and the environment. To guard against such risks, suitable methods, tools and development environments for ensuring systems' proper functioning and reliability must be provided and tested. Software verification plays a key role in such provision and testing. Secure, reliable software is becoming a quality feature in products "Made in Germany", a feature that enhances sales opportunities.

Multimedia is providing important impetus for efficiency, economic growth and employment. Development and testing of new multimedia technologies and services is thus an emphasis of the technology policy of the Federal Ministry of Economics and Labour (BMWA). Relevant efforts are aimed at developing new applications for electronic business transactions (eBusiness, eGovernment), eLearning and knowledge management. One of the central challenges involves the information and knowledge society's transition from stationary to mobile systems. Development of completely new hardware and software for mobile multimedia applications, along with pertinent new services and business models, holds great commercial promise.

2.4.3 Providing special support for SMEs

Small and medium-sized companies often lead the way in translating new research and development findings into new products, processes and services. In highly research-intensive industrial sectors, companies with fewer than 100 employees tend to have particularly high levels of R&D involvement. 8,5 percent of these SME's staff is engaged in R&D. These SMEs have research commitments that are easily comparable to those of large companies with over 1,000 employees. However, unlike these specialised companies, many small and medium-sized companies do not achieve the necessary minimum size

in their markets to be able to establish their own R&D departments, carry out research on a continual basis or pursue risky R&D projects on their own. Often, such companies can carry out research and development only in co-operation with external partners in science and industry. Small and medium-sized companies tend to place considerably greater emphasis on co-operation with partners from the science sector than do large companies.

This is why the BMWA, in co-operation with the "Otto von Guericke" Federation of Industrial Co-operative Research Associations (AiF), in a support programme focussing on industrial collaborative research, is supporting pre-competition-phase projects that are initiated, technically assisted and materially supported by industry – especially by small and medium-sized companies. The project results help to compensate for the disadvantages that small and medium-sized companies, without their own research departments, incur in developing innovative new products.

The Federal Government plans to do more to strengthen the innovation and competitiveness of small and medium-sized companies. The focus of relevant support is on young technology-based companies and on R&D co-operation and networking between innovative companies and research institutions. Careful attention is also being given to financing for young, innovative companies, with a view to providing incentives for technology start-ups and mobilising venture capital. Until the end of the 1990s, financing options via venture capital developed very favourably; after the year 2000, financing, especially for start-up and growth phases of young technology-based companies, became scarce, however.

For this reason, in early 2004, the Federal Government launched an initiative entitled "Innovation and Future Technologies in SMEs – High-tech Master Plan". In co-operation with the ERP Special Fund and the European Investment Fund (EIF), a new fund of funds for investment capital was launched; this fund, acting in co-operation with private investors, invests in German venture-capital funds for high-technology start-ups and young, technology-based companies. In addition, suitable divisions were defined between assets-managing and commercial private equity and venture capital funds, to ensure transparent, reliable treatment under tax laws. At the same time, the Federal Government welcomes efforts to permit carried interest of fund initiators to be taxed in accordance with the so called "*Halbeinkünfteverfahren*", whereby only half of shareholder dividends are subject to income tax. All this is improving the taxation framework for young, growing technology companies, and it is giving new impetus to the market for venture capital for early-stage financing. What is more, SMEs are participating strongly in subject-specific research-support programmes. Whereas in

1998 SMEs accounted for about half of all participating companies, in 2002 some two-thirds of all support commitments went to SMEs.

2.5 Research for people and the environment

Science and research play an indispensable role in meeting the challenges of our age. Much is expected of science's ability to solve problems: concepts for dealing with demographic change, impetus for managing economic structural change, progress in the battle against disease, better prediction and management of natural disasters and solutions to the problems of climate change and world hunger. We can shape an attractive future only if we efficiently support research for people and the environment. Fighting disease, protecting the environment, tailoring the workplace to human needs and safeguarding mobility are all important objectives of the Federal Government.

2.5.1 Applying findings from life sciences to medicine

Life sciences are now gaining new knowledge and findings at an unprecedented rate. Genomic research is playing an especially important role in improving our understanding of the causes of disease. Progress in this area is opening up new possibilities for more effective therapies and preventive measures. UMTS license proceeds have enabled the Federal Government to launch the "National Genome Research Network". This network is focussing on the five most common groups of major diseases: cardiovascular diseases, cancer, disorders of the nervous system, environmentally related illnesses and infections and inflammation. The close links between biotechnology and medicine are lighting a path that points directly toward the future. Many of today's new medicines would never have become available without biotechnological procedures.

2.5.2 Expanding research aimed at sustainable development

In recent years, science has shown convincingly that human beings are endangering their own natural environment. The growing world population's continually increasing energy consumption will have dramatic impacts unless effective climate protection policies are applied. And mankind must be able to respond to extreme climate events such as floods, storms and droughts.

These challenges call for a better understanding of the complex natural processes at work and for development of strategies for adapting to global change. The Federal Government is responding to these needs with two new framework research programmes: on "system earth" and "sustainable economy".

2.5.3 Research for the workplace of tomorrow

Innovation is a complex social process in which people play the central role. In recent years, science has shown that people are innovative especially when they have appropriate responsibility and latitude for their actions.

With research on innovative workplaces, and on innovative services, the Federal Government is exploring workplace concepts that provide such latitude and permit employees to make the most successful use of their options. The aim is to provide working conditions that promote motivation, reduce companies' internal barriers to innovation and thus contribute to entrepreneurial success.

2.5.4 Safeguarding mobility – minimising the impacts of transports

Mobility is one of the basic requisites for economic success, societal prosperity and individual satisfaction. At the same time, the negative consequences of the transports resulting from our mobility needs are becoming more and more visible: the world's growing transports produce traffic jams, noise and environmental pollution, and they consume resources and damage landscapes.

One of the Federal Government's key research policy aims is thus to design mobility systems that not only serve economic development and social needs but also protect our natural environment and resources. Research and development can play a significant role in enhancing the performance, efficiency, safety and user-friendliness of transport systems, as well as in improving the international competitiveness of such systems and in protecting jobs in the transport sector.

With its "Mobility and Transport" research programme, begun in 2000, the Federal Government has created the programmatic basis for achieving such aims. The aviation research programme of the Federal Ministry of Economics and Labour (BMWA), which has been co-ordinated with the relevant EU research programme, is also in line with these objectives.

2.6 Promoting women in the research sector

The times when mathematician Emmy Noether (1882–1935) was denied habilitation simply because she was a woman are long past. In today's Germany, more young women than young men obtain a higher education qualification (Abitur). In addition, more women than men, out of each age group, begin higher education studies. And in recent years women have also been catching up with men in the later stages of the educational path, the entryway into research. One out of every three doctoral theses is now written by a woman. On the other hand, only one out of every eight professorships is held by a woman. Nevertheless, the relevant percentage increased from 9 to nearly 12 percent between 1998 and 2002. And the relevant figure for junior professorships is 32 percent. But an international comparison shows that Germany still has a great deal of catching up to do in this category. This fact must be taken as a call for action – after all, equal opportunity for women is not only a matter of social justice, it is also an important factor in the success of a knowledge society.

The Federal Government is working to enhance equal opportunity for women in all areas of society. In doing so, it is concentrating especially on the following areas:

- Encouraging more young women to study and train in the natural sciences and technical fields,
- Increasing participation of women in the information society,
- Increasing percentages of women in management positions in science and research,
- Supporting women starting up in business.

2.7 Strengthening research in eastern Germany

The new Länder now have a state-of-the-art public research infrastructure that compares with the best in Europe. Research institutions such as the GeoResearch Centre in Potsdam, the Max Delbrück Centre for Molecular Medicine in Berlin, the Berlin Adlershof Science and Technology Park, the Leibniz Institute for Neurobiology in Magdeburg and the Leipzig-Halle Environmental Research Centre are recognised centres of excellence that conduct top-level research that is acclaimed world-wide. Eastern Germany's universities are among Germany's best – also for the reason that they provide

especially good support and assistance for their students. The region's higher education institutions have state-of-the-art equipment and laboratories.

As regards universities and public scientific institutions, eastern Germany's research infrastructure is now comparable to that of western Germany.

Many eastern German regions have specific strengths, in the form of qualifications and competencies, that give them a good basis to become growth regions. For example, the Jena "BioRegion" now has an especially dynamic start-up sector in the area of biotechnology. And Dresden, Berlin and Potsdam are also excellent biotechnology centres. The Leipzig-Halle-Bitterfeld region has become one of the world's leading new centres for environmental protection technology. Thuringia and Saxony have gained worldwide reputations as centres for electronics. Saxony-Anhalt and Saxony are creating competitive clusters in the automotive-supply sector. An innovative maritime technology alliance is emerging in Mecklenburg-West Pomerania.

In the interest of its future business success, eastern German industry has developed a comparatively high degree of specialisation in research-intensive key technologies. In so doing, it has been enriching Germany's overall research image and spectrum.

Nonetheless, the region's R&D intensity is still lagging behind that of western Germany, due to the persisting structural disadvantages in the economies of eastern German Länder. One of the region's main structural particularities is a lack of large companies, including a lack of headquarters and research departments of such companies. In contrast to the situation in western Germany, most industrial research in eastern Germany takes place in small and medium-sized companies. Over 40 percent of the region's R&D personnel is employed in such companies, while the comparable figure in western Germany is only about 15 percent. A pronounced shortage of capital hampers urgently required process and product innovation and clouds perspectives for competitive management. Most importantly, however, it hinders start-up of knowledge-based, R&D-intensive companies.

With the various programmes of its "Unternehmen Region" effort, the BMBF's innovation initiative for the new German Länder, the Federal Government has developed a new approach in innovation policy. This approach supports networks of different regional players and strengthens their innovative capability. With joint research and development projects and forward-looking entrepreneurial management, such projects gain competitive advantages in the market. As a result, unique economic and scientific regional profiles emerge, profiles that include new companies and suitable

training programmes. The "Unternehmen Region" elements include InnoRegio, Innovative Regional Growth Cores, Innovation Forums and Centres for Innovation Competence.

Today, five years after the commencement of the Federal Government's support, the InnoRegio-competition networks are producing a great deal of positive news. The following section presents the network of Saxony Anhalt's automotive-supply industry, as a representative example for the 23 regions involved in the programme. Since 1999, a total of nine new companies have been founded in this one InnoRegio region alone. A total of 3,000 new jobs have been created, the total revenue of the participating companies has grown by 30 percent and the region's image has been significantly enhanced via a range of additional co-operative arrangements. The support provided by the BMBF – totalling some € 10 million – has played a significant role in this success.

The successful approach used in InnoRegio, and in the UMTS-funded Growth Cores, is being continued within the "Unternehmen Region" effort by means of new support initiatives. In an effort oriented to the motto "Creating excellence – protecting talent", the Federal Government is supporting top-level research at universities: Centres for Innovation Competence are being established and expanded, and this is readying excellent research and commercialisation resources for international competition. In a first round of funding, six centres with a positive evaluation will receive a total of some € 50 million, distributed over five years, for support of international teams of especially talented young researchers.

Promotion of innovation in eastern Germany continues to have high priority. With a new programme, "Support of research and development of growth leaders in disadvantaged regions – INNO-WATT" ("INNOvative WachstumsTräger" = "Innovative Growth Leaders"), the BMWA's R&D support is being concentrated on promising growth leaders in structurally disadvantaged regions. The aim of this effort is to support promising growth leaders in eastern German Länder and Berlin in developing new products and processes.

The BMWA's PRO INNO programme is providing innovative companies in the new German Länder with major support in carrying out technologically sophisticated R&D projects in co-operation with other companies or research institutions. Each year, the new German Länder receive a disproportionately large share – 60 percent, averaging € 75 million – of this SME-support programme.

In the framework of the BMWA competition "Network Management East" (NEMO), small and medium-

sized companies in the new German Länder are being supported in developing innovative, business-oriented networks. This programme, designed to help eliminate existing deficits in network management, represents a continuation of co-operation support.

2.8 Intensifying internationalisation

Research is another area in which Europe competes with Japan and the U.S. Increasingly, European countries have been learning that they must network their resources if they wish to succeed in today's world. This especially applies to Germany. German industry has strongly internationalised its R&D and investment activities. At present, one out of every four euros that companies in Germany invest in R&D comes from foreign companies. For American companies, Germany is the second most important location for research – after the UK. Conversely, German companies invest in key foreign markets – and not only in production and sales, but also in research and development. The large-scale internationalisation that has occurred in the research sector has not been to Germany's detriment. On the contrary: Germany remains an attractive location for research. Among German companies, those that carry out research abroad have higher levels of R&D intensity in Germany than do those without any such international research. Increasing internationalisation of research activities, and the high quality of research conducted in Germany, are reflected in patent applications: German applications to the European Patent Office, for patents resulting from international co-operation, nearly quadrupled in the course of the 1990s. In the category of patents relevant to the global market, Germany achieved the highest growth of all major industrialised nations.

One of the Federal Government's continuing priorities is to enhance the international competitiveness of the German science and research system and to further intensify the sector's European and international connections. The especially significant achievements in this area include Germany's close co-operation within Europe, its bilateral co-operation, on the basis of agreements on scientific-technical co-operation, with a total of over 50 countries and its involvement in multinational organisations. Support for international studies and research stays by students and young scientists continues to be another priority. The Federal Government is working to make Germany one of the world's most attractive locations for young scientists. Initiatives such as "Brain Gain instead of a Brain Drain" have made it possible for German universities to become established abroad, and they have

helped increase the numbers of foreign students at German universities.

European integration has reached an advanced stage. Institutions such as the European Space Agency (ESA), and the major European research centres CERN and ESO, in which Germany is an active participant are fitting symbols of this integration. The Bologna Process is gradually leading to a unified European higher education area. Relevant efforts include European-wide introduction of a system of consecutive bachelor's and master's degree programmes, of diploma supplement programmes, of the ETCS credit-point system for academic achievement and of quality assurance via accreditation and evaluation of study programmes.

The importance of the EU's research-support programmes should also not be underestimated. The Federal Government is aiming for strong German participation in the EU's Sixth Framework Programme for Research and Technological Development (FP6). Germany's science and industry sectors are called on to take an active role in integrated projects and networks of excellence, and to assume consortial leadership as often as possible. A nationwide network of national contact points is helping German applicants make optimal use of the possibilities afforded by the Sixth Framework Programme. To assist innovative German small and medium-sized companies in finding suitable R&D co-operation partners abroad, the BMWA maintains an "International Technology Co-operation Network", a service organisation with a total of 15 contact points – in 13 central and eastern European countries, in China and in India.

2.9 Conducting a dialogue on research

A number of recent scientific advances, such as those in biomedicine, raise fundamental ethical issues regarding human life – issues that can be resolved only through dialog between scientists, policy-makers and society. Science, the political sector and society are therefore called on to engage in critical, open discussion regarding the opportunities of scientific and technical progress in such areas and, in the process, to highlight the economic interests at stake and weigh the relevant risks – and to eliminate such risks, if possible, or reduce them to acceptable levels. It is important to stress that this discussion does not involve issues that are black and white, i.e. conflicts between "good" and "bad" research – it concerns the joint search for ways of putting the progress and achievements of modern research to responsible use, for our own benefit.

The Federal Government continues to recognise its own responsibility to provide and develop a suitable legal

framework for biomedical research and its applications. In addition to clear legal regulations, there is a need for public discussion and ongoing supportive research into the opportunities and risks of scientific and technical developments in this area. The BMBF is therefore promoting dialogue with the general public, and it is funding research into the ethical, legal and social aspects of the life sciences in particular and into analysis of innovation and technology in general.

In addition, the Federal Government is working within the European Union, and within an international framework, for greater harmonisation of bioethical standards. The Federal Government supports reconciling research-friendly regulations with strict ethical standards.

Responsible discussion about opportunities and risks is possible only when a) there is clarity about what science has actually achieved; b) when the specific consequences of scientific progress are known; and c) when the available options have been clearly outlined. This is the basis on which exchanges between science and society must be conducted. Policy-makers are charged with providing initiatives that promote dialog between science and society – and with supporting relevant ongoing processes until they have become firmly established. Since 1998, the Federal Government, in co-operation with many different partners, has created a wide range of frameworks for participation.

The initiative "Science in Dialogue" ("Wissenschaft im Dialog"), an initiative sponsored by all major research organisations, by the Donors' Association for the Promotion of Sciences and Humanities in Germany (Stifterverband für die Deutsche Wissenschaft) and by the BMBF, is worthy of special mention in this context. This initiative devotes numerous events each year to a specific area of science (a different area each year). A special highlight is the "Science Summer", which lasts for an entire week and is held at a range of different venues. The "Year of Physics", launched in January 2000, was widely seen as a highly experimental effort. Since then, the "Science in Dialogue" initiative has had four successful years. Following a successful first year, the next year, the "Year of Life Sciences", surpassed all expectations. Over half a million people attended the year's wide range of different events, thereby promoting better understanding between science and society. The "Year of Geosciences" and the "Year of Chemistry" have added further chapters to the success story. 2005, coming after the "Year of Technology", will be the "Einstein Year", a year that will recall the great breakthroughs of Albert Einstein. In co-operation with the "Partners for Innovation", the "Einstein Year" will be used, in the framework

of the innovation initiative, to promote understanding and enthusiasm for science and research, and to enhance public awareness of science's and society's complementary responsibilities. The plans for the year include a major Einstein exhibition in Berlin.

The "Science in Dialogue" initiative has succeeded in encouraging scientists to communicate their research results

and findings more effectively and intensively to the public. An interested public has been given new access to the fascinating world of science, and many young people have been inspired to choose careers in science. The science sector will only receive the lasting social support it needs for its own development if it takes public expectations and criticism seriously and responds appropriately.

Contents

Page

Preamble on research policy

I

1	Basic principles	II
1.1	Reasons why the state supports research	III
1.2	Instruments of research funding	V
1.2.1	Institutional funding	V
1.2.2	Project funding at the interface between science and industry	VI
1.2.3	Centres and networks of excellence	VI
1.2.4	Indirect support	VII
1.3	Thinking about tomorrow – today	VII
2	Current political aims and measures	VIII
2.1	The task: increasing investments in the future	IX
2.2	Promoting and challenging human resources	X
2.2.1	Begin in the schools	X
2.2.2	Increasing the percentages of pupils who go on to higher education	X
2.2.3	Top-class universities can attract the best minds to Germany	X
2.2.4	Strengthening support for young scientists	XI
2.2.5	A brain-gain instead of a brain-drain	XI
2.2.6	Promoting personnel mobility	XI
2.3	Modernising the research landscape's structures	XII
2.3.1	Restructuring the division of competencies between the Federal Government and the Länder	XII
2.3.2	Intensifying networking among research organisations	XII
2.3.3	Increasing use of competition in awarding of research funding	XII
2.3.4	Being willing to take risks via new funding procedures	XIII
2.3.5	Ensuring that research is of high quality	XIII
2.3.6	Evaluating departmental research	XIII
2.3.7	Meeting the need for large-scale research facilities	XIII
2.4	Promoting technologies for new markets	XIV
2.4.1	Stimulating research and development in the business enterprise sector	XIV
2.4.2	Intensifying co-operation between science and industry	XIV
2.4.3	Providing special support for SMEs	XV
2.5	Research for people and the environment	XVI
2.5.1	Applying findings from life sciences to medicine	XVI
2.5.2	Expanding research aimed at sustainable development	XVI
2.5.3	Research for the workplace of tomorrow	XVI
2.5.4	Safeguarding mobility – minimising the impacts of transports	XVI
2.6	Promoting women in the research sector	XVII
2.7	Strengthening research in eastern Germany	XVII
2.8	Intensifying internationalisation	XVIII
2.9	Conducting a dialogue on research	XIX

Part I The German Research Landscape – Structures and Financing

1

	Introduction	2
3	Framework and work structures	2
3.1	The legal framework	2
3.2	Work structures	3
3.2.1	Bund-Länder Commission for Educational Planning and Research Promotion (BLK)	3
3.2.2	Science Council	3
3.2.3	Planning committee for construction in higher education	4

	Page	
4	State support instruments	5
4.1	Project support	5
4.2	Institutional support	5
5	Quality assurance	6
5.1	"easy" – the electronic application/offer system of the BMBF and BMWA and "profi" – the project-support information system for internal electronic processing	6
5.2	Commercialisation of project results	7
6	Research support – structure and players	7
6.1	Structure of German research support	7
6.1.1	Federal Government and the Länder	7
6.1.2	Industry	9
6.1.3	Foundations	9
6.2	European Union	10
7	Funding organisations	10
7.1	Deutsche Forschungsgemeinschaft (DFG)	10
7.2	German Academic Exchange Service (DAAD)	16
7.3	Alexander von Humboldt Foundation (AvH)	16
7.4	Institutions for promoting gifted students in higher education	17
8	German Foundation for Peace Research (DSF)	20
9	Deutsche Bundestiftung Umwelt (DBU)	21
10	"Deutsche Geisteswissenschaftliche Institute im Ausland" ("German Humanities Institutes Abroad") Foundation (DGIA)	21
11	"Otto von Guericke" German Federation of Industrial Co-operative Research Associations (AiF)	24
12	Project management agencies and DLR space-programme management	25
12.1	Project management agencies	25
12.1.1	Project management agencies of the Federal Ministry of Education and Research (BMBF)	25
12.1.2	Project management agencies of the Federal Ministry of Economics and Labour (BMWA)	29
12.2	DLR space-programme management	31
13	Organisations and institutions that carry out R&D	31
13.1	Universities	31
13.2	Max Planck Society (MPG)	53
13.3	Fraunhofer-Gesellschaft (FhG)	79
13.4	Helmholtz Association of National Research Centres (HGF)	97
13.5	Leibniz Association (WGL)	101
13.6	Federal and Länder institutions carrying out R&D	117
13.6.1	Federal institutions with research tasks	117
13.6.2	Länder institutions with research tasks	129
13.7	Academies and German Academy of Natural Science (Deutsche Akademie der Naturforscher Leopoldina)	159
13.8	caesar Foundation (center of advanced european studies and research)	162
14	Business enterprises	162
15	Extramural industrial research institutions in eastern German Länder	163
16	Specialised central information institutions and specialised central libraries	163
Part II	Resources for science, research and development in Germany: description and international comparison	171
	Introduction and explanation of terms	172
17	Science expenditures	175
18	Expenditure on research and development	176
19	Personnel involved in research and development	180
19.1	Structure and development	180
19.2	Percentage of R&D staff who have academic backgrounds	180
19.3	Percentage of R&D staff who are women	180
19.4	R&D density (R&D staff per 1,000 inhabitants)	183
20	Federal expenditure on research and development, 2000 to 2004	184

20.1	Structure and development	184
20.2	Federal expenditure on research and development, total and by government ministries	184
20.3	Federal expenditure on research and development, by funding areas and funding priorities	185
20.4	Expenditure of the Federal Government and of the BMBF for research and development – Profile –	190
20.5	Federal R&D expenditure, by type of funding	191
20.6	Federal R&D expenditure, by recipient groups	191
20.7	Federal expenditure on research and development, by region	194
21	Expenditure of the Länder on science, research and development	195
22	Joint research funding by Federal and Länder governments	197
22.1	Deutsche Forschungsgemeinschaft (DFG)	197
22.2	Max Planck Society (MPG)	198
22.3	Fraunhofer-Gesellschaft (FhG)	198
22.4	Helmholtz Association of National Research Centres (HGF)	198
22.5	Leibniz Association (WGL)	198
22.6	Academies programme	198
22.7	Deutsche Akademie der Naturforscher Leopoldina (German Academy of Natural Science)	198
23	Higher education resources for research and development	199
23.1	Importance of the higher education sector for research and development	199
23.2	Higher education expenditure on teaching and research	199
23.3	Higher education expenditure on teaching and research, by areas of science	199
23.4	Higher education expenditure on teaching and research, by type of higher education institution	199
23.5	Total higher education expenditure on R&D	199
23.6	Higher education R&D expenditure, by field of science	199
23.7	Higher education R&D expenditure, in western German and eastern German Länder and in Berlin	200
23.8	Financing of higher education R&D expenditures	200
23.9	Total R&D personnel in higher education	201
23.10	Higher education R&D personnel, by field of science	201
23.11	Higher education R&D personnel – regional distribution	201
24	Support for research and development in industry	202
24.1	Federal funding of research and development in the business enterprise sector	202
24.2	Structure of Federal R&D funding in the business enterprise sector	202
25	International comparison of resources for research and development	205
25.1	R&D personnel per 1,000 members of the work force	205
25.2	Government R&D expenditure as a percentage of gross domestic product	205
25.3	Government-financed R&D expenditure in the European Union	207

Part III The Federal Government's research and technology policy 213

	Introduction	215
26	Support organisations, construction in higher education and special programmes oriented primarily to higher education	215
26.1	Basic financing of the Max Planck Society	215
26.2	Basic funding of the Deutsche Forschungsgemeinschaft	217
26.3	Basic financing of the Fraunhofer-Gesellschaft	217
26.4	Expansion and construction at higher education institutions	218
26.5	Special programmes oriented primarily to higher education institutions	219
27	Large-scale equipment for basic research	222
28	Marine and polar research; shipping and maritime technology	226
28.1	Marine and polar research	226
28.1.1	Marine research	226
28.1.2	Polar research	229
28.2	Maritime and marine technology	230
29	Space research and space technology	232
30	Energy research and energy technology	235
30.1	Coal and other fossil fuels	235

	Page	
30.2	Renewable energies and energy efficiency	237
30.3	Nuclear energy research	239
30.4	Decommissioning of nuclear pilot and test facilities	240
30.5	Nuclear fusion research	241
31	Research oriented to sustainable development	242
31.1	System "earth"	243
31.1.1	Atmosphere, climate system, large science apparatus	243
31.1.2	Marine and geoscientific research oriented to sustainable development	244
31.2	Sustainability concepts	244
31.2.1	Societal action in the interest of sustainable development	244
31.2.2	Concepts for sustainable development in industry and business	245
31.2.3	Sustainable use concepts for regions	246
31.2.4	Sustainable use of natural resources	246
31.3	Peace and conflict research, humanitarian mine-clearing	248
32	Research and development in the health-care sector	249
33	Research and development to improve working conditions	261
34	Information technology	264
34.1	Software systems	265
34.2	Basic technologies in information technology	267
34.3	Microsystem technology applications	272
34.4	Production technology	274
34.5	Internet – basic principles and services	275
34.6	Multimedia	277
34.7	Global network of scientific and technical information	279
35	Biotechnology	281
36	Materials research; physical and chemical technologies	287
36.1	Materials research	288
36.2	Physical and chemical technologies	289
37	Aeronautical research	296
38	Research and technology for mobility and transport (including transport safety)	297
39	Geosciences and natural resources	300
39.1	Geosciences	300
39.2	Protecting the supply of natural resources	303
40	Regional planning and urban development; construction research	304
40.1	Physical planning, city planning, housing	304
40.2	Construction research – construction technology research; road-construction research	306
41	Research and development in the food sector	308
42	Research and development in agriculture, forestry and fishery	310
43	Educational research	314
43.1	Research in general education	315
43.2	Research in the area of vocational training	320
43.3	Higher education research	324
43.4	Lifelong learning / research into further training	327
43.5	Other areas of education research	329
44	Innovation and improved basic conditions	343
44.1	Innovation financing for technology-oriented companies and start-ups	344
44.2	Improvement of technology and science transfer / support for research co-operation and innovative networks	346
44.3	Technical-economic infrastructure	348
44.4	Other indirect support measures	348
45	Humanities; economic and social sciences	349
45.1	Humanities	350
45.2	Economic and social sciences	351
46	Other activities not assigned to other sectors	358
47	Defence research and technology	364
47.1	Research and technology	365
47.2	Development in defence technology	366

47.3	Non-technical research and studies of the German Federal Armed Forces	367
47.4	Research in the area of defence medicine and psychology (including veterinary medicine, dentistry and pharmacy)	367
47.5	Research in the area of geo-information systems	368
47.6	Research in the area of military history	369
47.7	Research in the social sciences	370

Part IV Research and technology policy in the Länder 373

Presentation by the Länder

	Introduction	376
48	Baden-Württemberg	376
48.1	Principles and priorities of research and technology policy	377
48.2	Higher education research, and technology policy not oriented to the higher education sector	378
48.3	Technology support and technology transfer	381
48.4	International co-operation	383
49	Free State of Bavaria	384
49.1	Principles and priorities of research and technology policy	384
49.2	Research within and outside of the higher education sector	385
49.3	Technology support and technology transfer	387
49.4	International activities	388
49.5	Other state programmes and measures	389
50	Berlin	389
50.1	Principles and priorities of research and technology policy	389
50.2	Higher education research	390
50.3	Research outside of the higher education sector	391
50.4	Technology support and technology transfer	391
50.5	International activities	392
51	Brandenburg	392
51.1	Principles and priorities of research and technology policy	392
51.2	Higher education, and research establishments outside of the higher education sector	393
51.3	Technology support and technology transfer	397
51.4	International co-operation	397
51.5	Other state programmes and measures	398
52	Free Hanseatic City of Bremen	399
52.1	Principles and priorities of research and technology policy	399
52.2	University research	399
52.3	Research outside of the higher education sector	401
52.4	Technology support and technology transfer	402
52.5	International activities	403
53	Free and Hanseatic City of Hamburg	403
53.1	Principles and priorities of research and technology policy	403
53.2	Research within and outside of the higher education sector	404
53.3	Technology support and technology transfer	405
53.4	International co-operation	406
54	Hesse	406
54.1	Principles and priorities of research and technology policy	406
54.2	Higher education research	407
54.3	Research outside of the higher education sector	408
54.4	Technology support and technology transfer	409
54.5	International activities	411
55	Mecklenburg – West Pomerania	412
55.1	Principles and priorities of research and technology policy	412
55.2	Research within and outside of the higher education sector	413
55.3	Technology support and technology transfer	415

	Page	
55.4	International co-operation	417
56	Lower Saxony	418
56.1	Principles and priorities of research and technology policy	418
56.2	Research within and outside of the higher education sector	419
56.3	Technology support and technology transfer	422
56.4	International co-operation	423
57	North Rhine – Westphalia	424
57.1	Principles and priorities of research and technology policy	424
57.2	Research within and outside of the higher education sector	425
57.3	Technology support and technology transfer	431
57.4	International co-operation	432
57.5	Other state programmes and measures	432
58	Rhineland-Palatinate	433
58.1	Principles and priorities of research and technology policy	433
58.2	Higher education research, and research outside of higher education institutions	433
58.3	Technology support and technology transfer	435
58.4	International co-operation	436
58.5	Other state programmes and measures	437
59	Saarland	438
59.1	Principles and priorities of research and technology policy	438
59.2	Higher education research	439
59.3	Research outside of the higher education sector	441
59.4	Technology support and technology transfer	441
59.5	International activities	442
60	Free State of Saxony	443
60.1	Principles and priorities of research and technology policy	443
60.2	Research within and outside of the higher education sector	444
60.3	Technology support and technology transfer	446
60.4	International co-operation	447
60.5	Other state programmes and measures	447
61	Saxony-Anhalt	448
61.1	Principles and priorities of research and technology policy	448
61.2	Research within and outside of the higher education sector	448
61.3	Technology support and technology transfer	452
61.4	International support measures and co-operation	453
61.5	Other state programmes	453
62	Schleswig-Holstein	454
62.1	Principles and priorities of research and technology policy	454
62.2	Research within and outside of the higher education sector	455
62.3	Technology support and technology transfer	456
62.4	International co-operation	457
63	Free State of Thuringia	457
63.1	Principles and priorities of research and technology policy	457
63.2	Research within and outside of the higher education sector	458
63.3	Technology support and technology transfer	461
63.4	International co-operation	462
Part V	Innovation indicators oriented to Germany's technological performance	463
	<i>Report of the Working Group on Innovation Indicators</i>	
	Introduction	464
64	Research and development in the German business enterprise sector	464
64.1	R&D resources in the business enterprise sector	464
64.2	Development of R&D intensity in the business enterprise sector	465
64.3	Sectoral R&D priorities and intensities – structure and development	466
64.4	R&D co-operation and order awards in the business enterprise sector	468

64.5	Importance of R&D in small and medium-sized companies	469
64.6	R&D in eastern and western German Länder	471
64.7	R&D by foreign companies in Germany	472
64.8	Balance of payments in the area of technology	476
65	An international comparison of research and development	478
65.1	Development of R&D resources as a whole	478
65.2	R&D resources and intensity in the business enterprise sector	479
65.3	R&D sectoral priorities in the business enterprise sector	481
65.4	The EU Commission's 3% goal	482
66	The foundation: education and science	484
66.1	Use of highly qualified people in the German business enterprise sector	484
66.2	Highly qualified young people in Germany – an international comparison	485
66.3	Capabilities in scientific research – an international comparison	487
66.4	Relevance of public-sector research for technological progress	489
67	Implementation: Inventions and patents, innovations, changes in company structures	493
67.1	Patents relevant to the global market: growth and structure	493
67.2	The technological orientation: high technology and sophisticated consumer-goods technology	493
67.3	Trans-boundary inventions	494
67.4	Innovation in German industry	494
67.5	Quality and efficiency of innovation	499
67.6	Start-ups in industry's research-intensive and knowledge-intensive sector	500
68	Market results: Employment, production and competitive position in the knowledge-/research-intensive sector	501
68.1	Germany's specialisation in trading in research-intensive goods	501
68.2	Production and employment in research-intensive industries	502
68.3	Sectoral structural change in the interest of the research-intensive and knowledge-intensive sector	504

Part VI International Co-operation in Research and Technology **511**

	Introduction	513
69	Co-operation with European countries	513
69.1	European Union, European Commission	513
69.1.1	Basis of research support in the European Union	513
69.1.2	The "Lisbon Strategy"	514
69.1.3	Substance of Community research policy	514
69.2	Bilateral co-operation with countries of western, northern and southern Europe	526
69.2.1	Basic principles and content	526
69.2.2	Bilateral institutions	528
69.2.2.1	Stiftung Deutsch-Niederländische Windkanäle (DNW – German-Dutch Wind Tunnel Foundation)	528
69.2.2.2	Franco-German University	529
69.2.2.3	Centre Marc Bloch	530
69.2.2.4	Villa Vigoni	530
69.2.2.5	The Saint-Louis Franco-German research institute	531
69.3	Bilateral co-operation with countries of central, eastern and south-eastern Europe	532
69.4	Bilateral co-operation with the states of the former Soviet Union	535
69.5	European initiatives, organisations and research institutions	536
69.5.1	EUREKA	536
69.5.2	COST - European co-operation in the field of scientific and technical research	538
69.5.3	European Space Agency (ESA)	539
69.5.4	European Organisation for Nuclear Research - European Laboratory for Particle Physics (CERN)	541
69.5.5	European Southern Observatory (ESO)	542
69.5.6	European Molecular Biology Conference (EMBC)	543
69.5.7	European Molecular Biology Laboratory (EMBL)	543
69.5.8	European Synchrotron Radiation Facility (ESRF)	544
69.5.9	Institut Max von Laue - Paul Langevin (ILL)	545
69.5.10	European Centre for Medium-Range Weather Forecasts (ECMWF)	546

	Page
69.5.11 European University Institute (EUI)	546
69.5.12 European Transonic Wind Tunnel (ETW)	547
69.5.13 Council of Europe	548
70 Co-operation with non-European countries and regions	549
70.1 Co-operation with the U.S. and Canada	549
70.2 Co-operation with Latin America	551
70.3 Co-operation with Mediterranean and African countries	552
70.4 Co-operation with the Asian-Pacific region	553
70.5 Co-operation with developing countries	557
71 Multilateral organisations	558
71.1 Organisation for Economic Co-operation and Development (OECD)	558
71.2 International Energy Agency (IEA)	559
71.3 International Atomic Energy Agency (IAEA)	559
71.4 United Nations Educational, Scientific and Cultural Organisation (UNESCO)	560
71.5 Intergovernmental Oceanographic Commission of UNESCO (IOC)	561
71.6 University of the United Nations (UNU)	561
71.7 UN Commission on Sustainable Development (CSD)	562
71.8 United Nations Framework Convention on Climate Change	562
71.9 Intergovernmental Panel on Climate Change (IPCC)	563
71.10 World Meteorological Organisation (WMO) – A UN specialised agency	563
71.11 North Atlantic Treaty Organisation (NATO)	564
71.12 Human Frontier Science Program Organisation (HFSP)	565
71.13 United Nations Convention on Biological Diversity	565
71.14 Global Biodiversity Information Facility (GBIF)	566
71.15 Consultative Group on International Agriculture Research (CGIAR)	566
72 List of international scientific and technical agreements	567

Part VII Tables / Statistics 585

73 Introduction and explanation of terms	587
74 Tables	590
Table 1: Science expenditure of the Federal Republic of Germany	590
Table 2: German R&D expenditure and financing sectors	591
Table 3: Gross domestic expenditure on R&D (GERD) in Germany, by performing sectors	593
Table 4: Government science expenditure, by functions and funding sources	596
Table 5: Government science expenditure by functions and by types of expenditure	598
Table 6: Joint research funding by Federal and Länder governments, 2001–2003 (basic funding of institutions)	600
Table 7: Federal expenditure on science, research and development, by government departments	602
Table 8a: Federal expenditure on science, research and development by funding areas and funding priorities	606
Table 8b: Expenditure on science, research and development, by the BMBF, by funding areas and funding priorities	612
Table 9: Federal expenditure on science, research and development, by type of funding	618
Table 10: Federal expenditure on science, research and development, by recipient groups	620
Table 11: Federal Government payments to business enterprises for science, research and development, by economic activity	624
Table 12: Expenditure of the Federal Government on international science organisations and intergovernmental research institutions	628
Table 13: R&D expenditure of the Federal Government and the Länder, by research objectives	630
Table 14: Basic funds provided by the Länder and by local governments for science, by functions and Länder	631
Table 15: open	

	Page	
Table 16:	Intramural R&D expenditure by the business enterprise sector, and proportion of self-financed intramural R&D expenditure, by economic activity	638
Table 17:	R&D expenditure of the business enterprise sector, by economic activities (intramural and Total R&D expenditure)	640
Table 18:	Labour force, turnover and intramural R&D expenditure of business enterprises, by economic activities and company size	644
Table 19:	open	
Table 20:	Higher education expenditure on teaching and research, by types of higher education institution	650
Table 21a:	Expenditure of non-university science institutions, by types of expenditure	653
Table 21b:	Expenditure of non-university science institutions, by fields of science	659
Table 22:	Receipts from, and expenditure on, patents, inventions and processes (excluding copyrights) in the Federal Republic of Germany, by economic activities	665
Table 23:	Receipts from, and expenditure on, patents, inventions and processes (excluding copyrights) in the Federal Republic of Germany, by major partner countries	668
Table 24:	Germany's receipts from, and expenditure on, technical research and development, in foreign trade, by economic activities and groups of countries	674
Table 25:	Gross domestic expenditure on research and development in selected OECD countries, by financing and performing sectors	678
Table 26:	Government expenditure on research and development in the countries of the European Union	684
Table 27:	Government expenditure on research and development in the countries of the European Union, by various criteria	688
Table 28:	Patents and licenses in the balances of payments of selected countries	692
Table 29:	Personnel in research and development, by occupations and sectors of employment	694
Table 30:	R&D personnel in the business enterprise sector, by economic activities	696
Table 31:	R&D personnel in the business enterprise sector, by occupations and economic activities	697
Table 32:	R&D personnel in institutions for co-operative industrial research and experimental development, by occupations and economic activities	699
Table 33:	Higher education personnel, by occupations and fields of Science	701
Table 34:	Personnel of non-university science institutions, by institutions and occupations	705
Table 35:	Personnel of non-university science institutions, by institutions and fields of science	717
Table 36:	open	
Table 37:	open	
Table 38:	R&D personnel in the European Union and in selected OECD countries, by occupations and sectors of employment	723
Table 39:	Federal R&D expenditure – regional breakdown	727
Table 40:	Länder R&D expenditure – regional breakdown	728
Table 41:	R&D expenditure for all of the Federal Republic of Germany – regional breakdown	729
Table 42:	Intramural R&D expenditures of the business enterprise sector – regional breakdown by host countries of research locations	730
Table 43:	Higher education R&D expenditure – regional breakdown	731
Table 44:	R&D expenditure of non-university science institutions – regional breakdown	733
Table 45:	Total R&D personnel in the Federal Republic of Germany, by Länder	734
Table 46:	R&D personnel in the business enterprise sector, by economic activities and Länder	736
Table 47:	Higher education R&D personnel – regional breakdown	742
Table 48:	R&D personnel of non-university science institutions – regional breakdown	744
Table 49:	World-trade shares of the most important OECD countries in R&D-intensive goods, by commodity groups, 1991, 1994, 1998 and 2001	745
Table 50a:	Basic data on education	747
Table 50b:	Budget for education, research and science, 1997 to 2002, by performing institutions	749
Table 50c:	Budget for education, research and science, for 2001, by financing institutions	750
Table 51a:	Reference data concerning population, labour force, etc.	751
Table 51b:	Population, employment and gross domestic product – Regional structural data	753
Table 52a:	Number of new entrants into tertiary education (ISCED 5A) as a percentage of the relevant age group – an international comparison	756

	Page
Table 52b: Numbers of new entrants into tertiary education (ISCED 5A) in Germany – absolute and as a percentage of the relevant age group, by subject groups and areas of studies	757
Table 53a: Number of university graduates (ISCED 5A) as a percentage of the relevant age group – an international comparison	759
Table 53b: Numbers of university graduates (ISCED 5A) in Germany – absolute and as a percentage of the relevant age group, by subject groups and areas of studies	760
Table 54: Employment of highly qualified people in knowledge-intensive industry sectors in Germany, 1998–2002	762
Table 55: Number of scientific publications per million inhabitants	763
Table 56: Patents relevant to the global market – an international comparison	764
Table 57a: Indexes for innovation in the mining and manufacturing sectors, 1993–2002	765
Table 57b: Indexes for innovation in the business-to-business services sector, 1996–2002	768
Table 58: Start-ups in research-intensive and knowledge-intensive industry sectors in Germany	771
Table 59: The research-intensive sector's contribution to the foreign trade balance, in selected industrialised countries, 1991 to 2001	772
Table 60: Production and employment in Germany's research-intensive industrial sector	774

List of figures

List of abbreviations

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