

1.1 Shaping a sustainable future based on new insights

Sustainability is both the goal and the yardstick against which future-oriented policies are measured. Preserving the stability and regenerative capacity of the ecological, economic and social systems has long been a core element of every future-oriented political decision-making process. Since 2005, with the launch of the FONA framework programmes “Research for Sustainable Development”, the BMBF has supported the research community’s contribution to attaining this goal. The new FONA³ framework programme will focus on two fundamental insights:

1. A deeper understanding of numerous interrelationships in nature and society is a prerequisite for a more sustainable future. Seemingly simple solutions frequently give rise to new problems. Therefore, this calls for a more systemic approach at the research stage.

2. Ultimately, it is not how much we know but what we implement that will be a decisive factor for the future. Thus, one of the central aims of FONA³ is to use the results of the research it supports to make mankind’s actions more sustainable. To this end, we plan to include all stakeholders and participants systematically, thereby orienting research to the actual demand from the outset; moreover, if required, we intend to nurture successful research until it takes root as an innovation on a wide scale.

To achieve this goal, FONA³ has been developed with a dual structure:

- Three flagship initiatives will focus on systemic approaches to ensure that research is application-oriented.
- In addition, four sectors of prevention research for sustainability will help to gain fundamental insight into managing climate change, maintaining biodiversity, conserving natural resources, preserving the marine ecosystems and generally enhancing our quality of life.

Finally, a number of innovative instruments and structural features ensure that FONA³ remains efficient and innovative as a learning programme. The features of the FONA³ framework programme are presented below.

The BMBF has been funding research for sustainable development for ten years in its framework programmes, FONA 1 (2005–2009) and FONA 2 (2010–2014). Recent areas of research include climate research, energy research, research on biodiversity, marine and polar research, Earth sciences, social-eco-logical research and research on the resources of water, land and commodities. The findings clearly indicate that, as a general rule, these areas of research should no longer be developed in isolation. For example, in the sustainable city system, the energy and resource supply should be connected to climate concepts and mobility systems as well as to socially sustainable innovations and economically robust strategies. Our aim is to consolidate research findings from individual disciplines to create system innovations, thereby taking a further step towards the implementation process. The new framework programme will initially focus on three systems of fundamental importance for sustainable development. Specific flagship initiatives have been launched that address these three systems:

- **Green Economy (Chapter 2.1)**
- **City of the Future (Chapter 2.2)**
- **The Energiewende – Germany's transformation of its energy system (Chapter 2.3)**

Thus, FONA³ focuses the majority of the funded sustainability research on implementing research findings in specific technical and social innovations. The goal is to maximise the impact of sustainability research on society and for research and innovation funding to be more closely linked in the future. This transcends the boundaries of conventional knowledge transfer methods. A central aspect of this approach is encouraging companies to adopt new research findings and apply them as quickly as possible for innovative products, techniques and services. One important method of implementing and disseminating scientific advances is by including them in norms and standards. The BMBF will be working closely together with other federal and state departments, allowing

the sustainability research results to have a direct impact on their decision making processes. The ultimate goal is for sustainable innovations to become established in our society; to this end, the flagships are designed to play an active role in raising awareness of applicable research.

Above and beyond these three flagship initiatives, the FONA 2 research fields will remain relevant. The intelligent use of natural resources like water and land, the ecologically sustainable production of raw materials on land and in the ocean, maintaining biodiversity, protecting ecosystems, reducing greenhouse gases and adapting to climate change still represent challenges that can only be overcome in the long term if we combine pre-existing, application ready solutions with advances in the individual fields of research, while striving to extend our fundamental knowledge.

Among other things, prevention research includes the development of regional climate models, as well as Earth observation and monitoring of the environment. The time is now right for new technologies for greater resources and energy efficiency; by the same token, the expansion of renewable energy sources is a must. Consequently, research in these classic fields must continue under FONA³. Thus, FONA³ focuses on four transdisciplinary fields of prevention research for sustainability:

- **Maintaining and enhancing quality of life and competitiveness (Chapter 3.1)**
- **Using resources intelligently and efficiently (Chapter 3.2)**
- **Protecting common assets: climate, biodiversity and the ocean (Chapter 3.3)**
- **Education and research: working together for sustainable development (Chapter 3.4)**

FONA³ will also interlink research and sustainability education systematically. Education and research go hand in hand: a sustainable society needs not just technological but also social innovations. Everyone has to do their bit for sustainable development. Information, heightening individual awareness and accepting the responsibility of each and every one of us are prerequisites for greater sustainability, regardless of whether it is a question of protecting the integrity of creation, establishing global socially sustainable standards, conserving resources, managing energy

prudently or enhancing our quality of life, now and for future generations. Research highlights the technological and societal opportunities that pave the way for a sustainable society, while education brings them to our door. Simply because education imparts the necessary knowledge and expertise to achieve and shape a sustainable society. Research and education are thus closely dovetailed in this framework programme.

In addition to the new research priorities, FONA³ is also placing emphasis on new and established structural elements (Chapter 5). FONA 2 achieved a high level of interdisciplinarity and transdisciplinarity in sustainability research; these features are now being developed and expanded still further. Research is now being carried out through broader engagement with partners from the fields of politics, administration, industry and civil society, as well as across disciplinary boundaries. One feature of transdisciplinarity is the new approach of including application requirements at the programme development stage. Therefore, this framework programme was developed in an agenda process. In other words, it is the product of extensive dialogue with science, industry, civil society, local communities and politics. Agenda processes are designed to help researchers find answers, ensure that their solutions are adapted for transfer and thus meet the criteria for transformation into a sustainable lifestyle and economic framework.

FONA³ regards itself as a “learning programme”. In other words, in cooperation with the other departments involved, the BMBF will liaise on an ongoing basis with representatives from science, politics and administration, industry and civil society in order to monitor the research priorities, the instruments and the effectiveness of the funding measures, adjusting them as necessary.

FONA³ continues to set great store by the established funding instrument of collaborative research: the next step is to integrate participants from civil society to a larger extent in the research projects, for example. Furthermore, existing synergies are to be used to greater advantage for institutional funding. With its “Sustainability in Science Initiative (SISI)”, the BMBF empowers the research community to apply the principles of sustainability in their own workplaces and to encourage them in research institutes.

1.2 From knowledge to innovation

The objective of the new framework programme Research for Sustainable Development is to increase the effectiveness of the BMBF's support in aiding politics, business and society to develop and implement key sustainability strategies that can withstand the test of time. The main drivers are the German National Sustainability Strategy, the Federal Government's High-Tech Strategy and the *Energiewende* project, Germany's transformation of its energy system. The Federal Government's new High-Tech Strategy expressly extends the definition of innovation to include social innovations. With sustainability as its guiding principle, it considers research and innovation for a sustainable economy and energy to be its main priority for the future.

By fostering a closer collaboration between science and industry, FONA³ aims to support the Federal Government's recently declared objective in the High-Tech Strategy of a green economy, which seeks to sever the link between economic growth and the use of resources. Moreover, FONA³ is an important contributor to the German Resource Efficiency Programme (ProgRess), the National Strategy on Biodiversity and the German Strategy for Adaptation to Climate Change.

FONA³ opens up new avenues of opportunity to achieve the sustainability goals set by the Federal Government. This may be demonstrated by a few examples:

- With regard to the National Sustainability Strategy, the research community is working to double resource productivity in Germany by 2020 (compared to 1994) and thus succeed in decoupling economic growth from the use of resources.
- It is making significant contributions to reducing greenhouse gas emissions in Germany by 40% and to doubling energy productivity for the period up to 2020, compared to 1990 levels.
- Research for Sustainable Development will lay the foundations for an increase in the share of renewable energy to 35% of gross electricity consumption by 2020.

- Sustainability research is developing concepts to reduce the utilisation of new land for settlement and transport purposes and to restrict it to an average of 30 ha per day by 2020.

In the interaction of the federal ministries, the BMBF regards its role as that of a facilitator, providing research findings that may be used as a basis for decision-making in other policy areas. Thus, sustainability research serves both as impetus and guide in Germany's transformation processes. The conservation of our natural environment and the international competitiveness of German industry and science are at stake.

The cornerstones of sustainability research are achieving the best possible balance between the competing demands and objectives and serving as an orientation tool regarding the complex interdependencies between ecology, economy and society. To this end, the research community aspires to present the decision-makers in politics and industry with scenarios and courses of action that are scientifically sound. Science encourages thinking in terms of alternatives and highlights the consequences of potential political and business decisions.

To enable new insight to be as effective as possible for a more sustainable future, the instrument also needs to be adjusted to match the funding: nevertheless, even promising research and development findings often lead to a dead end: many a solution that is technically feasible is not actually put into practice. This is due to the high entrepreneurial risk, combined with the necessary increase in scale from the laboratory or technical centre to the pilot and demonstration scale. The important consideration here is to guide, under industrial leadership, particularly promising, resource-efficient projects with the potential to reach the national sustainability goals all the way to application transfer. Small and medium-sized enterprises (SMEs) should also be able to benefit from such guidance. Their competitiveness and capacity for innovation will continue to be accorded a special significance as a result of the targeted funding of SME research and development projects under FONA³.

1.3 Assuming responsibility on an international level

Sustainability is an issue of global importance. Problems like climate change and resource depletion cannot be solved by any nation single-handedly. Consequently, by reinforcing the international partnerships for sustainability with its framework programme FONA³, the BMBF is assuming responsibility on an international level.

Within the scope of efforts to establish a coordinated approach to global challenges, international organisations play a prominent role, particularly the United Nations. FONA³ provides targeted support for their activities:

- The BMBF plays an active role in supporting the United Nations (UN) by synthesising, analysing and evaluating the current research status. By preparing data and sample calculations for research projects, the BMBF fosters the work carried out by the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). IPCC and IPBES provide a sound basis for knowledge-based sustainability policy decisions, uncover any gaps in research and present specific approaches for research policy. Moreover, the UN's Sustainable Development Goals (SDGs) are the most important strategic benchmarks in pursuing focused and coherent action on a global scale to address the major challenges.
- With the EU research framework programme "Horizon 2020", European research policy is also focusing the structure, content and instruments of its funding activities on overcoming major societal challenges. We should also make our presence felt in Europe in those research areas in which Germany excels. Consequently, the significant correspondence between the objectives of FONA³ and Horizon 2020 facilitates a wider dissemination of the research findings, thereby achieving greater impact. Furthermore, the national funding will help to maximise the success of German researchers from science and industry under Horizon 2020. Intensive collaboration in EU bodies and European platforms and initiatives, like the Joint Program-

ming Initiatives (JPIs), ensures that our voice is heard in co-determining the European research agenda. This also ensures that the activities of national and European bodies are both cooperative and complementary. The three transdisciplinary flagship initiatives (cf. Chapter 2) extend the scope of FONA³ beyond the concept of Horizon 2020. In addition, FONA³ is striking out in new directions with the extended definition of innovation, which includes both economic and social innovations.

But above all, bi- and multilateral innovation alliances are vitally important, particularly those with developing and newly industrialised countries. To date, the BMBF has invested approximately 100 million euros in international sustainability research cooperations every year. Within the scope of project funding, more than 100 cooperation networks focus on topics like sustainable water management, marine and polar research, climate, commodities, resources and energy, biodiversity, land and soil. One outstanding example are the regional Science Service Centres for Climate Change and Adaptive Land Management in West and South Africa. In the regions that are particularly vulnerable to the effects of climate change, scientifically sound solutions in the field of climate adaptation are being developed on an equal footing with partners in the region. A further example is the joint initiative with China for clean water, which seeks to address the serious problem of water pollution in the area with the help of German technology and, at the same time, aims to open up a market of the future for German companies. FONA³ will follow upon and revise these strategic initiatives, and link them with national projects.

The flagship initiatives for sustainability are the political priorities in FONA³. The three topics, Green Economy, City of the Future and *Energiewende*, address systems that are key to human coexistence; the transformation of these systems is crucial for the future viability of our way of life and business dealings. The innovative characteristics of FONA³ are inextricably linked to the prioritisation of these flagships:

- By making the very systems in which the research findings are to be implemented both the main focus and the structural feature of the flagship initiatives, research policy is forced to undergo a shift in perspective: we no longer ask ourselves what research can offer society but what solutions are required. Thus, the flagships aim to achieve the greatest possible relevance for transformation. This results in a shift in the programme logic from a supply orientation to a demand orientation. Hence, the dissemination of research results is extended from a classic “push strategy”, in which new applications are promoted to raise public

awareness, to include a “pull option”, in which consumers actively register their requirements.

- The city, the business world and the energy supply are all highly complex, man-made systems. If a research landscape is to contribute to a transformation of these systems, it must transcend the boundaries of established research fields and adopt a systemic approach from the word go. This applies equally to research policy: since different departments are responsible for the utilisation and implementation of the results, the BMBF intends to extend its role of knowledge mediator in the steering group and become the moderator of a cooperative development process. To this end, the well-honed inter-ministerial cooperation, particularly that between the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry for Economic Affairs and Energy (BMWi), will be systematically enlarged to include the entire process, from identifying research priorities, selecting

and carrying out projects, right through to their realisation and application.

- Maximum openness in all programme areas is a prerequisite in ensuring that the flagship initiatives are continuously geared towards the transfer of the research results. By its very nature, the programme serves as a platform: stakeholders and participants from the fields of politics, industry and administration, and representatives from civil society are involved in the project and research process from day one. They are given the opportunity to voice their concerns and set priorities. This enables the research community to combine state-of-the-art scientific and technical knowledge with the practical expertise of their partners. At the same time, the selected topics do not merely become part of the BMBF's agenda; instead, every group can focus its collaborative efforts on application-oriented topics that are worthwhile from a scientific perspective.

Accordingly, the three topics, Green Economy, City of the Future and *Energiewende* were identified as a result of dialogue and organised thematically in agenda processes. The initiatives were assigned specific activities in FONA³ and refined systematically in further discussions. They are the first flagship initiatives to be introduced. Since FONA³ regards itself as a learning programme, further flagship initiatives may be identified and researched as required.

2.1 Green Economy

The goal of a green economy is the transition to sustainable business management, with practices that conserve natural resources and mitigate negative environmental effects, thereby facilitating qualitative growth. In 2012, the green economy was the central theme of the Rio+20 summit, the UN Conference on Sustainable Development. In collaboration with the BMUB, the BMBF subsequently launched the Green Economy Agenda Process; it marked the beginning of a dialogue with partners and stakeholders from the fields of business, science, politics and social groups to develop new approaches to the green economy transformation process of society as a whole. A strategic

research agenda on building a green economy was developed under the agenda process, which gave rise to specific research initiatives and funding projects in FONA³. An integral part of the green economy is the blue economy for the marine environment, which aims to facilitate the transformation to a green economy by means of specific, application-oriented research and the direct involvement of stakeholders and users.

Furthermore, the green economy aims to pay particular attention to the interface between the public and private sectors: plenty of new sustainable processes, products and services cannot be introduced by the state but have to become established in the market.

The FONA³ funding measures are primarily designed to pave the way for such a market launch, thereby also generating visible economic leverage.

In specific terms, research that lays the foundation for a green economy should perform the following tasks:

- Provide the expertise required for decision-making – particularly in the field of politics – by means of systemic analyses and practical examples of a green economy
- Develop “green” innovations in cooperation with users, in other words, sustainable technological and social innovations on the market
- Monitor implementation processes together with stakeholders and actors

In addition to FONA³, the sustainable economy is one of the six future challenges relating to prosperity and quality of life that are prioritised in the Federal Government's High-Tech Strategy; it also focuses on safeguarding the supply of mineral resources, Construction of the Future, sustainable consumption, bioEconomy and sustainable agricultural production.

The Green Economy flagship initiative goes above and beyond the FONA³ framework programme. Other programmes are also involved, notably key technologies and BioEconomy, whose concerted effort is helping to achieve a green economy. Some of the research priorities listed below are part of the collaboration under the Green Economy flagship initiative in these programmes and in FONA. In particular, the “National Research Strategy BioEconomy 2030” uti-

lises biological processes and resources in compliance with the goals and guidelines of a green economy, then refines them to increase their efficiency, thereby combining technology, economy and ecology on a systemic, sustainable basis.

A detailed illustration of the funding topics and measures in the above fields of action can be found in the Green Economy Research Agenda (www.bmbf.de/pub/Green_Economy_Agenda.pdf).

The Agenda covers the following subject areas:

- Sustainable Production and Environmental Technology

Germany will continue to be a high-tech location with a strong focus on exports. In the global competition, Germany excels particularly in environmental technology and sustainable production. Research offers the opportunity to expand these areas still further, while at the same time moving toward a sustainable economy, together with our partner countries. Leaving ecological and economic factors aside, the social aspect of sustainability needs to be improved along the entire value chain. Thus, research is primarily tasked with evaluating and optimising socially acceptable, environmentally friendly production on an international level.

Resources: raw materials, water and land

In order to conserve non-renewable resources in the production of consumer and investment goods in the green economy, it is imperative that complete value chains and networks be examined, along with product cycles, whilst taking consumption patterns into consideration. The ultimate goal is a double decoupling: by means of greater efficiency and technical innovations, the link between the use of resources

and economic growth, prosperity and environmental impact is to be severed. Against this background, it is important to clarify how biodiversity and ecosystem services can be properly assessed and better incorporated in operational and economic processes. The research priorities being addressed here include assessment concepts and methods for ecosystem services, using CO₂ as a new source of carbon, using biomass for substance recovery, closing material cycles, the ecologically compatible development and use of marine resources, sustainable water management or the development and industrial-scale implementation of innovative technologies for resource efficiency.

The geological bedrock is of enormous economic significance, both as a ground water reservoir and energy storage system, and as a repository for energetic and mineral resources. However, subterranean space is limited; more importantly, the manifold conflicting claims on utilisation of this space today will only escalate in the future, thereby opening up the prospect of additional value creation potential. It must be ensured that the consequences of the interaction be-

tween the various uses for these geological formations are assessed to facilitate a realistic prediction of their impact on the environment. This assessment requires both intensive exploration of the geological system as a whole and its quantitative characterisation.

In order to secure the raw material base for German industry and pave the way for greater resource efficiency, FONA³ will set new research priorities in addition to the ongoing funding projects by researching, developing and tapping new sources of raw materials in a sustainable manner to broaden the raw material base.

A drastic shortage of suitable fresh water supplies is to be expected over the decades ahead. A sustainable economic framework requires the sustainable management of natural water resources in order to strike a balance between conflicting needs, while safeguarding supplies of clean drinking water for the world's population and providing adequate sanitation facilities. Moreover, new technologies and system solutions are needed ("Blue Innovations for a Green

Economy"). By international standards, German water management has reached an exceptionally high level. In order to maintain and expand this leading position, it is imperative that we develop efficient, innovative processes and demonstrate their benefits and suitability for practical application at national and international pilot locations. In addition to a high innovation dynamic, the considerable export potential of these areas is uncontested.

Biodiversity and natural capital form the basis of numerous economic processes and products. To date, insufficient recognition and scant consideration has been given to the fact that, apart from intelligent, sustainable use of resources, investments are also necessary to preserve the cornerstone of our economy on a long-term basis. Therefore, it is essential to develop concepts and systems that enable the operational and economic "services" that nature provides for industry and society to be estimated more accurately in future and allow these services to play a greater role in economic decision-making and strategic planning.

Financial services for sustainability

The financing and insurance of new technologies and infrastructures is a central pillar of a green economy. The overall aim is to provide funding for innovations, companies, business models, large-scale projects and infrastructures that meet sustainability criteria. Furthermore, as a general rule, financing and investment decisions set important parameters for sustainable production and consumption. This is because financial service providers, like credit institutes, investors or insurance companies, play a key role due to their economic function as lenders of capital or underwriters.

If we are to kick-start developments in the interests of a green economy and develop innovative solutions, ongoing dialogue with the various sectors and actors in the financial world is indispensable, particularly with relevant areas of business in the real economy, along with public decision-makers like local communities and authorities, and last but not least, stakeholders in civil society. Research priorities in this area of activity include the disclosure of emissions from investments (financed emissions), for example, or the financing of sustainable urban infrastructures and sectors (urban finance).

Sustainable lifestyles and sustainable consumption New technology alone is not sufficient to reduce the use of resources. Our individual lifestyles and daily consumer transactions are associated with so many interactive effects that, despite our realisation of the need for a change in consumer habits, this does not inevitably lead to greater sustainability. The purpose of such research is to encourage sustainable consumption by identifying ways of changing the attitude of society as a whole towards a sustainable way of life.

There is a demand for research into barriers to transformation and transformation drivers for sustainable consumption. Furthermore, in many cases it is still unclear precisely how the sustainability of products and services should be assessed. Therefore, evaluation systems need to be developed and tested in specific cases. We need to identify the obstacles that are blocking the path towards sustainable consumption, analyse the rebound effect of new efficiency technologies, explore opportunities for sustainable products to penetrate the market and find sustainable application, and develop new business models in which producers and consumers interact more closely than in the past. One special focus is on investigating the causes and effects of microplastics in aquatic ecosystems.

Sustainable energy supply and utilisation in industry

With regard to the green economy, innovations in every sector and across the entire value chains are a prerequisite for an increase in energy efficiency and productivity in commerce, industry, services and trade. In addition to technological innovations, there is a need for social-ecological and economic analyses to create a knowledge base in support of strategic corporate decisions and in the political arena. For example, research topics pertain to technologies for the spatial, temporal and material cross-linking of decentralised energy supply systems, harnessing internally generated energy to make companies self-sufficient, the use of waste heat in a whole variety of industry sectors as well as questions on the impact and costs of energy and climate policy framework conditions, like the organisation of emissions trading.

Sustainable mobility systems

A sustainable economy needs a sustainable transport system. It is important to bear in mind how medium and long-term trends, factors like demographic change, a shift in values and so on, on top of global transformations like climate change, influence the demand for mobility and the protection of its mechanisms. In close cooperation with other departments, this initiative aims to research the impact of sustainable mobility on society as a whole.

Employment and qualification in the green economy

The structural changes brought on by the move towards a green economy are having a profound impact, both qualitative and quantitative, on the working environment. Although the transition is creating new employment, other jobs are being axed or redefined.

It is not merely the sectors directly associated with environmental protection that are affected. Instead, due to the ecological modernisation of production and services, job tasks are changing in every sector along the entire value chain. Thus, the challenges inherent in the green economy, like the demands being made on energy and resource efficiency, are affecting virtually every sector, from the extractive industry to manufacturing, right through to the construction industry, the services sector and agriculture.

2.2 City of the Future

Around the globe, more than half the people are urban dwellers, with this figure even rising to three quarters in Germany. By 2050, more than 70% of the world's population will live in cities (over 7 billion); the urbanisation trend continues unabated, especially in developing and newly industrialised countries. Cities use 70 – 80% of the energy produced worldwide, generate 80% of the global gross domestic product and are responsible for up to 70% of mankind's greenhouse gas emissions. As the UN's High-Level Panel for the Post-2015 Development Agenda stated, "It is in the cities that the fight for sustainable development will be won or lost."

The support of research is essential to secure the sustainable development of urban and rural areas. We need to work with industry, local communities and social representatives to find solutions for sustainable development. The City of the Future flagship initiative includes research in three main fields: the development of sustainable cities in Germany, the interaction between urban and rural areas in demographic change and the development of urban centres from a global perspective. City of the Future is interpreted as an integrative approach that links the four tiers of building, district, city and hinterland.

Research Agenda – City of the Future

Since the beginning of 2013, experts from local communities, science, industry and civil society have been developing an overarching strategic agenda in the National Platform for the City of the Future (NPZ) to explore the ways in which research can contribute to the development of sustainable urban settlements in Germany. Four federal ministries are participating in the NPZ: the BMBF, the BMUB (joint coordinators), the BMWi and the BMVI.

The City of the Future strategic research agenda is primarily implemented by stakeholders from local communities, industry and civil society, in cooperation with scientists. This enables the participants and the process leaders to coordinate their own recommended courses of action as a joint effort with the support of the federal ministries involved. Testing the transformation processes in an urban environment is vital in ensuring that the research results are practicable. To this end, urban experimental areas are being set up as part of the model project (known as real laboratories).

The main research focus of the City of the Future lies in urban energy and resource efficiency (particularly in networking buildings and districts to increase energy efficiency, the integration of renewable sources in municipal energy supplies, the transition to flexible infrastructure systems for water and wastewater disposal), climate change adaptation, disaster preparedness and resilience, transformation management and governance research, urban economy and urban systems from a social and cultural studies perspective. The increasing population density, particularly in megacities, necessitates the creation and expansion of

infrastructures to supply the population with water, energy and commodities. An innovation platform is to be set up to implement the research agenda with the participation of stakeholders. The actual implementation in funding programmes (e.g. energy research, urban development) goes beyond the remit of FONA and continues to be the responsibility of the various departments.

Urban-rural interdependencies – “Region of the Future”

The relations between cities and rural regions are shifting as a result of urban development and demographic change. Value chains, delivery relationships, supply structures, area use, water and land management in urban and rural areas all depend on each other. In order to promote sustainable development in urban and rural areas, a deeper understanding of the multifaceted interdependencies within a region, in which cities and hinterland are considered as one entity, is essential. The search is on for solutions for urban and regional expansion that facilitate sustainable development, even in the face of demographic change.

The “Region of the Future” funding concept, currently in the planning stage, aims to pool research and innovation on the geographical ramifications of demographic change and on the sustainable management and utilisation of land and area resources. The research cooperation places the emphasis firmly on local authorities as initiators, partners and recipients of research, development and innovation for a sustainable growth that is prepared for demographic change in Germany.

Research will play a pivotal role in the field of action on “Promoting the quality of life in rural areas and integrative urban policy” in the Federal Government’s demographic strategy. Aimed at structurally weak regions that are particularly affected by demographic change, the planned concepts will lay the foundations for a good quality of life and place the development of urban and rural areas on an equal footing.

Urban regions around the world

Urban development processes must also be scrutinised around the world. In its Fifth Assessment Report of 2014, the Intergovernmental Panel on Climate Change (IPCC) observed that efforts to reduce the emission of greenhouse gases in urban areas represent an important lever in international climate and energy policy. As the population in many of the world's urban regions is growing significantly faster than the underlying infrastructure, cities are now facing enormous logistical and financial challenges of ensuring that millions of people enjoy the best possible standard of living by turning to sustainable investments. This requires targeted planning and investments with regard to the technical infrastructure – energy, water and wastewater supply, mobility, waste management, and the construction industry – and the social infrastructure – healthcare, housing, education, employment, public security and standard of living. Scientific expertise is called for as a basis for decision-making.

In developing and newly industrialised countries, the BMBF will work with local decision-makers, social groups and scientists in testing urban development concepts on the ground that will enable urban regions to grow in a sustainable and climate-adapted manner. Transdisciplinary, international cooperations will develop system solutions that comprise both technical and social innovations. The key issue here is the financing of these new solutions. Moreover, the interdependencies between a city and its hinterland must also be taken into consideration.

2.3 The *Energiewende* – Germany's transformation of its energy system

Germany has chosen to put a sustainable energy system into effect. The necessary transformation poses enormous technical and societal challenges. At the same time, the reform opens up new opportunities for the economy. With the *Energiewende* flagship initiative, the BMBF is fostering research and innovations that encompass all dimensions – i.e. the technical, ecological, economic and social aspects – of the *Ener-*

giewende. By combining all these aspects, the flagship initiative is raising the transformation process to a new level.

Fundamental energy research and technology development

Technical innovations are now laying the cornerstone for the transformation of the energy system. Three main objectives have been established for technology development:

- Increase the production capacity of renewable energy sources,
- Develop innovative distribution and storage infrastructures and
- Improve efficiency.

One purpose of research is to create a wide range of options in the field of renewable energy technologies to enable the particularly efficient production and use of energy, thereby facilitating the diversification of the German energy infrastructure.

New insights and inspiration from the science sector are needed to enhance the efficiency of existing generating technologies. Renewable generation plants like wind farms, photovoltaic systems, bioenergy and geothermal energy benefit from research. Besides optimising individual technologies, the main research priority is to integrate them into the system.

Grids and storage infrastructures are the backbone of the *Energiewende*. The increasing percentage of renewable energy sources is already making research necessary into future network structures. A further challenge for the research community is to develop new usage applications for excess power that are both cost-effective and efficient. Technologies for storing electricity produced from regenerative sources as hydrogen or methane (Power-to-gas) or converting it into alternative materials, like chemical products and fuels (Power-to-X), offer promising potential. Another priority is to develop the storage potential of subterranean spaces in a sustainable manner. Particular mention should be made here of the use of subterranean repositories for hydrogen and methane. However, the exploration and use of underground geological formations is also gaining in importance for another reason: geothermal

resources and hydrocarbon reserves play a vital role in an energy supply that is both reliable and environmentally friendly. The significance of geological formations for the prosperity and welfare of society demands a social discourse based on scientific findings in order to encourage social acceptance.

Energy conservation is a central pillar of the *Energiewende*. Research and development on the efficient, low-impact and environmentally friendly supply, recycling or substitution of the necessary raw materials are crucial for the *Energiewende*. For example, the valorisation of climate-damaging greenhouse gases via the industrial utilisation of CO₂ opens up new possibilities for the sustainable production of basic chemical products and fuels, e.g. for use in the manufacture of formic acid, gasoline, diesel or kerosene. Therefore, FONA³ will roll out additional measures in the fields of resource efficiency, sustainable industrial production and material cycles.

The *Energiewende* has far-reaching consequences above and beyond the energy sector: our reliance on rare earth elements, the manifold applications of water as a resource and landscape fragmentation are of paramount importance. We have not yet grasped the ecological and sociopolitical ramifications. The energy supply for the future can only be realised sustainably by adopting a systemic approach that enables all resources across the entire value chain to be used sparingly. For example, a steady increase in efficiency in managing water resources may lead to a marked improvement in the energy balance: wastewater treatment plants are currently the largest municipal energy consumers, whereas the material and energy potential of wastewater, sewage sludge and gas is not even close to being fully exploited at present. There is also enormous potential for the conservation, recovery and storage of energy in systems for the purification and supply of drinking water. With the help of new concepts for a joint approach between the drinking water and sewage industries and the energy sector, water management installations can facilitate the *Energiewende* by functioning as building blocks in an intelligent, decentralised infrastructure based on renewable energies.

Large-scale research projects implement the strategic research agenda by opening up new avenues of developing solutions for the energy system of the future. Five key topics are being set up on a long-term basis (approximately ten years):

- New network structures (more flexible, more decentralised, customised for pan-European connections),
- “Power-to-X” (utilisation of excess power),
- Material cycles for the *Energiewende* (especially recycling mineral resources),
- New industrial processes (adapting energy-intensive processes to a volatile energy supply),
- System integration (interaction of conventional and renewable energy sources).

The projects also include demonstration units and pilot installations to implement technological innovations. Therefore, industry participation is a prerequisite from day one. Due to their profound effect on the joint “*Energiewende* effort”, major projects like these are defined, developed and implemented in cooperation with all relevant stakeholders in politics, science and civil society.

Research for a socially compatible *Energiewende* The *Energiewende* will not succeed solely on the basis of technological innovations. Its success hinges on our also resolving the social aspects of the reform.

During the lengthy period of time required for the transformation of Germany’s energy supply, it will fall to us time and time again to find tailor-made solutions that are supported by those involved. The *Energiewende* must be in line with political objectives like the preservation of biodiversity and landscape protection. Therefore, a key element in the BMBF’s energy research projects is the integration of fundamental technological research and systems research with social-ecological research. In particular, our social-ecological research focuses on how we can increase citizen involvement in decision-making processes. The scientific community can make a crucial contribution by providing information or developing alternatives and innovative participation concepts. In addition, the community can go one step further and monitor decision-making processes in specific individual cases in an independent expert capacity. To this end, our scientists adopt the

role of an unbiased, neutral advisor, providing expertise and points of reference for decision-making. Therefore, in matters like grid expansion, storage solutions or the relevance of conventional energy production in affected regions, the BMBF offers to attend discussion forums selected by the citizens themselves, providing support in the form of scientific assessments. This gives the general public the opportunity to play an active, competent role in solution concepts, facilitating, in turn, a relationship built on trust.

Energiewende Research Forum

In view of the complexity of the *Energiewende*, it is necessary to achieve a balance between the diverse individual solutions for a future energy system: technical feasibility, economic implementation, ecological impact, energy policy conditions and social aspects should be considered in an integrative context. The BMBF's energy research projects are developed and implemented in a transdisciplinary process.

One exemplary format is the dialogue platform "*Energiewende* Research Forum", which was launched by the BMBF in cooperation with the BMWi. It provides an opportunity for high ranking representatives of the federal ministries and the *Länder* to meet with representatives from science, industry and civil society. The forum discusses and evaluates various courses of action proposed by the scientific community and society for the transformation of the energy system and prepares the "strategic Research Agenda *Energie-wende*" as its contribution to the further development of the federal government's energy research programme. This agenda comprises research projects of key importance for the medium-term and long-term implementation of the *Energiewende*, which need to be given the highest priority with immediate effect. The strategic research agenda will be updated on an ongoing basis both during the lifespan of FONA³ and thereafter.

Sustainability research means actively safeguarding our future: it provides the necessary know-how to overcome global challenges like climate change, shortage of resources, pollution of the environment, loss of biodiversity and the shift towards a sustainable society. Therefore, although it is essential, it is not sufficient for research to address complex systems like urban sprawl or the development of science and the energy supply (cf. the three flagship initiatives). Greater significance should be accorded to fundamental research on global challenges: if highly complex climate models are not accurate enough, if we are not able to evaluate interventions on the seabed adequately, if we want to understand why society fails to accept certain sustainable technological innovations, this means that there is still scope for further development in many of our established fields of sustainability research. The tasks of prevention research are as follows:

- Maintaining and enhancing quality of life and competitiveness
- Using resources intelligently and efficiently

- Protecting common assets: climate, biodiversity and the ocean
- Education and research: working together for sustainable development

For this reason, FONA³ is based on a matrix structure: the major flagship initiatives are not designed to replace the established fields of sustainability research but instead follow on from them, pooling the results in a new light and pursuing new lines of questioning. In other words: the following prevention research fields address new, up-to-date research aspects, lay the foundations for the flagship initiatives outlined in Chapter 2 as well as other future initiatives, and act as drivers for the flagship initiatives, in some cases, even extending beyond them. The matrix structure of FONA³ ensures that the inescapable political prioritisation of the flagship initiatives does not lead to thematic “blind spots”. On the contrary, further scientific advances in the relevant fields will still be extensively pursued.

In the following chapter, therefore, each individual section is divided into two subsections: the first outlines the new priorities in the respective fields of prevention research, while the second expounds how these relate to the three flagship initiatives. Finally, Chapter 4.2 enumerates the international cooperation initiatives in these areas of prevention research. The resulting duplications in the text reflect the fact that FONA³ processes the various rationales – the political priorities, research issues and international cooperation – in an integrated manner.

3.1 Maintaining and enhancing quality of life and competitiveness

Ensuring the highest possible quality of life for the population is policy making's ultimate goal. Nevertheless, the principle of sustainability implies that a high standard of living cannot be at the expense of a high consumption of resources and a drain on the environment. Quality of life means a great deal more than material security. For example, for many people, the natural environment has a significant influence on their quality of life. Measures to protect the environment and social cohesion must be organised in such a way that they uphold the competitiveness of the economy as a whole. This gives rise to a conflict between quality of life and competitiveness that calls for integrated analysis. The Social-Ecological Research (SÖF) funding priority provides an analytical framework in which various measures aimed at boosting economic capacity are examined in the context of social developments, while taking ecological constraints into consideration.

New approaches for a resilient economic and financial system

The objective of social-ecological research in this area is to consolidate the resilience of economy and society to crises and to lay the foundations for a sustainable economic framework. On the basis of integrated analysis, it reflects regulatory governance and economic policy instruments and draws up proposals for framework conditions that facilitate the competitiveness of economy and quality of life. For example, it studies the regionalisation of globalisation and evaluates models for the management of common assets.

Moreover, there is a need for research on the interdependencies between the financial system and society, on the regulation and service function of the financial markets for the real economy and on the various models of sustainable investment.

Participation and governance for a sustainable society

Science is also tasked with researching exactly how to effect the transition to a sustainable society, in other words, the governance of transformation processes. One factor is citizen participation, a significant aspect of quality of life that is gaining more and more importance in an increasingly open, knowledge-based network society. It begs the question of how citizens can become actively involved in political participatory processes, some of which relate to complex issues, while ensuring optimum efficiency of these processes at the same time. It remains to be clarified whether these should be governed by predefined standards and what form quality assurance could take. Therefore, theory-based, empirically proven, inter/transdisciplinary participation research is required.

Citizen participation takes different forms: "citizen science" refers to a field of scientific research in which interested members of the general public take an active role in scientific projects. Although citizen science is an established concept in the process of compiling biodiversity data, this method could also be used in social science projects, e.g. monitoring alternative prosperity and consumption strategies.

New evaluation methods for economic and social development

If quality of life is the ultimate goal: how to define quality of life? This is the subject of research on evaluation methods. Greater efforts have been made in recent times to identify the limitations of traditional economic measurements, like the gross domestic product (GDP), in gauging economic performance and social progress, and to develop suitable alternatives. The focus is shifting onto quality of life concepts, which should be evaluated in more than one dimension: material standard of living, health, education, personal activities including employment, political participation, social ties and social environment. In a knowledge-based society that derives its strength

from the productive capital of its social networks and autonomous social relationships, it is essential that public commodities like social cohesion and solidarity be included as productive assets in the national accounts. The evaluation of differing stocks of natural capital, “artificial” capital, human capital and social capital represents an enormous conceptual challenge for the scientific community. In addition to new insights into the adequate measurement and evaluation of growth and progress, shifting the focus onto the institutional, social and cultural aspects of innovation and creativity is also expected to produce valuable input for innovation research.

Supporting the flagship initiatives

In the framework of the SÖF, prevention research underpins the Green Economy flagship initiative in particular by developing new evaluation methods for the sustainability of economic activities and by submitting proposals for political frameworks that reinforce the resilience of the economic and financial system. Furthermore, new findings relating to consumer behaviour and new business models – especially in a sharing economy – are being utilised for the transformation into a sustainable economic framework. Contributions to the *Energiewende* flagship initiative include supplying and evaluating development options and scenarios for the energy system, submitting recommendations for the governance of the transformation process and developing and testing citizen participation in reform measures of the *Energiewende*. The City of the Future flagship initiative also receives backing in the form of research on governance and citizen participation, in existing planning processes for example, on the conflict between quality of life and competition in urban centres or on municipal transformation management.

3.2 Using resources intelligently and efficiently

The intelligent, efficient utilisation of natural resources like raw materials, water, land, energy, air, biodiversity and ecosystem services requires intensified research on public services like water and energy supply, environmental protection etc.

Raw materials – the focus of prevention research In light of the increasing global shortage of raw materials, supplying Germany’s industry with metal and mineral resources is crucial for growth and prosperity. Yet extracting and processing raw materials frequently has a severe impact on the environment. Therefore, it is imperative that economic growth be decoupled from resource use by means of innovative technologies and services. Research and development are making significant contributions to the objectives of the National Sustainability Strategy, in particular to doubling resource and energy productivity, reducing the emission of greenhouse gases and halving primary energy consumption.

Intensive inter-ministerial cooperation is pursuing the goals of the Federal Government’s Raw Materials Strategy and ProgRes, the German Resource Efficiency Programme. With regard to raw materials research, the national sustainability objectives are being implemented in six strategic approaches: improving resource productivity, securing and broadening the raw material base, promoting small and medium-sized enterprises, cooperating internationally and accelerating implementation.

Safeguarding the supply of technology metals for high-tech applications, from both primary and secondary raw materials, is a key prevention topic. “Raw materials of strategic economic importance for high-tech made in Germany”, the BMBF’s research and development programme for new raw materials technologies, pools these resource-related funding activities. Funding measures will continue to focus particularly on small and medium-sized enterprises, frequently drivers of development in innovative efficiency technologies.

Supporting the flagship initiatives

These raw materials are of strategic economic importance; without them, there can be no internationally competitive, environmentally friendly and socially compatible green economy nor a successful *Energiewende* in Germany. Key projects in raw materials research consist of developing and implementing innovative, resource-efficient technologies in industry, exploring the use of CO₂ as a resource and carrying out research on closing material cycles. The “r+im-puls” funding measure, an innovative instrument that will facilitate a faster transfer of research findings, is being introduced in the raw materials sector.

Water – the focus of prevention research

The primary objective of water research is to help supply the world's population with clean water in a sustainable manner and provide affordable sanitation facilities. The main challenges in achieving this aim are demographic change, sustainable economic growth and climate change. Furthermore, prevention research projects that focus on water will contribute to sustainable water management, thereby conserving the diversity and efficiency of the different aquatic ecosystems in the long term.

In future, research and development that aspires to bring about the sustainable management of water resources will have to focus even more closely on the complex goal of an interdisciplinary and cross-sectoral approach and on an integrative perspective of the system as a whole. Its goal is to develop innovations in interdisciplinary collaboration with partners from industry and practical application, adapt them to changing framework conditions and disseminate them on an international scale.

On the one hand, the BMBF's water research projects pursue the mandate of upholding public services and assume responsibility for preserving the basis of human existence. On the other hand, they are tasked with supporting the German economy in adapting to the changing international market and competition conditions.

Supporting the flagship initiatives

The BMBF funding priority “Sustainable Water Management” (NaWaM) develops the forward-looking planning and design of infrastructures (both urban infrastructures and the interlinking of urban and rural areas), which also play a major role in the City of the Future flagship initiative. In addition, as a key design element in urban centres, water in all its forms is conducive to creating climate-adapted cities and enhancing the quality of urban life. Both at national and international level, innovative system solutions for sustainable water management support the Green Economy flagship initiative, for example in the research and development of decentralised and semi-centralised systems for water and wastewater disposal. Moreover, innovations in the wastewater sector contribute significantly to the *Energiewende* at municipal level.

Land as a resource – the focus of prevention research

A growing world population and the high population density in many regions have exerted enormous pressure on this resource. In Germany, current developments, like demographic change or political decisions like the *Energiewende* are leading to a change in the use of land, which is often intensified, with usable space being ever more hotly contested. Germany and other countries around the world are in danger of losing fertile soil and important ecosystems forever, and of either overexploiting productive land or utilising it in an unbalanced manner. This is particularly true on a global scale: changes in land use are key factors in climate change, the loss of biodiversity and ecosystem services, the worldwide water shortage, safeguarding the world's food requirements, energy and natural resources, the fight against poverty and the social cohesion of the global community.

Developing innovative system solutions for sustainable, practice-oriented land management is a key prevention topic. Regional value networks, the integrated management of land areas, energy and material flows, and infrastructures all play a particularly significant role in this regard. Research aspires to gain a greater understanding of the correlation between fields of action like the rural economy, ecosystem services, energy production, urban-rural interdependencies

and climate protection, while resolving conflicts of interests. The challenges involved include evaluating the practical feasibility of the research findings and acquiring innovation competence. According to general consensus, the participation of science, industry, local communities and civil society from the very beginning of the research project is considered key to success.

Supporting the flagship initiatives

An integrated perspective of the interdependencies between the cities and their hinterlands, and of the cross-border and global resource and migration flows that link the cities with remote areas, is indispensable in facilitating the transformation of urban centres into sustainable Cities of the Future. Furthermore, the *Energiewende* must be structured in such a way that it leads to a permanent, future-oriented exploitation of land and area resources.

Use of terrestrial and marine resources – the focus of prevention research

Prevention research for resource use aims to develop environmentally friendly methods of extracting raw materials and tap the storage potential of subterranean spaces in a sustainable manner. The exploration and utilisation of geological formations is becoming increasingly relevant for the *Energiewende*. Especially in light of competing demands on resources, using subterranean spaces as repositories (compressed air, hydrogen and methane) or for permanent disposal is of crucial importance.

The specialised programme GEO:N (geological research for sustainability) focuses on the various issues and research tasks involved. The utilisation and further exploration of the ocean as a source of biological and mineral resources must respect the functionality and system integrity of the marine environment, with its unique biodiversity and manifold ecosystem services, in order to preserve it as a global source of food and resources for future generations. There is a substantial need for further research into the development of future-oriented technologies for the ecologically sound exploitation of marine resources. To accomplish these goals, the BMBF is proactive in the specialised MARE:N programme (marine and polar research for sustain-

ability), an interdepartmental cooperation at both national and international level.

Supporting the flagship initiatives

Prevention research into the use of terrestrial and marine resources supports the Green Economy and *Energiewende* flagship initiatives by providing concepts and monitoring instruments for their responsible exploitation.

3.3 Protecting common assets: climate, biodiversity and the ocean

Around the world, social, economic and technical developments are giving rise to an escalation of global change processes, in other words, to changes that no longer affect just individual nations or regions but frequently impact the entire world. Their common feature is that they are connected to the overexploitation of so-called common global assets. As a basic principle, natural capital like the earth's atmosphere, biodiversity or the ocean is freely available to every individual and every nation. A broad environmental policy spanning from self-imposed commitments through to regulations and bans is in place; in other words, efforts are indeed being made to prevent the overexploitation of these common global assets. Nevertheless, establishing an adequate level of protection is still proving extraordinarily difficult. Arguably the greatest global challenge of all is climate change; first-ly, because it requires countermeasures to be set up in numerous business sectors and areas of society, from energy production through to the transport system and agriculture. And secondly, it plays a pivotal role in the loss of biodiversity and in ocean warming and acidification, and thus in the degradation of other common assets.

Climate – prevention research

Climate change is one of the biggest global challenges. International efforts are being made to limit the increase in the global mean temperature to a maximum of 2°C. In order to achieve this climate protection objective and take effective action in adapting to climate change, prevention research in the field of climate is pursuing three goals: 1) Close crucial gaps in our knowledge on climate change through outstanding research, 2) Develop practical, efficient competence in the use of climate data and 3) Boost our innovation dynamism to ensure sustainable growth. Measures in the following three priority areas will help to achieve this objective:

- 1) National Initiative for Climate Modelling: a better understanding of the climate system forms the necessary knowledge base for climate protection measures and adaptation to climate change. Developing reliable, efficient climate models is crucial in order to evaluate climate trends and their impact, and to be able to predict and illustrate the necessary temporal and spatial scales for the decision-making process. Research priorities include cloud formation and precipitation processes in the climate system, ocean dynamics or sources and sinks in the carbon cycle (e.g. via climate-optimised land management). Furthermore, palaeo-climatology aims to create a new knowledge base to enhance our understanding of natural climatic fluctuations by the long-term, seamless reconstruction of past climates.
- 2) Regionalisation of climate data: climate protection and adaptation measures are ultimately implemented at the regional level. Therefore, plans are underway to expedite the development of regional and local climate projections and advance the prediction of extreme weather conditions. Following on from this, climate data are to be integrated in regional pilot projects, in planning, investment and policy-making processes for example. The goal is to develop needs-based climate services and kick-start innovations on the ground, which will lead to climate friendly urbanisation and regional development. The emphasis is thus placed equally on better climate protection and on adapting to the natural and socioeconomic impact of climate change, for example with regard to infrastructure and public health. In this regard, research policy momentum is currently picking up speed in this country, in the regions and beyond Germany's borders.
- 3) Integrated evaluations for climate policy and innovation: prevention research on climate change must broaden its horizons to include other issues above and beyond scientific questioning. It is essential to adopt both an integrated approach and evaluation of the costs, risks and potential of climate change and its interaction with other natural, socioeconomic factors in order to develop conclusive scenarios, efficient instruments and sustainable solution models for climate policy and innovations in society and industry.

Supporting the flagship initiatives

Above all, prevention research on climate change is facilitating the City of the Future flagship initiative by providing regionalised climate data and developing instruments and services that enable cities and regions, both in Germany and abroad, to identify climate-adapted perspectives for planning and growth. It supports the Green Economy flagship initiative by underpinning the economic foundation: the focus here is on issues relating to the costs of climate change, the effectiveness of climate policy instruments and international governance. Moreover, it also turns the spotlight onto the sustainability of financial services.

Biodiversity and ecosystems – prevention research By virtue of their biodiversity, ecosystems form the basis of human existence, provide food and water, and meet our recreational needs. At the same time, due to our consumer behaviour, agricultural land use and industrial production, humans are the main cause of the loss of biodiversity and ecosystem services. Approximately 60% of the world's ecosystems are regarded as severely impaired. Many species are threatened with extinction. This has devastating repercussions for natural resources and ecosystems, affecting not merely the terrestrial and limnic ecosystems, but also the marine environment. Four fields of action have been developed to conserve biodiversity and ecosystem services:

- 1) *Ecological and socioeconomic dynamics*: It is to be anticipated that many ecosystems will reach tipping point within the next few decades. Today's goal is to obtain a better understanding of the ecosystem processes and dynamics by studying socioeconomic dynamics and their interaction with ecological processes in order to define ranges for sustainable courses of action within the capacity of an ecosystem.
- 2) *Long-term data and data management*: The development of innovative, demand-oriented methods and tools used to generate and catalogue data and the safeguarding of data compatibility and data standards are indispensable in developing reliable models and scenarios. The objective is to provide innovative *smart monitoring* in order to support decision-making processes that conserve biodiversity and the ecosystems.
- 3) *Natural capital*: Apart from the products thereby created, nature's services are freely available for

the most part; in other words, there is no price on them. The first step is to draw up evaluation concepts, develop evaluation methods and instruments, and prediction tools in order to assess the economic and social value placed on biodiversity and ecosystem services. The second step is to identify what investments and measures are necessary to secure a sustainable economic framework in the long term. Of equal significance in this context is developing instruments to facilitate the integration of biodiversity, natural capital and ecosystem services into corporate management.

- 4) *Land degradation*: The degradation of the biodiversity of the soil and the environmental condition of aquatic ecosystems strike at the backbone of rural economies and are at variance with national food security endeavours. Conflicts over remaining resources and rural migration are the inescapable consequence. The object is to systematically realise sustainable options for small agricultural businesses by means of value chains and improved market access.

Supporting the flagship initiatives

First and foremost, prevention research on biodiversity and ecosystems supports the Green Economy flagship initiative by carrying out studies on the economy of biodiversity, natural resources and globalised habitats.

Coastal, marine and polar regions – prevention research

The interdependencies between the ocean, polar ice and the atmosphere, ocean currents as a driving force for global climate and the ocean's function as a heat and carbon reservoir are all of fundamental importance for an understanding of global and regional climatic events. The specialised MARE:N programme for sustainability research in the coastal, marine and polar regions includes research projects on the global material and energy cycles in marine and polar regions, their interaction with land masses and the atmosphere, and their impact on the global and regional climate.

The marine and polar regions are increasingly evolving into an economic area of international standing, which is gaining in importance both as a transport

route and a source of resources. With the use of modern, efficient technology, marine research is facilitating the exploration and exploitation of resources and developments in marine technology. It promotes synergies and (interdepartmental) cooperation in interdisciplinary subjects like maritime measurement technology and environmental engineering, the exploration and exploitation of marine mineral resources, coastal engineering or the generation of energy from the sea. The challenge is to uphold the ecological equilibrium of marine and polar regions, thereby safeguarding the exploitation of natural resources and ecosystem services, both for today's society and for future generations. The research findings thus lay down the foundation for a successful environmental and economic policy that respects and acts in the interests of sustainable environmental protection.

By virtue of their high population density, their important role as a versatile habitat and economic area, and their vulnerability to climate change, special emphasis is placed on coastal regions. Today, more than two thirds of the world's population live in a narrow coastal strip approximately 50 kilometres wide, including three quarters of all megacities; in Europe alone, almost 200 million people live near the coast. As part of FONA³, the BMBF is funding transdisciplinary research aimed at preserving coastal ecosystems and their ecosystem services, as well as projects on integrated coastal protection and sustainable management of the coastal zones. These projects will study the exploitation of coastal zones in conjunction with natural and anthropogenic interdependencies and their impact on the ecosystems. Other projects will focus on drawing up risk-based adaptation strategies and developing prognostic models to investigate the impact of climate change and the modified conditions of use.

Supporting the flagship initiatives

Maritime prevention research supports the Green Economy flagship initiative in developing sustainable concepts for the exploitation of marine resources by providing the necessary basic data. Moreover, marine science is collaborating with the terrestrial disciplines in the City of the Future flagship initiative to establish important knowledge bases for the sustainable development of densely populated coastal regions.

3.4 Education and research: working together for sustainable development

The Federal Ministry of Education and Research interlinks education and research for sustainability to advance their development.

Over the past ten years, research and education for sustainable development has received major stimulus: the year 2005 not only saw the launch of the first FONA framework programme, it also ushered in the UN World Decade of Education for Sustainable Development, known as ESD. Owing to the different prerequisites, the two initiatives adopted highly diverse approaches: while FONA merged the numerous previous research projects into one framework programme to create greater synergies, the ESD first had to develop a new focus based on education policy in assembling a great many, mainly smaller and individual activities.

Today, now that the UN Decade has drawn to a close, Germany's curricula includes ESD, there are sustainability strategies at *Länder* level, central municipal organisations have added ESD to their political agenda and an active group of representatives from academia aim to anchor ESD more firmly and disseminate the topic in a holistic approach at their universities or universities of applied sciences. Under the pronounced participatory approach adopted in ESD, platforms for exchange and implementation have been set up throughout Germany. Almost 2,000 "Decade Projects" attest to their widespread impact.

This resulted in the creation of a whole range of thematic, structural and procedural interfaces between FONA and ESD; these can now be used as starting points in forging stronger links between FONA and ESD over the next five years, when the 5-year Global Action Programme on ESD is to be launched at the same time as FONA³:

- a) Sustainability is becoming reality on the ground. Solutions must be conceived systemically and implemented across all areas. Therefore, local networks for sustainable development are frequently at the heart of funding measures, both in research and education:

- ESD paid tribute to 21 “decade communities”, who have successfully incorporated sustainable action as a guiding principle in many areas of municipal politics and administration. Regional education landscapes were supported by 31 local networks of expertise for sustainable development. This support on the ground was particularly effective. Plans are in place to extend the support and mobilisation of the broad social involvement by introducing a restructured award system and by increasing the professionalism of the participants in further training.

- Furthermore, sustainability was an important topic in the extensive funding of the integrated, data-based education management system in the “Lernen vor Ort” (On-Site Learning) initiative, to be rolled out in over 200 German communities in the near future.
- The “National Platform for the City of the Future” is developing the Research and Innovation Agenda, to be implemented as a flagship initiative under FONA³ over a period of five years. The Science Year 2015 is focusing on the City of the Future.

We aim to merge the numerous ongoing network activities, identify their interfaces, facilitate mutual learning to increase the professionalism of participants, enable the various stakeholders to exchange ideas and complement their skills effectively, scale good approaches by means of effective communication, link education and research on the ground more often than in the past, introduce these topics into internal and public dialogue and pave the way for integrated developments in the future.

- b) Special effort must be made to include universities as partners if education and research are to be pooled in the interests of sustainability. This has been demonstrated in the past:
 - Now numbering more than 100 participants from academia, science and university administration, the ESD university working group succeeded in prompting the German Rectors’ Conference and the German Commission for UNESCO to make a policy statement; it also realised a virtual academy with digital online courses on sustainability, some of which are eligible for ECTS credits. These include numerous ideas for implementing the “whole-institutional approach”, which focuses on a university’s sustainable development.
 - FONA’s “Sustainability in Science Initiative” (SISI) supported and empowered universities and the non-university research community in developing sustainable processes for their working place and research.
 - FONA provided funding for junior research groups at universities and non-university research institutes to establish interdisciplinarity and transdisciplinarity in scientific studies. These measures aim to reduce a structural problem of the subject-discipline-based higher education system.

Universities fulfil crucial functions by disseminating new findings as partners of local sustainability networks, developing new formats (e.g. real laboratories) right through to the practical transfer, studying technical sustainability issues and introducing international aspects. As sustainable local institutes, as employers and establishments of further education that generally enjoy a positive image, whose formative influence has a wide reach, they play a particularly significant role in the fledgling communication of sustainability topics.

- c) Vocational training is often critical where new, resource-efficient technologies and processes are to be implemented across a wide range of applications. This holds true for all innovations and also applies to sustainable development:
 - As part of ESD, a successful series of pilot projects were carried out with scientific backing in the fields of nutrition, energy and forestry.
 - Up to now, the development of new technologies has only been associated with training activities in isolated cases in FONA, for example in water management.
- d) All calls for proposals under the FONA³ framework programme include checks to verify whether specific funding of educational schemes would serve to further the implementation.

In addition, a number of issues affect FONA and ESD in equal measure and can be addressed as part of a joint approach in future:

- It is still difficult to communicate the issue of sustainability in the general public; not all aspects of education and research are generally well-known in the other discourses. By joining forces in public relations work and communication, both programmes can exert greater influence over public debate and assure their connectivity in specialist discourse and agendas in each other's sphere, as well as in higher-level discourse and agendas, like the Sustainability Strategy, the High-Tech Strategy or international discussion processes.
- This also applies to the methods and instruments: transdisciplinarity and interdisciplinarity in sustainability call for new approaches with regard to both education, including education science, and research, which should be communicated within

the scientific community but also made public. A virtual academy that refines these new methods and instruments and makes them available could be established at the interface between ESD and sustainability research.

- This also applies to the challenges: ESD and FONA have an interdisciplinary approach. As cross-cutting issues, they are more difficult to anchor than other topics in institutions with a sectoral structure. This also leads to certain challenges for junior research groups because there is neither an established field of study nor any relevant publication media that span several disciplines. Therefore, it is harder for young scientists to pursue a career than for those in clearly defined, classical disciplines.
- Statistics and indicators, quantitative techniques and quantifiable factors play an increasingly important role in research and education, as well as in politics and administration. The development of pertinent techniques, measurement parameters, indicators or benchmarks in education and research, and in sustainability policy, could trigger significant momentum for both ESD and FONA.

With this in mind, it is worth considering whether a joint ESD/FONA platform should be developed to edit relevant content for the other sector, further joint projects and advance potential cooperation by means of active mediation.

Supporting the flagship initiatives

Education for sustainable development takes place wherever people learn. Thus, during the past UN Decade, for example, the Federal Institute for Vocational Education and Training funded pilot projects for the integration of ESD in the organisation and further development of vocational training. It became evident that many companies regard sustainability as an image factor with intrinsic added value. The projects identified and analysed the qualification requirements in four sectors: renewable energies, construction/ interior design, the chemicals industry and nutrition, developed curricula and drafted teaching modules for the training process, for example restructuring the job profile of a mechatronic engineer for wind farms. The ESD initiatives, to be embedded in the education system, will be used to train those responsible for real-

ising a green economy in the future, in other words, an internationally competitive, environmentally friendly and socially compatible economy. By drawing up action-oriented, hands-on teaching materials for energy education, for example, ESD can play a vital role in the *Energiewende* flagship initiative and encourage individuals to transfer research findings into practice. For example, young people train as climate experts by carrying out their own experiments under scientific guidance and subsequently act as multipliers.

The structures created at municipal level as a result of the UN Decade will play an important part in the City of the Future flagship initiative: over the past 10 years, 21 communities were awarded the accolade of City and Local Authority of the UN Decade once again, some even with an increase in quality, for their endeavours to integrate ESD as a cross-sectoral issue. ESD is put into practice locally as a community task. Among other things, the scientific guidance for the ESD governance structures in local authorities revealed that sustainability is a particularly appropriate linchpin in defining identity and thus offers such a high mobilisation potential.

Research on global challenges can only achieve excellence and be effective as part of an international network. Therefore, international cooperation is an integral element of FONA³. The guiding principle of international research cooperation stipulates that it must be on an equal footing and for the mutual benefit of all parties. By implication, it is essential that the research and innovation policy objectives of the various partner countries be aligned and the funding processes structured accordingly. With the aim of extending the social relevance and impact of FONA research beyond Germany's borders, the BMBF is pooling the international cooperation activities in three programme lines:

a) European cooperation. Objective: Take joint action with our European partners to make even better use of research resources in Europe and enhance the mutual networking of national programmes, as well as with the European programme Horizon 2020.

- b) International Partnerships for Sustainable Innovations (CLIENT).** Objective: Work together with international partners to research and develop application-oriented, sustainable solutions and exploit the economic opportunities open to environmental technology that is "made in Germany", particularly in the emerging markets and developing countries.
- c) International cooperation in prevention research.** Objective: To acquire the knowledge required to preserve our common assets of climate, biodiversity, the ocean, water, coastal and polar regions, which can only be gained in international cooperation.

4.1 European cooperation

Germany is a European leader in sustainability research. On this basis, FONA³ will continue to pursue the cooperation with our European neighbours intensively.

Strategic cooperation and structuring of the European research landscape

Fundamental to the activities at EU level are the efforts of the various bodies at different levels (particularly the programme committee of “Climate action environment, resource efficiency and raw materials” in Horizon 2020), who shape the regulatory environment, set priorities and initiate activities. Moreover, a large number of strategic platforms have been established, which guide and coordinate European endeavours on diverse research topics on an ongoing basis. One new type of platform, like the planned Knowledge & Innovation Community (KIC) on raw materials and the ongoing Climate KIC initiative, aims to form closer links among leading German and European stakeholders in the knowledge triangle between education, research and industry in order to transform R&D results into marketable products and services more swiftly and effectively.

Additional requirements for international cooperation lie in marine and polar research, like the implementation of the European Marine Strategy Framework Directive, and as a basis for the activities of the Convention on the Protection of the Marine Environment, OSPAR COM or HELCOM. Finally, the joint European infrastructures serve as a focal point for discussion on topics and research policy.

The Joint Programming Initiatives (JPI)

The JPI aim to bundle national resources for the concerted planning, implementation and evaluation of national research programmes. A key instrument on the road towards the European Research Area, they are to be used intensively in FONA³. Under FONA³, the BMBF is participating in the following joint initiatives (JPI): JPI Water, JPI Climate and JPI Ocean.

The joint initiative “**Water Challenges for a Changing World**” (JPI Water) has set itself the objective of helping to find solutions to the water challenges faced by society in those areas in which a synergy of national research capacities clearly results in additional benefit. These include the management of aquatic ecosystems, supplying safe water systems in light of demographic and climatic changes, and increasing resource efficiency. The transnational co-funded calls for research proposals, in which the BMBF is participating, are an important instrument in this process. The core themes form an integral part of the Strategic Research and Innovation Agenda, which was drawn up in collaboration with the funding partner organisations.

The objective of the JPI “**Connecting Climate Knowledge for Europe**” (JPI Climate) is to coordinate European efforts in research and innovation to find solutions to the major societal challenge of climate change. The process aims to cover the entire chain, from the creation of new climate data right through to customising the practical application as a basis for specific decisions. One aspect is including a European perspective to the research results on the social dimensions of climate protection and climate change in Germany. Cross-border comparative research will add to our understanding of the societal challenges and transformation processes in different sociopolitical contexts that have been brought about by climate change.

In order to meet the growing demand for the resources of European ocean and coastal regions and safeguard the maritime economic power of the EU, the BMBF is collaborating with the JPI “**Healthy and Productive Seas and Ocean**” (JPI Oceans) on a research funding strategy to be coordinated with other European coastal states, and is initiating innovative pilot actions on pressing research issues. In pursuing a similar goal, the BMBF is adopting an integrated approach with a Strategic Research Agenda in the Baltic Sea region in consultation with the other neighbouring countries to ensure the sustainable use and protection of the ocean (BONUS).

Transnational and bilateral funding initiatives with European partners

Within the scope of FONA³, the BMBF intends to participate in or initiate European coordination projects, like ERA-Nets, and bilateral research cooperations. Joint transnational and bilateral research projects will be supported in selected fields to generate synergies from cross-border cooperation.

Germany is a leader in research on the material conversion of CO₂. The European SCOT initiative (Smart CO₂ Transformation) extends the scope of national activities in the field of the recycling and recovery of CO₂ by means of joint research and innovation funding with leading European partners.

Above all, research cooperation with European partners will spur on the transition to a modern, low carbon, safe energy supply in Europe. Germany and France both play a vital role in this undertaking and will continue to pursue their cooperation in the field of energy research. The main emphasis of this bilateral research project is on the areas of network technologies and materials research.

A further example of bilateral cooperation in energy research is the partnership between Germany and Greece. This research cooperation focuses on promoting energy research priorities like innovative materials for solar cells and highly efficient batteries.

In cooperation with the Netherlands, the bilateral Wadden Sea research project studies innovative protection and nature management measures, which aim to safeguard a natural and self-sustaining ecosystem for the benefit of all social groups, by ensuring its sustainable, coordinated utilisation.

4.2 International Partnerships for Sustainable Innovations (CLIENT)

FONA³ aims to develop the CLIENT funding measure (International Partnerships for Sustainable Technologies and Services for Climate Protection and the Environment), previously implemented in the FONA programme, still further. The BMBF is funding re-

search projects that are developing and implementing innovations as a joint effort with partners in developing and newly industrialised countries. The focus of CLIENT is on demand-oriented R&D cooperations, in which German research institutes and enterprises develop and implement innovative, needs-based technologies and services, together with international partners. Research priorities are resource and energy efficiency, along with water and land management.

Particularly for those countries that, by virtue of their rapid economic growth, are on the threshold of becoming industrialised nations, new technologies, processes, services and organisational forms will play a key role in overcoming the environmental challenges that lie ahead. In addition to the more economically developed countries, the resource requirements of emerging markets and developing countries are increasing and, accordingly, the impact on the environment; at the same time, these countries are important suppliers of raw materials for German industry. The successful international partnerships for sustainable technologies for climate protection and the environment are being maintained and refined to ensure that global resources are used intelligently and efficiently. At the same time, this is conducive to economic development in the partner countries and opens up export opportunities for German industry.

4.3 International cooperation in prevention research

As the basis of human existence, our common assets – climate, biodiversity, the ocean, coastal and polar regions – are of phenomenal global importance. In order to understand their complex systems and interdependencies, and protect them effectively, medium to long-term international cooperation, e.g. with those regions that are particularly affected by global changes, is essential.

Climate change research: With regard to prevention research on climate change, the IPCC constitutes an unparalleled risk monitor; by pooling, compiling and evaluating the complex data on climate change, the Panel offers indispensable guidance to enable us to

draw up forward-looking climate and sustainability policies. The results of German research groups are being fully integrated in IPCC inventories on climate change and climate protection, which are then made available to the general public as expertise and points of reference for decision-making.

Furthermore, as a significant industrial nation, Germany has an international responsibility to be proactive in supporting newly industrialised and developing countries in their efforts to protect the climate and adapt to climate change. Firstly, this support is directed towards those regions of the world that are particularly affected, yet lack the resources to find solutions to the challenges of climate change unaided. To this end, two regional competence centres for research into climate change and adapted land management have been set up with local partners in West and South Africa to provide the necessary capacities. Secondly, it is aimed at those regions of the world in which enormous dynamics of change, due to urbanisation processes for instance, are setting the stage for sustainable growth and development models.

Research on sustainable urbanisation: The trend towards rapid urban growth continues unabated, particularly in the developing countries and emerging markets of Africa and Asia. The priority is to manage urbanisation in such a way that the quest for commercial innovations and economic upswing does not compromise ecological viability and social participation. If efficient infrastructures and new consumption patterns can enable cities to significantly reduce their use of energy and resources on a long-term basis, this will prove to be a key factor in achieving global sustainability objectives. With the participation of the cities in rapidly expanding urban areas, international research projects will pave the way for innovations with a broad range of impact and excellent opportunities for “green” growth.

Research on biodiversity: In order to consolidate biodiversity protection and the sustainable use of ecosystem services on an international scale, the BMBF is supporting funding initiatives for cooperative research projects in newly industrialised and developing countries. The activities of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IP-

BES) are being supported in parallel. As an independent intergovernmental body, IPBES compiles current research results on the status of the global ecosystems as scientific policy advice, uncovers any research gaps and communicates its findings to political decision makers.

Research on sustainable water management: International cooperation is a prerequisite for sustainable water management on a global scale, especially with developing and newly industrialised countries. During the past few years, the BMBF launched Integrated Water Resources Management (IWRM), a process that promotes the coordinated development of expertise and the management of water, land and related natural resources; it has proved to be an extremely fruitful mechanism. The immediate objectives of the process are a) more widespread access to clean water and sanitation, b) the transfer of technical solutions by economic and industry partners to increase water productivity, c) improved solutions in wastewater management and to enhance water quality.

While the focus in earlier research stages was on identifying the actual global water problems, solution-oriented research projects are now increasingly required to build on these findings. The new “Water as a global resource” funding measure will help meet this need by addressing the global level, where key figures for the implementation of global sustainability objectives are defined from a regional perspective and by launching governance measures that are geared towards a more effective implementation of adopted solutions.

Research on sustainable land management: The international research cooperation on sustainable land management will place a geographical focus on arid, semi-arid and dry sub-humid regions. By their very nature, dry zones are not investment magnets. Moreover, they are severely affected by desertification and other aspects of global change, like climate change. In some cases, dry zones, even those located directly on Europe’s borders, currently have the highest poverty rates.

Coastal, marine and polar research: The imminent challenges for the protection and sustainable exploitation of coastal, marine and polar regions can only be

assured by international cooperation. The German research landscape is a world leader in this field. This is reflected not only in our participation in international programmes, but also in our scientific and technical cooperation with newly industrialised and developing countries.

German coastal, marine and polar research is closely linked to international research programmes related to global change, like IGBP (International Geosphere-Biosphere Programme) and WCRP (World Climate Research Programme) and has helped to advance their scientific progress.

The BMBF maintains research cooperations in line with bilateral agreements on Scientific and Technological Cooperation (WTZ). The WTZ projects are strategic partnerships for the realisation of the FONA programme objectives. Specific research policy topics stem from this agreement, e.g. joint efforts with partner countries like Russia in Arctic research and China in marine research.

International networking of education and research for sustainability

Education for sustainable development in Germany was spurred on considerably by the international announcement of a UN Decade in 2005. On behalf of the Federal Government, the Federal Ministry of Education and Research (BMBF) was responsible for supporting the national implementation. The German Commission for UNESCO (DUK) was tasked with coordinating the implementation under the parliamentary resolution of 4 July 2004 (BT-Drs. 15/3472).

The objective was to firmly establish education for sustainable development as a cross-sectoral issue in all areas of education. Thanks to this aspect, the international character was planned and institutionalised from the very beginning.

In 2015, this will be followed by a Global Action Programme with a lifespan of five years. The programme covers five priorities: “Policy Support”, “Whole-Institutional Approach”, “Educators”, “Youth” and “Local Communities”, all of which are international goals, particularly the first two and the fifth. In Germany these seeds will fall on fertile, well prepared soil, where they will continue to flourish if education and research work together.

As a vital component of prevention and fundamental research, excellent research infrastructures (RI) are of the utmost importance for Germany as a location of scientific and technological developments. Features of these modern research infrastructures include the German research fleet, innovative measuring technologies and surveillance techniques, geographical information systems and infrastructures for data storage and processing. Such infrastructures facilitate not just the interdisciplinary exchange of information, the guaranteed long-term observation of key climatologic processes and regions, prognostic modelling of the impact of climate change and improved early warning systems, but also the development of tools that verify the emission of greenhouse trace gases or the preparation of regional climate adaptation strategies. For example, infrastructures designed to observe, model and examine the sustainable application of geographical data guarantee efficient studies in the fields of geographical, marine, climate and polar research. With regard to a more integrated

approach and evaluation, one important research task involves combining earth system and geographical data with societal and socio-economic data.

Research infrastructures cover a wide range of research topics. In fact, they are a prerequisite for relevant research in numerous fields. Specific plans for the continued development of climate research infrastructure systems and components, and their use, focus particularly on safeguarding ongoing investments in a sustainable manner and on identifying strategic additions to the German Climate Computing Center (DKRZ), the HALO (High Altitude and Long Range) research aircraft, the twin GRACE (Gravity Recovery And Climate Experiment) satellites, the Zeppelin NT and the ATTO tower observatory in the Brazilian rain forest. Designed for use in tropospheric research, the IAGOS infrastructure consists of individual measuring stations, which are permanently installed in passenger aircraft. The autonomous devices enable in-situ, continuous monitoring of the atmosphere, thereby

revealing the impact on Europe of forest fires in Canada, for example. In the field of marine research, for example, the research vessel SONNE, commissioned in 2014, represents an essential “tool” for the multidisciplinary research of the ocean. In addition, an overall research fleet strategy guarantees the appropriate renewal and replacement of Germany’s research vessels according to current and future research requirements. Other major infrastructures are included in the BMBF roadmap process for research infrastructures; FONA³ will play a part in the implementation thereof.

In addition to supporting national infrastructures, participation in European research infrastructures also provides access to important research opportunities and transnational cooperation. Noteworthy examples here include the ESFRI projects (European Strategy Forum on Research Infrastructures) or the collaborative use of national research platforms, like that of OFEG (Ocean Facilities Exchange Group).

6.1 Agenda processes

Paving the way for innovations

Research priorities and a needs-based research approach can only be developed in dialogue with all scientific experts and the end users in industry, administration and society. The appropriate participation of stakeholders from all fields will serve to enhance the innovative capability and social relevance of sustainable research and accelerate the transfer of its findings for applications in politics, administration, industry and society.

Agenda processes make it easier to formulate central questions and establish common priorities; they serve as a guide in implementing the programmes and disseminate the results to the end user. Under the direction of the BMBF, together with the relevant stakeholders, the research agenda for FONA³ is being developed in this type of process with the goal of addressing specific requirements and translating them into research issues.

Identifying needs, finding solutions

The central research questions are identified, consolidated and prioritised in roundtables and workshops, and subsequently transferred to a joint research strategy. In order to generate specific, practicable expertise for decision-making through research, the questions are embedded in the process during the projects' entire lifespan, right through to the implementation of the findings. To this end, knowledge is not transferred exclusively from science to society, but is also passed reciprocally from the end users to the researchers and developers. Thus, practical user knowledge is firmly established in the research agenda from day one.

Specific lines of approach are developed from the agenda process, which are generally focused in themed calls for research proposals.

The competition procedure that is an integral part of the calls for proposals enables publicly funded re-

search groups to deliver needs-based, socially relevant and practicable solutions.

Consistent citizen involvement

Many sustainable innovations can only be realised with the involvement of the general public. Notable examples include expansion of the grid for the *Energiewende*, sustainable consumption or climate protection strategies in urban areas. Efficient forms of citizen involvement need to be tested and established in order for sustainability research findings to be transformed into successful applications. The general public should not just be involved in specific projects and measures because they are directly affected but also play an active part. The aim is to establish a dialogue between citizens, funding bodies and scientists that will scrutinise the societal relevance and acceptance of new ideas. This trans-disciplinary approach at all research funding levels will open up new opportunities for a transformative research landscape, which will then pave the way for a sustainable economy and society by providing specific, practicable expertise and products. In turn, this raises the standing of Social-Ecological Research (SÖF) in Germany, which has played a pioneering role in evaluating the various paths to transformation in this field for many years.

Interleaving research policy with other policy sectors

Customised, innovation-friendly framework conditions are a prerequisite for the development of groundbreaking ideas and solutions. This is especially true of sustainability research, as it addresses societal challenges that have a direct impact on human existence. These framework conditions are set by environmental, economic, consumer and transport policies, by urban planning and the provisos of economic cooperation. It therefore follows that, if sustainable research is to be effective, it has to take these policies into account from the very beginning, i.e. from defining the topics and setting priorities, right through to applying the results. Research projects are thus carried out in close cooperation with the respective Federal Government department in whose remit the topic falls. In the case of the City of the Future, Green Economy and *Energiewende* flagship initiatives, interdepartmental dialogue plat-

forms are to be set up, in which science, civil society and politics are actively involved. Thus, by preparing science-based recommendations and moderating the resulting social dialogue, research becomes a facilitator of politics.

6.2 FONA³: a learning programme

Evaluation and impact analysis

The objective of FONA³ is to support innovations for a more sustainable society. An evaluation of project results highlights the specific individual goals that were achieved in the pursuit of sustainability. Furthermore, the instruments used must undergo a validation process to review their effectiveness. These evaluations allow for feedback with the structure and content of the programme, and, if necessary, also lead to a realignment: the findings and insights of the individual projects are incorporated into new agenda processes, thereby contributing to FONA³ as a learning programme. Therefore, these programme evaluation instruments are introduced concomitantly, concluding with an impact analysis.

In order to guarantee the effectiveness of the FONA³ framework programme, the funding measures focus from the start on clearly formulated goals and their progress is reviewed in systematic evaluations. If feasible, the various results and impact of the funded projects should be reproduced and documented using measurable and temporally defined indicators that are as specific as possible. Moreover, the evaluation and impact analysis will provide a basis for the further strategic development of the programme structure and content.

Future priorities

In addition to the insight from the evaluations of the ongoing and completed measures, the content of FONA³ will be continuously monitored to verify whether new sustainability themes and trends should be included, either in a technological or a social dimension.

This topic radar identifies emerging future priorities. Following both an external and an internal evalua-

ation, for example by means of potential analyses or in roundtables, such priorities can be incorporated into FONA³ without delay and processed using flexible instruments.

6.3 Funding instruments

Extended portfolio of funding instruments

Joint research projects, which are selected in a competitive process, are a tried-and-tested instrument. In order to augment the applicability and innovative capability of the research findings, FONA³ demands high standards of transdisciplinarity in these projects. End users must be included throughout the project's lifespan. Likewise of great relevance are the aspects of innovation and process consulting, participative elements and a modern scientific communication that makes provision for collaborative and dialogue elements.

Moreover, FONA³ will make use of new project funding instruments, which will take better account of the requirements in innovation processes and enable continual dialogue with social groups. Mention should be made here of the real laboratories, which aim to extend the instrument portfolio of FONA research.

Real laboratories are social simulators, like city districts or even whole cities, in which the scientific community selectively encourages and supports processes of change (transformative research). These demarcated environments allow the relevant factors and participants to be easily observed and influenced. Such real experiments shed further light on cause and effect, facilitate the early detection of problems associated with the transformation and help in developing in situ solutions to these problems, together with the local population. In this way, real laboratories serve as places of reference in a transdisciplinary research process, where knowledge bases from different disciplines and groups of participants are merged.

Furthermore, in many cases, intensive accompanying research is advisable to support implementation processes (e.g. in political measures or products) and integrate them in a transdisciplinary context. These include accompanying analyses of factors that contribute to or hamper the transfer of results, the observation of socio-economic effects in implementing the results and a complete overview of the findings of larger funding measures, and thus of the cross-references between the individual funding projects.

Exploiting and optimising synergies between project funding and institutional funding

The BMBF's institutional funding provides valuable input for FONA³. The main priority of the BMBF is to strategically exploit the institutional research results of FONA³. The contribution of the non-university scientific community to the environment and sustainability sector is of fundamental importance. By optimising the division of labour, refining the key topics and the networking process, and increasing competitive orientation, we can create even greater synergies between institutional funding and project funding than in the past.

For this reason, FONA³ is focusing on intensive exchange and close interaction with the Programme-oriented funding (POF) of the Helmholtz Association (HGF), as well as with the Max Planck Society (MPG), the Fraunhofer-Gesellschaft (FhG) and the Leibniz Association (WGL). Project funding acts systematically on the fundamental research results of the research organisation institutions.

By the same token, institutionally funded research complements project funding by contributing to those issues, for which society, industry and politics require expertise as a basis for decisions. Thus, the Helmholtz Association was set research objectives that are in compliance with FONA³.

6.4 Interdisciplinarity and transdisciplinarity in the science system

Sustainable development has particular need of an interdisciplinary and transdisciplinary scientific landscape. Problems like climate change, a sustainable energy supply or the decline in biodiversity can only be resolved if the research community joins forces with the end users to tackle scientific, economic and societal issues. Interdisciplinarity and transdisciplinarity are thus prerequisites for maintaining the high level of German sustainability research in the long term, in order to consolidate Germany's position as an international leader in this field.

Despite a perceptible willingness to cooperate across disciplines in tackling these challenges, the science system is primarily biased towards a disciplinary approach. Interdisciplinary, and especially transdisciplinary, cooperation continues to be undervalued. To date, it has been particularly difficult to establish scientific careers on the basis of interdisciplinary or transdisciplinary collaboration, even though the promotion of young researchers is showing very real progress in this respect, for example in social-ecological research.

Universities play a key role in the further development of interdisciplinarity and transdisciplinarity in the science system. By virtue of their considerable autonomy, it falls to them to assume a high degree of individual responsibility in teaching junior research groups to adopt an interdisciplinary and transdisciplinary research approach and master the required methods and instruments. At the same time, it is essential to heighten the scientific community's awareness of the value of transdisciplinary research. Therefore, FONA³ will support efforts to promote junior research groups adequately and to gauge advances in the area of interdisciplinarity and transdisciplinarity by means of appropriate indicators. FONA³ will support these endeavours as part of the "Sustainability in Science Initiative" (SISI).

6.5 Sustainability in Science

Sustainability research and science gain particular credibility if they also apply the principles of sustainability to their own activity. The BMBF initiative for "Sustainability in Science" (SISI) supports researchers in achieving this goal. The content and measures are developed within the framework of the SISI agenda process in dialogue with scientists, administrative staff and students.

The BMBF will focus on the following areas:

Research in social responsibility

A precious asset, the freedom of research is enshrined in German Basic Law. However, since it also exists in a social framework, research bears responsibility for society and the environment as well. Scientists must themselves consider just what this responsibility means in practice. Firstly, scientists place great emphasis on the sustainable configuration of the research process as such (research as a sustainable process) and, secondly, on the part played by research in the sustainable development of society as a whole (research on sustainability issues). By supporting this process as a moderator, the BMBF shapes the framework conditions in a way that enables researchers to put sustainability into action in their community.

Sustainable construction and operation of scientific institutes

Research needs resources, particularly energy and space to develop. Numerous universities, research facilities and institutes are leading by example. They are implementing environmental and sustainability standards in their buildings and developing guidelines and concepts for green procurement. Together with other federal ministries, the BMBF is committed to the further development of the relevant guidelines and evaluation systems in the context of sustainability, and is backing their implementation. Both undergraduates and teachers are being trained, kept up to date and actively involved in the development of universities.

Linking sustainability research and teaching Within the scope of FONA³, innovative projects that combine research and teaching may also receive funding (cf. also Chapter 3.4). In addition to the internal networking of researchers, students and administration at universities, ties can be forged to stakeholders from local communities, industry and associations.

The BMBF also supports the corresponding accompanying research and evaluation.

Networking and supporting initiatives

FONA³ is funding initiatives that aim to encourage sustainability in research facilities and on research campuses. These include student sustainability initiatives, university initiatives and non-university research. The programme also promotes networking between universities and institutes, focusing in particular on the development of criteria, regulations and policies for sustainable research.

In order to facilitate ongoing exchange among the participants (scientists, administrative staff, undergraduates, representatives of local communities and enterprises) and develop other measures in dialogue with the community, the SISI agenda process for sustainability in science is to be pursued. This takes place on a regular basis in symposiums and round-tables, as well as on an interactive internet platform at www.fona.de.