Introduction

The future belongs to the generations to come. It is our responsibility to leave them an environment worth living in. As a result, economic and business models that have been established for decades are facing considerable upheaval with the coal phase-out, energy system transformation, the ecological restructuring of agriculture, and climate protection. At the same time, there is still a lack of solutions to major challenges such as resource scarcity, climate change, ocean acidification and species loss. This is where the 'Research for Sustainability (FONA)' programme of the Federal Ministry of Education and Research (BMBF) comes in – and where it has been active since 2005. The new FONA Strategy is based on the motto: 'Knowledge for a future that works'. FONA considers ecological, economic and social interests equally. FONA also addresses current developments that affect sustainability. The current Covid-19 pandemic, for example, is a harsh reminder of how vulnerable our coexistence and economies are. The aim will therefore be to make our society more resilient in the face of such and similar crises. This must be done in a sustainable manner. The Covid-19 pandemic is therefore not only a challenge but also an opportunity.

It is important that everyone benefits from this transformation and that no one is left behind. It is therefore particularly important now to understand the 'Leave no one behind' principle of the 2030 Agenda as a maxim for action and to align political measures with the global Sustainable Development Goals of the United Nations. The German Federal Government has committed itself to this. Achieving the goals of the 2030 Agenda has become the key mission for European policy. In Germany, it has been incorporated into the National Sustainable Development Strategy (DNS), which all ministries adhere to. The next ten years are crucial for implementing the United Nations' 2030 Agenda. The G-20 countries are responsible for about half of the unmet Sustainable Development Goals. Germany is currently falling short of 20 out of 25 environmental targets of the DNS.

This is also shown in the Global Sustainable Development Report (GSDR), in which independent experts pointed out for the first time in 2019 that there is still a massive need for action. The authors of the GSDR therefore also call for sustainability research to be even more strongly geared towards the global Sustainable Development Goals. This is exactly what we are doing in the present FONA Strategy, which is a key contribution of the BMBF to implementation of the 2030 Agenda. Through the FONA Strategy, we are acting in the knowledge that the next ten years are crucial to achieving the goals of the 2030 Agenda. We will do even more to ensure that knowledge finds its way into practical application more quickly. Knowledge with effect is therefore one of our pivotal concerns.

Research is tasked with providing the knowledge needed to sustainably design the change processes that have been and will be triggered, for example, by digitalisation, globalisation or pandemics. Research must help identify conflicting goals and point out innovative solutions. The FONA Strategy aims to bring together partners who can provide innovative solutions for more sustainable practice. Politics, business and society need this knowledge – for new technologies, new ideas and new options for action. FONA thus provides impetus for the ongoing development that our society needs.

The change towards greater sustainability is an opportunity to maintain Germany's competitiveness in the long term. Innovations are the key driver for achieving this. The High-Tech Strategy (HTS) 2025, coordinated by the BMBF, forms the strategic framework of the Federal Government's research and innovation policy. With its mission-oriented approach to sustainability, climate protection and energy, HTS is anchoring the model for sustainable and climate-friendly development in innovation policy. The FONA Strategy makes a pivotal contribution to this in six of the HTS missions. In order to accelerate the transfer of ideas, knowledge and technologies into practical application, the innovation potential of small and medium-sized enterprises in particular will be strengthened. Through research and innovation, we will pursue future technologies that are 'Made in Germany' in the fields of green hydrogen, the circular economy and the bioeconomy in such a way that we will remain or become technology leaders and world export champions in energy system transformation, resource efficiency and climate protection. And we will leave no one behind. Strengthening structurally weak regions and creating equivalent living conditions and social cohesion are therefore integral parts of our FONA Strategy. We are making sustainability internationally tangible through research and innovation that goes beyond national borders. By investing in sustainable innovation, we are supporting the European Green Deal as a driver for a green transformation of the European economy after the Covid-19 pandemic.

In the FONA Strategy, we formulate ten principles as strategic guidelines. These principles form the framework for our contribution to achieving international and national sustainable development goals. The FONA Strategy sets the impetus for launching into a crisis-proof and sustainable future.

How the FONA Strategy relates to research and sustainable development policy

What does FONA stand for? 10 principles for the FONA Strategy

We have repositioned FONA for the next five years. FONA is a strategy that addresses the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda. We are guided by the following ten principles:

1. FONA is targeted, transparent and verifiable.

We define overarching strategic objectives that will position research activities to substantially contribute to the 2030 Agenda. We support our strategic goals with fields of action and individual actions. The actions are our central implementation lever and are based on concrete implementation steps and milestones. This makes it clear where we have reached our goals or where we need to make adjustments.

2. FONA funds research that has a political and social impact.

Knowledge alone is not enough. It is important that this knowledge is implemented and applied in concepts, technologies, processes and business models, as well as in legislation. Only in this way can knowledge have an impact on sustainable development in the economy, politics and society. FONA is the BMBF's key contribution to this.

3. FONA forms the basis of a green reboot.

FONA sees itself as an innovation driver of skills, technologies and services for green growth. FONA will give the German economy a modernisation boost for its post-Covid-19 relaunch in order to make itself fit for green future markets.

4. FONA vitalises Germany as an attractive business location.

The future of Germany as a top knowledge and business hub lies in the development of future-oriented technologies and social innovations. With future technologies that are 'Made in Germany', we are creating new opportunities for prosperity and employment and at the same time increasing economic and social resilience.

5. FONA is European.

We are thinking FONA in European terms and are committed to stronger cooperation with our European partners. Through coordinated action, we can make better use of research resources in Europe and make a substantial contribution to the European Commission's Green Deal.

6. FONA is international.

The goals of the 2030 Agenda call for new international partnerships in which industrialised, emerging and developing countries share responsibility for a sustainable future. No country can meet global challenges alone. We are working together worldwide to protect our planet and preserve it for future generations.

7. FONA creates systemic solutions.

Isolated measures in individual sectors will not help us on our road to a sustainable society. Systemic solutions are required – for example, for a resource-saving circular economy, for the energy revolution and for sustainable mobility. To achieve this, ecological, economic and social concerns must be given equal consideration.

8. FONA is interdisciplinary.

Sustainability research in Germany is strong and varied. With FONA, we offer the strategic tool to bundle expertise and know-how by bridging subject, disciplinary and institutional silos and by bringing together non-university and university research. FONA is thus an internationally unique funding strategy.

9. FONA is transdisciplinary.

Involving stakeholders from science, industry and civil society in research projects contributes to a better systemic understanding. Moreover, stakeholders such as local governments, companies or NGOs are already involved in the design of the research projects. FONA thus ensures that research results are put into practice and that research benefits from the expertise of the stakeholders.

10. FONA reaches the communities and the people.

In FONA, we focus on participation and research that is relevant to everyday life. We create experimental spaces in the communities where innovative solutions are tested locally in close contact with the citizens. In this way, we make local expertise available to the science and research community and promote the active participation of citizens in the design of future solutions for the ongoing development of a sustainable economy and society.

Three strategic goals, eight fields of action and 25 actions

Evaluation of the previous FONA framework programmes since 2005 has shown that research can drive sustainable development very effectively. But it has also revealed development potential – effective knowledge needs clear objectives. That is what we aim to achieve with the new FONA Strategy. We are therefore focusing on three strategic goals to which research can make a decisive contribution for a sustainable future:

- Achieve the climate goals
- Research, protect and utilise habitats and natural resources
- Develop society and the economy – good living conditions throughout the country

The goals are set out in concrete terms in eight priority fields of action. For each field of action, we present the specific actions we have planned to achieve our goals. These actions form the key lever for implementing the FONA Strategy and are underpinned by concrete implementation steps and milestones geared towards the current research and innovation needs. The actions make the contribution of FONA research to the strategic goals transparent and comprehensible. This makes it clear where our goals have been achieved and where adjustments are necessary. FONA thus lives up to its claim of being an open framework for action.

The scope of our activities includes national and international strategic cooperation, the development of new strategies or roadmaps, providing research funding, and the implementation and dissemination of results. In the following 25 actions, we present the concrete measures we will apply over the next five years to contribute to more sustainability and resilience in Germany and worldwide. Issues that span all the goals, fields of action and actions we treat jointly as cross-cutting topics. In FONA, these concern digitalisation, knowledge and technology transfer, European and international cooperation and the strategic planning of research infrastructures (Cross-cutting topics, p. 48).

Goal 1: Achieve the climate goals

Goal 2: Research, protect and use habitats and natural resources

Goal 3: Develop society and the economy – good living conditions throughout the country

Goal 1: Achieve the climate goals

Global warming is mainly due to an increase in man-made greenhouse gas emissions. The consequences can already be observed worldwide. In Germany, too, we are feeling the effects of climate change: the incidence of heavy rainfall, drought and heat records is increasing, and sea levels are rising.

At the Paris Climate Change Conference in December 2015 (COP21), 195 countries reached a consensus for the first time on a general global climate protection agreement. Almost all countries in the world have thus committed themselves under international law to defining national climate protection targets for implementing the agreement. The aim is to limit global warming to well below 2 degrees and if possible, even to 1.5 degrees. To achieve this, emissions must be reduced to net zero by the middle of the century. The signatory states also want to improve the global capacity for resilience and adaptation. The decisions are closely related to the United Nation's Sustainable Development Goal 'Take urgent action to combat climate change and its impacts' (SDG 13). The current voluntary commitments are far from sufficient to achieve the agreed target. The European Commission has therefore announced, as a contribution the European Green Deal, that it would make Europe the first climate-neutral continent by 2050.

Germany has launched the Climate Action Plan 2050 to make its contribution to the Paris Agreement. Through the Climate Action Programme 2030 and the Climate Action Act, the Federal Government has adopted the first concrete steps towards implementation. Research and innovation are key components of this programme. They are a prerequisite for achieving the ambitious climate action goals of the Federal Government and the European Union, for initiating additional dynamics and for tapping into new climate protection potential.

Research and innovation will focus on key sectors to make substantial progress in reducing greenhouse gas emissions and in risk prevention and adaptation to climate change. New climate models and greenhouse gas monitoring systems provide the necessary data and information as a basis for an effective and credible climate policy.

Field of action 1: Avoiding and reducing greenhouse gases (mitigation)

Germany aims to be largely greenhouse gas neutral by 2050. To achieve this, greenhouse gas emissions must be reduced by at least 55 per cent by 2030 compared with 1990 levels in accordance with the Federal Climate Action Act. This requires competitive measures with a high leverage effect in terms of the potential to save and avoid greenhouse gases.

In 2019, Germany emitted around 805 million tonnes of CO_2. The biggest polluters are the energy sector at 254 million tonnes, the industrial sector at 188 million tonnes, and agriculture at 68 million tonnes of CO_2. Practicable solutions must be found in all sectors so that investment in climate protection pays off and greenhouse gases are substantially reduced.

Our actions on CO_2 reduction, CO_2 industrial use and green hydrogen are working towards this goal. Despite all efforts to avoid and reduce greenhouse gas emissions, we must also consider the possibility that the required greenhouse gas neutrality may not be achieved quickly enough to meet the Paris climate targets. Another field of action that we are therefore still developing is removing CO_2 from the atmosphere. A solid knowledge base is needed to better assess the opportunities and risks. Only then can a political course be set, and practical implementation take place.

Field of action 1:
Avoiding and reducing greenhouse gases (mitigation)

Action 1: Reducing industrial process emissions and using CO_2 as a raw material | p. 10
Action 2: Establishing green hydrogen in Germany | p. 11
Action 3: Examining eco-friendly methods of removing CO_2 from the atmosphere | p. 13

Action 1: Reducing industrial process emissions and using CO_2 as a raw material

We will use CO_2 and other waste gases as raw materials, avoid emissions of greenhouse gases and develop solutions for sustainable primary industries.

Where do we stand?

Climate protection and having a competitive industry are not incompatible. We want to reduce the carbon footprint of industry in the long term: directly, by optimising processes and increasing efficiency using new technologies and processes, and indirectly, by using CO_2 as a raw material (Carbon Capture and Utilisation, or CCU for short). This can significantly reduce the use of fossil fuels in industry as a whole.

What are the research needs?

The avoidance of process-related emissions from industry – especially from primary industries – can be achieved in several ways: 1) by increasing process efficiency, 2) by switching to renewable energy sources, 3) by using CO_2 as a raw material, and 4) by using completely new process approaches. In addition to the purely technical feasibility, it is important that the climate-neutral raw materials produced in this way can be produced or supplied competitively. Considerable research is needed, for example, to produce CO_2-free steel.

The efficient use of CO_2 as a carbon source, combined with renewable electricity and recycling, has the potential to pave the way to a circular economy and significantly reduce the carbon footprint of industries and products. The state of technical development of the various CO_2-use technologies varies greatly and requires research approaches at different levels. In addition to processes that are already marketable, there are also some promising approaches that are still in even earlier stages of development. These include innovative ideas such as artificial photosynthesis, where water and CO_2 are used to produce various products such as hydrogen, fuels or chemicals directly from sunlight.

Implementation steps and milestones

- With a new funding priority for the avoidance of climate-impacting industrial process emissions, we are devoting ourselves from 2021 onwards to the development of processes and process combinations that contribute to avoiding greenhouse gases in key industries such as the metal and chemical industries and the cement and lime industry. In addition to technological innovations, this also takes account of their competitiveness and the extent to which they are embedded in the economic environment.

- From 2020 onwards, the Carbon2Chem project will expand the large-scale recycling of emissions from steel production. To complement this, we are funding the development of innovations that replace coal with hydrogen as a reducing agent in steel production. Further funding priorities will be initiated with a view to the production of sustainable electricity-based fuels and chemicals.

- From 2020, in addition to Carbon2Chem, we will also be promoting the development of other CCU technologies for the use of CO_2 as a sustainable carbon source for industry. By 2024/2025, this will have thus identified concrete CO_2 use potentials and created the prerequisites for the ongoing industry-driven development of processes to reduce process emissions. Between 2025 and 2030, we will bring competitive processes and demonstration plants to market maturity on an industrial scale.

- With the implementation of the Research and Innovation Agenda for the utilisation of CO_2 as a raw material source in a carbon cycle economy by 2025, we will consolidate research approaches and support paths to industrial application.

- From 2020, we will also provide targeted support for promising new approaches such as artificial photosynthesis, in particular through a research partnership with the USA.

Action 2: Establishing green hydrogen in Germany

We will make green hydrogen marketable and enable its production, transportability and usability on an industrial scale.

Where do we stand?

Green hydrogen is the energy source of the future and indispensable for the success of the energy system transformation. Green hydrogen can also be used to reduce the climate impact of those areas that are currently the most harmful to the climate: industry (→ Action 1, p. 10), transport, and heat supply. Since Germany – like many other countries – will not be able to meet its demand for green hydrogen on its own, it will need imports of green hydrogen from regions with ample wind and sunshine. Close international cooperation on green hydrogen will therefore be all the more important in the future.

What are the research needs?

Hydrogen production from renewable energies is technically advanced – green hydrogen is produced in a climate-neutral way by electrolysis from renewable electricity and water. One challenge for research is found in the currently high production and transport costs. In addition, there is a lack of plants and supply chains on a commercially relevant scale. Depending on the technology, further technical potential in the areas of service life and process energy efficiency must be leveraged in order to make green hydrogen competitive. The question of suitable transport solutions, especially over longer distances, must also be clarified. In addition to the usual, energy-intensive processes – liquefying or pressurising it for transport – carrier chemicals which bind the hydrogen during transport may also be suitable for this purpose. An alternative option is to produce synthetic hydrogen derivatives such as fuel or ammonia and transport them using conventional infrastructures.

Implementation steps and milestones

- Together with three other ministries, we launched the National Hydrogen Strategy in 2020 as a coherent framework for action of the Federal Government. This is intended to facilitate Germany's entry into a hydrogen economy.

- Together with industry, science and civil society, we will draw up a roadmap for the hydrogen economy. The aim is to formulate the specific areas of research and the actions required.

- In 2020, we launched the 'Hydrogen Republic of Germany' ideas competition. Large-scale flagship projects are expected to lay the foundations for the broad use of green hydrogen in industry, transport and buildings. A crucial aspect will be to launch a competitive water electrolysis system on an industrial scale (larger than one gigawatt). At the same time, the ideas competition is also open to completely new technologies developed in application-oriented basic research.

- We will establish and deepen international research partnerships, for example on green hydrogen, through joint feasibility studies and funding announcements with other countries. For example, we plan to start a feasibility study with Australia in 2020.

- Together with foreign partners, we will investigate the prospects and diverse issues of a global green hydrogen economy. These include the production of green hydrogen and, subsequently, of its derived products such as methanol or ammonia in sunny and/or windy regions; its transportation at regional, national and global level; and its use, for instance in industry and transport.

- In 2020, we will present a first draft of the 'H2Atlas-Africa' on green hydrogen generation potentials in Southern and West Africa. The aim is to provide a science-based analysis of locations suitable for the production, transport and processing of green hydrogen in these focus regions. This includes an interactive presentation on climatic, political, legal, social, economic and environmental conditions for investments in green hydrogen infrastructures.
- By 2025, we will have enabled large-scale production of green hydrogen that is competitive with fossil alternatives, thus laying the foundations for a sustainable international hydrogen economy.

Action 3: Examining eco-friendly methods of removing CO_2 from the atmosphere

We will investigate methods of actively extracting CO_2 from the atmosphere and identify the most environmentally friendly courses of action.

Where do we stand?

If greenhouse gas reduction measures continue to be insufficient to achieve the goal of being greenhouse gas neutral by 2050, it may be necessary to remove the CO_2 emitted in the coming years from the atmosphere (carbon dioxide removal, or CDR for short). At present, however, we do not know whether the risks of the methods necessary to achieve this would be acceptable if CDR were used on a large scale. Future CDR research must therefore go beyond purely techno-economic perspectives to consider aspects of environmental impact, social acceptance and international cooperation, as well as addressing the implications for other UN Sustainable Development Goals and classic climate protection policy. By focussing on this integrative approach sound decisions can be made, including the evaluation, prioritisation and implementation of individual approaches.

What are the research needs?

Theoretical estimates of the potential and risks of CDR methods are already available. Considering that progress in combatting global climate protection is still insufficient, more research must now be devoted to feasibility studies. To do this, we want to focus on the effectiveness and the wider implications of using CDR methods. This includes both individual methods and their use in combination (for example, land-based and oceanic methods). Questions of feasibility arise in particular with regard to the goal of implementing the large-scale use of a method and the long-term nature of CO_2 storage. The analysis of the various CDR methods must cover the entire life cycle. Since it is foreseeable that no single CDR method will suffice, more weight must be given to the study and analytical comparison of these methods as a portfolio of options. This analysis and evaluation of the various CDR methods must be weighed in light of the fundamental premise of avoiding greenhouse gas emissions to achieve climate neutrality. The basic tenet is to avoid harmful impacts on ecosystems and to achieve sustainable development.

Implementation steps and milestones

- In 2020, we launched an interdisciplinary funding programme on CO_2 removal from the atmosphere to investigate the potential and risks of a comprehensive portfolio of possible CDR methods.
- At the same time, we are supporting the exploration of CO_2 storage potentials in seas and oceans as part of the interdisciplinary research mission of the German Marine Research Alliance (DAM) entitled ‘Marine Carbon Sinks in Decarbonisation Pathways’.
- In parallel to this funding programme, we are planning to support the research through comprehensive dialogue with stakeholders in politics, society and industry on the overall topic of CDR, including individual methods. An interdisciplinary support project will embed the topic in the wider climate policy debate.
- We will present the findings of these funding initiatives in 2024.

Field of action 2: Improving adaptability and risk prevention (adaptation)

Extreme weather events such as heat waves and droughts, heavy rainfall, floods and storms cause billions of euros in damage, some of which is life-threatening. Knowledge is therefore needed about how climate change affects the frequency and intensity of extreme events and how people, infrastructure and goods can be protected from these extremes. Preventive research on climate adaptation includes health considerations. This is because the increase in extreme weather events – for example, the rising number of hot days – also has direct effects on human health.

A political framework for this is provided by the German Strategy for Adaptation to Climate Change (DAS), which was adopted by the Federal Government in 2008 and has been undergoing continuous development since then. FONA research supports adaptation to climate change by providing data, information, models and tools on the impacts and risks of climate change. Timely and active adaptation to climate change can reduce damage and in the best case even prevent it.

Field of action 2:
Improving adaptability and risk prevention (adaptation)

Action 4: Researching climate change-induced extreme events in Germany | p. 15
Action 5: Understanding and preventing the health impacts of climate change | p. 16
Action 6: Increasing the resilience of cities and regions | p. 17

Action 4: Researching climate change-induced extreme events in Germany

We want to find out how severely Germany will be affected by extreme weather events in the future and how we can prepare and protect ourselves.

Where do we stand?

Extreme weather events have always been part of natural climate variability. However, these are often only incompletely recorded. These knowledge gaps make it difficult to identify long-term trends and future changes. Nonetheless, it can be assumed that the frequency, extent and intensity of extreme events will continue to increase due to man-made climate change. However, the exact causal relationships between natural climate change, man-made global warming and the occurrence of weather extremes have not yet been sufficiently investigated. This knowledge is needed to estimate the probabilities and ranges of future extreme events and their consequences and to take effective measures for prevention, protection and adaptation.

What are the research needs?

We must investigate how climate change alters the frequency and intensity of extreme events and what impacts it will entail for humans, the environment, the economy and society. In order to be able to make reliable statements on this, we need high-resolution data on the current and future climate. The basis for this is provided by high-resolution spatial modelling and powerful data assimilation procedures, as well as innovative data analysis methods and evaluation tools involving artificial intelligence (AI).

In the field of climate impact research, there is a need for research on how to deal with extreme water-related events, on the functionality and resilience of ecosystems, and on the development of preventive health measures, especially in cities. Here, concepts, methods and tools for damage prevention and minimisation must be provided.

Implementation steps and milestones

- Our research funding will enable us to present initial results as an evaluation base to assess current and future weather extremes in Germany from 2022 onwards.

- We will launch a new high-performance computing initiative in 2021 to develop a new high-resolution global climate model (→ Action 7, p. 19) that will significantly improve regional and local prediction quality, especially for extreme events.

- Our funding for research on extreme water-related weather events focuses specifically on the development of innovative monitoring, forecasting and communication concepts. Our support also includes the adaptation of water infrastructures and the development of operational and risk management strategies for dealing with contrasting hydrological extremes (→ Actions 13 and 14, p. 29/30). We will see the first concrete results in 2022, for example in the form of assessment tools for climate service facilities and coastal protection authorities.

- By 2023, we will establish six model regions in Germany for adaptation to climate change. We will support them in dealing actively and purposefully with climate change. This includes empowering local actors to implement adaptation measures autonomously and with foresight.

- As part of our support for the German Coastal Engineering Research Council (KFKI) and the research mission 'Protection and Sustainable Use of Marine Areas', we are working with the responsible state authorities to develop recommendations for sustainable coastal protection by 2024.

- We will support research into the predictions and consequences of climate-change-induced sea level rise through European initiatives from 2021.

Action 5: Understanding and preventing the health impacts of climate change

We are studying the effects of climate change and environmental degradation on human health. This creates the knowledge base for concrete precautionary and preventive measures.

Where do we stand?

The Covid-19 pandemic emphasises how dependent humans are on environmental conditions and how quickly local developments can become global challenges. The interdependencies and correlations between health, climate change, and environmental degradation and pollution are not yet well understood. Climate change influences, for instance, the diversity and distribution of species and thus the occurrence of pathogens and infectious diseases, such as those transmitted by mosquitoes. As an example, the first meningitis in humans caused by the mosquito-borne West Nile virus occurred in Germany in 2019. In addition to such communicable diseases, the population in Germany is at risk of extreme weather events caused by climate change, especially heat extremes. The connection between extreme heat and higher mortality is medically proven. For example, the risk of heart attack increases with prolonged heat. In the extreme summer of 2018, it is estimated that 740 people died in Berlin alone as a result of the extreme heat stress. In addition to an increase in mortality, an increase in illnesses and a decline in labour productivity is to be expected during such heat waves, so that heat events are also associated with economic losses. In addition, little is known about the overall effects of the creeping long-term changes caused by climate change on human health.

What are the research needs?

Protecting human health is an important part of our adaptation to climate change. The continuously evolving adaptation action plan, entitled the German Strategy for Adaptation to Climate Change, highlights the topic of health as being under-represented as well as the need for research across fields of action. This is where we come in: We will use interdisciplinary research approaches to identify correlations between climate and environmental changes and human health and develop application-oriented adaptation strategies. This will help to build sound and practical knowledge, including knowledge on how extreme weather and long-term, creeping temperature changes affect our health and on the interdependencies between climatic and other adverse effects on our environment that are relevant to human health. The main objective is to translate this knowledge into concrete precautionary and protective measures for the areas and sectors concerned and to build up competence in the health sector with regard to climate adaptation.

Implementation steps and milestones

- We will implement new funding measures to address different aspects of the interaction between climate change, environmental change and health. This will allow interdisciplinary research into the relationships and causal chains.

- From 2021, we will support young scientists who pursue particularly innovative approaches at the interface between climate and health research. By 2025, we will provide relevant options for action for practitioners and the public.

- As part of the BMBF Research Initiative for the Conservation of Biodiversity, we will also focus on the climate-induced increase in animal species in Germany that carry infectious diseases or can otherwise endanger human health.

- To act with foresight and transcending national borders to minimise the risks in the area of health protection in times of climate change, we will expand cooperation at the national and European level by 2025 – with other federal ministries, with European partner countries and with international partners, for example by participating in joint EU research initiatives.

Action 6: Increasing the resilience of cities and regions

We want to make cities and regions more resilient to the effects of climate change and improve risk provisioning.

Where do we stand?
Torrential rains, floods, but also heat and drought – the effects of climate change are also felt in German cities. In Germany, many cities and communities are not sufficiently prepared for weather extremes and creeping climate changes. It is therefore important to make cities and regions adaptable to the consequences of climate change and to improve their risk provisioning. This is not only sustainable, but also cheaper in the long term. Our funding has already made a major contribution to laying the foundations for German adaptation policy and for the implementation of adaptation measures on the ground.

What are the research needs?
Together with actors at the local and regional level, we want to develop tools and options for action that will enable them to plan effective and efficient strategies for dealing with the risks of climate change themselves. This requires the development of appropriate digital methods and digital information and assessment tools that bring together data on climate impacts, adaptation capacity, and the costs and benefits of adaptation measures. Data, tools and solutions must also be geared to the needs of local actors in order to make real progress in adapting to climate change and dealing with environmental problems. Therefore, transdisciplinary, demand-driven research is in the foreground here (→ Action 24, p. 45). In the international context, it is cities and conurbations where the greatest leverage can be achieved through adaptation measures in terms of preventing damage or minimising risk. That is why we also want to develop and test solutions for rapidly growing cities in developing and emerging countries.

Implementation steps and milestones

- We want to develop and test particularly innovative measures for adapting to climate change, as well as options for action in order to be able to meet regionally specific climate change challenges.

- Projects developed under the initiative for 'Climate resilience through action in cities and regions' aim to specifically increase the ability and the capacity for adaptation of cities and municipalities in Germany. This is our contribution to the Federal Government's progress report on the German Strategy for Adaptation to Climate Change (DAS) in 2020.

- We are funding the development of adapted solution strategies for the resilient development of fast-growing cities in developing and emerging countries. In addition to projects in Africa and Asia, from 2022 onwards we will also support projects focusing on climate adaptation and urban resilience strategies in Latin America which develop particularly promising models for perpetuation and implementation.

- With the initiative 'Local Climate and Environmental Models for Future Cities and Regions', which is anchored in our Digital Strategy, we are committed to improving risk provisioning in cities and regions through the use of digital tools from 2020.

- In 2021, we will use the BMBF's research results to contribute to the Federal Government's climate impact and vulnerability assessment.

- Our funding will provide newly developed digital tools for urban planning adapted to climate change. In 2022 we will publish the new urban climate model.

- In 2023, we will present the first version of our new climate information services, which will provide actors at regional and municipal level with tools for the integrated assessment of climate risks and for the impact analysis of mitigation measures.

To achieve an effective international climate policy, political decision-makers need reliable forecasts of global climate developments, including in the marine and polar regions. This is only possible with the most accurate climate models available. We are working on the development of a global climate model with very high spatial resolution, as well as on a better understanding of the role of marine and polar regions, including permafrost regions, for our global climate. Only if the processes and interdependencies in the climate system are sufficiently known, can political options for action and effective adaptation or avoidance strategies be identified. Closing the knowledge gaps on our marine and polar regions – the 'climate engines of the Earth' – requires more than excellent research. International networking and cooperation are also essential.

International cooperation is also required for global greenhouse gas monitoring. The aim of this is to monitor the implementation of climate protection efforts to reduce greenhouse gas emissions defined at the national level. A measurement-based greenhouse gas monitoring system does not yet exist and is therefore among our actions.

Field of action 3:
Knowledge for effective climate policy

Action 7: Improving global climate modelling | p. 19
Action 8: Monitoring greenhouse gases for climate protection | p. 20
Action 9: Understanding marine and polar regions – the climate engines of Earth | p. 21

Action 7: Improving global climate modelling

We want to reduce the uncertainties in climate modelling and make projections for the future more reliable.

Where do we stand?

Global climate models that depict climate-relevant processes for the entire Earth have existed since the late 1950s. Initially, the focus was on describing the basic processes in the atmosphere. Only in the last three decades has it been possible to take other important influences on climate into account by coupling atmospheric models with ocean, land surface and sea ice models. Ocean models, for example, simulate ocean currents (right picture), which transport gigantic amounts of heat and are a key factor in understanding climate change. Reproducing the climate system and its components will remain a key task for research in the coming years.

What are the research needs?

In order for research to better predict future climate change, the spatial resolution of global climate models needs to be increased by about two orders of magnitude, from approximately 100 kilometres to around one kilometre. This requires the use of new artificial intelligence (AI) tools, for example in the areas of parametrisation, downscaling and the complete screening of huge data fields. In order to increase efficiency and reduce computing time, it is also important that research focuses more strongly on modularised model systems. These systems allow a wider range of uses, more effective adaptation to new computer systems and specific issues, and uniform quality management.

Implementation steps and milestones

- The development of a high-resolution global climate model will be a central component of the National Climate-Modelling Strategy (NMS), currently in planning. For the NMS, we are working jointly with research institutions to professionalise modelling as a consulting tool. Based on the NMS concept, from 2021 we will primarily introduce a greater division of labour in model development. This is intended to lead to more programmatic standardisations, more modularised model systems, and more efficient model maintenance.
- From 2021 onwards, we will focus our funding on expanding the development of high-resolution climate modelling using innovative AI elements.
- From 2020, we will continue our research of climate dynamics on geological time scales with the help of model studies of the palaeoclimate. This will make it easier to assess the resilience of climate projections.

Action 8: Monitoring greenhouse gases for climate protection

We are developing a prototype for national greenhouse gas monitoring.

Where do we stand?

Germany has committed itself to reducing greenhouse gas emissions together with the states that are signatories to the UN Framework Convention on Climate Change (UNFCCC). To ensure international transparency and comparability, annual reports on national greenhouse gas emissions are submitted to the UNFCCC in accordance with the rules of the United Nations. An integrated monitoring system will therefore be developed, tested and operationally implemented for Germany. To this end, there will be a division of labour between the Federal Ministry of Research, the Federal Ministry for the Environment and the Federal Ministry of Transport. After successful testing, this system can be transferred to other countries.

What are the research needs?

The aim of the integrated monitoring system is, on the one hand, to enable the levels of greenhouse gas emissions to be determined and, on the other hand, to expand development of systems to forecast greenhouse gas concentrations in the atmosphere over time.

In order to collect the data, high-resolution measurements from different measurement systems (ground, aircraft, satellite) must be dovetailed with modelling in new ways. This requires high-performance computing resources.

Implementation steps and milestones

- In 2020, we will begin planning, developing and implementing an integrated greenhouse gas monitoring system – an integriertes Treibhausgas-Monitoringsystem (ITMS) – in a joint effort with scientific institutions, the Federal Ministry for the Environment and the Federal Ministry of Transport.

- The planning process for the ITMS will be concluded by the adoption of an inter-ministerial agreement between the Federal Ministry for the Environment, the Federal Ministry of Transport and the Federal Ministry of Agriculture, which will regulate, among other things, the financial requirements in 2020. Research funding will commence in 2021, and the prototype will be ready in 2025.

Action 9: Understanding marine and polar regions – the climate engines of Earth

We want to better understand the influence of marine and polar regions on Earth's climate system.

Where do we stand?
The interactions between the ocean and the atmosphere have a crucial influence on the global climate and how it evolves. Climate research is inconceivable without effective marine and polar research. For instance, polar research helps to reconstruct climate history using ice cores from the great ice sheets of our planet. If we want to protect our coasts and coastal settlements from storm surges and the dangers of rising sea levels, we need to understand the dynamics of the world's oceans. Large research expeditions and programmes such as MOSAiC and the missions of the German Marine Research Alliance (DAM) make a significant contribution to strengthen climate knowledge.

What are the research needs?
For a better systemic understanding of the marine and polar regions and their role in climate change, research on the physics, chemistry and biology of our oceans must be intensified. It is essential to reduce uncertainties in climate forecasts, especially in the polar latitudes. Based on improved modelling capacities, advanced and more reliably calculations on changes in Earth's climate system need to be evolved. This, together with the creation of an integrated data management system for coastal, marine and polar research, supports a better assessment regarding the potential, risks and opportunities of management concepts for the CO_2 uptake of the seas and oceans (→ Action 3, p. 13). Only an in-depth understanding of these interrelationships will enable political courses of actions and appropriate adaptation or avoidance strategies.

Implementation steps and milestones

- The Federal Government is pooling its activities on German marine research in the research programme MARE:N. The future research topics will be developed in three agenda processes. Results have been available since 2019 for the areas of 'Coastal Regions' and 'Blue Ocean'. In 2020 we will start the agenda process for 'Polar Regions'.

- The data sets from MOSAiC, the world's largest Arctic expedition, will be available from 2020. From 2020 onwards, we will specifically fund the evaluation of the data from the expedition to ensure that it can be used quickly for global climate policy.

- Within the framework of the German Marine Research Alliance (DAM), we are working with the northern German states to improve the data infrastructure and create an integrative and comprehensive data management system.

- In order to work together on a national basis and across national borders on marine protection and sustainable use of marine resources in times of climate change, we will expand cooperation within national and European initiatives until 2025.

- German research vessels and autonomous and robotic infrastructures are absolutely essential for marine research of our seas and coasts. Germany has a leading international role in this area. We will therefore continue to renew the German research fleet and increasingly equip the ships with autonomous and robotic systems. In 2020, we will launch a competition for participants for the procurement of a new research vessel to replace the two ships POSEIDON and METEOR. We will also enable the Alfred Wegener Institute to procure an efficient successor vessel for the POLARSTERN.

Goal 2: Research, protect and use habitats and natural resources

Biodiversity and healthy ecosystems are the basis of all life. However, due to rapid population and economic growth and the consequences of climate change, they are highly vulnerable. Globally, water scarcity, water pollution and land degradation increasingly threaten our ecosystems and affect the economic and political stability of entire regions and countries. The protection and sustainable use of natural resources is therefore a central theme of the 2030 Agenda – and also of FONA.

Whether on land, in fresh waters or in the oceans, it all starts with healthy ecosystems. Worldwide, however, the condition of natural ecosystems is deteriorating, habitats are disappearing, and many animal and plant species are on the brink of extinction. In order to maintain or restore ecosystems, it is important, among other things, to stop the degradation of land surfaces, promote sustainable land management and improve biodiversity. The SDGs therefore strive to achieve a land degradation-neutral world by 2030.

Humankind is dependent on intact ecosystems, among other things when it comes to the secure supply of water. But millions of people suffer from water shortages and lack of hygiene. In addition to natural water scarcity, a lack of or inadequate supply infrastructures, resource overexploitation, climate change and environmental pollution can be responsible for this. What happens on land has an impact on water resources. This applies to the entry of nutrients and pollutants into the waterways, for example through agriculture, as well as to the handling of waste. Plastic debris in rivers, lakes and seas is a major international problem. The G-20 countries want to completely stop the entry of plastic into the world's oceans by 2050.

The key to protecting resources lies in changing our way of operating the economy. Until now, economic activity worldwide has been largely linear. Resources are taken from nature in order to produce and consume economic goods and finally dispose of them as waste. Instead, we need a circular economy that uses natural resources without destroying their basis. This includes using resources more economically and efficiently. How this can work and what is required for it is what we address through FONA – to contribute to a future that benefits human health and the economy by protecting natural resources.

The current decline in biodiversity and changes in terrestrial, inland aquatic and marine ecosystems are unprecedented in history. Experts estimate that the rate of extinction of animal and plant species today is hundreds to thousands of times higher than the rate usually observed in evolution. Thus, the loss of biodiversity is as urgent a problem as climate change. The rate of species loss calls for action. At the same time, we do not yet know enough about the drivers of species extinction, the key factors, or the appropriate levers for engaging in countermeasures. In order to achieve the goals of halting species loss set out in the Convention on Biological Diversity (CBD) and the EU Biodiversity Strategy for 2030, scientifically substantiated options for action and targeted strategies are urgently needed. With the Research Initiative for the Conservation of Biodiversity, which was launched in 2019, we are creating the necessary scientific foundations and are providing biodiversity research in Germany with a systemic and action-driven orientation. This enables effective recommendations for action to be made in accordance with the precautionary principle.

Field of action 4:
Conservation of biodiversity and habitats

Action 10: Expanding development of biodiversity monitoring in Germany | p. 24
Action 11: Understanding the systemic correlations of changes in biodiversity | p. 26
Action 12: Conserving habitats and ecosystems | p. 27

Action 10: Expanding development of biodiversity monitoring in Germany

We want to use innovative methods and technologies to record biodiversity comprehensively and automatically in order to better understand and counteract the decline in biodiversity.

Where do we stand?

In order to actively counter the decline in biodiversity, it is necessary to record biodiversity and its changes to gain a fundamental understanding of ecosystems and the ways they interact – in keeping with the motto: observe to understand!

To date, biodiversity in Germany has been monitored in many areas in a decentralised manner, i.e. not across the whole country and fragmented over time. In addition, in many cases only selected species are recorded and data are usually not interlinked. Biodiversity monitoring by specialised authorities, civil society organisations and citizen scientists with excellent knowledge of the correct classification of species is being carried out with great commitment and, for some species (birds, butterflies), already with great success. The challenge for the future is that many volunteer experts are already at an advanced age and that there is a lack of younger species experts.

What are the research needs?

Research requires methodological and technological innovations that enable continuous and standardised monitoring of biodiversity and rapid analysis of biodiversity changes and their drivers, complementing current practices. The aim is to analyse the status quo and trends in biological diversity, ecosystem stress limits and interdependencies with social drivers within short periods of time and to develop appropriate early warning systems. Standardised, continuous and effective monitoring of the broadest possible spectrum of species, populations and ecosystems as well as drivers of biodiversity change is based on a wide range of optical, acoustic, biochemical and genetic observation data. An example of an efficient method is metabarcoding. In this process, species from mixed samples are quickly and cost-effectively identified and recorded on the basis of their DNA sequence. The basis for this method is formed by DNA sequences that are already available for around 20,000 of the 48,000 animal, plant and fungal species known from Germany. In addition, new forms of (digital) cooperation with citizens must be tested and expanded in order to further strengthen civil society's biodiversity monitoring. The aim is to further develop and establish such methods.

Implementation steps and milestones

- We will use new multi-sensor technologies to promote the implementation of 'weather stations' for nationwide standardised monitoring to record biodiversity. By 2025, we will provide ready-to-use

prototypes for automated acoustic, optical and biochemical detection of a wide range of species.

- By the year 2025, we will increase the number of species recorded in the GBOL reference library (GBOL: German Barcode of Life) by more than 1,000 insect species (so-called dark taxa), in particular those that have been insufficiently documented to date.

- By 2025, we will make available integrated systems or IT infrastructures for data acquisition, data storage, data management, data harmonisation and data evaluation.

- In 2021, we will set up a funding priority on marine biodiversity which, in addition to recording biodiversity, will also address research-driven measures to protect marine biodiversity.

- We support citizen science to enable interested citizens to participate in research projects. Wherever methodologically possible, interested volunteers can thus make their own contribution to German sustainability research and help to answer key social questions.

Action 11: Understanding the systemic correlations of changes in biodiversity

We want to close the knowledge gaps relating to the causes, dynamics and consequences of changes in biodiversity and obtain reliable projections of the development of biodiversity.

Where do we stand?

Many causes of biodiversity loss are known in principle, such as the expansion of residential, commercial and transport areas, land use change, the high use of fertilisers and pesticides, and climate change. However, there are considerable gaps in our knowledge about the specific contribution of individual drivers of species loss, how they interact, and how indirect social and economic factors (such as population growth, consumer behaviour and trade and supply chains) influence biological diversity. The extent of species extinction and the resulting changes in the ecosystems affected are only understood for a few well-studied species and natural areas. There is a high probability that a number of ecological tipping points will be reached in the coming decades at all levels of organisation (species, populations, biocoenoses, ecosystems).

What are the research needs?

Understanding the causal relationships between factors relevant to biodiversity changes in Germany, Europe and worldwide is a prerequisite for assessing future developments and deciding on appropriate measures. To this end, the extent, causes, dynamics and consequences of biodiversity loss on land and at sea must be researched more intensively. There is also a need for research on tipping points, i.e. critical thresholds above which there are irreversible consequences for ecosystem functions and services. A further task of biodiversity research is the analysis of the influences of economic, social, cultural and political drivers. In this area, more closely interlinking scientific research with society-related sustainability research will provide fresh impetus concerning the necessary social transformation towards more sustainability.

Implementation steps and milestones

- With the Research Initiative for the Conservation of Biodiversity, we will promote the detailed assessment of the consequences and risks of biodiversity loss for the provision of ecosystem services and for core areas of value creation and quality of life from 2020 onwards.

- We will strengthen research on the protection of insects through the Federal Government's Action Programme for Insect Protection. By 2025, we will present our findings on the extent, causes and drivers of insect mortality in protected areas, as well as on the possible consequences and risks of biodiversity loss for relevant species and ecosystems.

- By 2025, we will present assessments of the status and trends in biological diversity for Germany's most important habitat types in the 'Biodiversity Fact Check'.

- We will continue the international and interdisciplinary funding programme on the tipping points, dynamics and interdependencies of social and ecological systems beyond 2022. This will enable us to research the resilience of various biological and social systems and to develop solutions for identifying and avoiding tipping points.

- As part of the German Marine Research Alliance (DAM), we are funding an initiative to characterise biodiversity in the protected areas of the North and Baltic Seas from 2020 onwards, in order to assess the impact of bottom fishery on sediments.

- Via the Biodiversity Dialogue Platform, we will regularly discuss the findings from research and development with experts, representatives from politics, relevant business sectors and civil society groups in committees and stakeholder forums from 2020 onwards. By 2025, we want to achieve a better understanding of the socio-economic processes and drivers and use this to derive recommendations for appropriate countermeasures.

Action 12: Conserving habitats and ecosystems

We will develop concrete protection and management strategies to conserve biodiversity and ecosystems.

Where do we stand?

So far, biodiversity measures have focused on individual sectors such as agriculture, forestry and fisheries. However, broader, more reliable solution concepts and strategies are needed that involve all sectors and social groups affected.

What are the research needs?

In order to improve the conservation of biodiversity and of particularly endangered species, it is especially important to preserve, restore and interconnect sufficiently large habitats, not only on land and at the coast but also in inland waters and in seas and oceans. This will safeguard the viability of populations and their genetic diversity. We will develop actionable initiatives that are evidence-based and relevant. The aim is to enable decision-makers at all levels to use and conserve ecosystems sustainably. What is needed are innovative approaches that make it possible to transform our socio-ecological systems in order to preserve biological diversity. This also requires an analysis of the economic framework conditions and governance structures in various policy areas and economic sectors, and the identification of conflicts of interest and synergies for the protection of biodiversity and ecosystems. In this context, the potential of cost-effective nature-based solutions must also be developed. Strengthening ecosystems and how they perform can assist in meeting socio-ecological challenges such as species extinction, climate change, human health or land degradation.

Implementation steps and milestones

- Through the Research Initiative for the Conservation of Biodiversity, we are contributing to the development of science-based solutions and courses of action, and to decision-making and management instruments for regional and sectoral conservation measures. We are making these available to actors at different levels of decision-making. One area of focus will also be the development of integrative assessment methodologies for ecosystem services, for example with regard to the assessment of the costs and benefits of different development scenarios.

- In order to conserve biodiversity and intact ecosystems, we will develop innovative research-driven initiatives by 2025, for example on new agricultural management methods, economic accounting approaches, improved renaturation measures, and suitable policy and governance concepts, and implement them on a pilot basis.

- By 2025, we will present reliable scenarios and models for the development and protection of biodiversity in selected regions.

- By 2030, we will present evidence-based recommendations for the effective protection and sustainable use of German coastal waters.

- Together with local and regional players, associations and initiative groups, for example from companies, local authorities and civic initiatives, we will support the development of concrete integrative measures for the protection of biodiversity in model regions and experimental areas from 2020 onwards, which will be tested for their applicability on the ground.

- In the framework of European initiatives, we will fund research into the threat that noise pollution poses to marine ecosystems. Recommendations for measures to reduce marine noise pollution in order to protect the marine population should be available from 2026 onwards.

The global demand for resources already exceeds what the Earth itself can renew. Global population growth will further increase pressure on natural resources such as clean water and usable land. Two billion people live in countries with high water stress, and almost one billion people suffer from drinking water shortages. Over 2.6 billion people do not have access to adequate sanitation. Eighty per cent of the world's wastewater is not treated and pollutes natural water resources. It is estimated that around 1.5 million children under five die every year as a result of lack of water hygiene, and this while global water demand will continue to rise – by up to 40 per cent by 2050. Water resources must therefore be used more efficiently, pollution – including plastic debris in the oceans – must be minimised, and the proportion of treated wastewater must be increased. In addition, the possibilities of water extraction, for example through saline water treatment, must be improved and used on an industrial scale.

An equally ambitious approach must be taken to protecting and conserving land resources. Climate change, land overuse, deforestation and soil sealing are causing more and more soils to become infertile. As much as 75 per cent of the world's land area has already been degraded by erosion, salinisation, overexploitation or desiccation, and without active countermeasures, this could reach 90 per cent by 2050. In Germany, too, settlement and transport areas have more than doubled over the last 60 years. Every day, the natural environment of the Federal Republic of Germany loses an area of around 90 football pitches as a result. Through FONA, we want to make a contribution to counteracting this through sustainable agriculture and forestry concepts and intelligent urban planning.

Field of action 5:
Securing natural resources (water, soils)

Action 13: Mitigating water crisis events worldwide | p. 29
Action 14: Stopping the pollution of rivers and seas | p. 30
Action 15: Maintaining healthy soils and sustainable use of land | p. 31
Action 16: Expanding development of agri-food systems | p. 32

Action 13: Mitigating water crisis events worldwide

We want to mitigate the incidence of water crises worldwide and secure water supplies. We will develop innovative technologies for this purpose.

Where do we stand?

Reports by the Intergovernmental Panel on Climate Change show that droughts and heavy rainfall events are likely to become more frequent in many regions of the world in the coming decades than they are today. Groundwater reservoirs will diminish or even dry up if overuse persists. The number of regional water crises will increase and with it the number of water-related conflicts. But there are technologies and concepts for increasing water availability. The demand for water technologies that are 'Made in Germany' to avoid water conflict has been growing for years and can help sustainable regional development worldwide.

What are the research needs?

Further research is needed to provide water in sufficient quantity and quality for all. This can include the development of new technologies on the one hand, and the development of innovative forms of organisation and utilisation concepts on the other, for example to manage available fresh water sources as sustainably as possible or to develop alternative water resources. These can be, for example, treated saline water or marine freshwater deposits. In regions with water scarcity, it also makes sense to use water more efficiently. In particular, there is a need for concepts to reduce water losses in agriculture, to close water cycles in industry, and to treat and reuse wastewater specifically according to its type of use. But high-tech is not a must. Even simple and robust technologies can be the best possible option, both regionally and in terms of being tailor-made.

Implementation steps and milestones

- Reducing water crises globally is a priority topic in the inter-ministerial research programme on water, Wasser:N, which will be published in 2020. For the coming years, this government programme will form the Federal Government's framework approach for the promotion of water research and water innovations.

- In 2020, we will launch the Federal 'Water Safety in Africa' (WASA) programme. The WASA programme will work on solutions which meet both the needs of the African partners and the strategies and objectives of the Federal Government for international cooperation.

- Most of the countries in the world with extreme water stress are in the Near and Middle East. From 2020, we will expand our research funding with a new funding priority in this region.

- In 2020, we will publish the results of our research focus on water as a global resource, which will contribute to increasing management competence in the water sector and to SDG 6, 'Clean Water and Sanitation'.

- In 2021 we will launch the implementation of the funding priority on water technologies and reuse.

Action 14: Stopping the pollution of rivers and seas

We want to stop the pollution of rivers and seas and to ensure that water quality in this country is impeccable.

Where do we stand?

Although Germany has comparatively high standards, Germany's water resources are also subject to increasing pressures. For example, 97 per cent of the water in German watercourses did not achieve the 'good ecological status' required by the EU. Pollutants, microplastics and pathogens in the water cycle pose a challenge for drinking water purification and wastewater treatment and put a strain on the food webs in rivers and seas. The widespread use of antibiotics in humans and animals has led to an increase in multi-resistant germs that are not fully filtered by sewage treatment plants and are discharged via wastewater first into rivers and then into the sea. This anthropogenic pollution of water endangers the ecological status of waters and seas. This has far-reaching consequences for aquatic food webs and human health, some of which we do not yet know about.

What are the research needs?

The protection of water resources is only possible if we have a better understanding of material flows and processes in the water cycle and of threats arising from human impacts. To do this, we must broaden our perspective. Under the motto 'From source to estuary', we want to bring about closer integration of inland water and coastal research and better understand environmental impacts on water cycles, from river basins to the sea.

Implementation steps and milestones

- We will work with water sector stakeholders to establish resource protection policies and develop methods to prevent pollution at source and safely treat polluted water.
- Our 'Clean Water' initiative sets a key priority in the Federal water programme Wasser:N (→ Action 13, p. 29). Our goal is to strengthen the future of water research and water innovations that are 'Made in Germany' from 2020 onwards, thereby securing Germany's leading-edge role.
- In 2020, we will present the results of research funding on major sources of pollution and the risks of antibiotic resistance in the water cycle along with initial solutions for prevention measures.
- From 2021, we will be involved in a European funding initiative on the occurrence of anthropogenic trace substances, pathogens and antimicrobial-resistant bacteria in freshwater and saltwater ecosystems.
- In 2021, we will publish the results of our research on plastics in the environment. New technologies will be used to investigate the effects of microplastics on the environment, to effectively prevent the entry of microplastics into waterways (→ Action 19, p. 36), and to remove microplastics from the water. At the European level, we will present our findings on the ecological aspects of microplastics in the marine environment in 2024.
- In 2020, we are funding research at the EU level on the effects of ammunition contamination in the seas.
- From 2021 onwards, a new research initiative on groundwater will help to tackle the pollution of groundwater with nitrate, phosphate and chemical residues.
- We will continue to develop the online portal for the correct disposal of medicines (www.arzneimittel-entsorgung.de), thus providing citizens with all the information they need on safe and environmentally conscious disposal methods.

Action 15: Maintaining healthy soils and sustainable use of land

We will develop a holistic understanding of how to maintain healthy soils and use land sustainably.

Where do we stand?
At present, research usually only looks at individual segments of land use – such as soil and water quality, nutrition, infrastructure, nature conservation and climate protection. We cannot solve conflicts of interest between growing settlement areas, agricultural use and the requirements of environmental and climate protection in this way. The aim is to bring economic and ecological land use more closely into harmony.

What are the research needs?
Instead of research in individual segments, we need systemic, integrated analyses, especially at the landscape and regional level. To this end, approaches to solutions in agriculture and forestry as well as in local and urban planning (→ Action 6, p. 17) must be more closely integrated with nature conservation and water management in future. The issue of how soil should be managed and land used in the face of conflicting requirements is crucial to the sustainable development of urban and rural areas. For rural areas in particular, integrated solutions are needed which take account of the different interests between nature conservation, recreation and use. This also applies in the international context. This calls for transdisciplinary research cooperation and scientifically based concepts in which both the causal relationships and regional (natural and sociocultural) characteristics are taken into account. This is the only way to ensure that measures can have a long-term, sustainable and global impact on society and contribute to improving or securing local living conditions – including the preservation of intact ecosystems as a basis for life. In Sub-Saharan Africa, for example, the SASSCAL and WASCAL Africa Centres are already creating the conditions for this by bringing together the necessary scientific and social actors (→ Examples of our global commitment, p. 55). Future research projects will be devoted to the development of modern, environmentally and socially compatible land management. Digitalisation, knowledge transfer and governance are key instruments in this context.

Implementation steps and milestones

- We will develop new processes, technologies and products that lead to optimisation of soil functions; we will also work out new approaches for sustainable soil and land use with which existing dual- or multiple-use concepts can be further developed.

- From 2020, we will fund research into the complex interplay between soil, soil organisms and plants in cultivation systems. From 2020, we will also participate in a European funding initiative on soil research. The aim will be to investigate relevant key biological processes in the rhizosphere, the zone of soil around the roots of plants, in order to maintain or even improve the performance of soil ecosystems for efficient plant nutrition, humus balance and climate protection.

- By 2025, we want to establish a web platform that makes it easier for stakeholders from agriculture and science and policymakers to evaluate and implement sustainable land use concepts.

- The results will be available from 2025 onwards, along with more far-reaching approaches to international sustainable land management that will point out solutions towards ecologically, economically and socially sustainable development using knowledge-based measures in the areas of digitalisation and governance.

- We are funding resource-efficient urban districts for the future and the planning of urban development processes geared towards the efficient use of water, land and material flows in more than 20 model municipalities in Germany. Initial findings will be available in 2021. In 2022, we will start the implementation phase.

Action 16: Expanding development of agri-food systems

We are rethinking agricultural production and connecting up knowledge across system boundaries.

Where do we stand?

Agriculture, food and forestry systems are facing profound changes. Due to climate change, dwindling farmland and the steadily growing world population, maintaining a global food supply in sufficient quality and quantity is becoming an ever-greater challenge. Urbanisation, geopolitical instability and the decline in biodiversity further exacerbate the situation. It is becoming increasingly difficult for traditional forms of agricultural production to meet the changing requirements. In addition, agriculture and forestry must also make their contribution to climate neutrality. On the one hand, agriculture and animal husbandry release greenhouse gases – for example, through methane-producing cattle, sheep and other ruminants or fertilisers that release nitrous oxide – and on the other hand, sustainable agriculture and forestry can reduce global greenhouse gas emissions, for example through reforestation, humus formation or rewetting of peatlands. Management practices determine whether soils, forests or grassland are long-term sources or sinks of greenhouse gases.

What are the research needs?

Future agricultural systems will rethink production and link up knowledge across system boundaries. In inter- and transdisciplinary teams, different disciplines and sectors will be brought together in systemic approaches. On the basis of these and other planned subsequent and follow-up measures, we will continue or even expand and develop the breadth of sustainable agricultural and food systems. Future technologies and digitalisation are important drivers for agricultural systems and modern plant breeding research (genome editing).

A further goal of our research is to achieve more resilient agricultural operations that are more climate-neutral or even actively climate-protective and that extract more CO_2 from the atmosphere than they release. The focus here is on innovative, transdisciplinary approaches in regions and fields of action that have a particularly high potential to contribute to climate protection effectively and in harmony with the other Sustainable Development Goals.

Implementation steps and milestones

- The National Bioeconomy Strategy and the Climate Protection Programme 2030 will form our strategic and programmatic framework in the coming years. On the one hand, we will fund the development of sustainable agricultural, food and forestry systems – the main topics include agricultural systems of the future, plant breeding research for the bioeconomy, crops of the future, innovative plant breeding in the cultivation system, and the NewFoodSystems innovation space. On the other hand, we will expand development of climate protection in agriculture and forestry and contribute to the development of climate-friendly business operations, inputs and production chains.

- We will develop systemic concepts for climate-friendly agricultural operations and production chains by 2027, which will also involve the retail trade and the demand and consumer side.

- We will develop innovative key enabling technologies and integrate them into high-tech production processes in the areas of crop cultivation, smart farming, AI-based management systems and space-efficient production systems.

- Coordinated through the Office for Agricultural Systems of the Future and its online offering, we will work on the topic of ‘Transformation of agricultural and food systems’ in Science Year 2020/21 and beyond and present it in a way that is comprehensible to the wider community.

Our linear economy leads to excessive consumption of resources and produces large amounts of waste. Per capita demand for raw materials in Germany is twice as high as the global average. The extraction and processing of raw materials has a considerable impact on the environment and climate. Nevertheless, even less than 10 per cent of the raw materials used worldwide are currently reused in the system – and this despite the fact that a circular economy is not only environmentally friendly, but also a business model that can make money. In order to secure revenues in the long term, companies must question their business models and adopt the concepts of a circular economy. However, this requires more than just innovations in product design and production processes, for example, but also new consumer behaviour. There is a demand for holistic solutions for more reuse and recycling and less waste. With FONA, we show how this can be achieved.

Field of action 6:
The circular economy – efficient use of raw materials, avoiding waste

Action 17: Increasing overall raw material productivity | p. 34
Action 18: Bioeconomy: Utilising bio-based raw materials and avoiding waste | p. 35
Action 19: Closing the plastics cycle | p. 36
Action 20: Recycling phosphorus: Reusing waste streams, recovering resources | p. 37

Action 17: Increasing overall raw material productivity

The transition to a resource-efficient circular economy will enable us to create more added value with fewer raw materials.

Where do we stand?

The world economy is growing steadily – and with it the global consumption of resources. This could change if we decouple economic growth from resource consumption. The German Sustainable Development Strategy defines total raw material productivity to measure how economically and efficiently resources are used. This indicator shows the ratio between the value of goods produced in Germany and the amount of raw materials used in production. The explicit goal of the Federal Government is to increase total raw material productivity by 30 per cent by 2030 compared to 2010 (German Resource Efficiency Programme). Currently, total raw material productivity is increasing by an average of about 1.6 per cent annually. The aim of FONA is to accelerate the process and contribute to an increase in total raw material productivity in Germany of at least 2 per cent annually.

What are the research needs?

Through research and innovation, we aim to ensure that products in general are used longer, that their components can be reused and that their residual materials can be recycled. In terms of recycling, we focus in particular on bulk raw materials such as plastics and construction materials, as well as on critical raw materials such as electrowon and rare-earth metals. To achieve our goal, we need 1) a product design that ensures products can be repaired and/or recycled, 2) new business models that provide incentives for companies and customers to contribute to circularity, and 3) appropriate technologies for separating and sorting, reprocessing and recycling products and materials. This requires close cooperation between science and industry (designers, product developers, manufacturers, recycling companies, retail). The involvement of consumers and consideration of the general conditions for implementation also play a key role, as does the digitalisation of material cycles.

Implementation steps and milestones

- We are working together across ministries, in particular with the Federal Ministry for the Environment (lead management of the German Resource Efficiency Programme – ProgRess) and the Federal Ministry for Economic Affairs (lead management of the Raw Materials Strategy) and are involving professional associations, Länder and NGOs in the National Resource Efficiency Platform (NaRess).

- With our research funding, we want to strengthen German companies as leading international providers of technologies and business models in the field of recycling and the circular economy, in this way contributing to their competitiveness.

- We have been funding innovative potential solutions with our research priority on a resource-efficient circular economy since 2019: from the design of an asset, through its use for as long as possible, to the separation and recycling of its materials and components.

- In 2019, we launched a funding priority on innovative product life cycles. Measures on (a) construction and mineral material cycles and (b) plastics recycling will follow from 2020.

- Through the 'Circular Economy Initiative Deutschland' (CEID) of the National Academy of Science and Engineering (acatech), we will fund the development of a roadmap for a circular economy in Germany until 2021. An extension of the CEID to the whole of the EU is under discussion.

- The effectiveness of resource-efficient economic cycles can be weakened by the rebound effect. This is why we are funding projects as part of our Social-ecological Research programme that analyse and suggest measures for minimising rebound effects. The results of these projects will be presented from 2021 onwards.

- We are involved in the implementation of the EU's Circular Economy Action Plan (CEAP) and are expanding Germany's leading role. On the European level, we are cooperating in a transnational research and innovation programme on raw materials for sustainable development and the circular economy.

Action 18: Bioeconomy: Utilising bio-based raw materials and avoiding waste

We will add biogenic raw materials to our range of raw materials. These can be optimally utilised in various processing stages and then returned to the cycle. This avoids additional waste.

Where do we stand?

Biogenic resources are renewable and climate-neutral. This is because they never release more CO_2 during their use than they have withdrawn from the atmosphere during their growth. Another advantage is that, due to their nature, they are particularly suitable for use in cycles or cascades. This includes material and energy recovery. For example, wood can be used first as building material, then as furniture wood, then as pressed wood and finally as fuel or compost. A limitation results from the availability of the land required for biomass production. In 2020, when the Federal Government adopted the National Bioeconomy Strategy, it committed itself to the vision of a sustainable, land-saving bio-based economy geared towards natural material cycles. The aim is to expand the resource base in a sustainable manner – in terms of the biomass put to use and the number and form of biological production organisms used on the one hand, and the technologies and methods employed to achieve this on the other.

What are the research needs?

Research should expand the range of bio-based substances. Novel bio-based production systems can, for example, provide tailor-made ingredients for industry. Current petrochemical-based substances, chemicals and products should be substituted by biogenic raw materials where possible. However, these can do more than just replace fossil fuels. With their help, completely new types of products and composite materials can be created, for example for house or car body construction. In addition, the reuse of bio-based residual and waste materials is increasingly coming into focus. This is where cascading and the return of materials to the circular economy must be optimised. We want to develop the necessary biotechnological processes, bring them to market maturity and promote their use in production.

Implementation steps and milestones

- We will establish the German Bioeconomy Council in 2020, whose task will be to advise the Federal Government on issues relating to the implementation of the National Bioeconomy Strategy. The council will represent a broad range of expertise and will play an active role in developing implementation scenarios for the bioeconomy in Germany.

- As part of the National Bioeconomy Strategy, we want to examine the social, economic and political correlations for sustainable bio-based management and will analyse the contribution of this economic activity to sustainability. This means that, jointly with the Federal Ministry of Agriculture, the Federal Ministry for the Environment and the Federal Ministry for Economic Affairs, we will continue to fund the establishment of a monitoring system for the bioeconomy.

Action 19: Closing the plastics cycle

We want to achieve intelligent, resource-efficient and energy-efficient use of plastics – among other things through a genuine circular economy.

Where do we stand?

Plastics are an integral part of our daily lives. The versatile properties and cost-effective production of plastics compared to other materials make them an almost irreplaceable material. However, plastics also pollute the environment. This is the reason the German Packaging Act was introduced. It aims to increase the recycling rate for plastic packaging, create a better basis for plastics recycling, and offer new economic recycling potential. This is an important step towards reducing plastic waste in Germany. However, too much plastic waste is produced globally, and too little is recycled. Today, between 4 and 13 million tonnes of plastic waste land in the sea each year worldwide. The aim is to reduce this amount to zero by 2050.

What are the research needs?

To achieve this, innovative technologies and recycling processes and intelligent use concepts are necessary. Our funding therefore goes firstly towards research into economic and social strategies for avoiding and reducing plastics. Secondly, we are funding initiatives for the design of plastic products that are compatible with a circular economy. And thirdly, we are promoting the development of economically viable, digitally based solutions for the intelligent use, collection, sorting and recycling of plastics and their testing on an industrial scale. In doing so, our aim is to always take account of the consumers' perspective as well as that of the manufacturers – all with the aim of using less plastic, increasing the efficiency of plastic use, and establishing a true recycling economy in the plastics sector.

Implementation steps and milestones

- In collaboration with the Federal Ministry for the Environment and the Federal Ministry for Economic Cooperation and Development, we are working on improving the recycling of plastics (five-point plan to reduce plastic and increase recycling; PREVENT Waste Alliance).

- We are participating in the implementation of the EU Strategy for Plastics, and with our funding for the recycling sector, we are helping to maintain and expand Germany's leading role in this area.

- We are committed to greater cooperation with industry, for example in the 'Alliance to End Plastic Waste'; and, through research and development projects, we are supporting German companies in their efforts to be the leading providers in the field of plastics recycling.

- From 2021 onwards, we will fund the improved recycling of plastics and strive to achieve the strong participation of companies, as well as large-scale implementation along the plastics value-added chains.

- Our results on new and digital technologies and pilots for the use, collection, sorting and recycling of plastics will be presented from 2022.

Action 20: Recycling phosphorus: Reusing waste streams, recovering resources

We will secure the future supply of phosphorus by recovering it from wastewater and sewage sludge.

Where do we stand?

Intensive agriculture has led to phosphorus deficiency in arable soils. In order to maintain agricultural yields at a high level, phosphorus must be returned to the fields through fertilisation. One way to address phosphorus deficiency is to recover phosphorus from wastewater and sewage sludge. The phosphorus must first be recycled from the sewage sludge. If this does not happen and sewage sludge is fertilised directly, the soil will also become heavily polluted with substances such as heavy metals or multi-resistant germs. The Federal Government has therefore embedded the expansion of phosphorus recycling in the German Resource Efficiency Programme and created the legal framework by amending the Sewage Sludge Ordinance. Consequently, the recovery of phosphorus contained in sewage sludge is strictly required for larger municipal sewage treatment plants, and fertilisation with sewage sludge is prohibited. However, the implementation of phosphorus recovery entails high costs, which will have to be primarily borne by consumers via the water tariff. In order to keep the additional burden on bill payers as low as possible, solutions that are as economical as possible are therefore required.

What are the research needs?

The complex process of phosphorus recovery and the high costs entailed are the biggest obstacles to date to the implementation of the new Sewage Sludge Ordinance. In order to make the right investment decisions at regional level, decision-makers need scientifically sound knowledge and practical experience. These can only be obtained through the large-scale implementation of various phosphorus recovery processes. However, these technologies must not be considered in isolation, but must be part of a holistic regional phosphorus recycling and sewage sludge reuse concept. In this way, they can serve as a model for other regions with similar conditions.

Implementation steps and milestones

- We are funding innovative regional approaches to economic and sustainable phosphorus recycling and sewage sludge reuse and will start implementing previously developed concepts in 2020. Demonstration sites for industrial-scale implementation of various phosphorus recovery technologies are expected to be established by the end of 2025.

- With the help of long-term funding from 2020 onwards, we want to show how the entire value-added chain can be included in order to return the recovered phosphorus to the nutrient cycle via agriculture (→ Action 16, p. 32) or to industry as a raw material.

Goal 3: Develop society and the economy – good living conditions throughout the country

The 2030 Agenda addresses the issue of a sustainable and decent life for all people regardless of their place of residence and social background through a number of SDGs. The challenges of achieving this also exist in Germany. There are considerable regional differences in terms of economic performance and innovative strength. Strong economic areas stand in contrast to regions – both rural and urban – with lower income and employment opportunities. About 40 per cent of the population in Germany lives in structurally weak regions. These include old industrial centres, rural areas and numerous border and coastal regions in the east and west.

There are also significant urban–rural disparities and inequalities between and within regions in terms of economic and social structure. While economically weak regions are often particularly affected by population decline, strong regions usually face challenges such as congested infrastructure, unaffordable housing, traffic-induced noise and air pollution, and lack of space.

Current developments such as demographic change, digital transformation and climate change pose challenges for all regions of Germany. At the same time, they open up the possibility of breaking new ground and developing new solutions – for instance, for sustainable mobility or the structural transformation of former coal-mining areas.

The creation of equivalent living conditions is a declared goal of the Federal Government. In 2018 it therefore appointed a commission of the same name to develop proposals on how resources and opportunities can be fairly distributed in future for all people living in Germany. On the basis of their findings, initiatives have been launched in various areas such as public services, infrastructure, the economy and innovation. Through FONA, we want to activate regional potentials, initiate processes of change and create sustainable perspectives, also on a social level, thus contributing to the achievement of national and international sustainable development goals.

Making an innovation-oriented, sustainable and socially just future possible – that is our declared goal. To this end, sustainable and future-proof scientific and economic structures must be created in Germany and unequal developments within society, between urban and rural areas or between structurally strong and weak regions must be counteracted. More than ever before, we see the ecological challenges of our time – climate change, overexploitation of resources, environmental pollution – as an opportunity to boost innovative strength, promote successful business locations, build a resource-saving and environmentally friendly society, and maintain prosperity in our country, so that our social cohesion is also increased.

Field of action 7:
Shaping society together – strengthening cohesion

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Action 21: Equal living conditions – Strengthening prosperity, participation and democracy

We want to create viable and sustainable scientific and economic structures in Germany and are committed to democratic participation.

Where do we stand?

To stimulate sustainable economic dynamics and strengthen social cohesion, existing opportunities must be identified and seized locally. The aim is to create sustainable jobs and make them more attractive for skilled workers and companies. This requires long-term economic and science-based structural formation – in other words, sustainable structural change that builds on the region's existing competencies and mobilises a broad spectrum of actors is needed. At present, participation, democracy and our open society are under massive pressure from various social processes such as globalisation, climate change, digitalisation and populism. We want to counter this with sustainable structural change and participatory approaches to sustainability-driven solutions, while at the same time promoting prosperity.

What are the research needs?

Research and innovation are success factors for achieving structural change because they make a major contribution to boosting the competitiveness of companies in the long term and opening up new opportunities for growth – especially in environmentally relevant sectors. Research also offers the opportunity to develop new forms of civic participation and involvement. There is a need for research, for example, on the question of how suitable opportunities for participation can increase the legitimacy of measures that are geared towards sustainability or promote structural change while at the same time actively bringing the expertise of citizens into the research process. This contributes to both strengthening democracy as a whole, which is under pressure in many places in Europe, and rapidly transferring knowledge between society and science.

Against this background, there is also a need for research on how the rise of populism affects environmental research and the political goal of sustainability.

Implementation steps and milestones

- We are supporting the implementation of the findings of the Commission on Equal Living Conditions with tailor-made funding measures, also with the involvement of civil society and other regional actors. For example, the suites of programme on 'Innovation & Structural Change' and 'Entrepreneurial Regions', the funding priority for 'Innovative Communities' (Kommunen innovativ), and the funding of inter-company vocational training facilities are all being incorporated into the 'Nationwide funding system for structurally weak regions', which was launched in 2020.

- We have designed the suite of programmes for 'Innovation & Structural Change' as multi-year, open-topic innovation funding measures that build on the strengths of structurally weak regions. The aim is to further develop the scientific, economic and social innovation potential of the regions with the intention of achieving sustainable structural change.

- We will fund strategic partnerships for different regional contexts and actors (e.g. urban–rural partnerships, actors from politics, administration, local governments, the science and research community, business and the public) in the development of joint strategies and concepts. We will present the initial findings of the Stadt-Land-Plus (urban-rural-plus) funding activity from 2022.

- Based on a systematic review of political processes that can lead to the rejection of climate protection and sustainable development goals, we will further advance research from 2022 on the sustainability of democracy, new forms of democratic participation, and the challenges of the legitimation and implementation of sustainability policies.

Action 22: Supporting sustainable economic and financial systems

We want to support sustainable business practices and use the leverage effects of the financial sector in particular to promote gearing the real economy towards a climate-friendly mindset.

Where do we stand?

A sustainable financial system is a prerequisite for sustainable economic activity and sustainable investment in the real economy. However, current investment behaviour supports global warming of four degrees or more. So that the real economy will invest in more climate-friendly and sustainable technologies and processes, the financial sector must also become greener. And if financial markets are to become the central lever for green economies, policymakers must create the right regulatory environment. We want to provide the knowledge needed to ensure that the financial system will support the achievement of the Paris climate goals in the future, and we want to contribute to Germany and Europe becoming leading sustainable finance locations.

What are the research needs?

Through our research funding, we want to create green markets of the future (for example in climate-friendly technologies or in the bioeconomy), prepare markets for the future, and use the leverage of the financial sector to support the transition of the real economy into sustainable and climate-friendly structures. Research will be undertaken to explore ways to redirect financial and investment flows from unsustainable activities to sustainable ones. To this end, answers to the following questions will be developed: What could efficient financial markets for climate-conscious investment decisions look like? What could incentive structures for climate-friendly investments be like? How must sustainable financial market instruments and regulatory approaches be designed? This includes the development of new measurement and evaluation concepts to determine the environmental and social impacts of the financial sector, as well as of production and consumption in the real economy.

In the field of digitalisation, our research funding aims to develop secure digital solutions that support modes of production, organisation and consumption that are sustainable, climate-adapted, resilient and improve people's quality of life. There is great potential here, for example, in small and medium-sized enterprises, platform and sharing economies, and approaches in line with an economy for the common good.

Implementation steps and milestones

- As part of the National Bioeconomy Strategy, we are focusing on the investigation of social, economic and political correlations for sustainable bio-based management and are analysing the contribution of the bioeconomy to sustainability. This means that, jointly with the Federal Ministry of Agriculture, the Federal Ministry for the Environment and the Federal Ministry for Economic Affairs, we will continue to fund the establishment of a monitoring system for the bioeconomy (→ Action 18, p. 35).

- From 2022 onwards, we will focus on exploiting the opportunities digitalisation offers to synergise technological and social innovations, new business models, and corporate and policy innovations. In particular, we will tap the potential of small and medium-sized enterprises for new solutions.

- As part of the Federal Government's Climate Action Programme 2030, from 2022 onwards we will fund research to support the implementation of the German Sustainable Finance Strategy and the achievement of the Paris Climate Agreement targets. Building on the success of the research programme Economics of Climate Change, we will address the opportunities and challenges associated with climate change through the funding priority Finance and Climate Protection.

- From 2022 onwards, building on the basis of a meta-study, we will also strengthen research on the further sustainability impacts of the financial sector and on aligning the financial system with sustainability. In addition to ecological aspects, our research will also take account of social and economic sustainability in particular and open up opportunities to implement sustainable innovations and business models in the real economy.

We want strong, attractive and sustainable regions throughout Germany. That is why we want to promote innovation-based, resource-saving and climate-friendly structural change that will secure prosperity and jobs. Regions where lignite mining is still taking place today are particularly affected by structural change. The coal phase-out by 2038 poses unique challenges. This is because the regional development of the lignite regions is part of a more profound social transformation. Such a process is a generational project that depends on innovation and needs to involve the rural area and the local people from the very beginning.

Regardless of whether or not an area was a former coal region, structural change must create an equivalent quality of life across the board in urban and rural areas and provide access to mobility, education and infrastructure. This also means countering demographic pressure on cities and making rural regions attractive locations for business and innovation. We address these issues through our actions in FONA.

Action 23: Shaping structural change in coal-mining areas through research and innovation

We want to form structural change in coal-mining areas through research and innovation.

Where do we stand?

The Structural Development Act for coal-mining regions was adopted in July 2020. This will implement the structural policy recommendations of the Commission on Growth, Structural Change and Employment. It is planned to fund support for the affected coal regions in Germany to a total of around 40 billion euros by 2038. The funding of research and innovation is an essential component of the Act. These include measures to support energy system transformation and climate protection and to create concrete prospects for new, future-proof jobs and value creation. The end of coal-fired power generation represents a particular challenge for Germany as a highly industrialised export nation with a comparatively large share of coal in electricity generation.

What are the research needs?

Structural change must be successfully managed, and climate protection, the creation of future-proof jobs, the strengthening of economic power and regional development must be reconciled. The aim of this generational project is to use research and innovation to open up long-term sustainable prospects for transformation in the coal regions, while exploiting the opportunities offered by new technologies and business models.

We see the coal phase-out as an opportunity and are launching innovative and viable activities in the coal regions in joint efforts with local stakeholders. In this way we want to make the structural change in the lignite mining areas a real success story.

Implementation steps and milestones

- In the Rhenish lignite mining district, we are supporting the project 'Incubator for Sustainable Electrochemical Value Creation' (iNEW) as part of the immediate action plan. This establishes until 2021 an open innovation platform for crucial future technology in the transformation of the energy system called "Power-to-X". Through this project, we will expand development of the excellent research capacities in the region and make them accessible for local companies. In doing so we can maintain the Rhenish mining area as an energy region.

- Through the project 'BioökonomieREVIER Rheinland' (BioREVIER) we will develop the Rhineland into a model region for sustainable economic activity and launch 15 innovation laboratories by 2021. The focus here is on the use of biogenic resources, the transition from material flows to material cycles, and integration with the energy sector. In this way, the exit from coal-fired power generation is being used as an opportunity to make the region's available and established strengths the basis for a new and sustainable economic alignment of the region.

- In addition, we have introduced further initiatives in the draft of the Structural Development Act for coal-mining regions. With our funding, which is open to all topics, we support initiatives from structurally weak regions that aim to advance the region with new technologies or innovative business models.

- In the area of institutional funding, we intend to support the establishment of a new Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems in Brandenburg, Saxony and North Rhine-Westphalia. Two new research facilities are to be built in Lusatia and the Central German lignite mining district. A hydrogen cluster focusing on transport and storage is being established in the Rhenish mining district.

Action 24: Making urban, rural and regional transformation sustainable

We want to jointly develop viable strategies for urban and rural areas to make our regions sustainable and fit for the future.

Where do we stand?

Cities, towns, villages and regions face many challenges. These include, for instance, land take, coastal protection and energy system transformation. The regulatory conditions for meeting these challenges must be created at Federal and Länder level, but concrete implementation will take place locally and regionally. The development initiated by sustainable concepts opens up new opportunities and regional value creation potential. The Innovation Platform City of the Future (IPZ) was set up in 2015 as a joint effort with the Federal Ministry for the Environment, Federal Ministry of Transport, Federal Ministry of the Interior and Federal Ministry for Economic Affairs to promote the exchange of research on sustainable urban development, implement joint initiatives and identify successful solutions. New research needs are constantly being formulated with the relevant urban actors and implemented in research projects. FONA sees itself as a partner for cities, towns, local governments and regions to support sustainable transformation. On the ground, we want to develop joint projects in a strong alliance of municipalities that will move Germany forward. We set the impetus for innovation in metropolitan regions and regional cities and support the regional economy, the development of social innovations and the resilience of local authorities.

What are the research needs?

Sustainable development of cities and regions requires integrated, holistic concepts and strategies. The ecology, economy and social concerns need to be reconciled more strongly than before. The aim is to provide local actors and decision-makers with new, scientifically sound solutions, options and instruments to make cities and municipalities fit for the future and strengthen regional value creation. Research is needed, among others, to exploit digitalisation potential more efficiently for adaptation to climate change (→Action 6, p. 17). In addition, we must create and make greater use of opportunities for participation. There is also a need for new planning instruments and more intensive cooperation across administrative borders, for example to revitalise city centres, promote social and ecological urban development, provide sustainable, affordable housing and make mobility affordable in the long term. In supraregional real-world laboratories (for example in metropolitan regions or regional cities), we will therefore expand development of technologies and knowledge for digitalisation and sustainability, adapt them for the regions, and test new products, production processes and business models.

Implementation steps and milestones

- In an ideas competition, innovative concepts developed together with citizens will be implemented by 2023, and sustainable before-and-after effects will be made visible. Our research funding and the urban development funding of the Federal Government and the Länder are designed to complement each other.

- We will provide targeted low-threshold incentives for activation at the local level to enable the needs-based, concrete application of innovative, data-based solutions that are geared towards the citizens' needs.

- In order to create synergies, funding activities will be consolidated more strongly within the regions, but also on a supraregional level, and existing supraregional associations such as metropolitan regions and city regions will be involved. To achieve this, we are striving for close cooperation with the Länder concerned. The aim of the regional and supraregional real-world laboratories is to develop sustainable research and development strategies that address the entire value chain from research and (product) development to practical application.

- Starting in 2023, we will present results with a focus on transfer, implementation and perpetuation on issues of economic structural change in cities, energy system transformation at the municipal level, climate adaptation, sustainable infrastructure and quality of life in urban neighbourhoods, as well as social cohesion and migration.

- In order to revitalise city centres and promote new concepts for resilient cities, municipalities and regions adapted to climate change, we will make targeted use of the opportunities offered by digitalisation. To this end, we will provide new digital tools for urban planning adapted to climate change from 2021 onwards (→ Action 6, p. 17). We will also develop concepts for intermodal mobility and implement them in experimental spaces (→ Action 25, p.47).

- By 2024, we will present contributions to climate adaptation and urban resilience strategies that have already been implemented and tested (→ Action 6, p. 17).

- The REGION.innovativ programme will provide targeted support to enable regional alliances, networks and clusters in structurally weak regions to work together on topics relevant to the future. From 2020, for example, we will promote inter-municipal cooperation in the areas of the circular economy and regional value creation.

- Within the MARE:N research programme, we are placing special emphasis on coastal regions. As a member of the German Coastal Engineering Research Council (KFKI), we constantly support the development of concepts for the sustainable protection of German coasts on the North and Baltic Seas in cooperation with local stakeholders.

Action 25: Ensuring sustainable urban and rural mobility

We want to secure people's mobility with innovations and at the same time improve the quality of the environment and the quality of life in urban and rural areas.

Where do we stand?

Mobility connects people and is a prerequisite for economic prosperity, but it is increasingly polluting the environment with particulate matter and high CO_2 emissions. By 2030, the Climate Action Plan envisages a reduction in emissions in the transport sector of 40 to 42 per cent compared to 1990. So far, very little in the way of reduction has been achieved. For sustainable, resource-efficient mobility, we need a mobility transformation that builds on technological and social innovations. A transformation in mobility is not only necessary in Germany. Systemic concepts are key right from the start. In view of the dynamic development of new technologies and mobility patterns, we need research on the effects of different transport services and design options for sustainable mobility in urban and rural areas.

What are the research needs?

The research agenda 'Sustainable Urban Mobility' addresses the need for transdisciplinary and systemic mobility research. It integrates the results of participatory agenda processes from the years 2017 and 2018, in which numerous experts from science, municipalities, business and civil society have contributed their perspectives, needs and ideas. The aim is to secure individual mobility, improve the quality of the environment and the quality of life in urban and rural areas, and strengthen the innovative capacity of the German mobility sector. Small and medium-sized companies can profit from this just as much as start-ups. On this basis we have introduced various research initiatives on mobility in the package of measures for the Climate Action Programme 2030.

Implementation steps and milestones

- By the end of 2020, we will publish an action plan on mobility research which will look at research and innovation for safe, connected and clean mobility of the future in a comprehensive, systemic approach.

- By the end of 2020, we will be funding almost 50 municipal projects which, with support from science and research, will develop innovative, environmentally compatible and tailor-made local mobility concepts together with key stakeholders and multipliers on the ground. From mid-2021, 15 of the projects will be tested in real-world laboratories and the measures developed will be implemented.

- By the end of 2022, we will provide an innovation toolkit for sustainable mobility concepts in urban and rural areas which will support municipalities and regions with technical, political, administrative and social solutions.

- By the end of 2024, we will publish annual short dossiers on sustainable mobility to motivate municipalities to adopt sustainable urban mobility systems.

- The research questions elaborated within the framework of the National Platform for the Future of Mobility (NPM) will be used to develop new funding measures from 2021. Key issues include road safety with regard to new technologies, as well as logistics in the inner city and urban and rural areas.

- With a new initiative under the Climate Action Programme 2030, we will launch new research concepts on barriers to systemic innovation in climate protection from 2022 onwards – among other things following on from the results of the NPM.

- Starting in 2020, we will look at the digital options for environmentally and socially compatible management of passenger transport, for example through a German–Japanese research cooperation on socio-economic impact assessments of autonomous driving, on-demand solutions and mobile stations in rural areas.

- From 2021, we will develop funding measures to digitalise delivery and freight traffic between cities and their surrounding areas and within city centres.

CROSS-SECTIONAL ISSUES – COURSES OF ACTION IN FONA

The cross-sectional topics address issues of sustainable development that play a role across the board in all of the actions. These topics are therefore a connecting element between the individual actions and are essential for the success of their implementation. By taking account of these cross-sectional topics in all of the actions, we are ensuring that research in FONA is networked, effective and geared to the future.

Digitalisation, data and AI for sustainability and sustainability research

Whether in business or broader society, digitalisation is permeating and changing almost every aspect of our daily lives. At the same time, it is becoming increasingly clear that the way we live and our business practices have negative consequences for the environment and society, for example for the climate or social cohesion. Digital technologies and innovations can support and accelerate sustainable developments in many areas – such as urban development, the circular economy and energy system transformation. To make a sustainable, secure digital future possible, we want to consistently conceive of digitalisation and sustainability in tandem and use the opportunities offered by digitalisation to implement the 2030 Agenda.

We are shaping tomorrow's digitalisation today – 'Natürlich.Digital.Nachhaltig'!

The Federal Ministry of Education and Research's Digital Strategy, launched in 2019, provides the framework for informing digital change and data policy in education, science, research and innovation. The strategy formulates the Federal Ministry of Education and Research's ambition to design digitalisation in such a way that it serves society and the preservation of the basis of life. Digitalisation offers numerous opportunities for sustainable development – provided that it itself is made sustainable and secure. This is where we enter with the action plan 'Natürlich.Digital.Nachhaltig' (Natural.Digital.Sustainable). It promotes research and development in the field of digitalisation that is geared towards the Sustainable Development Goals and contributes to their implementation. The action plan has three main objectives: 1) to lay the foundations for digital sustainability, 2) to make digital technologies more sustainable, and 3) to achieve the Sustainable Development Goals through digital innovation.

Digital solutions for sustainability in FONA

The opportunities that digitalisation offers for sustainable development are enormous. Digital technologies can make processes more efficient, faster and more sustainable. They enable new insights and options for action, for example through improved sensor technology, AI-based applications and machine learning. In FONA, we are already making frequent use of the opportunities offered by digitalisation for sustainability research and will promote the use of digital technologies even more strongly in future.

Digital GreenTech – Environmental technology meets digitalisation

How can AI help to improve recycling processes? Which digital tools can be used to monitor and control water supply and disposal networks more efficiently? How can complex material flows be tracked in real time? These and other questions are to be answered in the 'Digital GreenTech' funding priority. Through 'Digital GreenTech', we are promoting the development of new innovative and sustainable products, processes and services by linking digital technologies with environmental technologies. Users from the fields of resource efficiency and the circular economy, water management, sustainable land management and geotechnologies are working closely with digital idea providers to conserve natural resources and reduce environmental pollution. This is how 'Digital GreenTech' contributes to the implementation of the action plan 'Natürlich.Digital.Nachhaltig'.

The fields of application cover the entire spectrum of FONA sustainability research. For example, intelligent digital solutions are already making a key contribution to the success of energy system transformation by

bringing the production and consumption of renewable energy into alignment. Another example can be seen in precision farming. It uses digital technologies to better manage water consumption and the use of crop protection products and fertilisers. Intelligent data collection and analysis through key enabling technologies such as machine learning and AI also helps us better understand climate change, biodiversity loss and natural hazards. And they help us design a resource-efficient circular economy. We want to use our funding to further expand this potential attached to digitalisation.

However, the relationship between digital innovation and sustainable development is often ambivalent. After all, what good is the use of digital innovations in the sustainability sector if AI algorithms or server farms consume more energy than they save? Questions such as these, especially regarding rebound effects, are also addressed in FONA.

Research data – the raw material of the future

Data is the raw material of the future – and digital data infrastructures are essential to use data for sustainable innovation. In addition to the development of new algorithms and digital workflows for data acquisition, processing and analysis, access to quality-checked research data is particularly crucial. The Federal Ministry of Education and Research is making a major contribution to the systematic development of research data through the National Research Data Infrastructure (NFDI). For example, in the area of sustainability, an NFDI will be established for biodiversity, ecology and environmental data. As part of FONA, we will use the associated synergies for sustainability research and pursue the process for the sustainable use of data.

In addition to data generated in the research context, public and private data also contribute to sustainability. FONA supports the cooperation between data owners, analysts and users for the purpose of sustainable development. With the 'Data Science for Sustainable Development' (DSSD) initiative, we are bringing together cities, municipalities and metropolitan regions with data scientists to develop and implement sustainable digital solutions at local level – for example, for land use or for recording environmental pollution and noise.

Knowledge and technology transfer for sustainable development

In order to create lasting viability through FONA, we are supporting the targeted transfer of knowledge, technologies and innovations. Our funding is aimed at providing specialist, guidance and transformation knowledge and at accelerating the transfer of research results into application. This is best achieved if from the very beginning researchers work together with stakeholders in the field and decision-makers.

In FONA we focus on participation. This includes involving stakeholders from the non-academic environment (such as municipalities, companies, NGOs and local citizens) in planning and decision-making processes and them working together with research to develop solutions. Science, politics, economy and civil society benefit equally from these cooperations.

We want to further strengthen transdisciplinary cooperation in FONA. Involving different actors results in a better systemic understanding. The issues of sustainability research are complex and, in return, require that transfer activities be geared to specific target groups. We therefore distinguish between three fields of action: political consulting, economic development and transfer, and participation of local authorities and the public.

Setting the right impetus with policy advice

Only if political decisions are based on an informed and evidence-based discourse can the goals of the 2030 Agenda be achieved. We are therefore promoting science-based policy advice through committees that identify new research needs, provide reliable data, expand the knowledge base and thus provide targeted impetus for sustainable development.

At the national level, the Science Platform Sustainability 2030 (WPN 2030) and the German Advisory Council on Global Change (WBGU) are two of several relevant examples. Both represent independent and open discussion of sustainability issues.

WPN 2030 was initiated in 2017 by the Federal Ministry of Education and Research together with the Federal Ministry for the Environment and the Federal Ministry for Development and has since been funded by the scientific community itself. It serves as an interface between politics, society, business and the science and research community, and with its scientific expertise it supports the implementation of the German Sustainable Development Strategy and the global Sustainable Development Goals. The open platform approach brings researchers together with practitioners from civil society, politics and business, thus enabling a transdisciplinary scientific dialogue.

The WBGU is an expert body that has been advising the German Federal Government on environmental issues of global significance since 1992. It is jointly funded by the Federal Ministry of Research and the Federal Ministry for the Environment. Its work consists primarily of preparing expert reports that examine selected priorities in detail, pointing out options for policy action.

As an independent advisory body, the interdisciplinary Climate Protection Science Platform supports the Federal Government in the implementation and ongoing development of the long-term German strategy for climate protection. Its task is to monitor the implementation of the Federal Government's climate package and make proposals for its improvement. Here, too, the Federal Ministry of Research and the Federal Ministry for the Environment are jointly supporting the work of the science platform.

As Germany's largest research organisation, the Helmholtz Association, which is funded by the Federal Government and the Länder, is committed to research for sustainable development and knowledge transfer. A total of seven Helmholtz Centres are therefore pooling their expertise in the research area Earth and Environment. In what is now the fourth funding period (2021–2027), the research area will build a synthesis and communication platform (SynCom) specifically designed for knowledge synthesis, knowledge dialogue, policy advice and science communication. The research area contributes in this way to providing factually sound and comprehensible reference knowledge to guide social debate and political decisions.

Other policy advisory bodies are dedicated to individual sub-fields of sustainability research. In the BMBF-funded initiative 'Energy Systems of the Future', for example, more than 100 experts from science and research are working to ensure that a sustainable, secure and affordable energy supply can succeed. The German academies of science acatech, Leopoldina and Akademienunion have been jointly advising policymakers and civil society since 2013.

At the global level, the United Nations is the most important forum for international exchange and cooperation – especially when it comes to implementing the 2030 Agenda. The importance of independent scientific advice is shown, for instance, in the negotiations on the global climate agreement. Founded in 1988, the

Intergovernmental Panel on Climate Change (IPCC) is probably the best-known advisory body, representing the Federal Government's most important source of knowledge for climate policy. We support the work of the IPCC through our extensive funding of climate research, the results of which are incorporated into the IPCC Assessment Reports. In addition, through the German IPCC Coordination Office, we join forces with the Federal Ministry for the Environment to support the work of the IPCC. In 2012, following the IPCC model, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was founded to help ensure that scientific findings are quickly incorporated into political action. We support sound advice and the monitoring of international biodiversity policy through the German IPBES Coordination Office, which we set up together with the Federal Ministry for the Environment (→ Internationally networked and globally committed to the SDGs, p. 54).

Promoting economic utilisation

Sustainable development and economic success no longer stand in contradiction to each other. Many companies and major investment agencies have recognised this and are participating in targeted research projects to develop and bring to market innovative and sustainable products, technologies and services. Funding for economic development in FONA includes both classical collaborative projects and long-term large-scale projects focusing on implementation on an industrial scale.

FONA's funding for economic development has grown steadily in recent years. In 2019, it accounted for more than a quarter of the BMBF's economic development funding. Most of the economic development funding in FONA goes to small and medium-sized enterprises (SMEs). But industrial companies also have a firm place in the FONA Strategy, and research on energy system transformation, for example, would be inconceivable without them. They are an important driver of innovation and an important interface for the transfer of research results to industry.

In future, we want to do even more for the economic exploitation of research results. We are continuing the successful promotion of SMEs under the auspices of 'Innovative SMEs'. This focuses on topics that contribute to solving the grand challenges of our time: raw material efficiency and the circular economy, the bioeconomy, energy efficiency and climate protection, adaptation to climate change, sustainable water management and sustainable land management. To ensure that more research results are transformed into competitive business ideas, we are stepping up our support for start-ups and the establishment of new enterprises. In FONA, we want to focus more strongly on young companies in the future and help to ensure that they do not fail due to a lack of seed capital or overly high start-up risks.

Norms and standards are an important instrument for economic success. They contribute to a more rapid dissemination of innovative and sustainable technologies. Translating research results into norms and standards is supported by legislation that is based on the latest scientific findings and can set global standards. Therefore, in FONA we aim to step up our cooperation with standard-setting actors such as public authorities and industry associations and to develop concepts

Strengthening innovation in enterprises: 'Innovative SMEs'

Germany already has an excellent position in environmentally related growth markets. Research, development and qualifications play a key role in this, because investment in research and innovation will secure jobs and living standards in the future. Small and medium-sized enterprises (SMEs) play a special role because they are often at the forefront of technological progress. Through the funding measure 'Innovative SMEs', we are supporting top-level research in the fields of environmental technologies and services. By funding industrial research and precompetitive development projects, we are targeting improvement in the innovative capacity of SMEs in Germany. SMEs will be encouraged to do more research and development and will be better equipped to respond rapidly to change and to actively participate in shaping the necessary transformation.

specific to standardisation, for example in applied water research. In this way we want to support German companies in their efforts to remain or become innovation leaders in global climate and environmental protection (→ International partnerships open up global market potential, p. 55).

Involving citizens and municipalities in sustainable development

Municipalities are the places where change towards more sustainability is determined. For FONA, too, municipalities are key actors who put ideas into concrete terms and implement sustainable innovations on the ground. For this reason, we support transdisciplinary cooperation in joint projects among municipalities, the private sector, the science community and civil society.

An important instrument for testing new ideas in municipalities is the creation of experimental and test spaces. This form of science–practice cooperation in which the focus is on mutual learning in a temporally and often spatially limited experimental environment is called a real-world laboratory. New concepts, technologies or business models for sustainable coexistence in cities and municipalities (for example in the areas of mobility, the circular economy or the sharing economy) are thus tested for their effectiveness. FONA research uses real-world laboratories to test how innovations are accepted by citizens and to what extent the legal framework needs to be further developed. And they help project participants to transfer successfully established developments more quickly to other regions.

Sustainable development in municipalities requires cross-sectoral coordination and cooperation. In order to ensure that the work of other federal ministries and other actors is compatible with our work, we are systematically promoting inter-ministerial cooperation and structured dialogue with municipal umbrella organisations as part of the Federal Government's Innovation Platform City of the Future (IPZ). Including the municipal user perspective will identify challenges faced by municipalities at an early stage so measures can be developed that are geared towards needs and impacts. The promotion of innovation and application in practice thus go hand in hand.

Our contribution to solving global challenges – Together in Europe and the world

Climate change, scarcity of resources, loss of species, marine litter, and economic, food and health crises such as the Covid-19 pandemic are interlinked global challenges that no country can tackle alone. If we want to protect our planet and enable future generations to live a decent life, we must work with partners worldwide. It is only through international knowledge transfer and cross-border cooperation that synergies can be created which we can mutually exploit to develop the greatest possible leverage. This includes both the public and private sectors. We are committed to science-driven technology development in order to reconcile economic progress, ecological compatibility and social justice. 'GreenTech made in Germany' is already defining new standards today and enjoys a high reputation on the international playing field. We want to promote the associated economic potential in global climate and environmental protection by expanding international science–industry cooperation.

FONA has been internationally aligned from its very inception and builds on a number of successful cooperations and partnerships. In the past five years, we have invested over 400 million euros in projects with non-European partners. This corresponds to about half of all international activities of the Federal Ministry

of Education and Research. Of the FONA-funded projects, around 27 per cent have an international dimension; around 13 percent are projects with at least one European partner. For the next few years, we have set ourselves three objectives with even greater focus: 1) effective coordination in Europe and worldwide, 2) close involvement of actors on the ground, and 3) needs-based cooperation that adds value for the local population.

Boosting cooperation in Europe

In the EU, the European Research Area has been created specifically for research cooperation across member states, joint programming and the use of large infrastructures. It is committed to free access to knowledge and its exchange – and to cooperating to tackle common problems. The main instrument for setting common objectives and priorities and coordinating the national research policies of individual states is the EU's long-running Framework Programme for Research and Innovation.

European Green Deal: Towards a climate-friendly and resource-efficient economy through innovative sustainability research

In December 2019, the EU Commission presented its 'European Green Deal', a roadmap for climate-friendly and resource-efficient economic activity in Europe. This includes no more net greenhouse gas emissions by 2050 and decoupling economic growth from resource use. The Green Deal also includes the EU Biodiversity Strategy for 2030 and the 'Farm to Fork' strategy. Both represent a new, harmonious synergy between agriculture, biodiversity and sustainability. Without Innovation, the ambitious goals of the Green Deal cannot be achieved. At European level, 'Horizon Europe' is the most important research policy instrument for implementing the Green Deal. FONA also has strong links to the Green Deal's areas of action. In particular, we will contribute to the implementation of the Green Deal through our actions on green hydrogen, the bioeconomy, the circular economy, biodiversity conservation, climate adaptation and sustainable financing (→ Three strategic goals, eight fields of action and 25 actions, p. 6).

'Horizon Europe' – EU Framework Programme for Research and Innovation

FONA is inconceivable without Europe. This is because all FONA research can be continued and expanded at European level. More importantly, the vision of a European Research Area that focuses more on societal concerns and develops solutions for the benefit of the people of Europe is in line with what drives us. The ninth iteration of the EU Research Framework Programme 'Horizon Europe' (2021–2027), following on from its predecessor 'Horizon 2020', is dedicated to solving major and pressing social and economic issues in a separate pillar ('Global Challenges and European Industrial Competitiveness') and is allocated just over half of the total budget of 'Horizon Europe'. Through FONA, we are taking up three of a total of six thematic clusters in this pillar: 'Digital, Industry and Space' (cluster 4), 'Climate, Energy and Mobility' (cluster 5) and 'Food, Bioeconomy, Natural Resources, Agriculture and Environment' (cluster 6). As members of the expert Programme Committees, we are directly involved in the design and topic setting for the Work Programmes of clusters 5 and 6.

'Horizon Europe' follows a mission-based approach. It is designed to address research issues in a cross-cutting manner so that the people of Europe benefit directly from scientific knowledge. Four of the five mission areas address sustainability and provision for the future,

and thus also the topics of FONA. These are adaptation to climate change, climate-neutral and smart cities, healthy oceans, seas, and coastal and inland waters, and soil health and food. Together with European partners from research and in the field, we discuss the goals and contents of the missions – and contribute to their implementation with our national funding activities (→ Three strategic goals, eight fields of action and 25 actions, p. 6).

Strategic cooperations play an important role in the implementation of the missions – for example initiatives in which EU member states have joined forces for joint research programme planning. In recent years, these 'Joint Programming Initiatives' (JPIs) have proved to be a particularly flexible instrument for FONA to coordinate and cooperate with experts at EU level. Under 'Horizon Europe' we will use the ongoing development of this European partnership landscape towards greater coherence to network more closely with actors from politics, business and civil society. In this way, we intend to develop joint funding activities, mobilise public and private sector actors for EU collaborative research, and strengthen the transfer of knowledge into practice.

Internationally networked and globally committed to the SDGs

The goals of the 2030 Agenda form the basis of a new international partnership in which industrialised, emerging and developing countries share responsibility for a sustainable future. Implementing the SDGs means recognising path dependencies, exploiting synergies and resolving conflicts of objectives. We are therefore dependent on development strategies and cooperation that span countries, sectors and institutions in order to achieve the Sustainable Development Goals on time.

Sustainable development requires global cooperation

The implementation of the 2030 Agenda goes beyond national borders and is not negotiable at national level alone. To achieve this, we must continue to actively support global governance structures. Germany is one of the strongest countries in the world in terms of research and innovation. We will continue to provide system and action knowledge for politics, business and society and make it available for the urgently needed progress in international sustainability and climate processes. To this end, we are cooperating with intergovernmental bodies that provide scientific policy advice to the United Nations, such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Panel on Biodiversity and Ecosystem Services, as well as the High-level Political Forum on Sustainable Development (HLPF), which has replaced the UN Commission on Sustainable Development since 2013. Other relevant forums for cross-border coordination and cooperation are the G-7 and G-20 countries and the OECD.

We choose our cooperation priorities so that they are demand-driven and of mutual interest. As a result, know-how flows in both directions, and value creation and local employment are strengthened. The African continent plays a key role for us in this context, but at the same time it is an example of the challenges facing many governments in emerging and developing countries. We are also involved in South East Asia (particularly in climate research), in Latin and South America (bioeconomy, atmospheric science research, sustainable urbanisation) and in the Near and Middle East (hydro-technology cooperation).

Examples of our global commitment

In addition to monitoring the IPCC and IPBES through German coordination offices (→ Setting the right impetus with policy advice, p. 50), which the Federal Ministry of Education and Research supports in partnership with the Federal Ministry for the Environment, further highlights of our global commitment are as follows:

- In the field of hydrology research, we are funding research projects to provide targeted support for the World Water Quality Alliance of the UN Environment Programme. We are also involved in the High-level Political Forum on Sustainable Development (HLPF), as well as in the activities of UN Water and UNESCO through our promotion of funding support for water as a global resource.

- In the field of marine, coastal and polar research, in a joint effort with national and international partners we are organising the launch event for the UN Decade of Ocean Science for Sustainable Development, which starts in 2021. In addition, through national research funding, we are working to implement the G7 Action Plan to Combat Marine Litter and the G20 Action Plan on Marine Litter.

- We have established scientific capacities in Southern and Western Africa with the Competence Centres for Climate Change and Adaptive Land Use SASSCAL and WASCAL, so that the participating states can make valid decisions themselves, for instance with regard to their land use and water supply. The objective is to make people and the environment better able to withstand the adverse effects of climate change by developing resilient and adaptable land use systems (→ Action 15, p. 31). In addition, we support cooperative research on the interdependencies between geosphere, atmosphere and ocean, as well as on the interactions between land and sea on the one hand and biosphere and atmosphere on the other.

- Together with seven other ministries, we are launching the government programme 'Water-Secure Africa (WASA)' in 2020. This is the first time that the different commitments of German funding agencies and implementing organisations have been brought together on this scale and expanded with African partners (initially in Southern Africa) (→ Action 13, p. 29).

- We plan to establish a green hydrogen partnership with the countries in Western and Southern Africa. We will start with an atlas of green hydrogen generation potentials for Western Africa, which we will publish in 2021. It will parallelly be expanded to further African regions, such as Southern Africa by 2021 (→ Action 2, p. 11).

- Together with Brazil, we are funding the construction and use of ATTO (the Atmospheric Tall Tower Observatory). This unique scientific platform for long-term research in the Amazon rainforest will enable scientists to understand the role of the Amazon as a 'hotspot' for global carbon cycles in the Earth's system.

International partnerships open up global market potential

The know-how of German GreenTech companies in the fields of climate protection, resource conservation and energy efficiency is enormous – as is the potential to open up new foreign markets and set global standards by expanding and disseminating environmental technologies and services that are 'Made in Germany'. For more than ten years now, we have been supporting the cooperation of German research institutions and companies with selected emerging countries through the funding measure 'CLIENT – International Partnerships for Sustainable Innovations'. The research and testing of sustainable solutions for the climate, environment, resources and energy sectors are just as much the focus of attention as proximity to market and to practical application. We are already funding more than 200 German institutions from science and

CLIENT at a glance: Key areas of our global commitment (as at September 2020)

industry that cooperate with partners in 27 countries worldwide (as at September 2020). We intend to pursue this successful model in the future.

Research infrastructures

Large research infrastructures are essential for FONA's preventive research. They determine the performance, innovative power and international competitiveness of Germany as a science and business hub. Only through research infrastructures will it be possible to fill elementary gaps in knowledge and open up new research areas. They are used, for example, to generate basic climate data or ecosystem information in order to better understand the complex correlations in global climate events or the dynamics and consequences of species loss. This knowledge is urgently needed to make political decisions and initiate social transformation processes.

The Helmholtz Association's Research Field Earth and Environment

Within the Helmholtz Association (HGF), sustainability research is strategically bundled in the Research Field Earth and Environment. In the fourth funding period (2021–2027), a total of seven HGF centres will be come together here: Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Forschungszentrum Jülich (FZJ), Helmholtz Centre for Ocean Research (GEOMAR), Helmholtz Centre Potsdam (GFZ), Helmholtz Centre for Material and Coastal Research (HZG), Helmholtz Centre for Environmental Research (UFZ) and Karlsruhe Institute of Technology (KIT). These centres work will together to expand and network long-term observation systems, to record processes in the Earth and environment systems and to improve forecasts. The aim is to answer the question of how resources can be used sustainably without destroying the basis of our existence.

The mission of the HGF in general and of the Research Field Earth and Environment also includes developing, constructing and operating complex research facilities. The research infrastructures in this research field established for this purpose include, for instance, marine vessels, aircraft, satellites, research stations, global observation networks, regional long-term observatories, mobile measurement systems for observation of the Earth and its environment, and high-performance computing centres. The research field also hosts and coordinates central European research infrastructures that make a significant contribution to cooperation in the European Research Area.

Due to their high costs, research infrastructures can often only be set up and operated jointly with several partners. In Germany, for instance, the non-university research organisations the Helmholtz Association (HGF) and the Leibniz Association (WGL) are the owners of large research facilities. The HGF is Germany's biggest provider of research infrastructures, for example in the form of large-scale equipment and research vessels, from which scientists benefit both nationally and internationally.

Sailing towards the future in the research vessel POLARSTERN

The research vessel POLARSTERN forms the backbone of the MOSAiC expedition – the largest and logistically most complex Arctic research expedition ever. Under the leadership of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), 600 scientists and researchers from 20 nations are involved in the international data-gathering campaign. Trapped in the ice of the Arctic Ocean, a network of observation stations is drifting along with the ship through the Central Arctic collecting comprehensive data over a period of one year (2019–2020). Evaluation of the gathered data by 2025 promises to provide new insights into the exchange processes between ocean, ice and atmosphere and a better understanding of the influence of the Arctic region on the climate of our latitudes.

IMPLEMENTATION OF THE STRATEGY

The FONA Strategy is designed as an open framework for action over five years. The 25 actions are therefore designed in such a way that the focus of the research content can be adapted in a targeted manner and continuously evolved. Key concomitant aspects are political decisions on the direction to be taken, science communication based on dialogue, and an evaluation of the FONA Strategy. In this way we aim to engage the broad participation of socially relevant stakeholders to support the implementation of the 2030 Agenda in a politically targeted way.

We base our evaluations on robust data, comprehensive balance sheets and established indicators, which provide orientation for us and all stakeholders involved. FONA also uses criteria derived from the catalogue of criteria recommended by the European Commission. Particular attention will be paid to effectiveness, efficiency, coherence and relevance. In principle, a FONA evaluation always aims to improve quality, increase the effective achievement of objectives, raise efficiency, and develop appropriate recommendations for action. In addition, we pursue systematic research monitoring that provides information on the impacts of projects and funding measures. In doing so, we keep an eye on current research and innovation needs and market developments, taking them all into account.

Target group-specific science communication will bring research outcomes into social and political discourse in the form of orientational knowledge, an understanding of systems and operational know-how, and can thus serve as a basis for knowledge-based decisions. It is therefore the basis for transferring insights from research to politics, economy and society. The FONA.de website is a portal we have created to report continuously on our research projects and findings – it is diverse, multimedial, and tailored to the general public and relevant multipliers.

One of our key instruments for professional ideas exchange is the FONA Forum. This is where we discuss and evaluate future issues, conflicting goals and risks with stakeholders from the science and research community, businesses, local authorities and civil society at an early stage of development. With our eye on finding solutions and based on this multi-stakeholder approach, we involve our target groups in agenda processes in which we discuss research needs and policies for the coming years – and we aim to raise the involvement of the broader population in this process.

We want to connect open discourses and practices in science, business and civil society more intensively across the disciplines – especially in the handling of data, digitalisation and sustainability. The BMBF is pursuing this goal as part of the High-Tech Strategy's mission 'Finding new sources for new knowledge' in collaboration with the Open Innovation Culture Forum (innOsci), which is organised by the Stifterverband (donors' association for the promotion of humanities and sciences in Germany). The forum sees itself as a platform, think tank and experimental space; it networks initiatives and brings stakeholders together. We want to make knowledge freely and digitally accessible and harness it through Open Access. In this way, we can guarantee an unhindered flow of information within science and research as well as into all areas of business and society. Accordingly, we support Open Access as a standard for scientific publishing – for example, by covering publication costs for Open Access publications through our project funding.