The
Federal Government

Wasser:N

**Research and
Innovation
for Sustainability**

PROTECTION. USE. INNOVATION.

**An initiative of the Federal Ministry
of Education and Research (BMBF)**

PREFACE

Water is one of humankind's most important resources – without water, there is no life. There is no substitute for water; supply is limited, and demand is growing. Drinking water supply and agricultural production of food are just two of the ways that water is used. There are many other fields where people use water resources, be it medicine, energy generation, industrial production, or freight transport.

Since time immemorial, water has been a prerequisite for the cultural and technical development of society: settlements and towns were built along rivers or on coasts. Water is an essential component of the ecological balance – it is needed to maintain a healthy environment and supports a diversity of habitats.

Water is a global resource, but solutions to water management must be local. While views on water management may be correspondingly diverse, in essence it all comes down to the concept of sustainable water management and governance ensuring a balance between water supply and demand, while simultaneously conserving water resources.

Higher demands are placed on sustainable water management as a result of the challenges faced by today's societies: challenges such as dealing with the consequences of climate change, population growth, and the need for improved energy efficiency. Water scarcity and water pollution are growing threats to ecosystems the world over and they undermine the economic and political stability of entire regions and countries.

If we are to achieve sustainable development for future generations, too, our water resources must be protected. To be able to do so, a better understanding is needed of the complex processes in the water cycle, mechanisms of change, and the threats caused by human impacts on the environment.

The German government addresses these challenges by consistently supporting long-term water research projects. For the coming years, the Wasser: N research program will form the German government's framework approach for the promotion of water research and water innovations. The program is backed by several ministries, led by the Federal Ministry of Education and Research (BMBF), in close cooperation with the Federal Foreign Office (AA) and the Federal Ministries of Food and Agriculture (BMEL), Health (BMG), Transport and Digital Infrastructure (BMVI), for the Environment, Nature Conservation and Nuclear Safety (BMU), Economic Affairs and Energy (BMWI), and Economic Cooperation and Development (BMZ).

Wasser: N sets out common goals for innovative water research as the basis of future-oriented political decisions for responsible water management.

1

INTRODUCTION

The United Nations estimates that almost half the world's population, equivalent to around 3.6 billion people, live in regions that are at risk of water shortage at least one month a year.

According to forecasts, if we continue as we are, global demand for water is expected to increase by around 55 % by 2050 with as many as 5.7 billion people facing water shortages. Clean water is vital to health, secure food and energy supply, industrial growth, intact ecosystems, as well as peace and security.

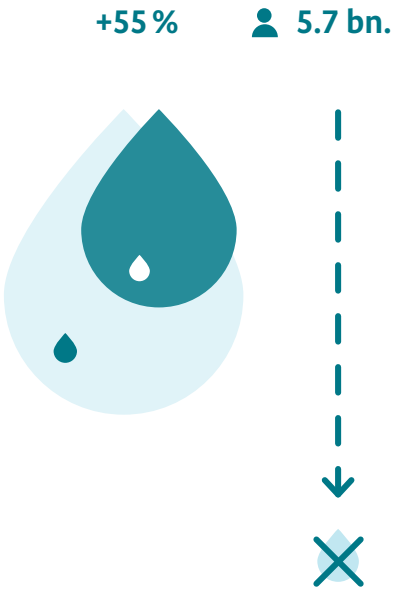
The global significance of water resources is underlined in the UN's Agenda 2030 and the Sustainable Development Goals, with SDG 6 stating the need to ensure availability and sustainable management of water and sanitation for all. Making sure there is enough clean water available for populations, the environment, and industry in the future calls for effective protection and sustainable use of water resources today.

This requires forward-looking water research involving key stakeholders from the science and research community, business, civil society, and politics working together to develop the requisite technological, sociopolitical, and conceptual innovations. A coherent research policy and close integration of the different funding instruments are imperative here.

The German Federal Government designed the research program "Wasser: N – Research and Innovation for Sustainability" with precisely this objective in mind. Wasser: N is conceived as an open learning framework for action. Within this framework, there is the flexibility to adapt the relevant activities to current research policy as well as to social, economic, and environmental issues and developments as required.

The aim is to use suitable measures to promote innovative research on the topics listed below. To link basic and applied research and bring research results into practice more quickly, effective coordination and continuous dialogue between the participating government departments and experts from the science and research community, industry, and practice are essential.

Wasser: N is part of the BMBF strategy "Research for Sustainability" (FONA) and lends important impetus to field of action 5: "Securing natural resources (water, soils)".



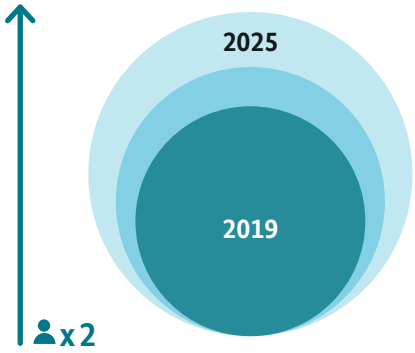
According to forecasts, global demand for water is expected to increase by around 55 % by 2050 and as many as 5.7 billion people will experience water shortages.

2

OBJECTIVES AND CHALLENGES

Around 70 % of the Earth's surface is covered with water. Yet, less than 1 % of the available volume can be used as freshwater by the world's population. Due to population growth, water consumption has increased almost threefold since 1950. Demographic change, climate change, and global economic growth mean that the strain on limited water resources is set to continue its steep upward trajectory.

The proportion of the world's population living in arid and semi-arid countries is set to double by 2025.



This is bound to exacerbate the situation in developing and newly industrialized countries, in particular, where water is already scarce: the share of the world's population living in arid and semi-arid countries is set to double by 2025. Yet, for the majority of Southern European countries, which are heavily dependent on agriculture and tourism, climate models forecast that the availability of naturally occurring water resources will fall by half in the next 50 to 100 years. Parts of the UK already face continuous water shortages. More recent experiences, in particular between 2018 and 2020, show just how susceptible Germany is to a lack of rainfall. Against this background, sustainable water management that reconciles the growing global population's need for clean water and proper sewage disposal, the demands of a globalized world economy, and the protection of water resources and ecosystems is therefore an existential challenge.

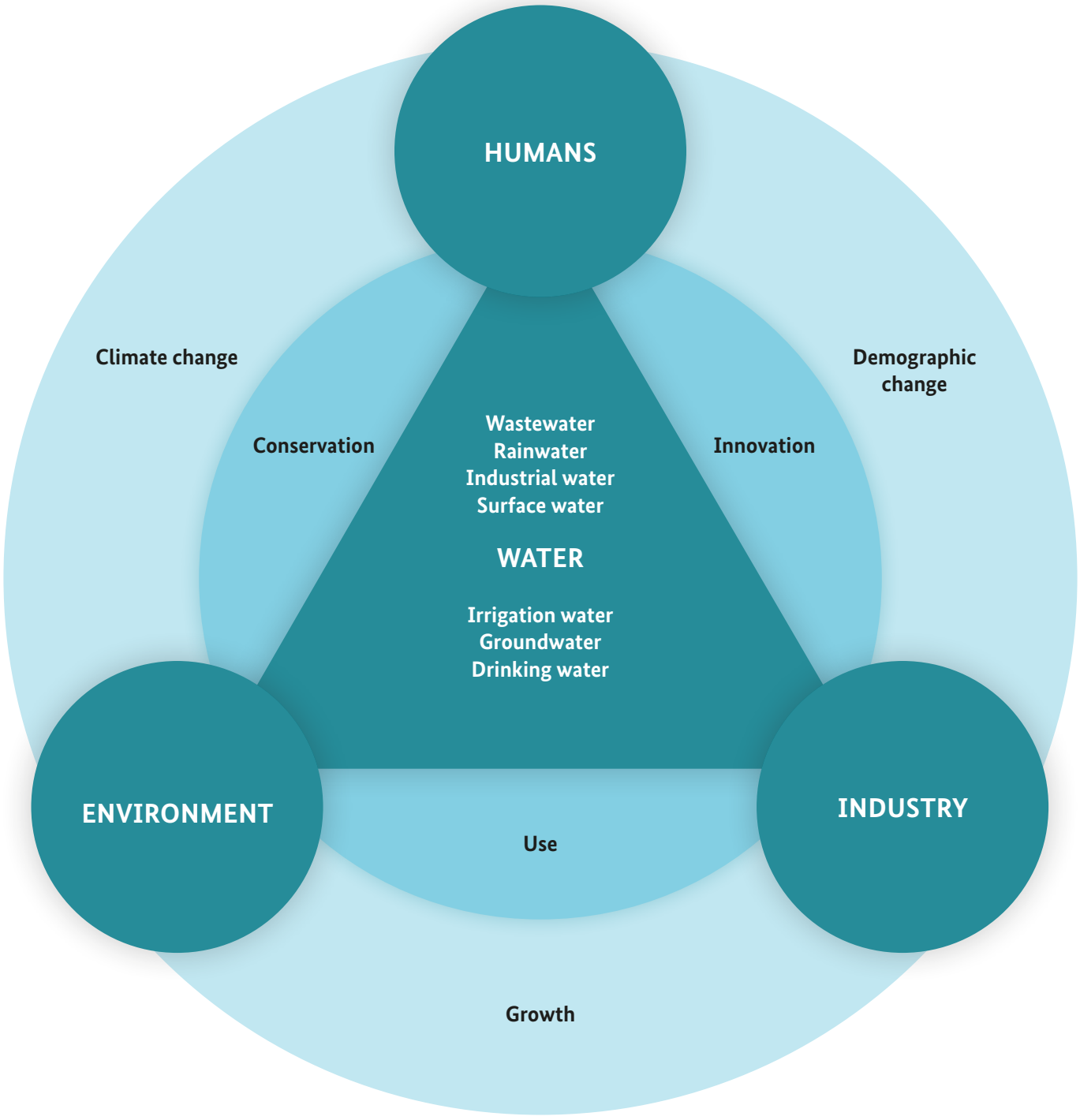
Innovation is needed to be able to continue to supply everyone with sufficient clean water for the decades to come. This can take the shape of new technologies as well as new organizational forms and innovative utilization concepts.

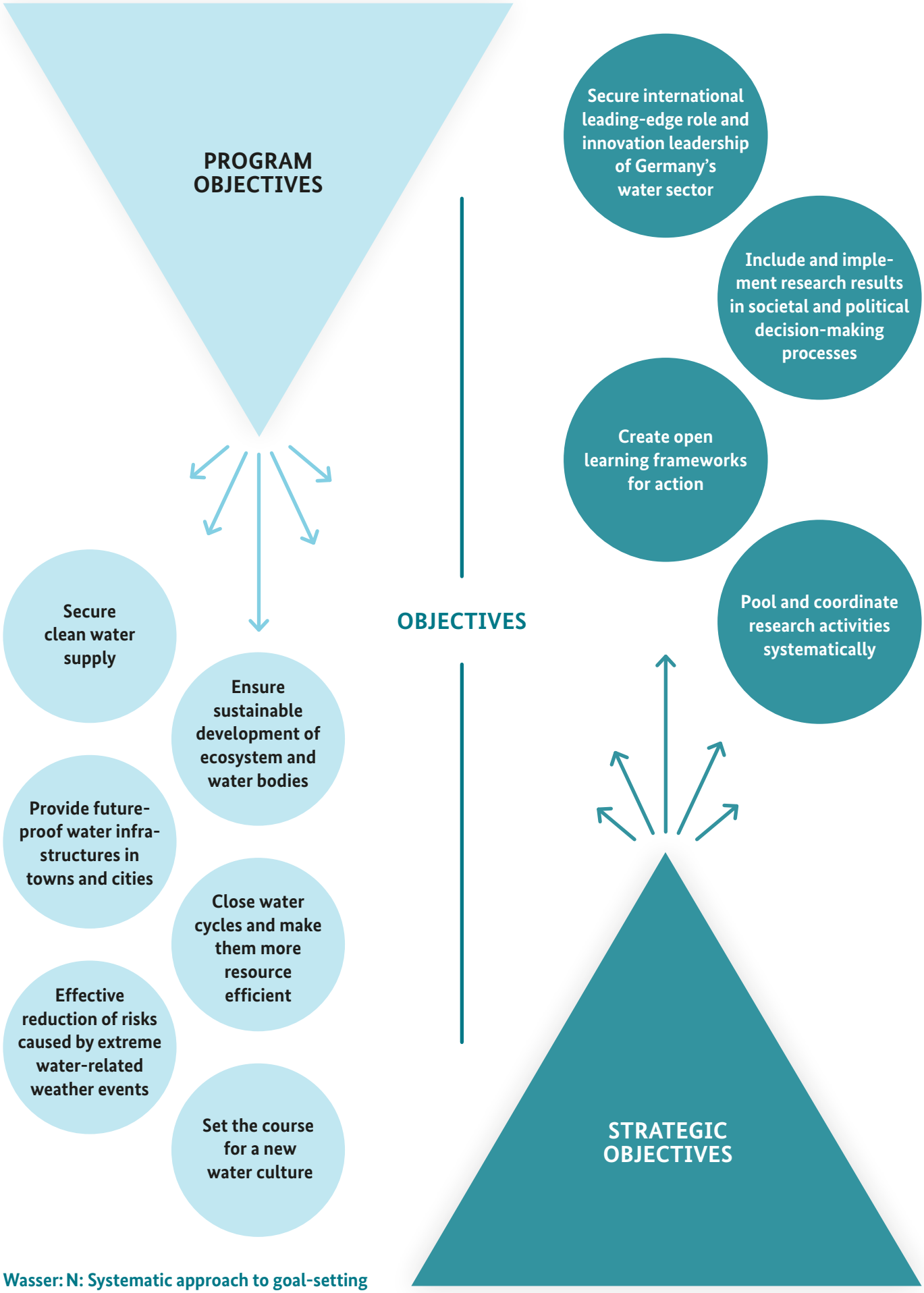
Research can provide the requisite foundation for this. Technology-based developments such as digitalization offer significant opportunities that must be seized. It is just as important, however, to avoid the potential risks that come with such technological developments. It does not always have to be high-tech. In fact, simple and robust technologies that are tailored to local needs can also be the best solution.

To make sure that research results are translated into innovations that have broad application, research must be conducted on an inter- and transdisciplinary basis. Besides taking different disciplines into account, the relevant stakeholders must be involved in the research project from the very start. This participatory approach makes it possible to identify the topics to be addressed and the possible solutions along innovation and value chains collectively. Facts must be organized into a format that can be presented at the political level. And, at the same time, using education measures tailored to specific target groups, the subject matter must be made readily accessible to those it is aimed at. This not only raises awareness of the issues but also helps ensure that new solutions are accepted.

In line with the German government's High-Tech Strategy, Wasser: N will help further enhance and develop the country's competitive and innovative strength as a global leader in water management and governance. The goal is a sustainable water management system, geared toward reuse and recycling, a system, which, as well as being competitive, is also environmentally and socially sustainable.

Model for forward-looking water research





Wasser: N: Systematic approach to goal-setting

In future, new approaches that explore the relationship between people, the environment, and the economy will be needed. Our management of water resources will have to be geared more toward the water cycle than has been the case so far. Here it is important to analyze the relationship between rainwater, surface water, and groundwater and to take the impact of anthropogenic use of water resources into account.

A central role is played by the analysis and closure of water cycles. In regions suffering from water scarcity, a higher level of utilization efficiency can be achieved, for example, by closing process water cycles in industry and employing different reclaim and reuse processes for water that has been subject to anthropogenic influence depending on what it is going to be used for. Here it is important to assess the extent to which we can increase the amount of reclaimed wastewater currently being reused for industrial or other purposes. But what steps need to be taken to treat wastewater so that it can be safely reused for irrigation or to shore up drinking water supply in certain regions around the world, if needed?

For an analysis as comprehensive as this, linkages between sectors and inter-disciplinary cooperation are even more important. This also applies to the management of river basins, which not only influence the quality of the water in rivers, but also have a significant impact on the quality of the groundwater and the water in the oceans, affecting nutrient dynamics, among other things.

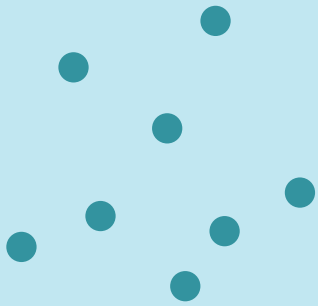
It is thus essential to take the water cycle and all associated material flows into consideration, from source to estuary and beyond. In future, water research must also focus on the relationship between groundwater, inland waters, estuaries, and coastal seas, including their interaction with the geosphere, pedosphere, biosphere, and atmosphere.

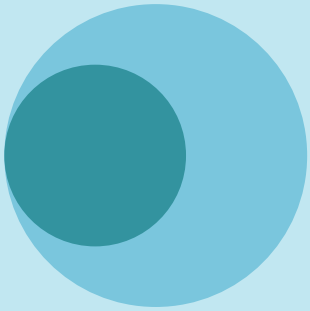
In order to make the connections and provide the tools necessary to achieve these objectives, new research infrastructures and additional resources are needed. As a program funded by the German government, Wasser: N will provide these resources, thus creating the foundation for a forward-looking water research program.

GERMAN WATER SECTOR

Water supply and wastewater management are key public services and fall within the jurisdiction and the remit of the municipalities, which can use different organizational forms and legal structures to provide these services.

Water supply is something the municipalities can provide independently, they can form water and special-purpose associations as part of a municipal partnership, or they can outsource the service to third parties. As a result, various public service and private sector enterprises exist in parallel.





In Germany, around

6000

plants and enterprises are engaged in the supply of water.

The number of private sector companies has increased to

40 %

in the last few years.

Private companies meet over

60 %

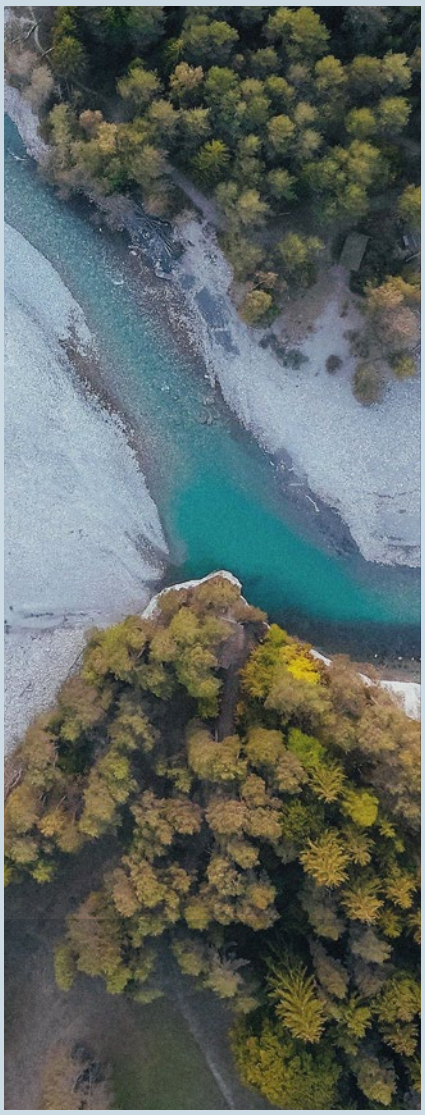
of the country's water needs.

Unlike other European countries, the German water sector comprises a small number of large companies and a wide range of small and medium-sized utilities and waste management companies. Worldwide, water management is considered one of the lead markets boasting significant potential. Especially in developing and newly industrialized countries, the demand for innovative technologies in water and wastewater treatment is on a steep upward trajectory. The German water sector is at the forefront of the world market. According to the Environmental Technology Atlas for Germany (BMU, 2018), German companies have, on average, an 11 % share of the sustainable water management lead market, and for certain technology lines (e.g., novel sanitation systems) the share is as much as 25 %.

3

SCIENTIFIC RESEARCH PROGRAM

The Wasser: N program centers on three pillars: people, the environment, and the economy. Wasser: N will provide the foundation for extensive preventive research on water; it seeks to supply the knowledge and skills required for decision-making and action and to contribute to the development of future-oriented and innovative technologies and concepts for sustainable water management and governance. The research program comprises six priority topics and two cross-cutting issues. All of the priority topics are to be addressed not only at the national but also at the European level as well as in the global context.



1.

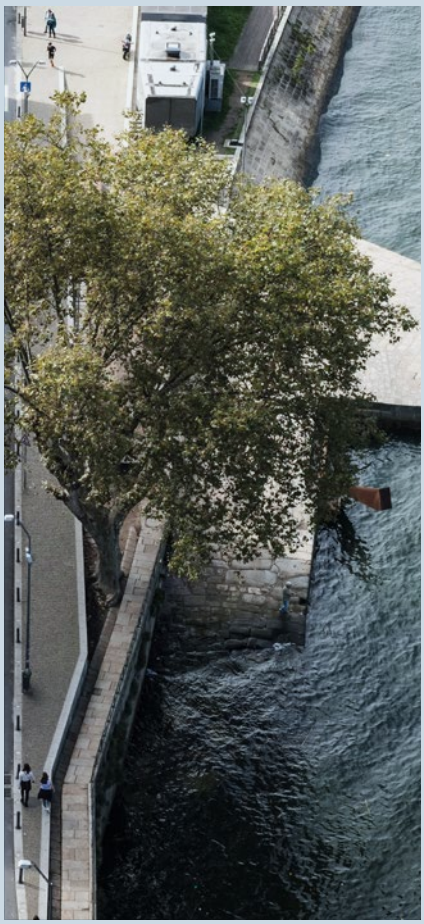
CLEAN WATER

The aim of the CLEAN WATER priority topic is to identify ways of guaranteeing a supply of clean, safe water to the population. The environment, agriculture, and industry are also dependent on high-quality water supply. Water research should be used to establish resource protection concepts and develop methods to prevent pollution at source and safely treat and process polluted water.

2.

INTACT ECOSYSTEMS AND SUSTAINABLE DEVELOPMENT OF WATER RESOURCES

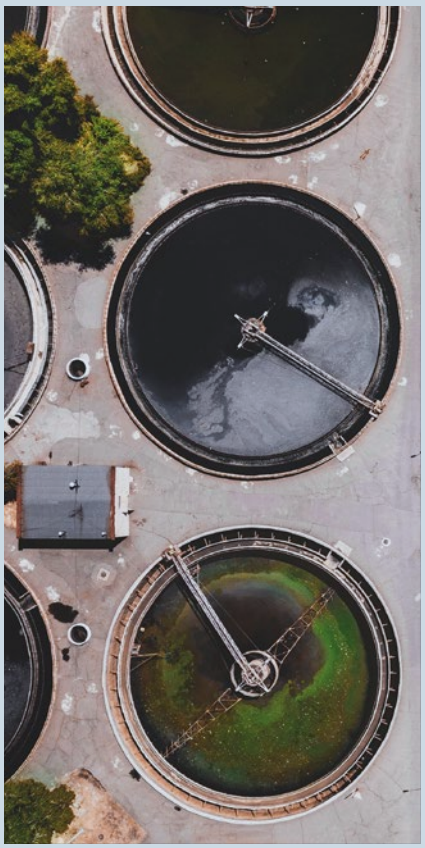
INTACT ECOSYSTEMS AND SUSTAINABLE DEVELOPMENT OF WATER RESOURCES are the cornerstones of for a livable environment. The world over, semi-natural ecosystems as well as those altered by human actions are endangered due to climate change, pollution, and overuse. Against this backdrop, research must provide the requisite foundation for the development of sustainable management strategies, ensuring that all the interest groups affected are involved in the process.



3.

LIVABLE CITIES AND REGIONS

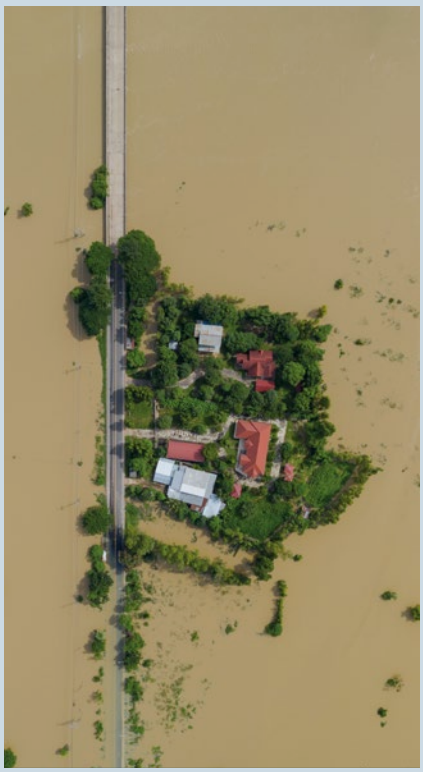
By the middle of the century, around 70 % of the world's population will live in towns and cities. The development of a future-proof urban water infrastructure thus makes a crucial contribution to the priority topic LIVABLE CITIES AND REGIONS within the Wasser: N program. It is essential for this infrastructure to be compatible with other infrastructure systems (e.g., energy supply, transport, communication, green infrastructure) and strategic fields of urban development.



4.

RESOURCE-EFFICIENT WATER CYCLES

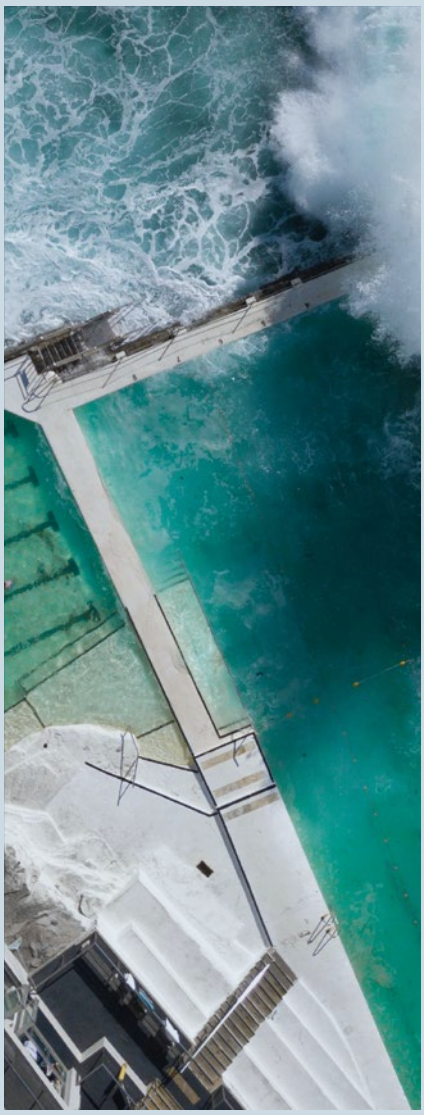
The different water treatment processes that make it possible to reuse wastewater are at the heart of the priority topic RESOURCE-EFFICIENT WATER CYCLES. As a consequence of global change in many regions – both in Germany and elsewhere in Europe – water availability is increasingly being threatened by periods of scarcity. Research will highlight ways in which, through reclaim and reuse, alternative water resources can be used to secure a sustainable supply.



5.

PROTECTION FROM WATER-RELATED EXTREME EVENTS

It is now a more or less foregone conclusion that we will see an increase in weather-induced NATURAL HAZARDS AND EXTREME EVENTS in the coming decades. In the last few years, the annual cost of damage caused by flooding and drought in Europe alone has run into billions of euros. Beyond technical measures, our research will make valuable contributions to the development of extensive and effective risk management.



6.

NEW WATER CULTURE

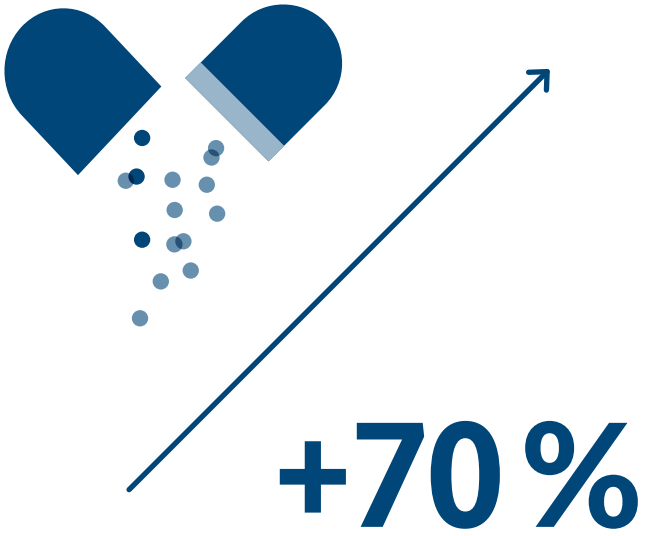
Worldwide, water is a key factor in ensuring sustainable development and thus also securing peace. To prevent the impending water crisis, we must set the course for a NEW WATER CULTURE, both at the national and the international level. This requires stronger involvement of water consumers and those affected by water crises, which would facilitate greater appreciation of water resources.

3.1
CLEAN WATER

According to the 2018 UN World Water Development Report, 2.1 billion people worldwide do not have access to clean drinking water. As many as around 884 million people do not even have a basic water supply, while 4.5 billion lack safe sanitation.

Worldwide, 80 % of wastewater is not treated, resulting in serious contamination of water resources. According to a 2017 WHO report, as many as 360,000 children under five die every year from diarrheal diseases due to unsafe drinking water, inadequate access to sanitation, and poor hygiene.

Although Germany has comparatively high standards, even here, water resources are subject to increasing pressure. For some years, traces of numerous new substances of environmental concern have been detected in runoff from sewage treatment plants, flowing waters, soils, and sediments. These substances are categorized as anthropogenic trace elements or xenobiotics.



By 2045 we can expect to see an increase in pharmaceutical consumption of up to 70 %.

In Germany, there are currently around 3,000 authorized pharmaceutical agents. As the average age of populations continues to rise, we can expect to see a rise in pharmaceutical consumption of up to 70 % by 2045. Against this backdrop, the more widespread use of antibiotics both for humans and animals has led to an increase in multi-resistant pathogens, which enter the environment via the sewage system, for instance. Research has shown that sewage treatment plants cannot completely contain multi-resistant pathogens, and these are even detected in semi-natural bodies of water and swimming lakes. The main sources of antibiotics or antibiotic-resistant pathogens entering the environment are, for example, medical facilities. However, resistant pathogens can also be released into the environment and bodies of water through dung or slurry from livestock farming, where antibiotics are used to fight infection.

Hormones, cosmetics, sunscreen, detergents, or fireproofing agents from a wide range of consumer products can also include substances of concern, which can enter the environment and endanger human health. At the political level, various steps have been taken to monitor these substances. In the EU, for example, the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation, which entered into force in 2007, contains extensive provisions for particularly hazardous substances. In Germany, in 2016, under the aegis of the BMU, the German Federal Government's Trace Substance Strategy was launched with a multi-stakeholder dialog.

By the end of 2007, the European Community had received around 8,000 applications for the registration of new chemical substances, around 2,200 of which were from Germany. There are over 22,000 unique chemical substances registered under REACH and contained in the database of the European Chemicals Agency (ECHA). We can expect countless other substances to be identified, which up till now could not be assessed in terms of their health or environmental impact. Many of these substances may demonstrate poor biodegradability and high potential for accumulation in the environment. What is more, the transformation and degradation of substances can create products which actually give more cause for concern than the original substances, but which are not subject to direct regulation.

The use of fertilizers and pesticides can result in pollution of groundwater, especially in major agricultural areas. In certain regions, nitrate pollution is already making drinking water production more difficult. At the same time, nutrient loads in surface water resulting from nitrogen and phosphorous from agriculture and runoff from

sewage treatment plants are also too high. Rivers then carry these nutrient loads as far as the North Sea and the Baltic Sea.

In this context, the German Fertilizer Law and Fertilizer Ordinance are important political instruments for the protection of waters. Against a backdrop of applicable and tighter legislation (program of measures based on the EU Water Framework Directive, new Surface Water Ordinance, amended German Sewage Sludge Ordinance, Substitute Building Materials Ordinance, and tighter regulations at federal state level), given that they are major sources of phosphorus input, sewage treatment plants urgently need improved processes for the elimination of excess nutrients and for the recovery of nutrients.

One serious challenge, the magnitude of which has become increasingly evident in recent years, is environmental pollution caused by plastics, with microplastics posing a particular problem.

Nowadays, plastic particles can be detected in the stomachs of fish and seabirds, while beaches around the world are littered with pieces of plastic of every shape and size. And inland waterways are certainly not immune to this problem, with scientists around the world finding evidence of plastic pollution here too.

In German cities, both pollutants and microplastics enter urban surface water or groundwater in large volumes via rainwater discharge. Recent studies suggest that even with normal levels of precipitation, trace elements of concern can enter the environment or water bodies in larger volumes than has been assumed to date. Heavy precipitation putting additional stress on the drainage systems can then further aggravate the situation. When rainwater is discharged, a mixture of dirt and rainwater is introduced directly into the surface water, contaminating aquatic ecosystems.

Undesirable substances should not enter the environment in the first place. To ensure this is the case we need a better understanding of the sources of these substances as well as their environmental behavior. Close collaboration between science and industry can make an important contribution to the development of alternative products and can help make them widely available. Moreover, waste and wastewater must be treated appropriately. Innovative approaches based on the natural ability of sediments and soils to filter out potential pollutants can be especially cost-effective solutions here. In addition to the development of strategies for the treatment of municipal wastewater, solutions for industrial and agricultural runoff must also be found.

To identify and classify pollutants and pollutant degradation products, as well as to assess the impact they have on the environment and human health, more sophisticated measurement techniques and methods of analysis are needed, among other things. This would make it possible to reliably detect even very low concentrations of substances that may still be harmful to the environment, as well as allowing samples to be processed more quickly and efficiently. In complex causal networks, it can be vital to draw on ecotoxicological models and tests which integrate various different factors, and to continue to develop and improve the technology and concepts behind these models. In doing so, internationally recognized toxicological standards must be taken into account, for instance those based on methods that aim to replace animal testing.

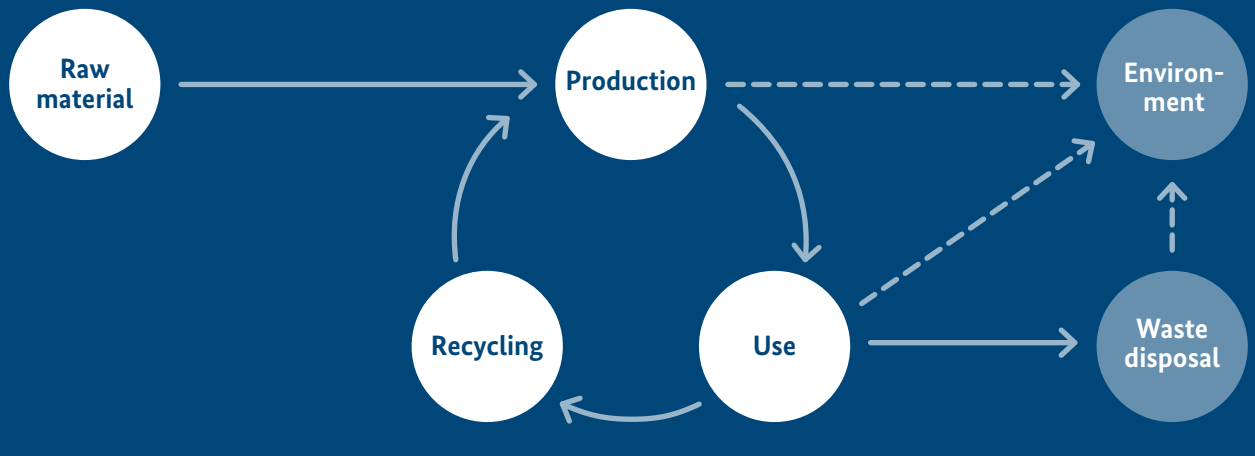
Transparent communication of risks is also important, as this raises awareness of the dangers that are associated with unregulated release of potentially environmentally harmful substances. At the same time, feasible alternatives for the use and disposal of these substances are also needed.

Water supply is a critical infrastructure which must be maintained for the purposes of protecting society against natural hazards, human and technical error, and even from potential criminal and terrorist attacks. An important foundation for this is a comprehensive risk management strategy which takes mutual dependencies between different sectors into account (e.g., energy supply and water management). Taking this as a basis, it is possible to create or improve policies, guidelines, and other types of support that form part of a networked infrastructure with the aim of protecting the water supply system and making it more resilient. Important areas of action in this context are early detection of hazardous substances and pathogens in raw and drinking water, as well as evaluation of the contaminant removal capacity of multi-barrier systems with a view to using them to supply clean water. Current detection methods are often far too time consuming and logistically complex. In light of this, we require compact, fast, and reliable procedures or sensors which also report potential hazards to a central monitoring body online. Here, standardized data collection and processing procedures are an important basis for standardized assessment of water quality.

RESEARCH IS VITAL FOR COMBATTING PLASTIC WASTE IN THE ENVIRONMENT

Since 2017, the Federal Ministry of Education and Research (BMBF) has been funding the research focus PLASTICS IN THE ENVIRONMENT – SOURCES, SINKS, SOLUTIONS as part of the Framework Program Research for Sustainability (FONA)
[↗ https://www.fona.de/de/ plastik-in-der-umwelt-20982.html]

In a total of 18 joint projects, in cooperation with more than 100 partners from the science and research community, business, and the water sector, a wide range of aspects covering the entire plastics cycle are being studied. The aim of the program is to determine the volume of plastic in the environment, identify the cause, distribution, and accumulation of plastic debris, as well as to analyze the impact of plastics entering the environment on living creatures. One of the objectives is to establish commercially viable methods for the sustainable production of plastics from bio-based materials. The intention is to further improve the circular economy for plastics by means of more recycling-oriented designs, for instance. In addition, the program seeks to identify economically and ecologically sound solutions for avoiding or substituting plastic. The Wasser: N program helps fulfil the High-Tech Strategy objectives defined in the program's mission to "substantially reduce plastic inputs in the environment".



3.2

INTACT ECOSYSTEMS AND SUSTAINABLE WATER DEVELOPMENT

Semi-natural rivers and their shore zones and floodplains are home to some of the most biologically diverse ecosystems in the world. Yet, at the same time, these are also among the most endangered habitats on Earth.

Rivers are subject to a wide range of demands. They are used, for example, as a source of drinking water as well as transport routes, they fulfil an important purification function by absorbing large volumes of treated wastewater, and they provide people with areas for recreation and relaxation.

At the same time, rivers also support a significant share of biodiversity, the conservation of which is directly related to the protection of aquatic ecosystems. This also impacts insects, for instance, whose life stages are closely linked to these ecosystems (see, for example, the Federal Government's Action Programme for Insect Protection). Inadequate water structures and persistently high levels of pollution frequently cause environmental problems, despite the significant improvement in water quality in recent decades thanks to increasingly sophisticated wastewater treatment processes. Similarly, there are various human-induced threats to groundwater, one of the largest and oldest continental habitats and the most important source of drinking water.

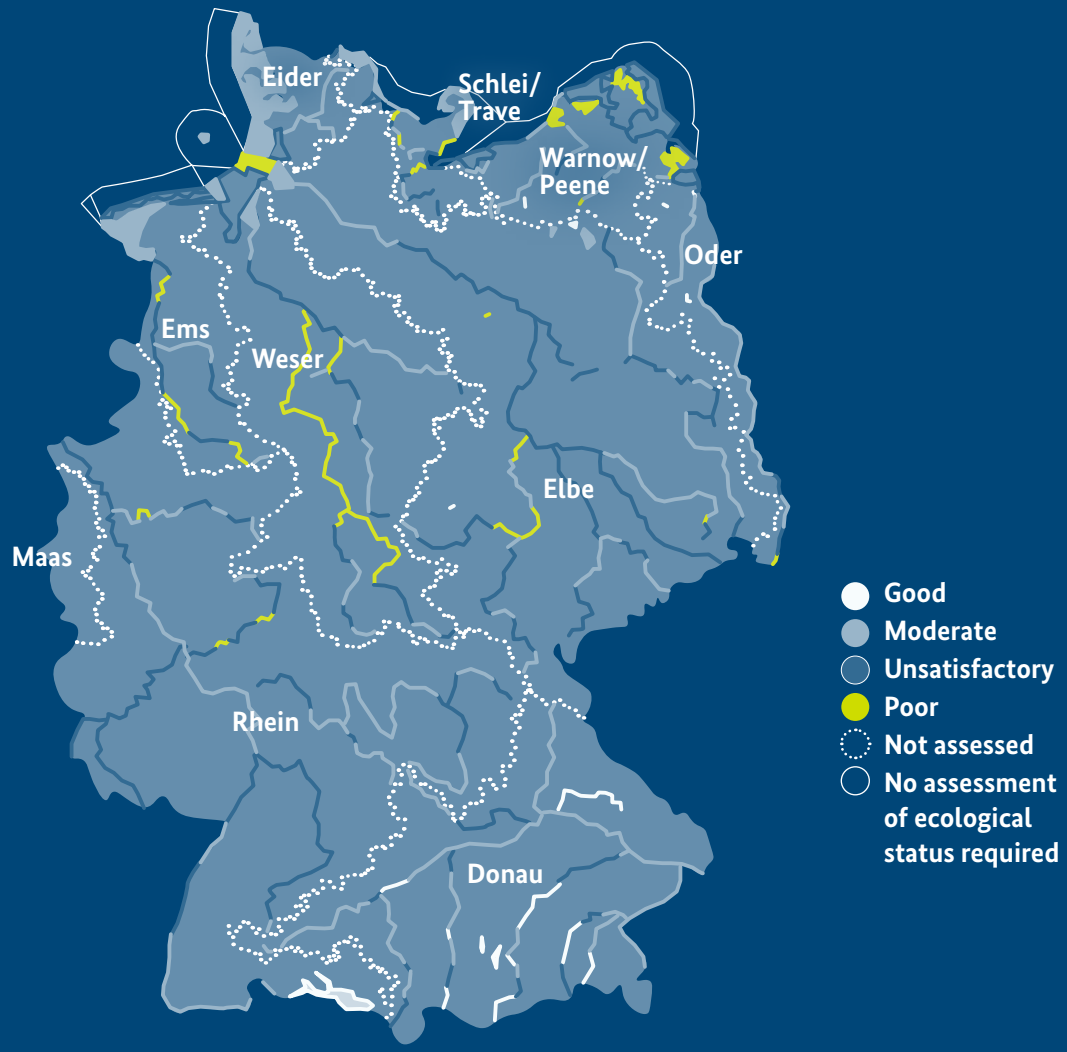
Based on the criteria set down in the EU Water Framework Directive, only a very small proportion of the waterbodies tested in Germany currently have good ecological status.

The intensive use of waters and their catchment areas is one of the reasons why Germany has not yet achieved the overall good ecological status it aspires to. Experts estimate that up to two-thirds of the world's aquatic ecosystems have been lost or damaged in the last century. The loss of these structurally diverse and species-rich ecosystems as well as the negative impact that contaminant inputs and a lack of ecological continuity have on the remaining habitats significantly reduce the genetic and functional biodiversity of water bodies and wetlands overall. Not only can this influence the resilience of these ecosystems, but it can also reduce the benefits they provide for people, such as the retention and transformation of nutrients and pollutants.

The interdependencies between land, nature, and humans require data, analysis, tools, and scenarios in order to develop an integrated understanding of the processes and systems. What is urgently needed, therefore, are sustainable management strategies which achieve a balance between the protection and use of water resources.

Another essential factor when it comes to improving ecological status is sustainable land use and management along water bodies. It is increasingly clear that sustainable water protection is a task that goes beyond water management and that other social and political actors – for example, from agriculture, industry, cities, and municipalities, but also tourism and environmental protection – must rally behind that goal too.

WATER QUALITY IN GERMANY



According to the Federal Environment Agency (Waters in Germany: Status and Assessment, 2017), a mere 9 % of natural rivers and streams in Germany have good or very good ecological status. And as little as 2.2 % of the heavily modified bodies of water, such as reservoirs, and 5 % of artificial bodies of water have good ecological potential. The chemical status of surface water is poor, primarily due to ubiquitous substances. Overall, 96 % of Germany's groundwater bodies have a good quantitative status but just 64 % have a good chemical status owing to the high nitrate concentrations they often contain. To combat this, the EU Water Framework Directive (WFD) states that all European waters (rivers, lakes, transitional waters, coastal waters, and groundwater) must have achieved good status by 2027. On the basis of ecological, chemical, and quantitative indicators, the WFD thus sets ambitious targets for the protection of groundwater and surface waters. To meet these requirements, national and international management plans are created and regularly reviewed and updated. These management plans show that while progress has been made in water protection, significant steps still need to be taken to achieve the requisite good status for all waters. [↗ Federal Environment Agency (2017): Waters in Germany: Status and Assessment]

3.3

LIVABLE CITIES AND REGIONS

Today's urban spaces face a whole raft of challenges. There are growing demands to provide populations with a CO2-neutral, climate-adapted, energy and resource-efficient living environment. Urban areas are among the largest consumers of resources and are both the cause of environmental impact and the most directly affected.

Increasingly frequent extreme water-related weather events mean that sewage systems and constructed urban waterways are often unable to cope with the increased surface runoff – resulting in flooding, usually with considerable damage. The intensive land use in cities and the surface sealing this causes exacerbates these problems due to the lack of water infiltration in cities. At the same time, the phenomenon of the urban heat island effect caused by climate change is increasingly evident proportional to the size of the city.

Structural challenges in urban water management stem mainly from the fact that a large proportion of Germany's existing infrastructures have already been in operation for a long time.

Despite significant annual investment, municipalities will still be faced with considerable reinvestment requirements in the short to medium-term future. Germany's dilapidated, outdated infrastructures are less efficient and less adaptable – and this has dire consequences for the environment. Leaky sewage pipes or overflows during heavy rain result in substances entering the environment, for instance. In highly populated areas, water infrastructures can also reach the limits of their capacity, while in less populated rural regions, the water installations in place are often disproportionately large. Another problem seen in cities and regions with large populations is wastewater and refuse material flows combined with high energy and resource consumption.

The development of innovative technologies to separate substances at source, the use and continual improvement of innovative wastewater treatment concepts such as treatment plants with systems for separating and classifying material flows for the purpose of nutrient recycling, as well as separate rainwater harvesting must feature more prominently in modern urban planning concepts.

The implementation of rainwater management concepts, such as processes for infiltration and evaporation, the treatment of rainwater runoff, the development of industrial water systems alongside drinking water systems, the implementation of green infrastructures, or even the integration of rainwater as a design element, all have a key role to play in this context. Green infrastructures, such as facade or roof planting, also have a favorable impact on the microclimate by helping to prevent overheating of cities and the development of urban heat islands. Roof greening, in particular, serves as water storage, which can slow the runoff of excess quantities of water.

In order to meet people's demand for livable cities and regions, an urban development policy that takes a cross-sectoral approach is needed. Acceptance of urban environmental targets and the involvement of regional actors, as well as of a change in the behavior among the population have an important part to play here. This poses new challenges from an administrative perspective. This also means taking into account the institutional requirements and trialing new forms of inter-municipal cooperation, for example.

Additionally, integrated water resource management requires water management to be linked more closely to urban, infrastructural, and building planning, as well as to the energy and resource sectors.

THE CITY OF THE FUTURE

One European capital that is already in the process of transforming into a Green City is Amsterdam. This city of bikes has set itself the ambitious target of a 25 % reduction in CO2 emissions by 2025 (against 1990 levels). To achieve this target, the city will be promoting solar energy, energy-efficient construction, and a reduction in the city's car traffic.

1990 → 2025

-25 %

Another metropolis that is endeavoring to become a Smart City with the help of various processes of transformation is Singapore. Currently, this city of 5.5 million inhabitants is exploring state-of-the-art technologies for seawater desalination and water recycling, roof planting, sustainable mobilities, and energy conservation with a view to implementing such technologies in the future. Germany's NATIONAL PLATFORM CITY OF THE FUTURE outlines the process of preparing a comprehensive strategic innovation and research agenda for sustainable urbanization. This will be implemented under the leadership of the BMBF and the BMU in cooperation with other departments. The overarching theme of the "City of the Future" research program includes the following focal points: energy and resource efficiency in the city, climate adjustment and resilience, transformation management and governance research, and the urban economy, as well as the city as a system including social and cultural research aspects.

3.4

RESOURCE-EFFICIENT WATER CYCLES

Sustainable and safe water recycling of purified municipal wastewater and of industrial water flows is seen as having huge potential. A resource-efficient wastewater reuse system of can, among other things, help to protect valuable water resources and avoid costly transport and water losses over long distances. Sustainable circularity can also help avoid conflicts over the use of water.

RECLAIMED WATER USED IN AGRICULTURAL IRRIGATION

In northern Namibia, a research project entitled EPoNa is currently exploring the potential of using reclaimed water in agricultural irrigation. For this purpose, existing sewage reservoirs in the city of Outapi will be adapted to enable them to cope with municipal wastewater and new practice-oriented processes incorporated (including anaerobic biological pretreatment, mechanical fine mesh filter screens, outflow filter), making recovery of irrigation water possible and thus facilitating year-round production of fodder crops. Northern Namibia is characterized by a comparatively high population density and a lack of available water resources. On the other hand, the sewage reservoirs regularly overflow during the rainy season, causing health risks for the population. For these reasons, there has been growing pressure to implement a regulated system for reusing existing water resources.

In their 2017 World Water Report, the United Nations called for a rethink. According to the report, wastewater from households, agriculture, and industry should be regarded as a resource that provides energy, nutrients, and water for reuse.

To achieve the globally agreed sustainable development goal SDG 6, which states that availability and sustainable management of water and sanitation must be ensured for all, technologies and concepts for resource and energy-efficient treatment and safe recycling of used water are urgently required. Here, there is a particular need for robust, easy-to-use, and affordable, yet effective low-tech solutions.

Intelligent resource-efficiency as part of a circular economy allows for the retrieval not only of water but also nutrients such as phosphorous from various sources including sewage sludge from wastewater purification. Industry, in particular, has considerable potential to make a more significant contribution to avoiding contaminant inputs into the environment by separating industrial water cycles from the natural water cycle more effectively.

The safe use of treated municipal wastewater for agricultural irrigation purposes is subject to current EU legislation, where establishing minimum standards for water quality, the monitoring of these standards, and a corresponding risk management system is of crucial importance, also in terms of social acceptance of multiple-use water systems.

Avoiding wastewater and conserving fresh water are attractive approaches, especially from an economic perspective. Alongside the technological solutions and intelligent management of material flows, when it comes to reusing purified municipal wastewater, in particular, improved governance structures and incentive mechanisms are needed, as are measures for raising public awareness on the issue of safety. Another important factor that must be taken into account here is what to do with wastewater treatment by-products and concentrates.

In industry, water is instrumental in production. The United Nations estimate that as a result of the increasing industrialization of developing and emerging economies, industry's demand for water will increase by approximately 400 % between 2000 and 2050 – which is more than in any other sector. To meet this increasing demand in a sustainable manner and avoid conflicts over water use, needs-based solutions are needed that will open up business opportunities for German technology providers in the growing international market that emerges as a result.

3.5

PROTECTION FROM WATER-RELATED EXTREME EVENTS

Damage caused by flooding and droughts is on the rise, with devastating flooding making up around one-third of global natural disasters. In fact, in the period between 1996 and 2005 the number of flood events doubled over the reference period 1950 to 1980. The economic losses are now fivefold.

Moreover, climate research provides strong evidence that extreme weather conditions will occur more frequently in future, increasing the risk of flood events. Drought-induced damage and loss around the world, however, is no less serious. Droughts not only directly and severely affect the availability and quality of water resources. They also lead to crop failure, resulting in famine and disease.

Studies show that the percentage of the Earth's land surface that is extremely arid has more than doubled over the past 50 years.

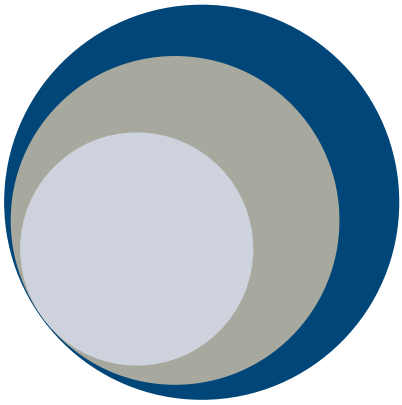
Over the last few decades, an increase in the number of extreme heat and extreme dry days has also been seen in the summer months in Germany. By the end of the century, a further increase in the number of dry periods in summer is anticipated, increasing the risk of crop failures, the consequences of which can be major financial losses in the agricultural sector as well as increased food insecurity.

At the same time, heavy precipitation in recent years has increasingly led to major flooding, causing billions of euros worth of damage. Since it is virtually impossible to provide total protection from the impacts of flood events, the primary objective of modern prevention strategies, regulations, and legislation is to provide effective risk management. Research covering the entire chain of effects can help improve these strategies.

With the help of improved planning instruments and forecasting tools based on precise measurement systems and faster processing of larger volumes of data facilitated by digitalization, at-risk areas could be warned earlier and more reliably. The integration of state-of-the-art communications technology into early warning systems has an important role to play here.

Extreme flood events such as the heavy flooding in the Elbe and Danube basins in 2002 or the flooding that occurred along many rivers in Central Europe in 2013 may not be frequent occurrences. The risk they pose to human life and the damage they cause to property, however, is extremely serious. In such cases, proactive transregional preventive measures as well as technical flood protection measures are all the more important. The use of innovative materials, for instance in combination with state-of-the-art early-warning and monitoring systems, opens up new possibilities for temporary flood control measures and dike construction.

+100 %



Studies show that the percentage of the Earth's land surface that is extremely arid has more than doubled over the past 50 years.

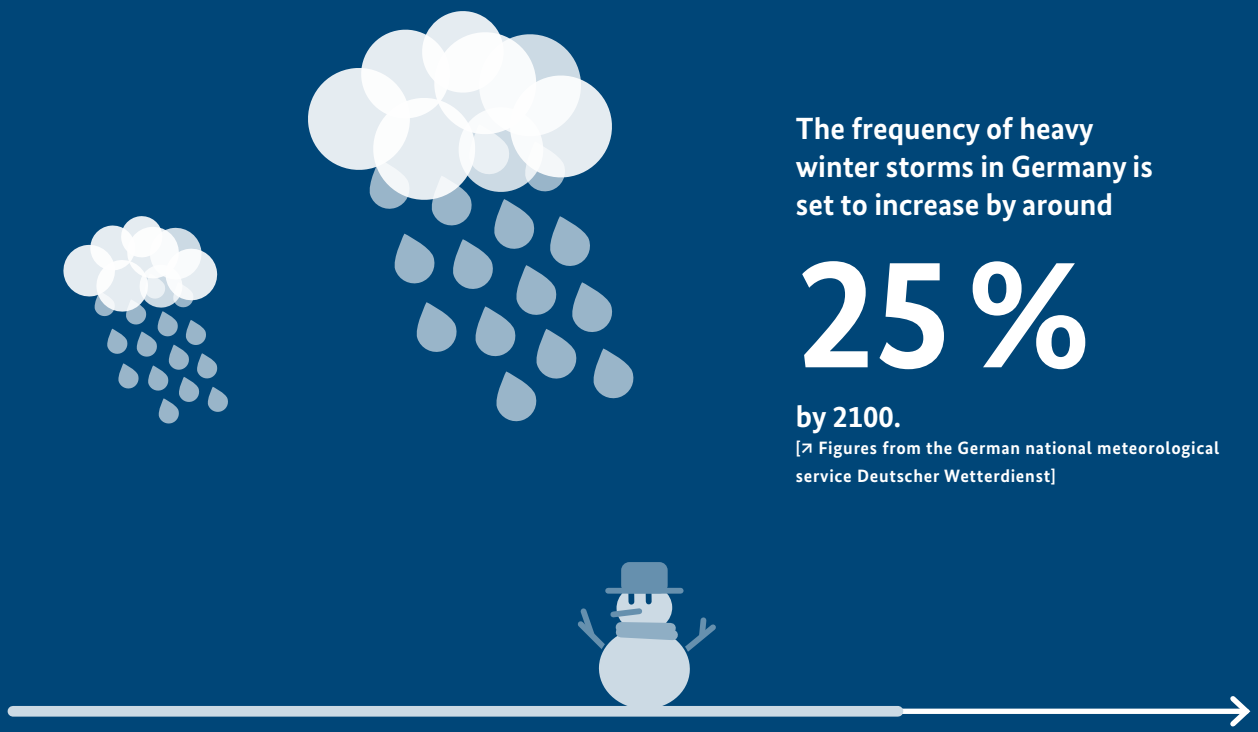
Owing to the high population density, complex infrastructure, and development density, urban areas are, by their very nature, hit hardest by flooding. Research has an important role to play here by bolstering flood control measures in a variety of ways.

By providing new and improved models, dedicated research can support the development of a new form of urban planning and development that factors in climate adaptation and flood management in order to mitigate the risk of flood-induced damage. Further development potential can be seen in the adaptation and intelligent control of sewage systems to help combat the increasingly frequent situations where they cannot cope with additional stress placed on drainage systems during heavy rainfall. This can be effectively combined with an integrated rainwater and pollutant management system in urban areas. Local flash floods, in particular, which are caused by small-scale precipitation events that are difficult to accurately forecast, typically have very short forecast lead times. In such cases,

LOCAL HEAVY RAINFALL IN GERMANY

In July 2014, within just a few hours extreme rainfall caused damage in the amount of some 300 million euros in the Greater Münster area. In this short time as much as 292 liters of rain per square meter had fallen, which is equivalent to more than 40 % of the total annual precipitation.

In June 2016, extreme precipitation caused flash floods that had catastrophic consequences for the town of Simbach in the southern German state of Bavaria, resulting in seven fatalities and around one billion euros in damage. According to the German national meteorological service Deutscher Wetterdienst, such extreme weather events indicate that Germany can expect to see more storms, extreme rainfall, and heatwaves in the future.



The frequency of heavy winter storms in Germany is set to increase by around

25 %

by 2100.

[↗ Figures from the German national meteorological service Deutscher Wetterdienst]

effective preparation is of the essence, enabling quick mobilization and activation of protection measures.

Additional benefits can be achieved by identifying and making use of synergies. Flood risk management measures, for example, can also offer advantages in the event of extreme water scarcity – through effective soil management strategies based on more precise soil data or forecasting systems, for instance. Even if – at least for now – water scarcity is not a nationwide problem, there are places in Germany with water shortages where irrigation may be needed. As an alternative, therefore, water-saving cultivation and production processes (crop type, cultivation methods, soil tillage, irrigation technologies) as well as storage technologies for groundwater recharging ought to be taken into consideration.

3.6

NEW WATER CULTURE

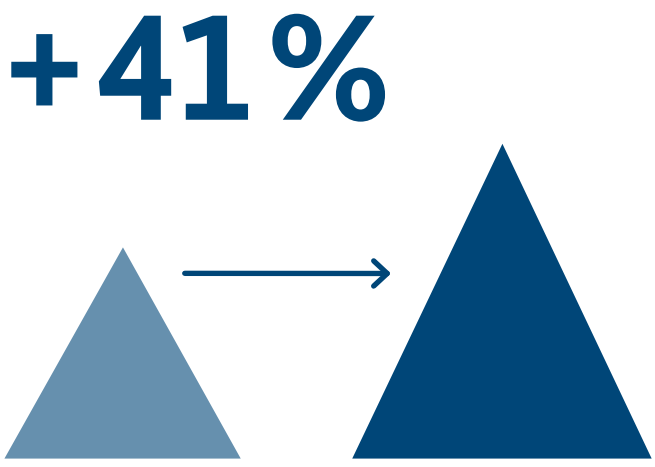
Our culture determines how we use water resources, and the development of cultures the world over has depended on water since time immemorial. The conditions underlying our cultural use of water, however, are currently undergoing tremendous change – not only due to the increasing water demand resulting from population growth and changing consumption patterns, but also, for example, in response to increasing water pollution with both known and unknown contaminants, as well the loss of natural reservoirs and water-dependent ecosystems.

The United Nations' Sustainable Development Goals, the UN Water Action Decade, as well as Germany's National Sustainability Strategy represent a new culture of sustainability. And where better for such initiatives to begin than with water – because water is something we all come into contact with every single day. This inextricable link between humans and water puts immense pressure on the Earth's population to use this primary resource more efficiently.

This is where research comes into play. For research is the key to developing both the requisite knowledge and innovative, credible models. Besides technological innovation, we also need to see a greater focus on socioecological, ethical, and legal aspects, as innovative solutions in the water sector can only be successful if they are compatible with the respective cultural norms and value systems, or if they go hand in hand with changes in these value systems. Indeed, large-scale projects such as water reclamation and reuse projects are often unsuccessful due to cultural barriers and a lack of acceptance – despite quality and safety guarantees and widespread awareness-raising campaigns.

What are needed are success stories – examples that show the positive synergy effects that can come from giving equal consideration to social, environmental, and economic aspects in the planning and implementation of innovative water projects.

Potential 41 % increase in global food production achieved by integrated water management



Here, as in other areas, participatory formats are becoming increasingly important for water resources. Besides technical modifications, the development of suitable operator models is particularly important for water supply, for example. Another important aspect here is ensuring that the interactions and relationships between the different sustainability goals are properly evaluated and considered.

These complex relations are illustrated by what is known as the water-energy-food security nexus: water is needed both for energy supply and to feed a growing global population. Recent studies by the Potsdam Institute for Climate Impact Research (PIK) estimate that improved water management can increase food production by 41 %. This could reduce the demand-supply gap for food by half by 2050.

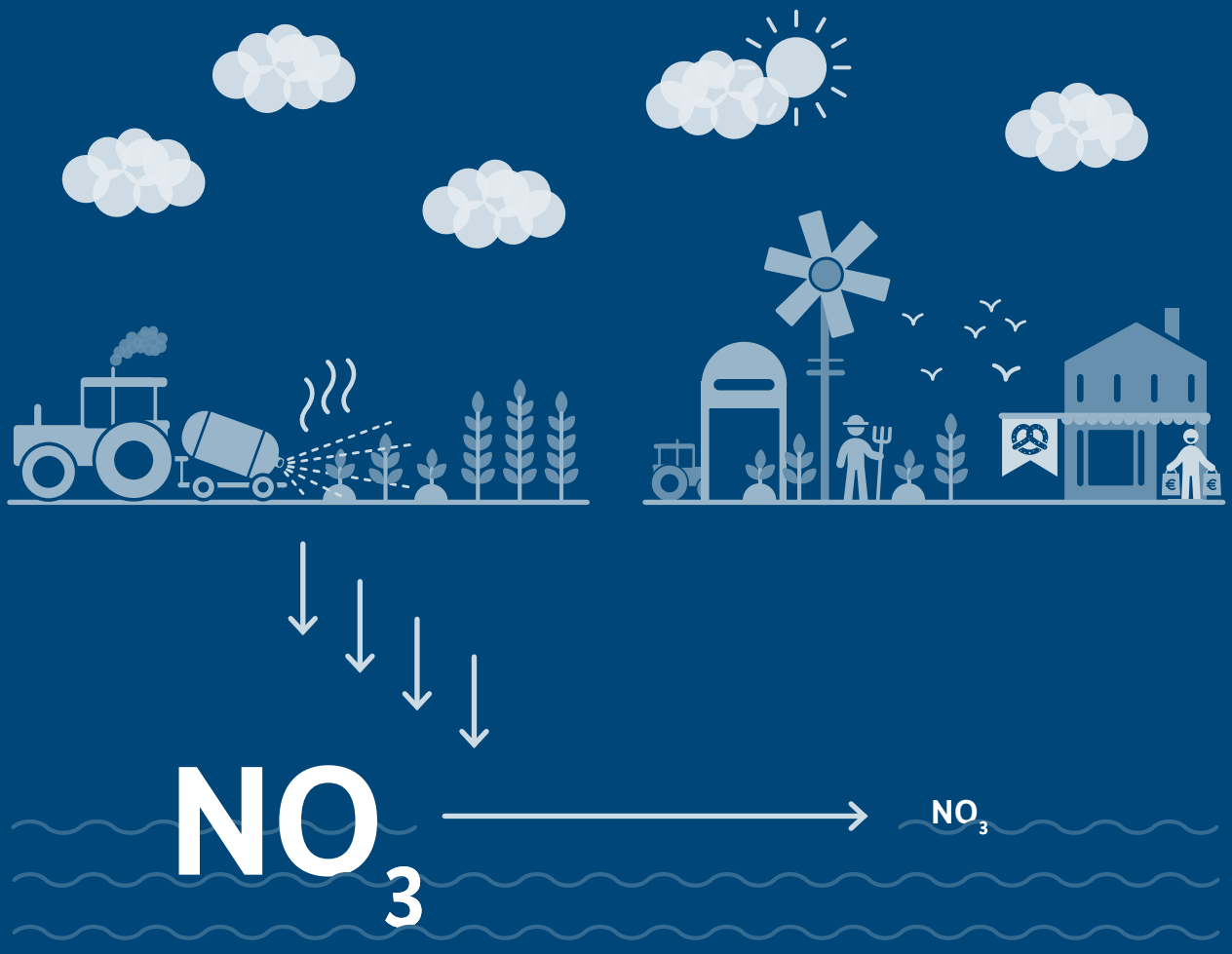
Ethical aspects are increasingly pervading the public perception of the issues surrounding sustainability and product responsibility. This is because today our products are manufactured in global value chains, meaning the biggest water consumers can be found outside Germany.

Often the very regions that suffer from severe water scarcity are those that require huge quantities of water in the early stages of production, e.g., for cotton in Central Asia, grain in North Africa, or for ore extraction in arid regions. For this reason, it is important to consider the actual water consumption of the exploration and production industry at the production site. A new approach here, for example, is to assess the water footprint of companies and products along the entire value chain.

What is needed, therefore, is worldwide support for good governance and transparency in the water sector as well as fair globalization in this area. Instruments that factor in the water footprint and consider environmental standards in the supply chains can help ensure that environmental sustainability becomes firmly embedded in corporate social responsibility.

WATER PROTECTION – A SHARED RESPONSIBILITY

The WASSERSCHUTZBROT (water protection bread) project involves farmers refraining from using nitrogen-based fertilizer on their wheat for the pre-harvest fertilizer application, in doing so reducing the risk of nitrate entering the groundwater as a result of runoff of the fertilizer. After all, nitrogen not only contaminates the groundwater, but it is also an essential nutrient that serves to build protein in the grain, which is important for grain quality and baking properties. The mill involved in the project pays the farmers a fair price for wheat with a lower protein content while the local water supply company gives the farmers financial compensation. The bakeries involved use their baking skills to compensate for the slightly different baking qualities of the flour. Customers who choose to purchase the bread are contributing to sustainable consumption and helping to protect the groundwater. Soil samples from these fields were found to have lower nitrate concentrations, underlining the success of the project, which made the jury's top 3 in the 2017 German Sustainability Award in the category of Research.



4

INTER-NATIONAL WATER RESEARCH

4.1 GLOBAL ACTIVITIES

Water is a global resource that transcends political borders. Overuse of local water resources and water scarcity are becoming growing concerns and the negative impacts of these developments are increasingly visible, especially in the international context. Since 2012, the World Economic Forum's annual Global Risk Report has classified water crises as one of the top five global risks in terms of impact.

Water crises can exacerbate geopolitical and social risk factors such as the risk of domestic or regional conflict or even migration, especially in fragile regions. Sustainable solutions to these global challenges can only be found by working with our partners in Europe and around the world (e.g., EU, UN, G7/G20, OECD).

Being one of the most innovative and competitive countries in the world with one of the strongest research landscapes, Germany will continue to provide impetus for and actively engage in the implementation of collaboration initiatives in the research, development, and innovation sector, not only at home but also on the international stage.

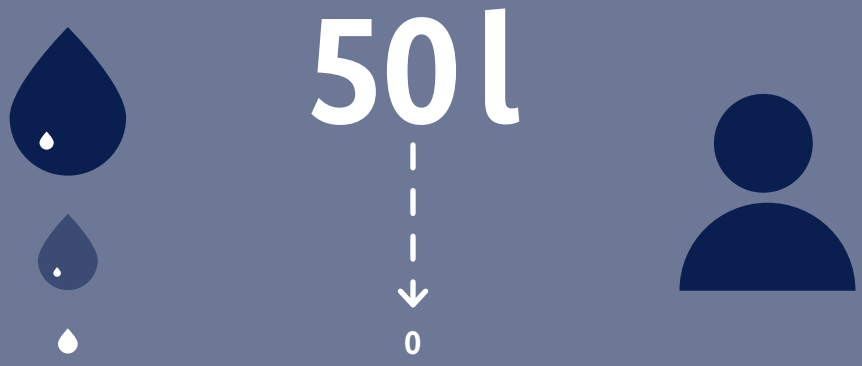
Against this background, Wasser: N explicitly draws on the German Federal Government's strategy to internationalize education, science and research. Collaborative projects carried out as part of the Wasser: N initiative will strengthen R&D excellence, help develop and reinforce Germany's innovative strengths on the international stage, as well as strengthen knowledge transfer and skills development.

Through international research cooperation in the water sector, the German Federal Government is also helping to ensure that water, as the basis of life, is protected worldwide, and promote the implementation of the human right to safe and clean drinking water, a basic right that was officially recognized by the United Nations General Assembly in 2010. This basic human right is indispensable for people to lead a life in dignity and can help maintain stable societies.

DROUGHT IN AFRICA — DAY ZERO IN CAPE TOWN

In 2018, following three consecutive years of drought, water resources had reached the point where consumption had to be restricted to 50 liters of water per person per day. Cape Town's "day zero" – meaning the day where the dams supplying the city could reach a crucial low and municipal water supply would have to be switched off – was barely averted and would have meant further water restrictions for the city's residents.

Studies on such droughts and their impact are conducted as part of the BMBF funding measure Global Water Resources (GROW), e.g., with the help of early-warning systems or reservoir/dam management systems combined with seasonal climate forecasting. Some four billion people currently live in regions where food production is majorly affected by global climate fluctuations such as the El Niño-Southern Oscillation.



To be successful in the many dimensions of sustainable development, including health, food security, and the fight against poverty, the aforementioned water and sanitation sustainable development goal (SDG 6) must be met, including the secondary aims. To be able to achieve this, a holistic approach based on integrated water resource management (IWRM) is needed. IWRM is based on the coordinated development of water, land, energy, and other resources and seeks to promote economic and social well-being in a fair and just manner, without negatively impacting the sustainability of our ecosystems. IWRM will thus also be one of the guiding principles in the Wasser: N initiative, especially on an international level.

Here, too, research is needed in order to unearth complex correlations and dependencies that are not visible with isolated, individual analyses. For instance, it is important to consider that water is also needed for energy generation as well as to produce virtually every commodity traded around the world, from wheat to smartphones. Consequently, industrial manufacturing and agriculture are contributing to the overuse of local water resources as well as to local water pollution. At the same time, energy is needed for water conveyance as well as for water recovery and reuse. Measures such as the incorporation of sustainability principles into mission statements, the transparent implementation of such principles, and incentives for sustainable water use can help reduce these negative effects and improve conditions for populations living in the regions where the production sites are located.

In addition to predictive analytics and modelling, we also need water governance and coordinated efforts on the part of diverse stakeholders, especially on an international scale. A further important aspect will be to factor in mutual dependencies between water availability and water use, on the one hand, and trade and consumption patterns, on the other. Case studies are used to examine regional, local, and, more importantly, transnational solutions.

The aim of the Wasser: N initiative is therefore to promote actual implementation in selected developing and newly industrialized countries, one of the main focuses being joint, needs-based research with the partner countries.

This will enable us to unlock new market potential for export-oriented innovative German companies – in particular small and medium-sized enterprises (SMES). Research can also provide the basis for successful water diplomacy. Many international examples show that the transnational character of water resources, with all its economic and social impacts, leads to negotiations between parties in conflict over transnational river systems, for instance. Research has a huge role to play here in terms of analyzing such processes and providing fact-based information on matters such as the structure, distribution, quality, and quantity of water resources.

Additional educational measures, both in the area of basic and further education, can help ensure that the necessary expertise, e.g., on how to operate water-related systems, is available in the target countries permanently, and not only in the academic community.

SUSTAINABLE DEVELOPMENT GOAL 6

A report by the United Nations found that in 2015, 29 % of the global population did not have safely managed drinking water services while 61 % had no safely managed sanitation facilities. [↗ Sustainable Development Goals Report, 2018]

In combination with water scarcity, flooding and the lack of effective waste disposal or sewerage systems, this hinders social and economic developments and is the motivation behind the UN's sixth sustainable development goal:

TO ENSURE AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL.

By 2030, the UN Member States aim to:

... achieve universal and equitable access to safe and affordable drinking water for all

... achieve access to adequate and equitable sanitation and hygiene for all

... improve water quality worldwide (e.g., by reducing pollution, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally)

... substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater

... implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

... and, by 2020, they commit to protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

4.2 EUROPEAN ACTIVITIES

Every year, the Member States of the European Union put huge sums of money into research and development in the water sector. Substantial funding also comes from the European Commission. By cooperating with other EU Member States, Germany can contribute to the joint effort to tackle challenges that affect society as a whole – a task that, given its scale, no one country would be able to take on single-handedly.

The establishment of transnational protection commissions (e.g., the International Commission for the Protection of the Rhine (IKSR)) facilitates close cooperation between the countries and regions that lie in the respective catchment areas with a view to achieving a balance between the different interests when it comes to water use and protection. In connection to this, it is crucial for transnational activities to be continually maintained and expanded. The development of common standards and strategies for the implementation of European directives (e.g., EU Water Framework Directive, EU Floods Directive, EU Marine Strategy Framework Directive) also calls for transnational cooperation.

To facilitate water research in Europe, various initiatives and collaborations will be established under the auspices of the European Research and Innovation Programme (2014 to 2020: Horizon 2020; 2021 to 2027: Horizon Europe), with the German Federal Ministry for Education and Research representing Germany.

The Horizon Europe funding program will respond to global challenges set down by the UN in the 17 Sustainable Development Goals at the heart of the 2030 Agenda for Sustainable Development.

Horizon Europe will therefore support activities in the area of water research and innovation as a complement to international and national funding programs. Germany's involvement in such European framework programs is not aimed solely at setting up transnational cooperation in water research but is also about enabling the German research community to access European funding. A further benefit is that the German government's priority research fields can then be pooled together and addressed at European level.

Such international cooperation and pooling of national resources will make research in Europe and elsewhere more efficient. The Joint Programming Initiatives (JPIS) will help make this happen. The German government has demonstrated its commitment to water research through active involvement in the Joint Programming Initiative Water Challenges for a Changing World (Water JPI), which is supported by the participating EU Member States, other associated partners, and the European Commission. The Water JPI seeks to deepen strategic cooperation between existing national programs and set up new funding programs for the purpose of establishing a sustainable water economy at European and international level. The European partnerships are a new strategic element of cooperation within Horizon Europe. In the Water4All partnership, for example, the aim is for all the relevant actors to come together to create the necessary foundation for translating the findings from water research into innovative practical solutions more quickly.

For research on flowing bodies of water, the pan-European research infrastructure DANUBIUS-RI, which is part of the roadmap of the European Strategy Forum on Research Infrastructures (ESFRI), plays an important role. The DANUBIUS-RI research infrastructure examines river-sea systems from the source to the sea (i.e., rivers and their catchments and transitional waters such as estuaries and deltas), integrating a wide variety of research priorities at a total of twelve selected supersites (including the Elbe North Sea estuary). This initiative underlines the relevance of transnational cooperation in the study of inland waterways, transitional waters, and coastal waters. It also shines a spotlight on the issue of water protection – something which is particularly important in view of the fact that river systems and coastal strips do not stop at national borders.

In the past 12 years, a growing awareness of the specific challenges that the water sector faces in the Mediterranean region has led to more and more research cooperation between EU Member States and countries in the Southern and Eastern Mediterranean/Southern and Eastern Mediterranean countries.

WATER JPI – WATER CHALLENGES FOR A CHANGING WORLD

The Water JPI, which was established by the Council of the European Commission in 2011, is one of ten JOINT PROGRAMME INITIATIVES based on an intergovernmental approach to tackling the multiple social challenges facing Europe and the rest of the world in the areas of environment, climate, health, nutrition, and culture. The aim of the Water JPI is to take on the mammoth challenge of creating water systems for a sustainable economy in Europe and throughout the world.

The Federal Ministry for Education and Research (BMBF) represents Germany in the corresponding bodies of the JPI Water, participating in the development and implementation of the strategic research and innovation agenda, where the research priorities are defined and continually refined. Cooperation with the European science and research community and relevant stakeholders helps ensure that the activities of the Water JPI are relevant and lend themselves to practical application. Three priority fields of action that are essential for sustainable development in the water sector were identified: protection of our aquatic ecosystems, increase in resource efficiency, and adaptation to demographic and climate changes.

In this context, Germany and other EU Member States are involved in the PRIMA funding program (Partnership for Research and Innovation in the Mediterranean Area). PRIMA seeks to develop joint solutions for sustainable water management and secure supply of food in the Mediterranean region.

Besides funding research and innovation projects, this program also has an important role to play in the development and expansion of local education programs which are hoped to create future prospects, improve development opportunities, and mitigate the causes of flight and migration over the long term.

5

RESEARCH LANDSCAPE AND INFRA-STRUCTURES

There is barely a single university in Germany that does not conduct research in the field of water from all manner of perspectives, from science and engineering to water resources law, water policy, and economics.

This wide spectrum underlines just how relevant the issue is. Non-university research centers and research communities also conduct research in the field of water (Helmholtz Association of German Research Centers, Leibniz Association, Max Planck Society, Fraunhofer Society). In addition to this, the German federal states and government departments have their own research facilities, such as the German Federal Institute of Hydrology, with the associated International Center for Water Resources and Global Change (ICWRGC) of UNESCO. The institutions in this diverse research landscape are the mainstay of the necessary infrastructures and ensure that research activities continue over the long term.

Publicly funded water research is conducted in every region in Germany. The growing challenges of future water management, however, call for better networking and combined efforts.

To achieve this, we need to foster interdisciplinary collaboration and create a closer link between basic and applied research – an absolute must for improved competitiveness and capacity to cooperate at international level. By establishing the joint national water research program Wasser: N and interdepartmental cooperation involving the relevant stakeholders, the German Federal Government is rising to this challenge.

Better cooperation between key stakeholders in German water research also enables the development of and better access to bigger research infrastructures that are used by the different partners. To be able to make valid statements and predictions on long-term trends such as the impact of climate change, studies have to be conducted that have wider geographical scope and longer duration. This calls for the development and expansion of the corresponding institutions on the meso and microscale. Mesocosm experiments can help bridge the gap between laboratory experiments and field investigations and combine the benefits of the two, as seen in the example of the Lake Lab in Lake Stechlin (Brandenburg), an experimental setup developed by the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), while the German Federal Environmental Agency's Marienfelde test site is an experimental setup representing the main components of the water cycle. At the Helmholtz Terrestrial Environmental Observatories (TERENO), studies are carried out on four selected regions in Germany to investigate how climate change and land use change can impact the regional water cycle and biodiversity. In what are known as hydrological observatories, the relationship between the water and mass balance, surface runoff processes, and changes in groundwater are examined. This data can then be linked to other environmental data, the insights gained serving as a basis for the development of adaptive strategies and sustainable water use concepts.

MOSES – RESEARCH INFRASTRUCTURE OF THE HELMHOLTZ ASSOCIATION

Nine of the Helmholtz Association's research centers have joined forces to create a new research infrastructure that will explore the impact of dynamic events on the long-term development of the Earth and environment.

The new infrastructure, which goes by the name of MOSES (Modular Observation Solutions for Earth Systems) and is led by the Helmholtz Centre for Environmental Research (UFZ), is a novel, mobile, high-resolution, event-based observation system, which is designed to investigate the long-term impact of short-term dynamic events (hydrological extremes, heatwaves, ocean eddies, and melting permafrost) on the Earth's systems. Innovative processes embedded in long-term campaigns are used to measure the event-related data, which is then taken as the basis for developing measures to protect the Earth from extreme events. Looking to the future, the aim is to integrate MOSES into the BMBF's Roadmap for Research Infrastructure.

Satellite-based terrestrial observations and the subsequent integration of the data collected into Earth system models are crucial to acquiring a better understanding of the many different, interwoven processes that take place on the Earth's surface. Within the European Earth Observation Program Copernicus, satellite systems and in-situ observation systems are used to acquire extensive data, e.g., hydrological parameters such as precipitation, air humidity, and soil moisture, and this data is then made freely accessible. Germany is heavily involved in the Copernicus program (National Copernicus Strategy). To advance the technical scope of this program, increasingly powerful systems have to be developed. This applies both to satellite image analysis and unmanned aerial vehicles (UAV) with data acquisition capabilities, such as those used in the Helmholtz Association's event-oriented observation system MOSES. At the same time, the more data that is acquired, the greater the demands placed on data and information structures. [↗ Chapter 9]

6

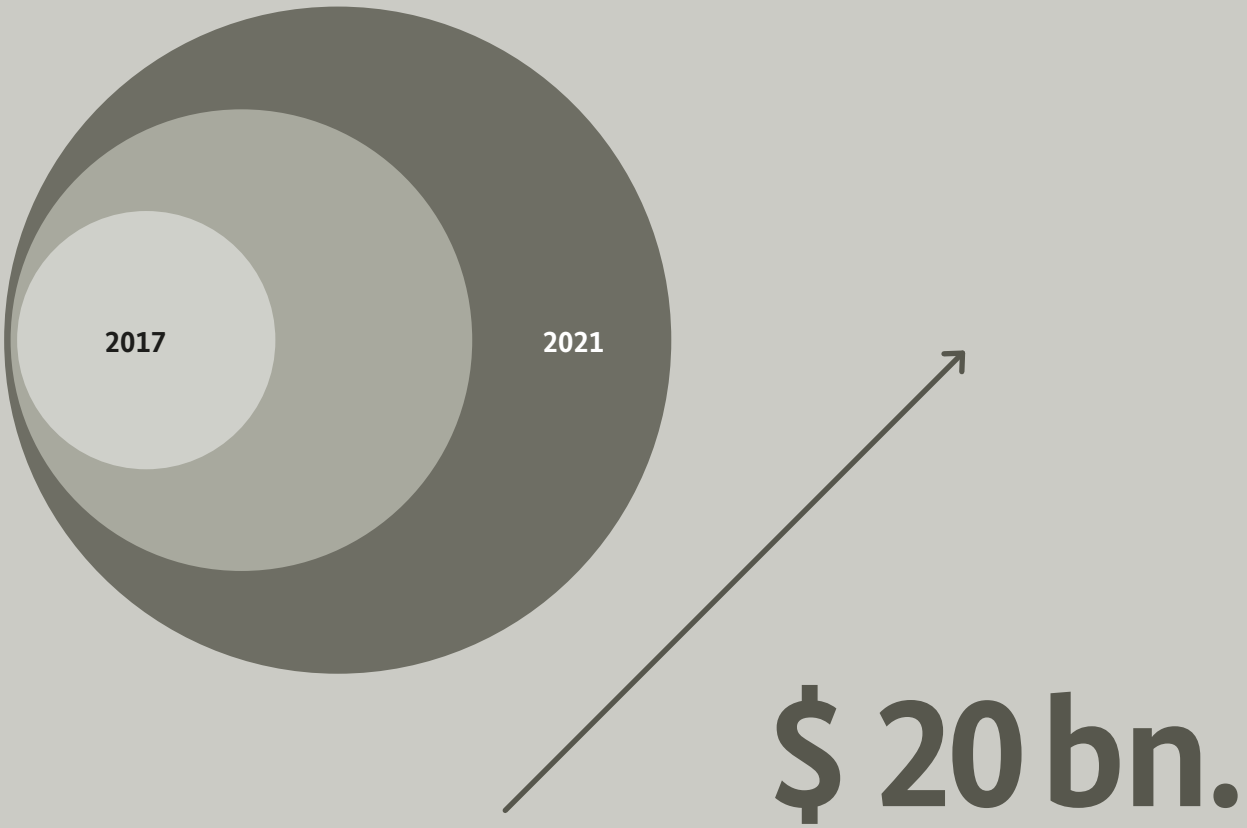
DIGITALIZATION, DATA MANAGEMENT, AND STANDARDS

Digitalization opens up promising opportunities for resource and energy-efficient water management. Digitalization delivers the components and smart networks needed for better water management, ensuring efficient, sustainable use and protection of water resources. When it comes to the possibilities that digitalization opens up in the area of water research and water management and governance, we have barely begun to scratch the surface.

HOW CAN DIGITALIZATION FOSTER SUSTAINABILITY?

The rise of digitalization in value-adding processes opens up huge potential for improving efficiency. According to the 2017 Global Opportunity Reports, by 2021 the global market for smart water management will be worth as much as 20 billion US dollars. As published in the Environmental Technology Atlas for Germany (2018), Germany's green tech lead market "sustainable water management" is expected to record additional growth of around one billion euros thanks to digitalization. Whether in industry, municipal water and wastewater treatment, or private households, existing infrastructures have to be replaced or improved and new components and systems installed to ensure water systems are managed in a cost-effective, resource-efficient manner.

The economic opportunities resulting from digitalization are huge – although digitalization can drive change beyond mere economics. In fact, entire societies, politics, and the environment are all impacted. A food for thought paper by the German Advisory Council on Global Change (WBGU) highlights the huge role played by digitalization when it comes to driving sustainable development and achieving the UN's 17 Sustainable Development Goals. This process of digital transformation, however, must be actively shaped – and extensive debate and discussion between private and public stakeholders is absolutely essential here. For if the SDGs are to achieve long-term success, we need to have a better understanding of the impacts of digital transformation on economic and political processes as well as on individual members of society and their privacy.



Market for smart water management

Wasser: N takes up the digital transformation strategy of the Ministry of Education and Research, addressing the following three target areas: boosting knowledge transfer and innovation, technological sovereignty, and safeguarding Germany's pioneering role in research.

In line with this, the Wasser: N initiative seeks to use the opportunities offered by digitalization to achieve sustainable water research and water management, in doing do actively shaping and driving digital transformation.

One way to ensure water resources are being used sustainably is to employ smart, sensor-based systems that ensure resource and energy-efficient water and wastewater treatment.

Smart modular solutions are ideal for operating and controlling water and wastewater treatment systems and offer huge potential for needs-based water and wastewater management, while monitoring technology make predictive maintenance for water supply and wastewater systems possible, reducing costs and the frequency of water system breakdowns.

Intelligent monitoring and data management enable better control of – and can even help mitigate – the effects of extreme weather events, sea damage, and safety-relevant damage, where applicable. Web-based data delivery systems are the starting points for new operator models which enable systems and components made by German manufacturers to be controlled and monitored abroad. Any such IT systems must be properly secured and protected from unauthorized access. In addition, real-time condition monitoring has not been sufficiently exploited in the area of water supply and wastewater disposal or in other cases where natural resources are used, despite the opportunities this technology offers for the development of smart and sustainable services and, thus, for new business models. The increased integration of users and consumers into the resource cycle can result in a more sustainable, more efficient use of water resources in private, commercial, and municipal applications.

Very often, much of the potential lies in the combination of existing technologies and methods, the ever increasing availability of data, and simulation-based planning and optimization. In connection with this, it is down to the research community to drive digital integration with the help of digital data provision and modelling and by continuing to develop and improve new automation and networking technologies and mechanisms.

Digitalization in water research and management will impact the education and training sector as well as the workplace, resulting in a huge demand for educational and training concepts and measures for all those involved in the value chain.

This refers to training and further education programs for existing staff as well as training for future employees and includes the creation of new vocational fields. A particular challenge here is data protection, data security, and data management strategies, in particular the secure transmission, processing, and storage of large data sets.

Availability of and smart access to environmental data and the corresponding databases have a crucial role to play in meeting the challenges of sustainable water research and management.

In this context, structures, strategies, and standards have to be put in place that will make research databases and official environmental data more accessible to the public, in doing so creating usable data for research and allowing for intelligent connections to be made. The Council for Information Structures (RfII), for instance, has already made initial recommendations for research data management and the creation of a National Research Data Infrastructure (NFDI). At European level, the European initiative INSPIRE (Infrastructure for Spatial Information in Europe) will help create a geodata infrastructure that will improve data compatibility, availability, quality, and accessibility beyond national borders. The INSPIRE geoportal can be used to research, view, and combine spatial data sets from different sources.

Standards are not only relevant for data management but are also an important instrument for ensuring that given quality standards in environmental policies and legislation are met across the entire water sector. Applied water research is often relevant in the area of legislation and standardization and should contribute to the establishment of corresponding standards, e.g., through close cooperation with relevant stakeholders and the development of concepts geared specifically toward standardization.

7

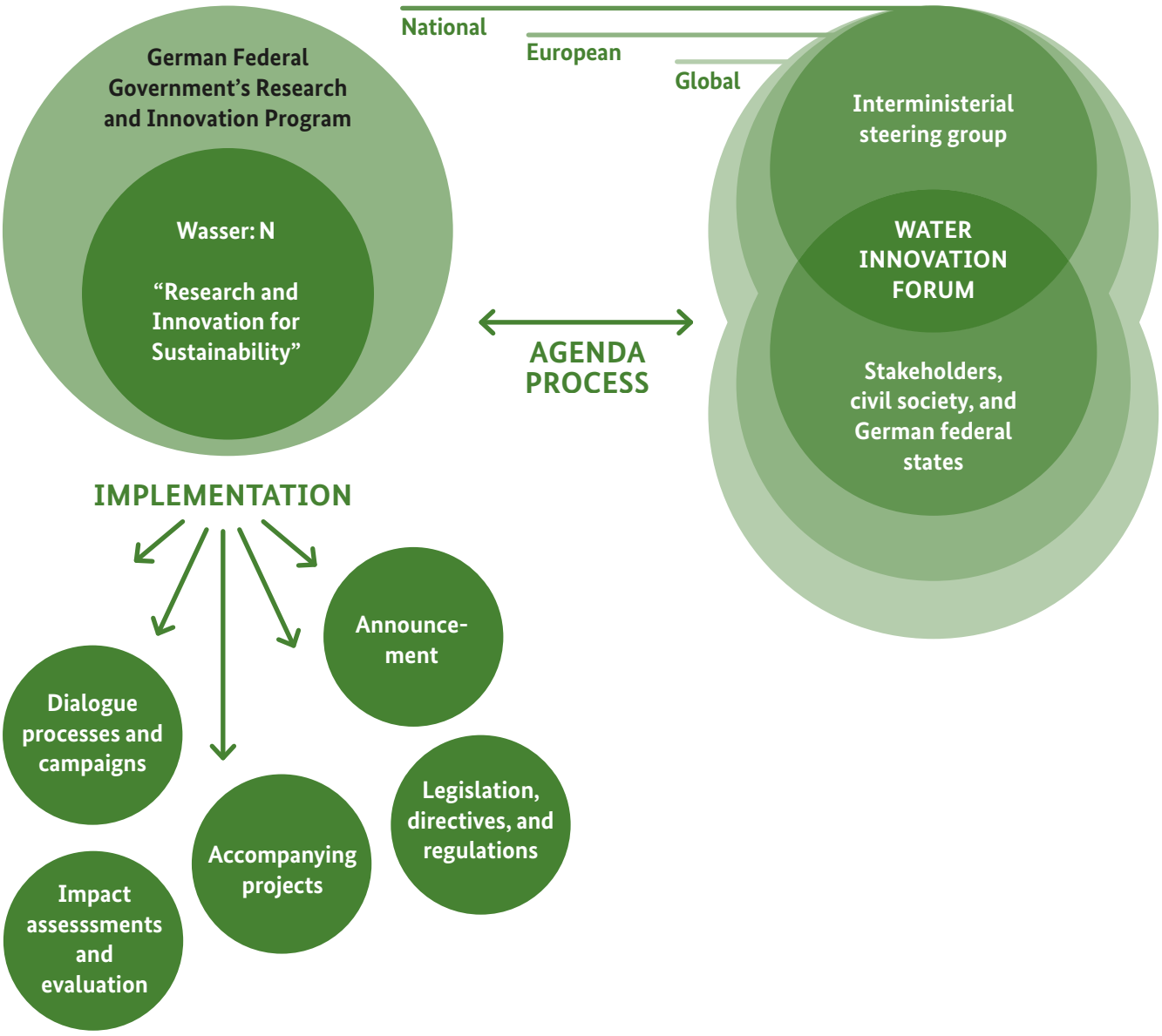
IMPLEMEN-TATION

The five-year Wasser: N research program is an open learning framework for action which is part of the BMBF strategy “Research for Sustainability” (FONA). Research and innovation needs, market developments, and priority topics for water research and water resource management are continuously monitored and identified though the dedicated participatory agenda process.

1. WATER INNOVATION FORUM

Forward-looking water research requires closer cooperation between the different disciplines and a stronger focus on cross-sectoral synergies than has been the case so far. This calls for a strategic research policy approach, pooling and coordinating research and development activities.

In this process, national considerations (e.g., the German Strategy for Adaptation to Climate Change, the Trace Substance Strategy of the German Federal Government, the German National Biodiversity Strategy, the National Water Dialogue initiated by the BMU), European, and international issues (e.g., as part of the EU Water Strategy and the achievement of the SDGs) are all equally important.



Wasser: N Structure

For the duration of the Wasser: N project, if required, this dialog should therefore take place in the context of a National Water Innovation Forum involving relevant stakeholders from science, society, politics, and business, which can help strengthen the transfer of research results to social and political decision-making processes.

This forum can also help create a consistent and effective presence in the context of international European collaboration. The research and development activities initiated through Wasser: N can therefore make an important contribution to achieving the UN Sustainable Development Goals.

Another aim of the forum is to bridge the gap between research and innovation needs, market developments, and regulatory and legislative processes to ensure that the fundamental insights and knowledge acquired through the project is fed into any decision-making related to the development of legislation, directives, and regulations.

2. FUNDING BODY, PROJECT STRUCTURE, AND LEVEL OF FUNDING

A key instrument of research funding is financial support for joint projects conducted on an inter- and transdisciplinary basis with partners from the science and research community, industry, and practice to successfully translate research results into practical applications more quickly.

The German government's research program is aimed at university and non-university research institutions, commercial enterprises, as well as public bodies at the municipal, federal state, and national level.

The involvement of the relevant groups of users as well as scientific communication geared toward different target groups are essential for the implementation and dissemination of project results.

The project funding areas identified are generally published in the form of an announcement in the Federal Gazette (Bundesanzeiger). The applicable funding modalities and regulations are set forth in the published funding regulations. The project proposals submitted compete with one another for the available funding. The assessment and selection criteria are published in the announcement text for the relevant funding measure. The BMBF's regulations governing the funding of projects also apply. The relevant regulations and terms for applications for expenditure or cost- based grants can be found in the Ministry's funding portal.
[↗ foerderportal.bund.de]

The project implementation focus is of vital importance and is to be documented in the funding application in the form of partner-specific utilization plans and standardization-related concepts, which are then continually updated throughout the duration of the project.

3. TRANSFER

Wasser: N seeks to further strengthen trans- and interdisciplinary research and collaboration between university, non-university, and government departmental research projects. Moreover, by facilitating better connections between the relevant organizations and dovetailing the content of the individual research programs, this initiative seeks to develop expertise and pool resources, thereby creating a closer link between basic and applied research.

It is not enough to gain new insights into water and developing sustainable technologies, however. In fact, for the positive effects for the environment and society to fully unfold, these have to be successfully translated into marketable products and processes. Experience shows that not every good idea comes to fruition. The risks often seem too great or there is a lack of funding for the all-important steps between conception and market launch.

To improve the transfer of research insights to practical applications, relevant political provisions are needed, as is intensive networking between researchers and potential users at an early stage.

This ensures that market and industry requirements as well as technical requirements, regulatory obstacles, or cost-related factors are borne in mind in the early stages of the research and development process. This paves the way for scientific knowledge to be successfully translated into competitive products and processes.

A range of factors including the timing of transfer, the target group, and the type of research findings have a significant impact on what formats are considered best suited for transfer. For example, reference projects designed to demonstrate the practicability of newly developed technologies and concepts in Germany or abroad are important for the international positioning of German firms and technology providers as well as for the transferability of research findings on an international level. Other tools that can be used to transfer research findings are workshops for potential users and roadshows, for instance. It is also important to create dedicated spaces where scientific insights can be transformed into marketable and competitive applications. Real-world laboratories provide an opportunity to test innovations by integrating them into processes that have already been established. This context also provides an experimental platform for communication with civil society in a modified regulatory framework.

4. SCIENTIFIC KNOWLEDGE AND COMMUNICATION

Water research and water innovations, as an overall concept, are so far something the German public are largely unfamiliar with. Given the global importance of water resources and the related challenges, however, it is essential to give proper consideration to the demands and expectations of society when it comes to the development of forward-looking water research, and also to discuss key future issues and evaluate possible conflicts of interest and risks at an early stage. Research must be open and transparent.

What are needed, therefore, are modern approaches to scientific knowledge and communication that ensure visibility and effective transfer of research and development insights and the resultant water innovations.

By helping to make innovations more tangible, this would also play a crucial role in the successful implementation of Wasser: N.

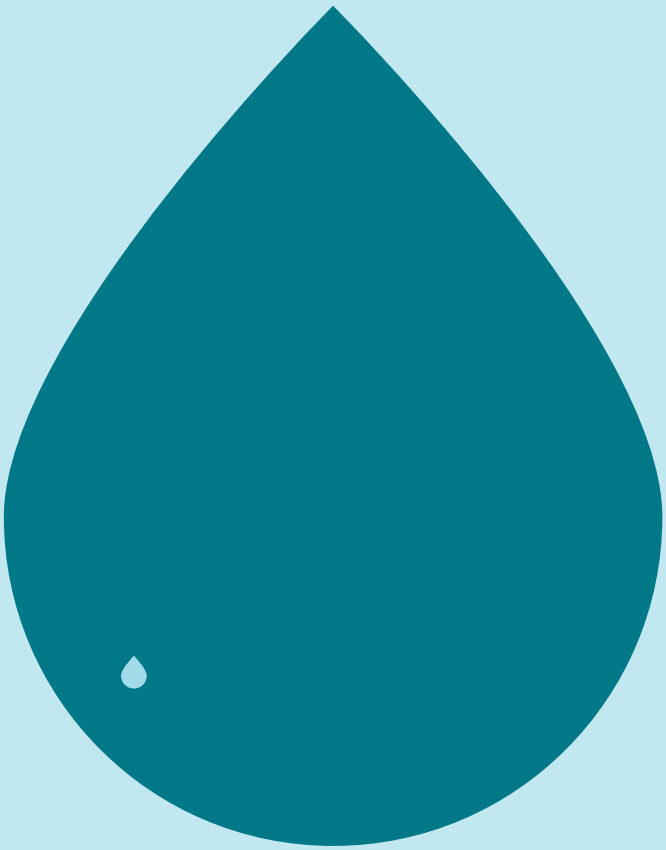
Accompanying research projects can support those activities that are an integral part of the research and funding initiatives, particularly when it comes to networking activities and transferring research results to practical application. The open access principle helps make research findings freely accessible and usable, thus facilitating an unrestricted flow of information within the science and research community and into all spheres of industry and society. Publications in the press, announcements on websites and in social media as well as a presence at national and international trade fairs will help the project participants from water research and the water management sector promote the technologies and concepts they have developed under the “Made in Germany” label and establish them on the market. Beyond the aim of conveying complex scientific knowledge to the outside world, scientific communication also seeks to actively involve interested members of society in research. Participatory formats like citizen science are particularly well suited for this purpose. They offer members of society an opportunity to make their own scientific contribution to sustainable water research and to work on finding answers to questions that are important for society.

5. EVALUATION

As an open learning framework for action, Wasser: N is constantly adapting and developing. The needs-based adjustment of research content is thus closely linked to the evaluation of individual initiatives, funding measures, and the entire research program. In addition, current research and innovation needs as well as market developments are all taken into consideration. Continuous and ex-post evaluations should constantly feed into the strategic adjustment of aims and objectives as well as the eligibility conditions for funding, but should also help assess the impacts, effectiveness, and efficiency of the research funding as well enable appropriate tools to be selected for the implementation of the research program in practice. Accordingly, about halfway through the project, Wasser: N will undergo an evaluation in conjunction with the review of the "Research for Sustainability (FONA)" strategy.

For proper evaluation, the relevant actors and stakeholders need a solid foundation based on reliable data, comprehensive results, and sound indicators. This systematic monitoring framework that will provide insights into the actual impact of the projects and funding measures.

Not only is the monitoring system a key tool for supporting and evaluating the initiatives, measures, and projects that are part of Wasser: N, but it will also map the development of water research overall and provide sound knowledge for practical application.



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