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National Research Strategy BioEconomy 2030

Our Route towards a biobased economy

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Preface

Tackling climate change is one of the greatest tasks facing mankind in the 21st Century. The challenge will be – under changing climatic conditions – to sustain a growing world population both with sufficient food and with renewable resources for material and energy use. The "National Research Strategy BioEconomy 2030" is thus striving towards a natural cycle oriented biobased economy that is in accordance with technology and ecology.

We must better understand and characterise the complexity of the building blocks and blueprints of biological systems, and improve our predictions about their reactions to external influences. Only then will we be able to better exploit them technologically – for the benefit of mankind and the environment. This will require integral research approaches that take equal account of economic, ecological and social factors, and which focus on entire value chains.

Research and innovation lay the foundations for a structural change from an oil-based to a biobased industry. This change is also related to great opportunities for growth and employment, and to significant improvements in our quality of life. With these research efforts we also want to take on our international responsibilities on the issues of global food supplies, biomass-based commodities and energy, and of climate- and environmental protection. This research strategy, which we will adjust to current developments, lays out clear cross-departmental priorities for the years to come.

These priorities involve major societal and scientific challenges that go far beyond the boundaries of any single scientific area or country. The complex underlying research issues provide incentives for the sciences to work interdisciplinarily and to cooperate internationally, and also accelerate transfer into practice. This is key for the establishment of a knowledge-based bioeconomy.

Prof. Dr. Annette Schavan, Member of the Bundestag
Federal Minister for Education and Research

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Summary

Global food security, renewable raw materials and energy from biomass, the conservation of biological diversity, climate- and environmental protection, and Germany's competitiveness are some of the major challenges facing this country at the beginning of this century. Meeting these challenges will require not only great social, economic and political effort, but also intense research efforts and new approaches to research and innovation. This is the endeavour of the Federal Government's new research strategy, which has been created to expand the groundwork for the further development of a knowledge-based and internationally competitive bioeconomy. The National Research Strategy BioEconomy 2030 is a component of the High-Tech Strategy and provides vital impetus for the demand areas energy/climate and health/nutrition, among others.

With the National Research Strategy BioEconomy 2030, the Federal Government is establishing the conditions for the vision of a sustainable bio-based economy by 2030. This carries the promise of global food supplies that are both sufficient and healthy, and of high quality products from renewable raw materials. This vision derives from the development of a free, dynamic, and innovative knowledge-based society. Therein, results from the life- and technological sciences will be accommodated with open-mindedness and curiosity, and (bio)technological progress and globalisation regarded as decisive opportunities. The central objective is the optimal utilisation of the chances created by the knowledge-based bioeconomy, and to translate these into enduring economic growth. Germany is set to become a leading research and innovation centre in the bioeconomy. The effect of this will be to accelerate the growth of bio based products, energy, processes, and services, and to strengthen the competitiveness of German industry on a global scale. This structural change from a petroleum- to a bio-based economy must be continued. The long-term objective is technology leadership, and to achieve the role of pioneer in solutions for global challenges though promotion of research and innovation in the bioeconomy – also as an obligation to international partners and to future generations. Thereby, a major source of impetus is the field of biotechnology.

The concept of the bioeconomy covers the agricultural economy and all manufacturing sectors

and associated service areas that develop, produce, process, handle, or utilise any form of biological resources, such as plants, animals, and microorganisms. This spans numerous sectors, such as agriculture, forestry, horticulture, fisheries and aquaculture, plant and animal breeding, the food and beverage industries, as well as the wood, paper, leather, textile, chemicals and pharmaceutical industries, and aspects of the energy sector. Bio-based innovations also provide growth impetus for other traditional sectors, such as in the commodity and food trade, the IT sector, machinery and plant engineering, the automotive industry, environmental technology, construction, and many service industries.

The research strategy lays out five priority fields of action for further development towards a knowledge-based, internationally competitive bioeconomy. These are: global food security, sustainable agricultural production, healthy and safe foods, the industrial application of renewable resources, and the development of biomass-based energy carriers. Thereby, food security always takes the highest priority. Holistic approaches are essential to resolve conflicting aims between these fields of action, to give equal consideration to environmental, economic and social issues, and for these

to be integrated in terms of sustainable solutions. Serving as guidelines in the implementation of the research strategy are thus the sustainable provision of foods, renewable raw materials, products and energy, the identification of all biomass-based paths of application, as well as the consideration of entire value creation chains.

The National Research Strategy BioEconomy 2030 identifies the measures that are required for each of these fields of action. These measures also serve to build on current strengths in science and industry, and to compensate for weaknesses and remove obstacles to innovation. Here, it will be crucial to attain interdisciplinary competencies, to accelerate the transfer of technology, to expand international cooperation, and to intensify the dialogue with the public. The National Research Strategy BioEconomy 2030 relies on scientists' ingenuity, innovation, and individual initiative, and aims to provide support to these ends with targeted funding. The research strategy defines priority areas for the coming years, and adaptations to current developments, in the sense of a learning programme, will also be incorporated over the duration of the strategy.

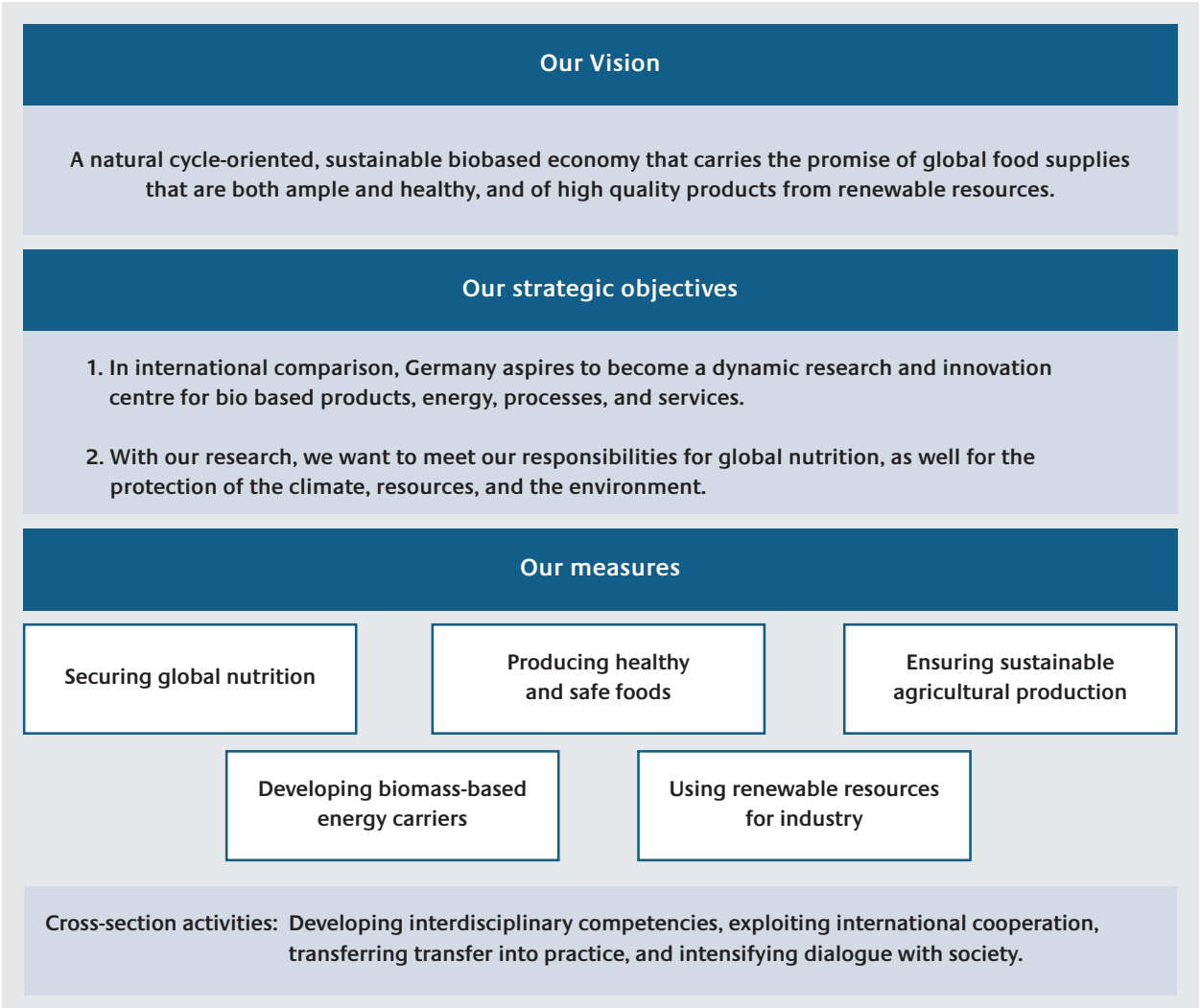


Figure 1: Summary overview of the vision, objectives and measures of the National Research Strategy BioEconomy 2030

1. The Challenges of the 21st Century and the Perspectives of a Bioeconomy

One of the greatest global challenges of the 21st Century in times of climate change will be to sustain a growing world population both with sufficient foodstuffs and with renewable commodities – as industrial raw materials and for energy production.

Providing adequate and healthy nutrition

The world population is expected to grow to over 9.5 billion people by 2050. Combined with changes in consumer preferences, the consequence is that global food security is certain to become a critical future challenge. Alongside, the world's available arable land is steadily decreasing as a result of soil degradation and expansion of residential areas, and climate change will exacerbate this surface loss. In industrialised countries, however, the frequency of nutrition-related diseases – obesity, diabetes, allergies, heart and vascular diseases, for example – is rising. This will have far-reaching social consequences, such as higher costs for the health system.

Securing resource-efficient and competitive supplies of energy and raw materials

The finite nature of fossil resources and the related increase in prices means that demand will rise sharply for renewable energy and raw materials. Of all the various sources of renewable energy, bioenergy has to date made the largest contribution to electricity, heat, and fuels. Biomass also represents the only renewable carbon source for use as an industrial raw material. Furthermore, biological resources hold a vast reservoir of natural materials for industrial purposes, which can be produced using limited resources.

Protecting the climate and environment for sustainable development

The challenge lies in the employment of effective and location-adapted agricultural production that places minimal burden on air, soil and water, climate and ecosystems, which promotes biological diversity, and which makes responsible use of limited resources such as soil, water, and nutrients. At the same time, agricultural production is both affected by climate change as well as being a greenhouse gas emitter. The efficient and sparing use of natural resources and their sensible and sustainable utilisation – without endangering the livelihood of future generations – are urgent tasks to assure sufficient nutrition for all people.

Taking international responsibility and the opportunities of globalisation

The provision of food, energy and resources, and the protection of the climate and environment are not only in the national interest, but are also a global commitment. Making proper use of technological progress is thus an obligation that makes demands on science and industry in equal measure. For business, innovative products and procedures provide an opportunity for technology leadership and the possibility of helping to shape the necessary transition to sustainable production. Furthermore, this transition represents a chance to benefit from international partnerships and growth markets. Knowledge-based approaches and market-oriented solutions significantly increase the competitiveness of the German economy.

The perspectives of a knowledge-based bioeconomy

The aforementioned challenges illustrate that, with decreasing arable land, greater quantities of biomass will have to be produced in an internationally competitive and sustainable manner. Under this premise, it will be important to find efficient and holistic (systemic) solutions.

A promising approach for this structural change from a petroleum-based to a biobased economy, which has the potential to enable economic prosperity with ecological and social compatibility, is to strengthen the knowledge-based bioeconomy[1] through the strategic promotion of research and innovation. This includes the agricultural economy, as well as all manufacturing sectors and associated service areas that develop, produce, process, handle, or utilise any form of biological resources, such as plants, animals, and microorganisms. The bioeconomy spans a wide range of sectors such as agriculture,

1 In the following, the terms ‚bioeconomy', ‚knowledge-based bioeconomy' and ‚biobased economy' will be treated as synonyms.

forestry, horticulture, fisheries and aquaculture, plant and animal breeding, the nutrition and beverage industry, as well as the wood, paper, leather, textile, chemicals and pharmaceutical industries, and elements of the energy sector. Biobased innovations can also provide growth and development impetus to other sectors, such as in commodity and food trade, the IT sector, machinery and plant engineering, the automotive industry, environmental technology, construction, and many service industries. Conversely, these sectors also significantly determine the productivity and performance of the bioeconomy.

An internationally competitive, knowledge-based bioeconomy can make a significant contribution to the perception of global responsibility in the present, and to appropriate foresight for future generations. These challenges will also result in growing demand for innovative products, processes, and services. In turn, this is an opportunity for the technology and business location Germany. Thus, the bioeconomy represents above all a strengthening of competitiveness, as well as growth and employment.

The economic, ecological, and social perspectives of the bioeconomy can only be realised through increased knowledge of the underlying biological processes and systems, alongside the associated technical possibilities and their interaction with the ecosystem, as well as an understanding of social implications. The many diverse and dynamic interactions – from the molecular level to the level of organisms, to interactions between the biosphere and the climate system, up to changes in society – are currently only rudimentarily understood.

New quantitative techniques, such as high-throughput analysis and synthesis, automated imaging, and the ability to capture and process large quantities of data for modelling, will accelerate this process of understanding. Knowledge of biological structures and related functions at the micro- to nano-scale can give rise to a wide range of applications in the areas of materials science, analytics and

material- and energy conversion and storage. An improved understanding of biological processes, particularly in the temporal dimension, will enable reliable and reproducible predictions to be made as to how these systems react to outside influences, how performance can be optimised, or how they can be utilised sustainably, i.e. with no direct or indirect harm to other areas of nature and the environment. Models for predicting the impact of climate change on individual species and/or ecosystems, and for understanding the most important ecosystem services for mankind, are examples of optimised knowledge management. The better we are able to quantitatively describe and understand the full complexity of the building blocks and blueprints of biological systems, as well as to predict their responses to external influences, the better we will also be able to apply them for the benefit of mankind and for environmental technologies. These perspectives provide the basis for the establishment of a knowledge-based bioeconomy (see Fig. 2) in which joint projects and networks work in an interdisciplinary manner, and in which knowledge is integrated holistically (systemically), leading to innovation.

Figure 2: Perspectives of the knowledge-based bioeconomy

2. The Bioeconomy in Germany

Germany's bioeconomy rests on numerous pillars. It is rooted in a broad research environment. On the economic side it includes above all agriculture and forestry, further sectors of the manufacturing and supply industries, and parts of the service sector. Thereby, a major source of impetus is the field of biotechnology.

Research

A majority of research activities in the bioeconomy takes place in the context of industrial research in the private sector, which is investing significant resources in this direction. These are spent both on research in private companies as well as increasingly on joint projects with partners in the scientific community. The research conducted in this sector is, of course, highly application-oriented, and is intended to yield immediately useable results (see the following paragraph for more information on industry activities).

Basic research into the utilisation of biological resources integrates a range of different scientific disciplines, including agricultural- and nutrition sciences, biology and other natural sciences, mathematics, environmental-/geo- and climate research, computer science, aspects of the engineering sciences, and the social and economic sciences. In the framework of government-funded research, these disciplines are embedded at numerous universities, other non-academic research facilities, academies, and departmental research institutes.

In the area of the bioeconomy, the non-academic research landscape comprises about 50 institutes from the four large German research organisations (see Fig. 3), which work exclusively or in part on research questions relating to the bioeconomy. These are jointly funded by the federal and state governments.

Alongside non-academic research facilities, some German federal ministries also fund comprehensive departmental research with relevance to the bioeconomy. The central objective of departmental research is the development of scientific decision guidance for the nutritional, agricultural, consumer, environmental and nature conservation policies of the respective ministries. This includes the provision of measurement infrastructure, without which it would not be possible to reliably stipulate regulatory limits or determine violations. Their research depends on the specialist work of the various departments. The knowledge gained in these facilities also serves the public good and consumers.

- The Helmholtz Association of German Research Centres (HGF) conducts research above all into key technologies in and around the area of the complex issues of the bioeconomy, using large-scale facilities and following long-term strategic programmes. These include, among others, institutes for plant-, environmental-, geo- and climate research, biotechnology, and the engineering sciences.
- In the life sciences, the Max Planck Society (MPS) institutes in particular conduct key basic research for a knowledge-based bioeconomy.
- More than 15 institutes in the Gottfried Wilhelm Leibniz (WGL) science community work on bioeconomy-related issues, mainly in the life sciences area, and also provide infrastructure and research-based services.
- Institutes within the Fraunhofer Society (FhG) conduct application-oriented research for the bioeconomy, and transfer scientific findings into practice via a life sciences network, and increasingly through other networks.

Furthermore, the majority of state-funded universities also provide an important pillar of research. Research with relevance to the bioeconomy is being carried out at over 100 universities and universities of applied sciences.

Overall, publication and patent analyses show that, on a scientific level, Germany is in an excellent position for a knowledge-based bioeconomy. The institutional diversity is both a strength and a weakness of the German scientific landscape. Because competencies at the universities and non-academic research facilities are distributed

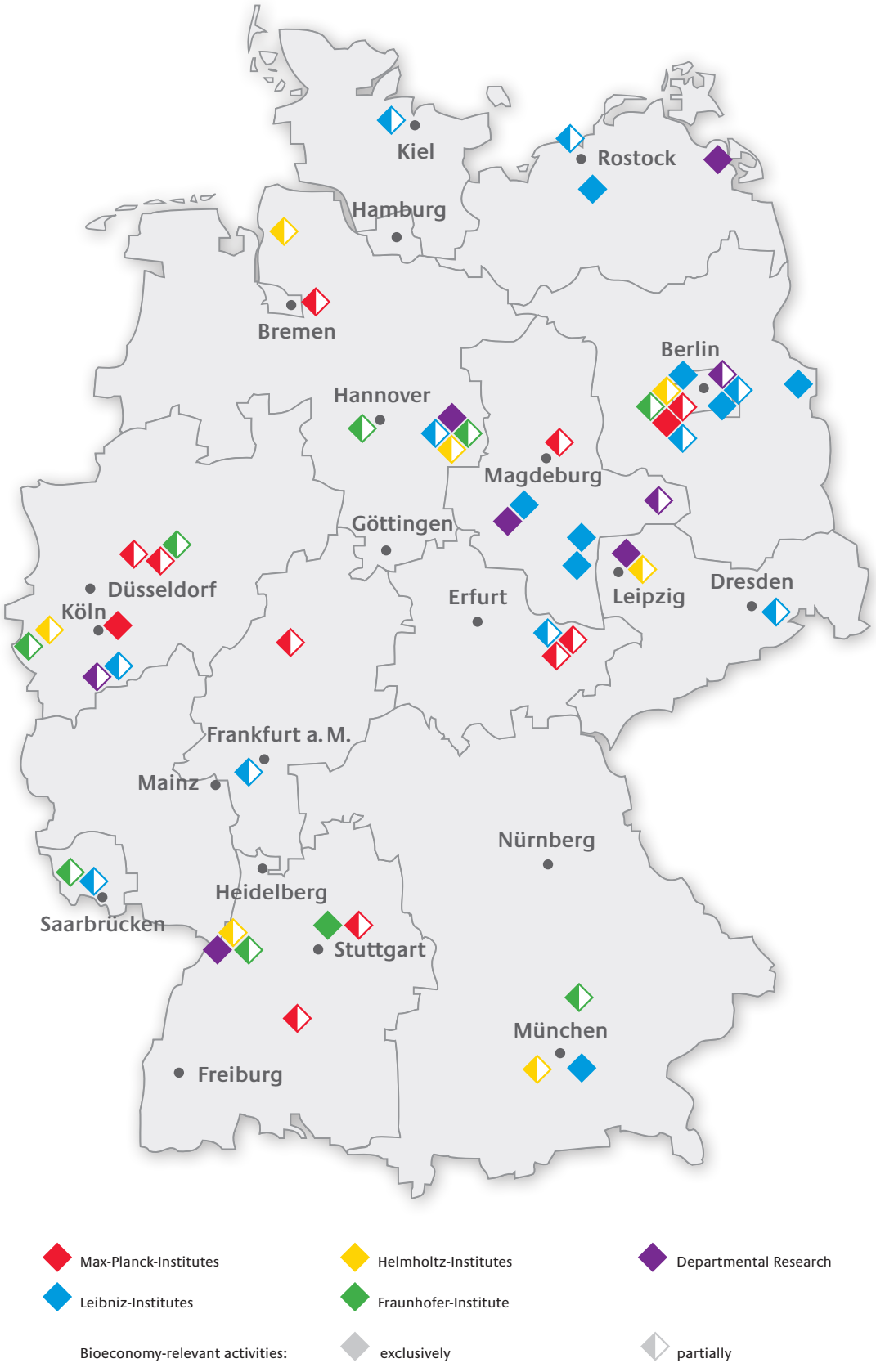


Figure 3: Federal Government-financed research facilities focusing on the bioeconomy

nationwide, the result in some cases is subcritical and poorly visible units. This is accompanied by an equally diverse setting of priorities. One reason for this is classification according to subjects and disciplines that are inherent in the scientific community. Despite an increasing willingness to collaborate, cooperation across disciplinary and institutional boundaries remains halting. It is therefore vital to bring together the relevant stakeholders in the research community in order to bundle ideas and capacities via networks and associations.

On an international level, the Federal Government has since 1971 supported the unique international network Consultative Group on International Agricultural Research (CGIAR). Support here focuses on research activities across a network of 15 research centres worldwide to increase food production while safeguarding natural resources. CGIAR also promotes the placement of German scientists in international centres. This improves ties between international agricultural research centres and German agricultural research, and makes specialised know-how from German agricultural research internationally available.

Innovation potentials

The provision of biological resources is achieved above all through agriculture, forestry, and fishery; these sectors therefore represent an important basis for the German bioeconomy. Germany also maintains a number of innovative young biotechnology companies, and is traditionally strong in the chemical and pharma industries, the energy economy, plant and machine engineering, as well as medium-sized seed companies and plant breeders – all of which are vital for the bioeconomy. Companies in these sectors are particularly dependent on bioeconomy-related innovations if they are to maintain and enhance international competitiveness. Not least, all of these sectors also provide impetus for growth both upstream and downstream, specifically the less research-intensive areas, such as the food, beverage, textile, and paper industries. In turn, these sectors fuel demand among other sectors. Germany finds itself in an outstanding starting position.

In many sectors of the economy it will nevertheless be necessary to place an even stronger focus on research and innovation in order to maintain a continuous supply of innovation advantages in global competition. As a result of their high flexibility as regards rapidly shifting demand patterns, small and medium-sized enterprises (SMEs) are in this respect particularly significant for a national economy. For example, biotechnology SMEs are the drivers of innovation in the bioeconomy. Through cooperations and networks with large companies and academic partners, they frequently introduce new technologies into traditional industries. Moreover, SMEs play a major role in employment policy, above all as the engine for regional economies.

A rapid and continuous transfer of technology from science to industry is of central importance for a dynamic development in the bioeconomy. However, to some extent, this remains too slow, as well as not adequately efficient. An effective approach in technology transfer is cooperation projects between science and industry, as well as direct spin-offs from the scientific environment. Alongside the relevant framework conditions, a prerequisite for a new founding boom is the strengthening of entrepreneurship in universities and other non-academic research facilities, and a general willingness to work with business.

Bioeconomy – potentials for growth and employment

According to estimates from the Bioeconomy Council, the bio-based economic sector in Europe currently generates annual turnover of about 1.7 billion euros, and employs around 22 million people.

In Germany, one in every ten jobs is related to the agriculture- and food industries. In agriculture, the around 1.25 million full or part-time workers in 370,000 companies produce goods worth around 40 billion euros every year. Furthermore, agriculture and forestry utilise over 82% of Germany's surface area, and thus have a significant determining effect on the appearance of our landscapes.

In 2009, renewable resources for energetic use and for use as an industrial raw material were grown on around two million hectares – nearly 17 percent of the arable land in Germany. In addition, the 11.1 million hectares of forest – accounting for around one third of the German land surface – provides wood for industry and energy supply. In the area of organic foodstuffs, Germany is the largest market in Europe with 5.8 billion euros of annual turnover.

Alongside jobs in the agriculture- and food economy, there is a growing number of jobs in industry, increasingly in labour-intensive sectors such as the chemical/pharma industries and the energy economy. Within the total of approximately 21.7 million tons of organic raw materials used in the chemical industry in 2008 were 2.7 million tonnes of renewable raw materials. This corresponds to around 13 percent.

At 69 percent, biomass continues to make the greatest contribution to end energy produced using renewable sources. About 90 percent of regenerative heat derives from biomass, above all wood. Biomass is currently the only renewable source in the fuel sector. In total, more than 100,000 people in the field of bioenergy production are active in the economy. At 11.4 billion euros, the bioenergy sector accounts for some 34 percent of turnover from renewable energies. However, the further development of internationally competitive forms of bioenergy is required, as Germany has to date been heavily dependent on imported fossil fuels: 97 percent of mineral oil, 83 percent of natural gas, and 61 percent of black coal.

Biotechnology counts as one of the most important triggers for bio-based innovation. Biopharmaceuticals, i.e. genetically engineered substances, already play a major role with a global turnover of almost 80 billion US dollars. Biotechnological processes and products are also an economic factor for industry and agriculture, particularly in larger chemicals and seeds companies. Biotechnology opens up opportunities for businesses to become more resource-friendly and efficient, and thus more sustainable, and to develop alternatives to petroleum-based raw materials.

The World Wide Fund For Nature (WWF) estimates that biotechnological production processes can save up to 2.5 billion tonnes of CO2 worldwide every year. The knowledge-based bioeconomy can thus combine economic prosperity with environmental compatibility.

Germany, with more than 500 biotechnology companies, is well placed in a European comparison. Added to this is a further 100 companies in which biotechnology makes up a part of business activities. Despite the financial and economic crisis, sales and employment figures are growing continuously among biotechnology companies in Germany. This very young sector currently generates about 2.2 billion euros per year. Moreover, around 30,000 highly skilled workers now work in commercial biotechnology in Germany.

Economic and founding dynamics also depend on the social and political framework. Legal requirements, for example, play a role in the protection of environment and health in the authorisation and utilisation of specific products, the availability of financing, or in the acceptance of new technologies among the public.

Need for action in research and innovation

The National Research Strategy BioEconomy 2030 serves to develop strengths in science and industry, and to compensate for weaknesses. Thereby, opportunities must be exploited for a knowledge-based bioeconomy – among other things for global food security and for biomass-based raw materials and energy supplies – and obstacles to innovation must be overcome (see Fig. 4).

Strength

- excellent and diverse research
- highly qualified personnel
- innovative companies

Opportunities

- increase in demand for sustainably-produced, high-quality foodstuffs
- limits in fossil and mineral supplies means demand increase for renewable raw materials for industrial and material-energy use
- changes in agriculture, small trade, in industry, and in the services sector
- conservation of the natural resource base

Weaknesses

- fragmented research landscape
- lack of incentives, readiness, and professional structures for technology and knowledge transfer
- low R&D expenditure in some sectors
- the diffusion of bio-based innovation in traditional sectors could be enhanced
- inadequate sources of financing for venture capital

Barriers

- technology transfer is too slow
- halting readiness as regards the necessary changes
- inadequate inter- and trans-disciplinary approach to holistic (systemic) solutions

Figure 4: SWOT analysis (strengths, weaknesses, opportunities, and threats)

In the scientific area and in industry, the strategy places an emphasis on individual initiative. Thereby, support provided by federal funds is both complementary and necessary, in as much as essential research projects are not sufficiently funded by any other body or are not being quickly pursued.

Excellent science, highly skilled professionals, and innovative companies are all traditional strengths in Germany upon which the bioeconomy can build. These must now be further developed. Strengthening technology transfer and permanently speeding up the application of scientific results will require a close integration of science and industry, alongside professional scientific management.

On the other hand, weaknesses such as a fragmented research landscape, low research intensity in some sectors, as well as barely existing professional structures for technology and knowledge transfer – and lack of incentives in this regard – must be compensated for. In particular, the diffusion of biobased technologies and processes in established industries is capable of further development – to speed up structural change towards international competitiveness, to develop new markets, and to meet new societal needs. The lack of capital of German companies and the underdevelopment of the venture and private equity market in Germany has an inhibiting effect on innovation.

The National Research Strategy BioEconomy 2030 is a component of the High-Tech Strategy; here, among other things, it provides vital impetus for the demand areas energy/climate and health/nutrition. The objective of the High-Tech Strategy from the Federal Government is to combine support for research, and the structuring of framework conditions. Against this backdrop, the implementation of the research strategy with the relevant federal programmes across a variety of policy areas (see Fig. 5) will be combined with technology-open measures to promote innovation, in particular for SMEs. This will create an innovation-friendly and sustainable

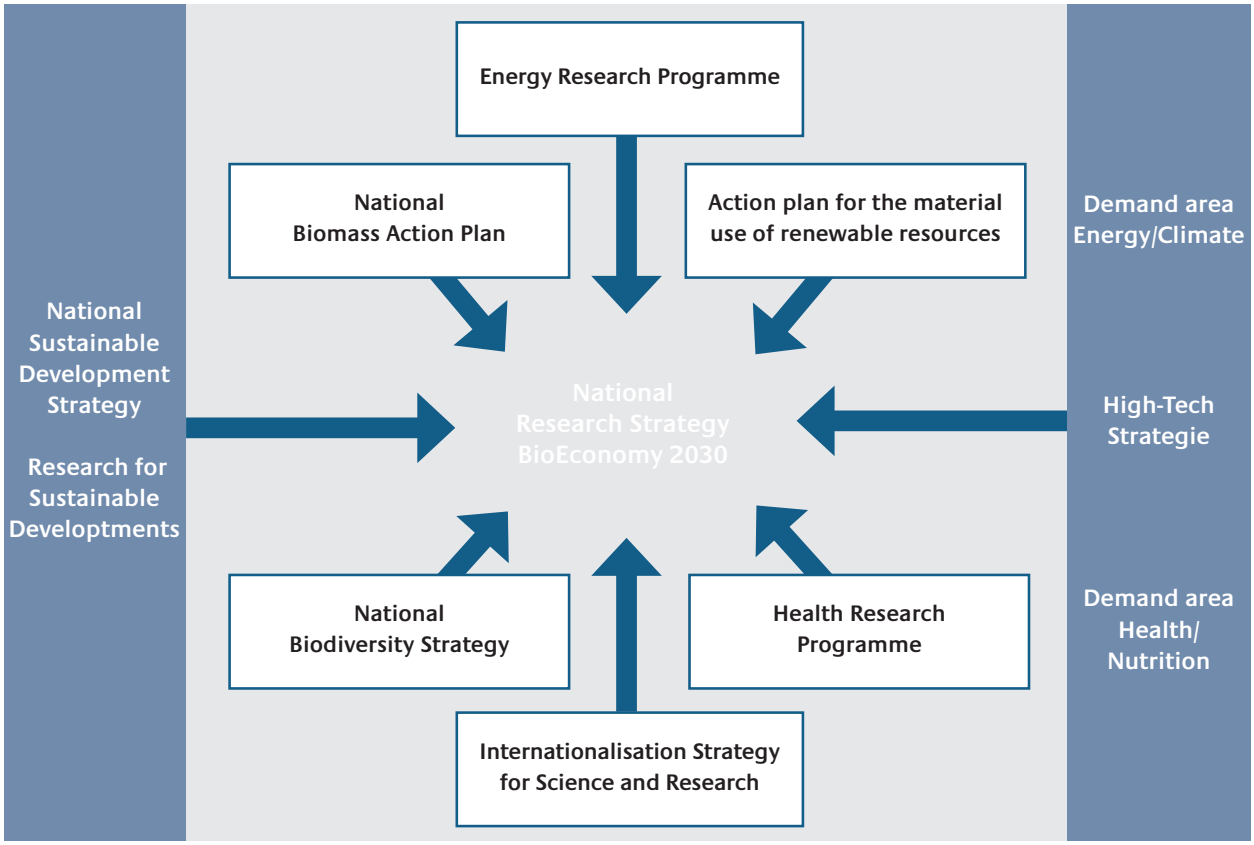


Figure 5: Integration of the National Research Strategy BioEconomy 2030 with relevant research-related Federal Government programmes

framework for the creation of a globally competitive bioeconomy. This demands that, in greatly differing policy areas and in an ongoing process, decisions must be evaluated with regard to their implications for research and innovation conditions, and adapted if required.

The changes in agriculture, small trade, industry, the service sector, and in society towards a biobased economy require readiness for change. Bringing this about and ensuring that the changes are successful requires not only the broad-mindedness of science and industry, but also acceptance among the public. The results anticipated within the context of this research strategy are likely to make a contribution in this regard. In addition, a strong willingness for change will be essential against a backdrop of international competition, for example from dynamically developing countries.

The opportunities presented by the knowledge-based bioeconomy are enormous. This is reflected in increasing demand and rapidly growing markets for products, processes and services in the relevant sectors. The described integration of innovation policy must be matched by incentives to expand the scientific basis, but also to translate scientific discoveries into new technologies, processes, products, and services, and towards eventual application. Synergies created through the integration of highly differing research disciplines can provide holistic (systemic) solutions for global challenges that take in entire value and process chains. Alongside the natural sciences, these also include economic- and social science skills. The necessity for these holistic approaches and the increasing international division of work in research, as well as the growing number of technologically competitive countries, also demand an internationally oriented research strategy.

3. Vision and Objectives for Biobased Economy

Supporting global nutrition, securing biomass-based raw materials and energy supplies, and protecting the climate and environment, all while strengthening Germany's international competitiveness, will be a major challenge. With the National Research Strategy BioEconomy 2030, the Federal Government is pursuing the vision of a sustainable biobased economy by 2030 that will be able to provide a wide range of healthy foodstuffs and high value products from renewable raw materials.

The biobased economy of the future will provide sustainably produced products, as well as an adequate and broad range of healthy foodstuffs of plant and animal origin. The knowledge-based bioeconomy takes biological processes and develops them technologically to make them more productive, and their utilisation more efficient and sustainable. Such innovative products and processes for agriculture and industry require a minimum of energy, conserve natural resources, prevent unwanted by-products, minimise emissions, do not adversely affect the ecosystem and biological diversity, and – as much as possible – return resulting products back into the natural cycle. The knowledge-based bioeconomy therefore represents a bridge between technology, the economy, and ecology.

Critical here is the further development of collaboration between academia and business, between partners from a broad range of countries and disciplines, and between different institutes, whereby the knowledge of one is enriched by the discoveries of the other. These collaborations are interfaces and sources of innovation. By 2030, aided by the research strategy, an understanding of biological systems and their sustainable utilisation will ensure a structural change in German industrial production, secured by scientific creativity in synergy with engineering ingenuity. Through innovative products and processes, the biobased economy will create new opportunities for economic growth and employment, also in traditional sectors.

This vision derives from the development of a free, dynamic and innovative knowledge society that knows how to think in complex contexts, and which can apply this knowledge to the benefit of future generations. Here, foresight-oriented, science-based framework conditions can create trust whilst leaving ample room for creativity and innovation. New technologies will be discussed without reservation and towards open outcomes, as well as responsibly applied. Thereby, no approach will be prematurely abandoned that could contribute to solving important future issues. In 2030, Germany will be a bioeconomy location that accommodates results from the life- and technological sciences with open-mindedness, curiosity and enthusiasm, and which understands and exploits the opportunities of (bio)technological progress and globalisation.

The country will attract creative minds from around the world, and will be a preferred cooperation partner. Furthermore, Germany will play an important role and take international responsibility in addressing global challenges such as global nutrition, biomass-based raw materials and energy supplies, as well as climate- and environmental protection. Not least, this also means supporting biobased innovations in other parts of the world.

The following strategic objectives derive from this vision of a biobased economy:

A) In international comparison, Germany aspires to become a dynamic research and innovation centre for biobased products, energy, processes and services. The competitiveness of German industry will be strengthened by the development of novel products, processes, and services from renewable resources. Germany aims to assume a leading international position among comparable developed countries as regards the number of employees and companies.

B) At the same time, research results can make important contributions to global responsibilities, especially in the field of global nutrition, and to climate-, resource- and environmental protection with the use of biological resources. Thereby, equally high importance is attached to a healthy diet. The Federal Government strives to take a leading role in research and development into solutions for these global challenges.

Above all, because the vision of a natural cycle-oriented biobased economy is yet to clear a number of important hurdles, it is essential to set the right course today. The fields of action described in the following serve as strategic markers for science and industry, towards the establishment – in dialogue with society – of a growth-oriented and sustainable economic structure. Thereby, the emphasis is on the ingenuity, innovation, and initiative of individual researchers, and on targeted funding to these ends.

4. Fields of Action

The vision of a biobased economy demands a set of measures that is able to exploit a range of different competencies – a result of the variety of involved raw materials, processes, products, techniques and applications. The following fields of action form the research policy framework along the value and process chains. These include agricultural production, utilisation for nutrition, industrial products and processes, bioenergy and related services.

The individual fields of action are associated with major social, economic, and scientific challenges, each of which goes far beyond the boundaries of any single scientific area or company, or even any single sector. The underlying large-scale research issues provide incentives for interdisciplinary scientific work, and are attractive for business. The eventual solutions have the potential to improve quality of life. However, the establishment of a knowledge-based bioeconomy can only succeed if the fields of action are implemented with target-oriented ('top-down') approach. Thereby, there must be enough freedom for unusual approaches and visionary ideas, so that individuals perceive creative initiative and responsibility in the sense of a 'bottom-up' approach. The National Research Strategy BioEconomy 2030 defines the programmatic framework for the coming years. The fields of action and the resulting goals and measures provide a foundation that is nevertheless variable. The research strategy defines the interdepartmental priority areas for research promotion for years to come. Adaptations to current developments will also be incorporated over the duration of the strategy.

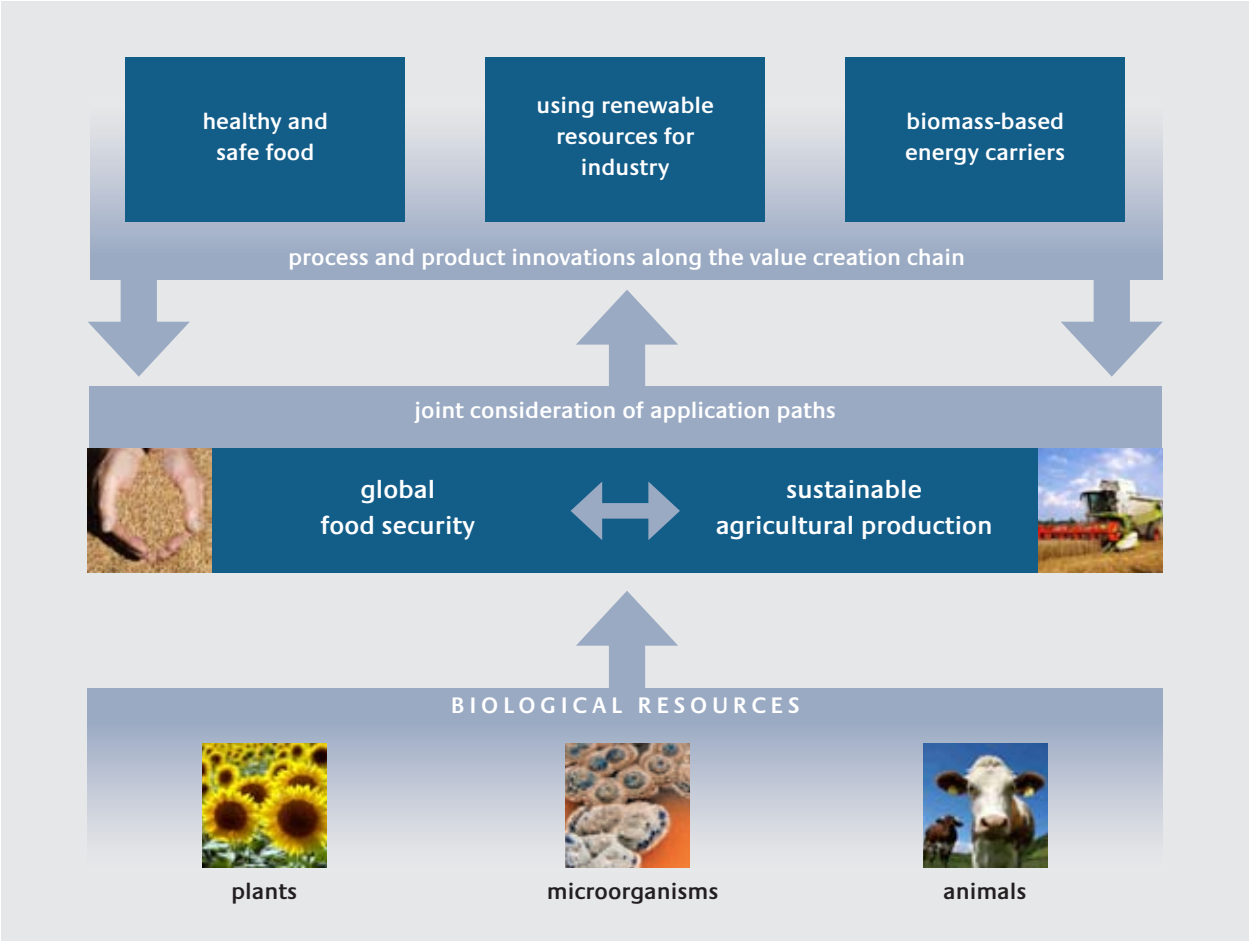


Figure 6: Interrelationships between the fields of action

Holistic implementation for fields of action

The fields of action must not be considered in isolation. This is to avoid potentially conflicting aims, or so that they can be weighed against each other. In a limited agricultural area, there is a tension between an adequate supply of foodstuffs on the one hand, and biobased, industrially utilised products and bioenergy on the other.

The production of foodstuffs, and biobased, industrially applied products and bioenergy should not put into question the objectives of climate protection and resource conservation, protection of biodiversity, and other goals of environmental protection. To abrogate or at the very least mitigate these trade-offs as much as possible, holistic research approaches are encessary that follow the principles of sustainable development, and which take equal consideration of economic, environmental and social aspects.

Five priority fields of action are identified in the research strategy: global food security, sustainable agricultural production, healthy and safe foods, the industrial application of renewable resources, and the development of biomass-based energy sources. The following guidelines should be noted in the implementation of these fields of action (see also Fig. 6):

Guidelines

- **Sustainable provision for everyone:** The impact on humans, the environment, and nature must be considered in the provision of nutrition, renewable raw materials, and bioenergy. Resource-, nature-, environment- and climate-conserving, as well as animal-friendly and ethically acceptable production must also remain as a standard of evaluation for a bio-based economy. Alongside the environmental and social aspects, economic factors are also crucial for sustainability. In particular, research projects working towards the utilisation of biomass with a conserving effect on ecosystems, and which are internationally competitive, will be supported.

- **Collective consideration of application paths:** To identify competitors, and to set priorities at global, national, and regional levels, the biomass application paths (food, as industrial raw material, energetic use) must be considered in terms of their reciprocal effects. Thereby, food security always takes the highest priority. Furthermore, products with higher added value potential are preferred. Where possible and appropriate, a cascading and coupling application of biomass is desirable, for example as applied in biorefineries. Potential competition in application paths can be eased – and innovation potential tapped – through the intelligent connection of value- and process chains.

- **Consideration of the entire value creation chain:** The fields of action must be pursued with system-oriented research approaches that take the entire value chain into account. This means closely related research topics that cover the individual aspects of agricultural and industrial production systems within the bioeconomy, and which are appropriately integrated through research funding. It is hoped to create synergies with funding through the bundling of individual research topics. Because the fields of action are influenced by a variety of political, economic and social factors, it is paramount that the technological- and natural sciences, and the economic- and social sciences cooperate more closely.

These guidelines are the compass for the organisation of individual measures. The measures that span different fields of action will also be considered as direction setting, to make efficient use of funding, to create synergies between fields of action, and ultimately to resolve the conflicting aims mentioned above.

4.1 Securing global nutrition

To ensure nutrition for 9.5 billion people in 2050 – with changed consumer demands – food production must be increased significantly and the availability of foodstuffs improved for vulnerable population groups. The arable land needed for production is limited, and in many areas is above all qualitively and quantitatively affected by soil degradation. In the long term, agriculture will also be affected to a significant extent by the effects of climate change, and will have to cope with soil deterioration, water shortages and floods, and the spread of plant pests. As regards raw materials, rising prices with increased volatility is anticipated. Determined engagement is critical – above all in agricultural research and in the biosciences – to tackle the challenge of global food security. This commitment must be strengthened both at a national and international level. Given the number of years that typically elapse from the start of a research project to the transfer of the results into agricultural practice, this is a pressing issue.

Research needs and objectives

To increase agricultural production in accordance with regional requirements, research must be applied on different levels.

Plant breeding is above all focused on the expansion of the productive potential of crops, on stabilising yields through improved resistance to pathogens, and on enhanced tolerance. Among others, this takes the form of tolerance to heat, drought, cold, and salinity, as well as suitability for sustainable forms of farming. This requires that the causes and effects of abiotic and biotic stress factors (including investigations into plant diseases) – and the corresponding plant reaction mechanisms – must be better understood in order to make them usable for plant breeding and cultivation. In addition, it will be necessary to preserve locally adapted forms whilst also broadening the range of cultivated plants, also taking into account plants and cultivation conditions that are of high relevance for developing countries.

Particularly relevant in developing countries are new approaches to regionally- and locally-adapted land management, for example and in particular research in the area of organic farming on maintaining soil fertility and achieving stable yields with low input of resources. This necessitates international cooperation that also integrates local competencies through partnerships. Also significant are research approaches for the optimisation of vital nutrients that can prevent or even eliminate malnutrition in humans and animals. Overall, the development of sufficient quantities of robust plants must be ensured, as well as a cultivated yield potential that makes as efficient use as possible of scarce resources (water, nutrients). Accompanying this, the social implications and scenarios as regards holistic (systemic) approaches must be given proper analysis, making use of the economic and social sciences (see Chapter 4.2).

A combination of approaches in breeding, plant biotechnology, and other disciplines will be necessary to provide technical solutions for these requirements. This includes not only methods such as genome analysis – including epigenetic studies, proteomic- and metabolomic research, bioinformatics, and the system-biological integration of these approaches – but also the responsible application of genetic engineering.

In turn, quantitative and automated analysis tools and optimised sensor technologies enable the systematic clarification of interrelationships between environmental factors and plant traits (phenotypes) in their spatial and temporal variability. In combination with genetic, molecular-biological, and (eco-)physiological approaches, these provide an important basis for speeding up the breeding of adapted crop varieties and improving production conditions.

Innovations are also required in crop production, for example with regard to region-specific climate changes, but also with regard to the application of new varieties and new agricultural techniques.

The availability of appropriate genetic resources represents the foundation of future breeding – in plants as well as animals. Genetic diversity, above all of agricultural animals and plants (agricultural biodiversity), is thus an important resource for the bioeconomy. For their proper

Funding example: Increasing the fitness of rice in saline soils

After wheat, rice is one of the most important cereal crops, and is a staple food for much of the world's population. Cultivation often takes place in poorer regions where the need for rice is especially high, but where saline soils cause difficult conditions, meaning that farmers produce only low yields. German researchers from the Max Planck Society, with support from the Federal Ministry for Economic Cooperation and Development (BMZ), and under the coordination of the International Rice Research Institute (IRRI), are working on the development of rice varieties that exhibit high fitness against stress factors, and which can withstand salty soils.

application it will be necessary to conduct a thorough stocktaking. This can be accomplished, for example, by compiling genomic data in metagenomic databases, which are used to analyse the genomes of entire populations. The same applies for the identification of interrelationships between phenotypic traits and their genetic causes. An important element in this process is physical inventories of genetic material from agricultural crops and livestock, as well as from closely related wild species. The collection, processing, cataloguing, preservation, and provision of genetic materials via gene banks for breeding and research is a necessary prerequisite for the utilisation of genetic diversity.

Advances in agricultural technology – e.g. satellite-guided navigation and mapping systems for tractors (precision farming), fertiliser-, seed- and harvesting equipment, and innovative irrigation techniques and water treatment technologies – must be integrated with plant-based innovations. Furthermore, the often significant post-harvest losses must be reduced. The technical as well as logistical approaches along the entire value and process chains should be further investigated.

To meet to growing global demand for foodstuffs of animal origin, considerable research efforts and the development of new approaches are also essential to achieve increases in productivity. This should be achieved in harmony with humans and animals, nature and the environment. One example could be provided by vegetable proteins, which have a similar composition to animal proteins.

Further important foundations are holistic (systemic) optimisation approaches for feedstuffs, investigations of genetic, epigenetic and physiological characteristics for performance improvements, animal health measures, and more efficient conversion of feed in animal production, in line

with animal welfare. On this basis it will be possible to develop improved and new approaches to breeding, reproduction, animal health management, animal husbandry, as well as fish breeding.

Independently, the breeding of animals that are more resistant to diseases can likewise result in improvements in efficiency and output. These research efforts must be complemented by investigations into the reciprocal effects of animal production with the protection rights of humans, animals, environment, and nature. An anticipated outcome of climate change is more frequent and more intense weather extremes, and a long-term rise in temperature. Consequently, farmers will require assistance in cultivation planning, which itself calls for reliable short-, medium- and longer-term forecast models on local, regional and global levels, as well as studies into the interactions of the climate system and the biosphere.

Measures

- Highly significant is research into the breeding of agricultural crops, among others using modern methods of plant biotechnology. Thereby, basic research projects and the transfer of knowledge into breeding practice should be supported.
- Research promotion activities focused specifically on the requirements and problems of developing countries will be driven forward (the sustainability issues named in Chapter 4.2 should be considered here). Here, approaches for regionally- and locally-adapted land management must be researched, or new approaches developed, among other things including the participation of farmers and scientists in the respective locations.
- Suitable phenotyping technologies based on scientific concepts for the investigation of environmental influences on plant traits must be put into place.
- Modern approaches plant cultivation and agricultural technology are needed to achieve sustainable gains in efficiency and productivity. Likewise, post-harvest losses can be reduced through new technical and logistical solutions.
- New, efficient, animal-friendly and consumer-accepted procedures must be developed for the breeding of healthy, adaptable and high-performance animals. Here, feed efficiency, stress tolerance (heat, etc.), as well as reduced greenhouse gas- and air pollutant emissions, must also be taken into consideration.
- There is a need for research in the development of regionally adapted climate prediction models, as well as investigations into the interaction between the climate and biosphere.
- Investigations into agricultural biodiversity in agricultural organisms and close wild relatives to uncover potentially important characteristics, including the relationship between phenotypic trait expression and its genetic basis, must be strengthened.

Implementation of measures will proceed along the following guidelines:

- Sustainable provision for everyone (see also Chapter 4.2 for the ecological, social and economic dimensions)
- Collective consideration of application paths (see Chapter 4.3 to 4.5)
- Consideration of the entire value creation chain (among other things through bundling of individual fields of research, from breeding to post-harvest loss prevention)

4.2 Ensuring sustainable agricultural production

Natural resources are the means of production for the bioeconomy, and thus their sustainable management is in the highest interest. The required increase in agricultural production[1] must be achieved by means of efficient and resource-friendly management. The implementation of this must correspond to the challenges posed by climate change, environmental and climate protection, raw material supplies, water availability, and biodiversity protection. This also demands research efforts that take into account all the factors of agricultural production systems – for terrestrial as well as aquatic biomass production – according to specific location requirements, and allowing for aspects of sustainability.

1 Here, agricultural production refers to the entire area of agriculture, forestry, fisheries, and aquaculture. This applies regardless of the respective production processes.

Research needs and objectives

The production factors 'land' and 'water' occupy a special position because they are not increasable, and because regional distribution is predetermined. Important nutrients such as phosphorus and potassium are only limitedly available in the concentrated deposits in use today. Deterioration or shortage of these production factors in regional and global scales must be confronted with environmentally sound protection-, utilisation- and reclamation concepts. This requires research into an improved understanding of the complex agricultural production system, and for concrete solutions for nutrient recycling or for nutrient optimisation.

Alongside improved farming practices, plants optimised for sustainability are of particular importance in the production of plant-based biomass (see Chapter 4.1). Plant protection is nevertheless an integral component of agricultural production, and of protection of stocks. Above all, integrated plant protection methods should be further developed in order to mitigate related unavoidable risks to humans, animals, and the natural environment. Included here, alongside biological and technical plant protection measures, is the technical further development of plant protection equipment and advanced procedures for the economisation of plant protection products. For example, precision farming, sensor-based controls, robotics, as well as prevention of introduction and spread of harmful organisms. All of these aspects are gaining in significance in the context of climate change and expanding international trade.

Because genetic engineering is being increasingly applied around the world, a responsible handling of genetically modified plants is crucial to ensure sustainable agricultural production. To these ends, biological safety research is indispensable. This must be able to keep pace with the dynamic development of genetic engineering. Furthermore, the social and economic disciplines can make an important contribution to questions of sustainability. The coexistence of agricultural production systems is likewise an area to be investigated, in order to bring into line the legitimate interests of society and farmers, conducting either traditional agriculture or the cultivation of genetically modified plants.

In the context of the bioeconomy, it is crucial to retain ecosystem services. The concept of sustainable land management integrates biodiversity conservation with soil and water protection. Sustainable land management covers a variety of issues on the interaction between production systems and ecosystem services. These include correlations between land use/ecosystem services/climate change, analyses of source and sink functions of systems used in agriculture as regards greenhouse gases, as well as investigations into the socio-economic framework conditions. To relate this to knowledge- and implementation-oriented research requires, in addition to a high degree of interdisciplinarity, also transdisciplinarity through the incorporation of decision-makers and relevant stakeholders.

There is often a tension between the use of biological resources and the conservation of biological diversity (biodiversity). Solutions to this will require considerable research work, among other things including the determination of an optimal level of biodiversity in agricultural production systems, the quantification of biological diversity with regard to ecosystem services, and the development of procedures for future-oriented biodiversity management.

An integrated approach will also be pursued in agricultural and forestry research, which increasingly places climate and environmental issues in the foreground in the context of management/husbandry and value creation. This can contribute, for example, to the development of energy-efficient, soil-friendly and low-carbon agricultural production- and processing systems, and to advancing the sustainable use of pesticides and fertilisers. Research into organic farming should be further developed in this context.

With regard to the spectrum of cultivated plants, there is also a need for research that combines diversity and performance. Here, essentially two directions of development can be brought forward: 1. All properties that influence plant growth and yield formation. 2. The quality properties of the product. This is because properties that are present from the beginning facilitate all subsequent processing steps, and improve efficiency (see also Chapter 4.3).

Further research is required for the production of agricultural animals and in aquaculture. Necessary for climate-, nature-, environment-, resource-conserving, animal-friendly as well as efficient production, are innovative concepts for animal breeding, -husbandry and -nutrition (see also Chapter 4.1) – among other things with a targeted reduction in emissions – as well as analyses and scientifically-founded improvement strategies for animal welfare. Furthermore, the development of animal-friendly and low emission housing and transport systems contributes to environmental- and animal welfare protection, as well as industrial safety. The entry of veterinary drug residues into the environment should also be given consideration.

Agricultural-technical innovations will have to be driven forward to be able to realise these sustainable concepts (see also Chapter 4.1). This is also to enable reductions in emissions of greenhouse gases and environmental pollution along all the stages of agricultural production, and to improve resource- and energy efficiency. The economic and social implications of agricultural production will likewise be investigated and action strategies derived, e.g. analyses of competing uses, as well as the development of control systems for more efficient societal use of scarce land area.

Funding example: Environmentally friendly aquacultures through integrated bio-filters

The consumption of fish is increasing worldwide. To satisfy need, in the future ever more fish will be bred in aquacultures. To make this fish production more environmentally friendly, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has supported the development of a new method that integrates recirculation systems into fish farms. Extremely fine biomembranes filter the water and remove bacteria, viruses, and residues of feed additives and therapeutics. In the meantime, a number of German manufacturers offer membrane filtration across Europe and in Asia as an export technology.

Measures

- Internationally oriented concepts for the protection of climate, nature, soil, water, air and important nutrients must be researched.
- The integration of agricultural crops with novel characteristics and cultivation techniques can be further improved (to be implemented together with the measures described in Chapter 4.1).
- Integrated pest management techniques should be optimised or newly developed in the light of scientific knowledge.
- Biological safety research and co-existence research should be continued.
- Methods for the quantification of biological diversity with regard to related ecosystem services, and towards the development of future-oriented biodiversity management on a national and international level, are required.
- Inter-and transdisciplinary research for sustainable land management should be expanded.
- Research into organic and environmentally friendly farming must be further developed (also due to relevance for developing countries; to be implemented in the context of measures described in Chapter 4.1).
- Research and innovation into breeding, feeding, housing, and into the health of livestock (including bees) and fish supports the sustainability objectives of the bioeconomy (to be implemented together with the measures described in Chapter 4.1).
- Innovations in agricultural technology along the entire agricultural value chain should be advanced (to be implemented together with the measures described in 4.1).
- Investigations are required into the optimisation of the sustainability effects of agricultural production systems, and the efficient use of resources on national and international scales.
- Social-, economic-, policy- and planning research to strengthen institutions in rural areas should be supported.

Implementation of measures will proceed along the following guidelines:

- Sustainable provision for everyone (ecological, social, and economic dimensions)
- Collective consideration of application paths (see Chapter 4.3 to 4.5)
- Consideration of the entire value creation chain (among other things through the bundling of individual research topics, from production factors up to products)

4.3 Producing healthy and safe foods

Consumers expect healthy, high-quality, safe and at the same time inexpensive foods. Demographic change and changing lifestyles and circumstances are altering dietary behaviour. A healthy diet presupposes a corresponding availability of food that meets individual requirements.

Research needs and objectives

Prevention and positive influence over diet-related diseases, including among others obesity, diabetes, allergies, heart and circulatory diseases, as well as the positive influence of aging processes through diet, represent important social and scientific challenges. Research topics on the effectiveness of foodstuffs and their components in the human body will be taken up by the Federal Government's Health Research Framework Programme. These should provide a basis for recommendations concerning healthaware dietary habits. Here, the objective of the National Research Strategy BioEconomy 2030 is to support complementary consumer-oriented product- and process innovation for healthy, high-quality, palatable, inexpensive, and safe foodstuffs. Because this will have to build on the above-named research results, there should be integration with comprehensive support initiatives from the bioeconomy and health research. For this reason, food-specific innovation chains should be considered in their entirety.

The nutritional value and processing quality of vegetable and animal starting products can already be optimised in agricultural production (see also Chapters 4.1 and 4.2). Furthermore, the effects of production- and environmental conditions on food quality should be clarified. The health effects, quality, and safety of foodstuffs can be optimised according to specific need profiles, e.g. the development of suitable products for allergy ufferer. This is thanks to innovative concepts and methods, that can specifically enrich or add positively acting substances, to agricultural products, or reduce/eliminate negatively acting substances, such as allergens.

Ecologically produced foods contain almost no residues of chemical-synthetic fertilisers and pesticides. Research approaches for the prevention or reduction of residues of chemical-synthetic fertilisers and pesticides also in normal agricultural production, should be expanded. In particular in the field of food processing, gentle approaches, with further reductions in the use of additives and processing auxiliaries, should generally be further developed. This can also reduce allergenic potential.

Healthy foodstuffs of animal origin are possible only with healthy animals. Many factors – such as the increasing production of animal foodstuffs, global trade, and also climate change – have an influence on animal diseases spreading more frequently and quickly. Besides the effects on animal health and the economic damage to agriculture, specific animal diseases are also associated with a risk of transmission to humans.

There is therefore a high need for research into the clarification of the causes of epizootic and animal diseases, as well as for measures for their prevention and control. Epidemiological studies are of high importance in order to engage with and comprehend disease occurrences more quickly – in terms of both time and spread – as well as for improved prediction capabilities, thus aiding control and prevention. Furthermore, application-oriented research work for quick, sensitive and specific diagnostics, as well as developments for innovative vaccines and veterinary drugs, must be driven forward. In parallel, strategies should be developed to minimise the use of veterinary drugs, and for their careful management. Nevertheless, the future sustainable production of animal foodstuffs will come hand in hand with other animal health challenges. New concepts for animal hygiene measure, and for increasing resistance to infection through modern breeding methods, represent further research objectives (see also Chapter 4.2).

Funding example: Biological baking agents for chewy bread

As a form of adhesive, proteins in baking batter give dough firmness and stability. However, these batters also always contain the substance glutathione, which will eventually cause the dough to go soft. This process can to date only be suppressed with great difficulty. Enzymes, however, offer a more elegant solution. The biotech company Stern-Enzym has been working on this problem within the BioIndustry 2021 initiative, which is funded by the Federal Ministry of Education and Research (BMBF). In the meantime, suitable enzymes as useful baking agents that deactivate the glutathione have been found. Now the task is to make these biotechnological processes available on a larger scale for the baking industry.

Funding example: Finding molecules with an intense salty flavour

A pinch of salt can give food flavour, but too much is damaging to health. Researchers at the German Institute of Human Nutrition, working in cooperation with the flavouring manufacturer Symrise, are therefore attempting to track down molecules that allow a little salt to taste like a lot. With the support of the Federal Ministry of Education and Research (BMBF), they are analysing specific amplifier substances and their effects on human taste receptors. The salt-reinforcing candidates identified in this process must be taste-neutral, safe, and inexpensive to produce. The end result – so the assumption goes – won't be a single substance for all application areas, but numerous substances that can be used selectively.

Another important issue is the verification of the safety and quality of foodstuffs of animal and plant origin. Required here are innovations for analytics, monitoring and above all prevention measures, including quality- and risk management systems. New technologies and methods, for example from nano- and biotechnology, and the development of IT-based traceability systems, can improve hygienic quality and safety, as well as shelf life of foodstuffs. Innovation potential is also seen in process improvements that make optimal use of substance flows – including bioprocess technology – for the handling and processing of foodstuffs.

Here, innovative solutions are required not only to improve conventional preservation methods influencing freshness, naturalness, and nutritional value, but above all to improve the sustainability and efficiency of production processes. Moreover, the growing demand for convenience products, and increasing away-from-home consumption, require efficient and flexible distribution channels and generally optimised processes along the value creation chain (Food Supply Chain Management). There is hence a need for research that is both of a technical as well as organisational nature. This will lead to innovations, for example in the packaging industry, in the transportation and logistics industries, in trade, and in food-related service sectors. Moreover, it is important to continuously observe need profiles and consumer behaviour in accompanying studies, and for these results to be used to align research questions. Alongside benefits to consumers, innovative products, processes, and services provide opportunities for the German food industry in dynamically expanding markets. For this reason, the predominantly medium-sized companies that conduct own research activities only to a limited extent should enter into cooperations with the scientific community as early as possible and to a greater extent.

Measures

- The development of health-promoting foods is called for (to be implemented together with the measures described in 4.1 and 4.2).
- To improve food security, the inter-relationships between environmental conditions and production techniques in animals and plants should be further clarified and optimised.
- Gentle and conserving methods for organic and conventional food processing are in need of further development.
- Animal health research should be supported alongside the development of appropriate measures for prevention, control and treatment, among other things through studies into causes, spread and disease processes.
- For food safety, there is a need for high-performance analytics, and monitoring- and prevention measures, including quality and risk management systems.
- The development of sustainable and quality-retaining food technologies is required.
- Technical and organisational innovations for the optimisation of processes along the food production chain should be supported. Of particular importance is the development of effective and efficient certification systems for social and ecological standards.

Implementation of measures will proceed along the following guidelines:

- Sustainable provision for everyone (see also Chapter 4.2 for the ecological, social and economic dimensions)
- Collective consideration of application paths (together with Chapter 4.4 to 4.5)
- Consideration of the entire value creation chain (among other things through the bundling of individual research topics, from agricultural production to trade)

4.4 Using renewable resources for industry

Biobased products, which combine biotechnical, chemical, thermal, or mechanical methods in their manufacturing process, not only help protect nature, the environment, and the climate, but also enable greater independence from fossil raw materials. Furthermore, they make a significant contribution to the structural change from a petroleum-based to a biobased industry with related opportunities for growth and employment. Industrial biotechnology, also known as white biotechnology, is an important driving force in this transition. This field of activity is given high priority in the Federal Government.

Research needs and objectives

In the changeover from industrial, petroleum-based raw material supplies, renewable materials, as a result of their wide variety of ingredients, provide numerous opportunities for innovative applications in medicine, industry, agriculture, and for the environment (see Fig. 7). Furthermore, biomass can also already be modified for subsequent processing in the development process, e.g. through plant selection, cultivation methods, or breeding using modern methods of biotechnology (see also Chapter 4.1). Because of the inherent ingredients, their rapid growth, as well as the high degree of efficiency for the plant world, algae is garnering increasing interest as a source of raw materials. Likewise, wood represents a large biomass reservoir for traditional application in the construction, paper and pulp industries, as well as for sustainable husbandry as a renewable source of raw materials.

In the future, the various biomass raw materials can be further processed into high-quality products, among other things through cascading and coupling. In analogy to petrochemical refineries, the term biorefinery is used when all the components of various plants and/or waste, as well as residual materials, are used to as great an extent as possible (zero waste). For example, in the production of food and feed products, chemicals, fuels, electricity, and heat. There are many research topics to be worked through towards the concept of biorefineries, for example on the decomposition, processing, and conversion of biomass, in particular of wood (lignocellulose), and on product purification. All of these must be incorporated in a project plan (roadmap) for biorefinery development.

For the application of biomass as industrial raw material, previously unused microorganisms and molecularly optimised production systems open up as-yet untapped opportunities with regard to substrate spectrum, product variety, and production efficiency. Greatly promising here is the combination of concepts and methods from the biological sciences – e.g. genome research, biocatalysis, systems- and synthetic biology – with chemical process technology. The expansion of these competencies provides opportunities both for start-ups and for the expansion of technology leadership in the light of global competition. For wider diffusion in traditional industry sectors, it will be vital to be able to identify high-quality bio-based platform molecules that can be modularly combined and integrated into product trees.

Competitive bio-based, industrial raw material products are a substitute not only for conventional petroleum-based products. They frequently also represent true product innovation with highly specific customer benefits, e.g. biodegradable plastics, and enable significant improvements in production efficiency. With its high growth and employment potential for the bioeconomy location Germany, products of industrial biotechnology, or so-called 'white' biotechnology, are gaining in economic importance. These include, among others, basic and fine chemicals, pharmaceutical products, food additives, detergents and cleaning agents, bio-based plastics, textile products, and cosmetics.

Biopharmaceuticals represent an economically important sector among the products from the bioeconomy. In health research programmes the focus is on, among others, proof of efficacy in patients, whereas here, production processes are in the foreground. As these process developments are closely tied to clinical development, broad support initiatives should be used to closely integrate topics in the bioeconomy with topics in health research.

Funding example: Manufacturing cosmetics with yeasts

The majority of upmarket skin creams contain so-called ceramides. These fatty substances are an important component of human skin, and ensure that it does not dry out. Although ceramides are sought after as cosmetic additives, the current means of production are complex and expensive. A research group headed by the company Evonik is currently working on modifying a yeast to produce an equally suitable ceramide preform. The BMBF-funded project is being conducted under the umbrella off the CLIB2021 cluster, composed of 15 research facilities, seven large, and 26 small and medium-sized enterprises.

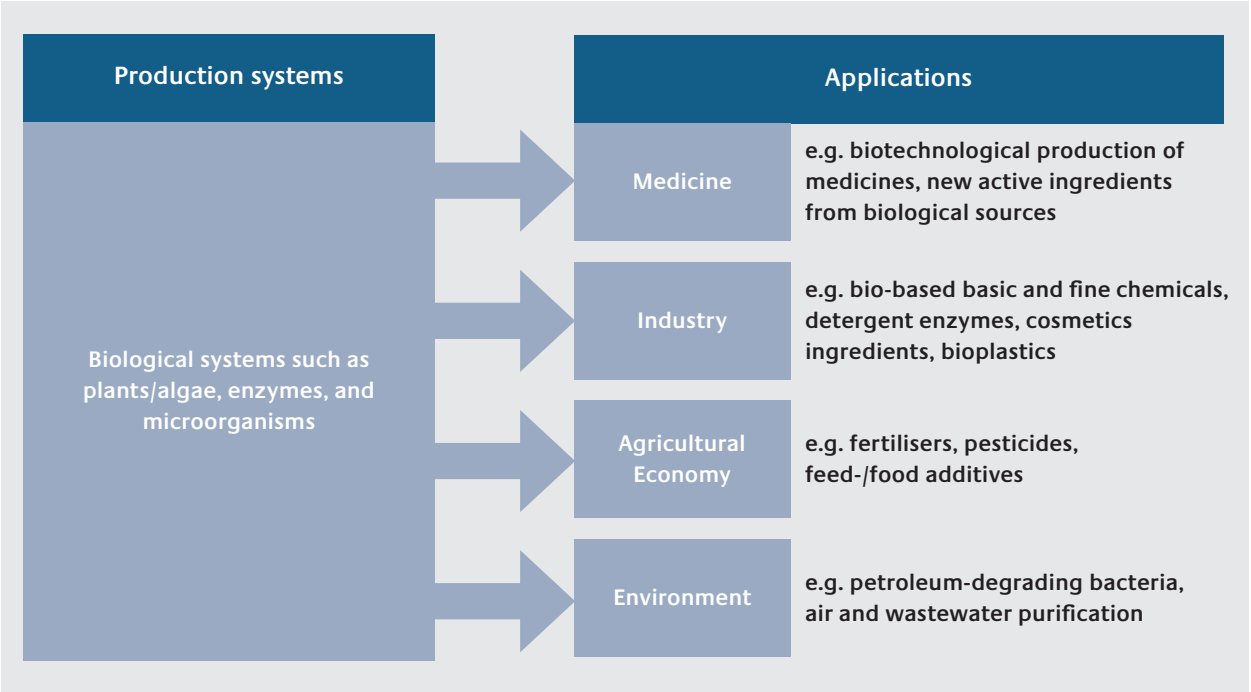


Figure 7: Biological systems for material-industrial utilisation

Numerous pharmaceutical proteins, vaccines, and diagnostic agents are manufactured, among other techniques, using bacteria, fungi, and mammalian cell cultures. In the future, new forms of production systems will be used, i.e. plant bioreactors, thereby opening up market opportunities for technology providers. Many active ingredients will also continue to be found through systematic researching of terrestrial and marine species (bioprospecting). Innovative processes for the biotechnological production of these complex active ingredients are vital, to take advantage of and maintain the rich diversity of natural resources.

The next generation of biotechnological procedures includes miniaturised, standardised, and – in a long-term perspective – possibly also cell-free production systems, which promise to be energy efficient and provide high space-time yields. Their development will benefit from advances in nanotechnology, the computer sciences, and the materials- and engineering sciences, and will be accelerated by the dynamic development of systems biology and synthetic biology. To develop the necessary platform technologies, these competencies must be joined together in in-

Funding example: Making the production of biotech drugs more effective

Antibodies are proteins that can specifically bind to other molecules, and influence – as well as turn off – their function. For this reason, they are frequently used as medicines. Production of these antibody molecules takes place in genetically modified bacteria or mammalian cells. However, they require isolation in extremely high purity, and with highest possible yield. This purification process is currently not highly efficient. A network funded by the Federal Ministry of Education and Research (BMBF) under the coordination of Biberach University together with the University of Karlsruhe, as well as the companies Boehringer Ingelheim and Rentschler, is now working on a technique known as protein crystallization that has previously only been used in research. The end result will hopefully be a purification method for the industrial production of medicines.

terdisciplinary project teams. This will have to take place as soon and as efficiently as possible, and in the context of a strategy process. Pilot- and demonstration facilities should also be established so that the next generation of production processes is able to demonstrate its practical application.

Sustainability considerations should be further developed throughout the lifecycle in order to optimise the positive environmental and climate effects of bio-based, industrially applied products or processes. Biotechnology can make a direct contribution to environmental protection through processes that biodegrade contaminants (wastewater treatment, bioremediation). Further research into the environmental and health effects of these products should be supported.

Innovative network structures along the process and value chains are required to take commercial advantage of technological knowledge, and to guide the transformation process towards a bioeconomy. This will involve strategic alliances between research facilities, manufacturers and user companies, as well as associated institutions, among others from finance. Included here are exceptional partnerships between companies at different positions along the value creation chain, or from very different sectors, e.g. cooperations between companies from biotechnology and from automotive or energy sectors. In such a way, experience of biological processes that are already firmly established in some areas of the economy (e.g. pharma industry), can be transferred to other – also unusual – application areas.

Funding example:
Innovative SME – From automotive supplier to biotechnology expert

Many innovations emerge from medium-sized companies, especially at the interface between different industries. For example, Vulkan Technic Maschinen-Konstruktions GmbH is known above all as an automotive supplier. Today, the owner-operated medium-sized company also manufactures equipment for customers in the field of biotechnology, and has now established an own business area for these activities. With the support of the Federal Ministry of Education and Research (BMBF), Vulkan Technic is currently working on new screening- and process development tools that combine micro-system engineering and biotechnological approaches. Among other projects, the company is designing biorectors in chip format.

Measures

- Plant raw materials, in particular those not used as animal/human nutrition, can already be optimised in development, e.g. through plant selection, cultivation and breeding (here, attention should be paid to the research activities described in Chapters 4.1. and 4.2).
- The use of biomass from different sources in zero-waste biorefineries will require intensive process developments, as well as investigations into industrial feasibility, which must be incorporated into a project plan (roadmap).
- The technical and economic aspects of the integration of bio-based platform molecules in industrial product trees should be investigated
- The next generation of biotechnological processes for new useful and pharmaceutical substances must be driven forward in the context of a strategy process.
- Research with the objective of identifying new bioactive substances as basic chemicals and as end- or precursors products, e.g. for pharmaceuticals, food additives, detergents and cleaning agents, textiles, cosmetics, is necessary.
- The scientific assessment of the technological, economic, environmental and social aspects of the various fields of application of bio-based products and processes requires further development.
- Effective and efficient conversion processes for biomass (thermochemical, chemical catalysis, biocatalytical) require interdisciplinary development along the process chain.
- This will require the establishment of strategic alliances between research facilities, manufacturers, and user companies, as well as with associated institutions.
- The contribution made by energetic- and material utilisation of renewable raw materials in efforts to reduce CO2 must be investigated and evaluated.

Implementation of measures will proceed along the following guidelines:

- Sustainable provision for everyone (see also Chapter 4.2 for the ecological, social and economic dimensions)
- Collective consideration of application paths (together with Chapters 4.3 and 4.5; priority area: Nutrition)
- Consideration of the entire value creation chain (among other things through the bundling of individual research topics, from plant production to industrial use/disposal of products)

4.5 Developing biomass-based energy carriers

Energy from biomass will continue to gain in importance as a component of the overall energy mix. In the framework of regional health provision concepts, this can contribute to local creation of value, and to the creation of jobs in agriculture, forestry, and industry. Extensive technical research work and studies into sustainability as well as scientific monitoring of demonstration projects and market introductions will be essential if bioenergy is to become internationally competitive. The challenge also lies in establishing modes of production and utilisation that climate-, nature-, and environment-friendly. Systems should be designed to be efficient, sustainable, and economical along the entire process chain.

Research needs and objectives

One objective of the National Research Strategy Bio-Economy 2030 is to enable an internationally competitive and sustainable use of biomass in Germany, which will contribute to energy self-sufficiency, and which will establish local technology leadership. Thereby, it will be essential to develop and combine new methods (cascading and coupling application, see also Chapter 4.4 on biorefineries), in order to make efficient and sustainable use of the limited quantities of biomass raw materials, and without limiting food supplies. Sustainability considerations suggest that the potential of residual biomass, as well as wood- and straw-containing plant materials, is very high, and long-term use should be exploited to a greater extent than is currently the case.

Biomass can find application in a wide variety of areas (material use, as a source of energy). In the area of energy, in the future biomass can make an increasingly significant contribution to balancing fluctuating renewable energies for needs-based electricity supplies. Here, research into the optimisation of power-heat coupling and the production of biomethane from the gasification of biomass will also play a role.

Next generation biofuels – with improved economic efficiency and environmental compatibility – can be of significance in certain mobility segments. The need for research in the area of bioenergy takes in the entire process and value creation chain – from breeding, to cultivation and harvesting, up to the processing of raw materials and conversion process-

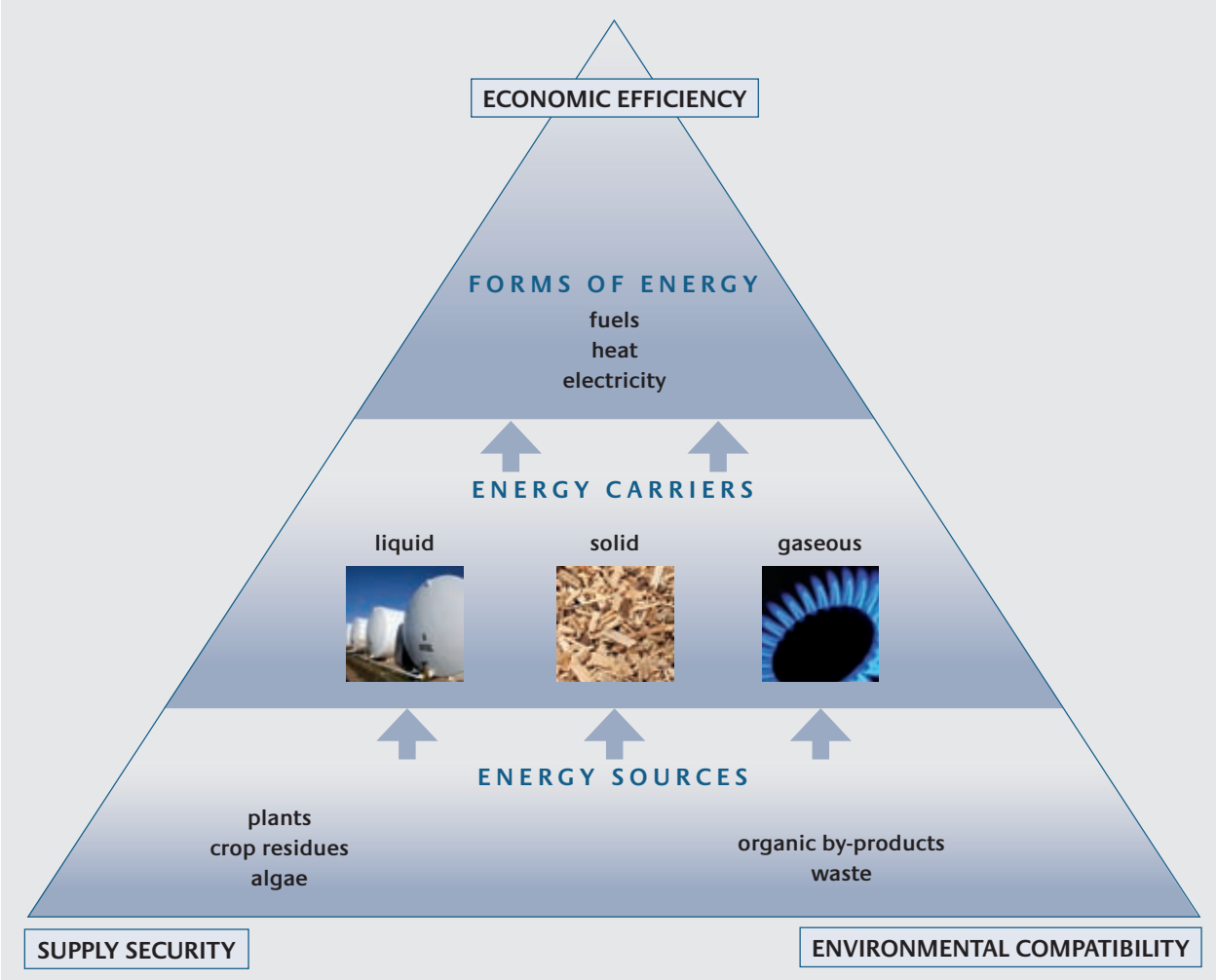


Figure 8: Bioenergy production in framework of the energy policy triangle

es. The objective of research efforts must be to reach the economic efficiency of processes, and to improve and increase resource efficiency and environmental compatibility. The priority of this work should be to sustainably optimise yields and the use of resources, as well as to increase net energy yields. This means that, in the future, the highest possible yields will be achieved with a minimum net use of resources per unit area. Included here, among other things, are research aspects towards increasing process efficiency, achieved, for example, with the assistance of the development of new strains of anaerobic bacteria, and enzymatic products from biogas production. These could contribute, among other things, to robust and productive plants that are optimised for conversion processes. Likewise, the potential of algae should be further researched. CO2 reductions should be considered with regard to climate protection goals and ecological aspects in the course of process optimisation.

Furthermore, studies should also be carried out into whether and how food production will change though increasing competition for land use in Germany, and into the impact this may have on the EU internal market and the world market. In addition to reducing storage and processing losses, among other things via improved agricultural logistics systems, system studies are required to estimate monetary and resource costs for different plant sizes and conversion technologies. Here, appropriate technical and technological process issues will have to be solved, as well as entirely new processes developed so that these can be enduringly established on the market. Included among these are (bio-) catalytic processes, alongside methods for combustion, pyrolysis and gasification, among others of organic residues and waste materials. In addition, studies should be carried out into synergies between biotechnological and chemical-physical processes. Sustainability effects throughout the entire process chain also require investigation. Overall, the solid, liquid and gaseous sources of bioenergy will have to be optimally secured for fuel, heat, and electricity-production in the energy policy triangle between environmental compatibility, economic efficiency, and supply security (see Fig. 7).

The growing global demand for bioenergy will increase the need for related process technologies. Here, international research collaborations form the basis of export opportunities, and support the climate protection efforts of other countries. Opportunities for value creation and employment potential in rural areas through domestic production of bioenergy should be investigated, and action strategies derived.

Funding example: The bio-plant of the future for climate protection and resource efficiency

A modern biorefinery research centre will be established in Leuna in Saxony-Anhalt under the direction of the Fraunhofer Society. Here, cooperation partners from business and science are in close proximity in Germany's traditional chemical triangle of Halle-Bitterfeld-Leipzig. The research centre is aiming to develop methods that make use of all the parts of a variety of plants – above all those that are not used in the food chain – for the production of chemicals, fuels, electricity and heat. The implementation of the biorefinery concept requires substantial efforts towards the demonstration of technological and economic feasibility on a large industrial scale. The biorefinery research centre is open to all parties looking to test innovative biotechnological processes. The costs of over 50 million euros are being borne by the federal state government of Saxony-Anhalt, the Federal Ministry of Education and Research (BMBF), the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Measures

- Intensive research is needed towards improvements in the breeding, cultivation, harvesting and processing of plant biomass (including algae), above all those not used in animal/human nutrition (attention should be paid here to the research activities described in Chapters 4.1. and 4.2).
- Efficient conversion processes for biomass, including the identification, analysis and development of systems for the coupling of these procedures, should be strengthened as field of research.
- The entire process chain, including cultivation, processing, and process and manufacturing technologies must be optimised with regard to efficiency and sustainability criteria.
- Research is necessary towards the establishment of sustainability standards and certification systems, as well as concepts for the parallel development of markets for food and feeds, and for biomass for energy and material use.
- Research to demonstrate the technical and economic feasibility of bioenergy plants must be driven forward.
- Efforts must be made to optimise energetic use of agricultural and forestry residues and waste materials.
- Innovative concepts must be devised for the efficient and environmentally compatible supply of renewable raw materials for different plant sizes and conversion procedures.
- Technologies suited to storage, and to approaches for compensation of fluctuations in bioenergy power feeds, as well as to the optimisation of applied heat-power cogeneration concepts, should be further developed.
- The development of market-viable processes for increasing resource efficiency, and for further reducing negative environmental effects and greenhouse gas emissions, should be strengthened.
- Improved technological and organisational biogas concepts are essential. The scientific and process-engineering basis for the effective political guidance of this sector must be further developed (interaction with the food sector, as well as with regional economic development objectives).

Implementation of measures will proceed along the following guidelines:

- Sustainable provision for everyone (see also Chapter 4.2 for the ecological, social and economic dimensions)
- Collective consideration of application paths (together with Chapters 4.3 and 4.4; priority area Nutrition)
- Consideration of the entire value creation chain (among other things through the bundling of individual research topics, from plant production up to energy production)

5. Cross-Section Activities

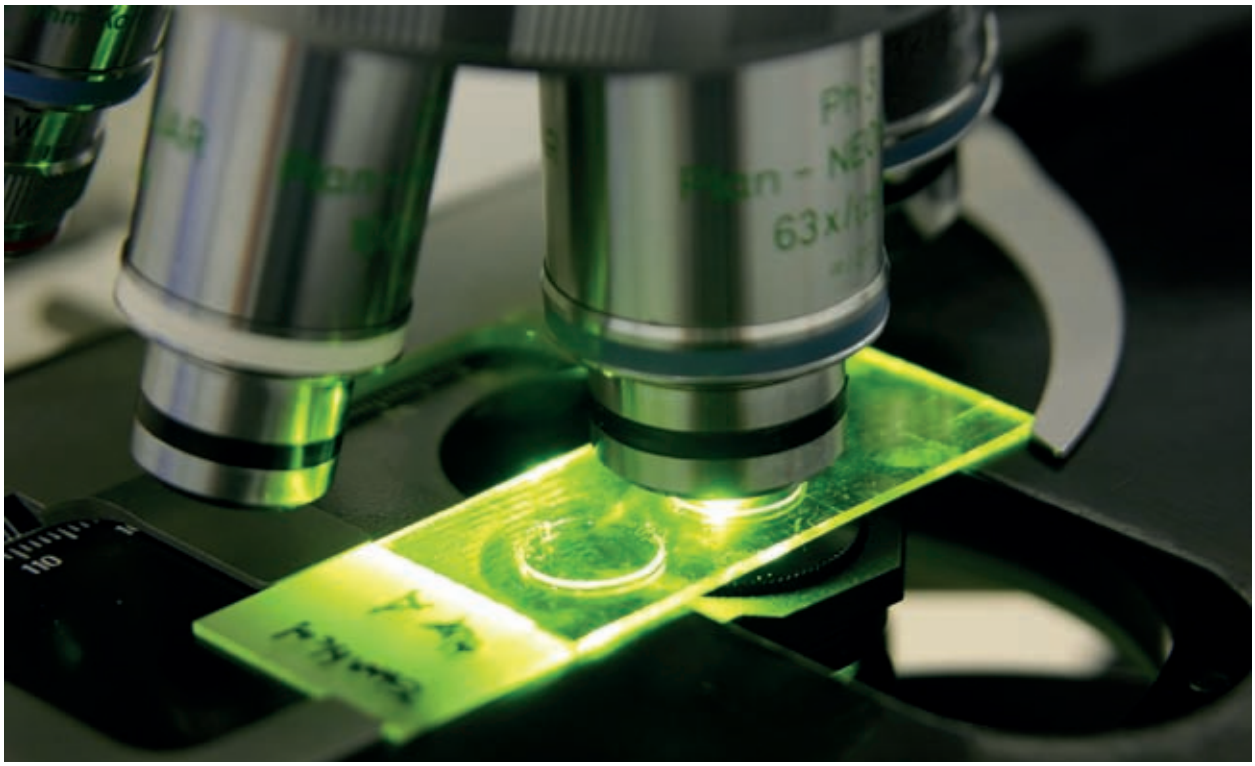
All of the fields of action require integrative research that transcends institutional boundaries and individual disciplines. These efforts will span the gamut from basic research to application, have an international outlook, and drive forward results in ongoing dialogue with society. In this sense, the following cross-section activities affect all partners – in science, in business, abroad, as well as among the interested public. For the success of the National Research Strategy BioEconomy 2030, it will be crucial to strengthen the individual initiative and interaction between these stakeholders, and, on a subsidiary basis, to address major research deficits.

Interdisciplinarily expanding competencies for a knowledge-based bioeconomy

A basic understanding of biological systems and their individual components can give rise to a range of innovations for food, energy, and industrial processes and products. These are characterised be the advanced technologies from a variety of natural and technical sciences that are employed in their development.

The creation of a knowledge-based bio-economy requires the integration of the life sciences with agricultural-, natural-, environmental- and climate sciences, as well as with further key technologies such as computer science and mathematics, nanotechnology and materials sciences, microsystems engineering, process engineering, and plant engineering Systems research and research in the economic and social sciences must be adequately funded to be able to tackle issues of sustainability, including economic and social dimensions. The integration of all of these competencies also enriches the individual disciplines. Promoting collaborations in projects means that existing structures can be networked and utilised efficiently – across disciplines and institutional boundaries. This should be accompanied by the professionalisation of the business of these structures for scientific management.

Platform technologies play an important role in the bioeconomy, for example in the study of biological systems and processes using molecular-



Funding example: New approaches in the promotion of young scientists

In the 'Bioenergy Ideas Contest' from the Federal Ministry of Education and Research (BMBF), young researchers can apply with ideas that are unconventional for their field. Following a preselection, they go through a series of training sessions and educational workshops. Alongside the discussion of new technological developments, the objective of these workshops is to broaden the knowledge of economic and environmental needs in the energetic use of biomass. In addition, the BMBF is aiming to establish technical skills through the expansion of interdisciplinary qualifications: This will cover work in interdisciplinary teams, and the development of leadership skills. A further priority area is the intensive exchange of practitioners. Excursions to companies enable deeper insights into production structures and processes. These funds have already helped young scientists from the internationally renowned universities of Cambridge, Zurich, Stanford and Berkeley to be brought back to German universities.

biological and biochemical methods. This includes technical processes such as fully automated high-throughput analysis and precision analysis equipment, imaging processes, databases, or bioreactors. These platform technologies can also lay the groundwork for commercial applications, and provide the basis for new business models. The required expertise and research infrastructure apparatus, which is frequently geographically scattered in Germany, will have to be bundled through the integration of project- and institutional funding, and extended in corresponding bioeconomy research centres. In terms of start-up financing, project promotion can build up competences for a defined period of time, which can then be transferred to institutions.

In addition, the corresponding setting of priorities in training and professional development is essential to convey the necessary skills and knowledge. The knowledge-based bioeconomy requires that understanding of complex interrelationships is attained and implemented at all levels of training and education. Here, knowledge of socio-economic issues is of major significance. To counter the lack of well-trained skilled workers caused by demographic changes, and to compete in the global competition for talent, the promotion of the next generation of engineers and scientists is a priority area in the National Research Strategy BioEconomy 2030.

Measures:

- Adequate socio-economic and systemic accompanying research is required for the creation of a sustainable bio-based economy.
- Discipline- and institution-spanning cooperation, for example through joint projects and the expansion of research centres, should be supported. Alongside, structures for scientific management must be professionalised.
- The development of platform technologies can be promoted through the integration of project- and institutional funding.
- Interdisciplinary priority areas that include multidisciplinary qualifications for young talent assist in the training of skilled workers for the bioeconomy.
- The expansion of funding for young scientists provides advantages in the competition for talent.

Speeding up transfer into practice

Economic and social benefits can only be delivered if scientific results are quickly transferred into practice. The aim of the National Research Strategy BioEconomy 2030 is to give greater significance to technology transfer activities in science.

Through promotion policy, the scientific community will be offered incentives for the early development of commercialisation perspectives. Assessment systems for science will award both publication activity and application-oriented research. Through working in their own working groups, young scientists from Germany and abroad will be given the opportunity to forge a career in science, as well as to found a new business. Particular significance is given to the teaching of business skills, which will be increasingly integrated into the promotion of young scientific talent. In general, the conditions and the climate for start-ups must be improved.

To validate new scientific knowledge, and to assist transfer into business, the promotion of cooperative projects between science and industry must be expanded. Likewise, industrial researchers can transfer their development and process know-how to the scientific community. Consideration should be given to new forms of cooperation between industry and science, and to unusual alliances between partners from very different areas.

Small and medium-sized enterprises (SMEs) in industry and agriculture are the innovation drivers of the bioeconomy. It is essential that the technological capabilities are strengthened, and that cooperation with science and corporate clients is successful. The bioeconomy research strategy thus strives towards the highest possible participation, e.g. in the form of collaborative projects between science and industry, as well as cooperations between many companies. This company cooperation in research and development can increasingly be seen in bioeconomy-relevant sectors. They often provide the basis for promising business models aimed at highly specialised services and products for clients in industry and agriculture. Such approaches often achieve market leadership, thereby driving forward the performance of SMEs in the bioeconomy.

Measures

- Technology transfer activities and also other forms of commercialisation of scientific results through improved conditions for business start-ups must be supported.
- Scope for young scientists in research funding should be enlarged.
- Exchanges of personnel and cooperation between science and industry should be intensified.
- The involvement of SMEs in research projects and the promotion of cooperations with science should be strengthened.
- Business cooperations among innovative SMEs in research and development should be driven forward.

Exploiting the potential of international cooperation and sharing knowledge

The knowledge required to create a bioeconomy is scattered around the world. Bundling this into international partnerships and transfering it into national innovation processes represents a significant opportunity of globalisation. As described in the preceding chapters along the thematic fields of action (see also Fig. 8), it is intended, for example, to complementarily and targetedly address shortages of competencies in Germany with the assistance of general partners in international cooperation, thereby also meeting global responsibilities.

In accordance with the Federal Government's strategy for the internationalisation of science and research, national research priority areas will be expanded through collaborations with key partner countries and institutions worldwide and in the European Research Area (ERA), with the objective of enhancing local competitiveness. Included here is active participation in European measures, e.g. in the context of ERA-NETs, in joint programme planning ('Joint Programming'), as well as through the implementation of the EU strategy 'Europe 2020'. Moreover, Germany is actively supporting the European Commission in the creation of a knowledge-based bioeconomy in Europe. Further-

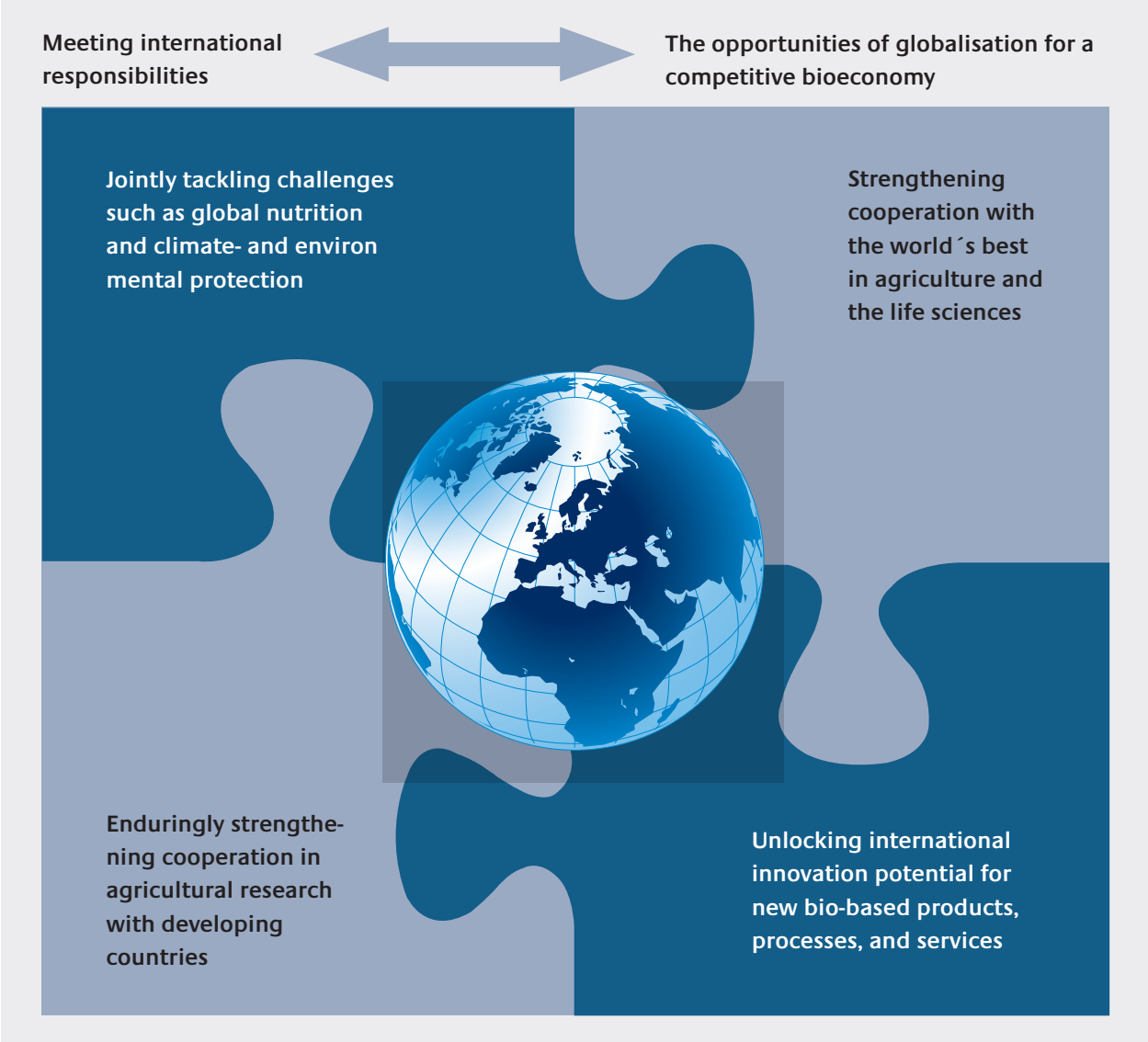


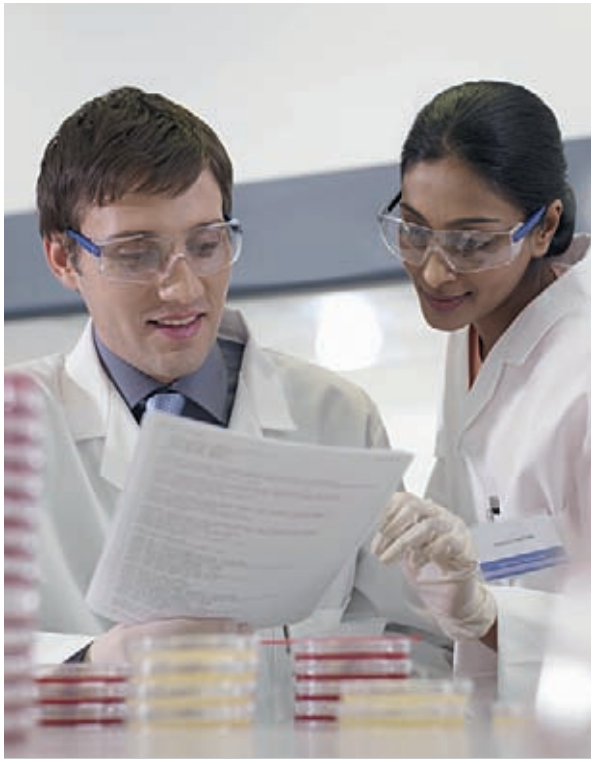
Figure 9: Potential for international cooperation

more, the establishment of multinational research infrastructures, as well as access to international infrastructures, will be accelerated.

Increased international mobility means that there is growing competition for talent. Thereby, the potential and the appeal of Germany as a bioeconomy location will be significant. The spread of know-how and advanced technology from Germany can lastingly strengthen dynamic economic development in emerging and developing countries. Along with other partners from the industrialised countries, Germany bears a special responsibility for global nutrition, and for climate, nature, and environmental protection.

The early inclusion of local skills assures the joint development of custom-fit knowledge-based solution strategies. Therefore, in the area of agricultural research, international research institutes will continue to receive intensive support within the framework of the Consultative Group on International Agricultural Research (CGIAR).

It will also be important to contribute to research-related capacity building in partner countries, and to joint research through long-term and also institutional partnerships between research facilities in Germany and in developing countries. In this way, German competencies can also be strengthened in an important area of development-oriented research, and in the long term, German scientists will be able to position themselves internationally. Furthermore, cooperation with developing countries will be expanded at the project level, focused above all on food security requirements for small farmers. This objective will be pursued alongside appropriate development cooperation initiatives, and with research cooperations at a European and national level.



Measures:

- The creation of national support measures for international partnerships will enable more opportunities for collaborations with other countries and institutions.
- There will be active participation in the shaping of the European Research Area (ERA), for example in the implementation of the EU's Research Framework Programme, in joint programme planning, in the EU strategy 'Europe 2020', in the creation of a European knowledge-based bioeconomy, and in the establishment of international research infrastructures.
- Cooperation in international programmes for support for young scientists is set to strengthen the international appeal of the bioeconomy location Germany.
- International development cooperation in the area of agricultural research should be expanded.

Diving into the fascinating world of agricultural research and biotechnology on the Internet

Fisa Online: To highlight the range of topics in agricultural research, the portal **fisaonline.de**, funded by the Federal Ministry of Agriculture and the federal agricultural ministries, provides an overview of research projects supported by the federal and state governments. This is made possible through the 'ForschungsInformationSystem Agrar/Ernährung' (Research Information System Agra/Nutrition), FISA in short. The core of the site is a searchable database of all research projects and research facilities in Germany.

biotechnologie.de: Complementary to this, **biotechnologie.de** informs the general public on all relevant issues in the innovative research field of biotechnology. The main component of the site is a database searchable for all companies and research facilities active in biotechnology in Germany. In addition, visitors to the Internet portal, which is funded by the Federal Ministry for Research, are given a thorough overview of legal issues, training opportunities, supported projects, and funding measures. There are regular reports on scientists, their research findings, and their personal motivations. Up-to-date news and extensive thematic dossiers highlight trends in biotechnology.

Intensifying dialogue with society

To meet the challenges of the 21st Century, Germany will need an innovation-friendly social and economic climate. Open-mindedness towards research and innovation and reliable legal frameworks are essential if the objectives of the National Research Strategy BioEconomy 2030 are to be achieved.

Technological progress is not an end in itself; it must serve the people, and they must also participate in the process. New developments in technology often raise questions that go far beyond their original scientific contexts. They often affect people directly, and also touch on ethical, legal, and societal aspects.

In the future, progress will also depend decisively on the extent to which the general population gives it its support. For this reason, the dialogue and interaction between science, industry, and the public must be further strengthened.

The formation of opinions and participation in public discourse on this subject presupposes an adequate basic knowledge about the opportunities and risks of new technologies. An important task will be to clarify scientific contexts and their benefits for individuals and society. Researchers in science and industry must also independently take on this task, and they should be supported in their efforts. They are encouraged to reach out to the public through personal dialogue, media contacts, courses for interested parties, and using the many new communication opportunities of the Internet.

In addition, accompanying research in the framework of interdisciplinary projects provides a scientific basis and contribution to discussions surrounding the ethical, legal, and social aspects of the modern life sciences and the bioeconomy. The humanities and social sciences can provide critical illumination of both the sustainability strategy and questions of acceptance, technology transfer, and technological assessment.

Measures:

- It will be necessary to convey a sufficient basic knowledge, e.g. through non-formal learning sites.
- There must be participatory dialogue with the public on the initiative of science and industry.
- Relevant information must be made available in an understandable form through a variety of communication channels.
- Research to clarify the ethical, legal, and social aspects of new technologies, taking into consideration aspects of efficiency, and environmental- and animal protection, will be supported.

6. Implementing the Strategy

The implementation of the measures requires appropriate tools to promote research, to strengthen the creativity and innovation of science and industry, and to provide a steer towards the strategy objectives.

6.1 Research promotion

The promotion of research by the Federal Government will be conducted through medium-and long-term institutional support, as well as through short- to medium-term project funding. In the implementation of the research strategy, project funding and institutional support should be examined for possible synergies more closely than to date.

Institutional research promotion
Institutional support refers to the operation of and investment in research facilities that are funded over longer periods of time by the Federal Government, or jointly with the federal states. Playing an important role here, with their different profiles and priority areas, are research organisations such as the Helmholtz Association, Max Planck Society, the Fraunhofer Society and the Leibniz Association.

Project funding
Project funding is a tool used to support delimited projects – in terms of subject, time, and financing – with high scientific and technical risk that are of significant interest to the Federal Government. In addition to individual projects, joint projects with numerous peer partners can also be funded. The competitive character encourages both inventiveness and quality. The project funding instrument enables quick and flexible responses. It is aimed at companies, research institutes, and universities. Participation from small and medium-sized enterprises is welcomed above all. The involved research always has a pre-competitive character.

Project funding by the Federal Government is only considered if the work cannot be completed using the core funding of the research institutes and universities, or using private sector resources. This means that funding is provided on a subsidiary basis, in order to quickly target sufficient research capacity in specific areas.

Project funding by the Federal Government takes place within the legal and policy framework conditions set at European and national level. More specific details on funding arrangements have already been published in department-specific funding programmes and guidelines.

6.2 Departmental research

The Federal Government can fall back on modern departmental research in the area of the bioeconomy, above all because knowledge-based agricultural and food policy has a long tradition in Germany. Departmental research in the bioeconomy is thus substantially covered by the area of operations of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). Worthy of mention here are the Federal Research Institutes (Julius Kühn Institut {JKI} for Cultivated Plants, the Friedrich Loeffler Institute {FLI} for Animal Health, the Max Rubner Institute {MRI} for Nutrition and Food and the Johann Heinrich von Thünen-Institut {vTI} for Rural Areas, Forestry and Fisheries) as well as the German Biomass Research Centre GmbH (DBFZ). The objective of these institutes is to gain scientific knowledge in order to attend to specialist tasks and political consultation.

6.3 National and international coordination of research and innovation

In its implementation, the research strategy strives towards close coordination with the federal states and other R&D-financing stakeholders (e.g. foundations) on issues that affect all partners in the area of national, European, and international research policy. This can include joint initiatives, as well as briefings on essentially individual planning and decision-making that is not covered by joint funding.

On an international level, and in addition to the measures relating to institutional and project-oriented support, the Federal Government will participate in the organisation of international activities. For example, with the objectives of the National Research Strategy BioEconomy 2030, Germany will be actively involved in the development of the 8th Research Framework Programme towards strengthening the competitiveness of Europe. To take full advantage of the opportunities for research promotion at a EU level, German applicant

bodies will provide diverse advisory services in the area of the bioeconomy through the National Contact Point Life Sciences. In addition, Germany will strengthen multilateral initiatives from a variety of research-policy stakeholders in the area of the bioeconomy, for example in the context of the G8, G20, and the OECD.

6.4 Quality assurance

In further implementation, the Federal Government will be advised by competent and independent experts, in particular as regards the content of individual measures and instruments. For the membership of advisory bodies, such as expert groups in the context of research promotion, it is planned to give special consideration to women, young scientists, and individuals from abroad and from adjoining disciplines, among others.

The ongoing monitoring of the strategy implementation will be jointly pursued by the participating departments. An external evaluation will be carried out after four years at the earliest, which will be evaluated in the context of an impact assessment of the progress of the National Research Strategy BioEconomy 2030. This will be based on evaluations of department-specific measures. The evaluation is intended to enable an assessment of direct and indirect positive effects, taking into consideration the various levels of impact, but will also pinpoint deficits. On this basis, recommendations can be given for the further development of the strategy.

7. Prospects

The National Research Strategy BioEconomy 2030 lays the groundwork for the development of a knowledge-based and internationally competitive bioeconomy. On the basis of this vision, priority fields of action will be determined to promote research and innovation, and corresponding objectives and measures derived.

Adaptations to current developments, in the terms of a learning programme, will also be incorporated over the duration of the strategy. As a result of the long-term lead character of research and innovation, the National Research Strategy BioEconomy 2030 represents the first and necessary step for a broad establishment of the bioeconomy in Germany. The opening up of future markets and the opportunities for society of a bioeconomy are the duties of all policy areas that help shape the conditions for the innovation behaviour of the economy and society. In accordance with the High-Tech Strategy, research promotion in the area of the bioeconomy calls for innovation-friendly framework conditions.

The following examples illustrate in an exemplary manner the interaction between research promotion and framework conditions:

- For far-reaching investment decisions, companies require a favourable innovation climate and planning security. The Federal Government will therefore seek to ensure that framework conditions – also at the European level – are organised in such a way that there is ample room for creativity and innovation for the bioeconomy location.
- The prerequisite for successful innovation policies are highly qualified personnel with outstanding skills. Thus, the implementation of the Qualification Initiative is intended to foster a skills base for the knowledge-based bioeconomy.
- Due to the capital- and time-consuming work in research and development in the bioeconomy, sufficient financing – particularly for SMEs and innovative start-ups – is of major importance. For this reason, favourable framework conditions must be created for an internationally competitive venture capital and private equity market.
- Furthermore, norms and standards for transparency and comparability provide for the high quality, safety, and sustainability of bio-based products and processes. These open up markets and create equal conditions for entry, particularly for small and medium-sized enterprises. The Federal Government will therefore make greater use of the potential of norms and standardisation through targeted integration with research promotion.
- Modern regulations for the protection of intellectual property rights, effective plant variety rights, as well as public procurement – all of which can help make full use of the potential of new technologies and promote market opportunities for bio-based products – are further important factors.

With this research strategy, the Federal Government is putting into place a new, future-oriented, conceptual, and interdepartmental approach. The desired efficiency benefits in research will be achieved by bringing together a variety of policy areas and sectors, and by working along – and potentially combining – the relevant value chains.

Federal Ministry
of Education
and Research