



Federal Ministry
of Education
and Research

Research for a biobased economy

Success stories and challenges facing the German bioeconomy



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Preface

The bioeconomy offers tailor-made solutions to the most pressing challenges facing our societies such as food security, climate change and the protection of natural resources. The bioeconomy is based on renewable rather than fossil resources and applies biological principles. As such, it dovetails economic growth with sustainability. This makes the bio-based economy an important driver of innovation and thus ensures that our industry will be fit for the future.

The transformation of the economy and society is already moving us towards a sustainable way of life and economic activity that is based on biological resources and principles. The bioeconomy is demonstrating its power of innovation even today and in a growing number of sectors ranging from the pharmaceutical and chemical industries to car manufacturing. Society stands to benefit from novel materials, products and services as well as a sustainable economy.

Germany's Federal Ministry of Education and Research (BMBF) set the course for change as early as 2010 with its interdepartmental National Research Strategy BioEconomy 2030 which has taken Germany to the global forefront of research and development of bio-based innovations.

This brochure describes activities and success stories from six years of research and puts the spotlight on the challenges of the future. We are continuing to develop the research strategy on the bioeconomy in dialogue with science, industry and civil society in order to help solve these challenges. This is because we still have a long way to go in unlocking the enormous potential of the bioeconomy.

A handwritten signature in white ink that reads "Anja Karliczek". The script is fluid and cursive.

Anja Karliczek, MdB
Federal Minister of Education and Research



National Research Strategy BioEconomy 2030

The bioeconomy enables us to use natural resources responsibly, while also guaranteeing the continued prosperity of developed societies. The bioeconomy is universal in nature and encompasses a range of sectors. That, in addition to its great potential for innovation, means that it spans every area of the economy, offering the opportunity to reconcile economic growth with the protection of nature and the environment. Orientation according to natural material cycles is one of the guiding principles of the bioeconomy.

In 2010, under the chairmanship of the BMBF, the Federal Government took concrete steps towards the development of a German biobased economy thanks to its 'National Research Strategy BioEconomy 2030', in the process becoming a global leader in the field. Research funding programmes provided huge support to the German bioeconomy, resulting in the development of considerable competencies and key infrastructure, not only in the scientific sector, but also in the economy.



Bioeconomy – foundation for a sustainable economy

The availability of raw materials, accelerating climate change and a growing world population require strategies for sustainable and resource-efficient economic activity. That is where the bioeconomy, based on natural material cycles and innovation, can really come into play.

Over the past 200 years, global economic growth, to a large extent based on the use of fossil raw materials, has brought prosperity to the world's industrialised nations. Increased technical and engineering knowledge led to ore, minerals, petroleum, natural gas and coal being mined and consumed in large quantities. Those industrial activities laid the foundations for continual technological advancement and worldwide economic growth.

Germany also evolved as a result of those developments, into one of the strongest industrialised nations in the world. We need only consider the raw materials contributing to such industrial success, however, to see that it was based on one-sided dependence that developed over the course of the years. Today, petroleum is still the most important source of energy and raw ma-

terial for many industries, even though its drilling and use cause major damage to the environment and have a negative impact on the climate. Bearing in mind that current forecasts predict a global population of more than 9 billion by 2050, a shift in thinking is required.

How can the economy and ecology be reconciled?

And yet another important question remains to be answered: how are billions of people going to be nourished in future without further depletion of the natural environment? That challenge can only become greater as developing and emerging countries begin to prosper and demand for products and services, energy, and industrial infrastructure increases on a global scale. With those challenges in mind, the 21st century brings with it the need for the global community to develop new solutions and approaches to sustainable economic activity that result in fairness across the generations and the responsible use of natural resources.

What is the guiding principle driving the bioeconomy?

The bioeconomy’s potential for innovation can make an important contribution in this context. It offers a smart solution to the issue of reconciling economy and ecology, allowing for sustainable, biobased economic growth in the long term.

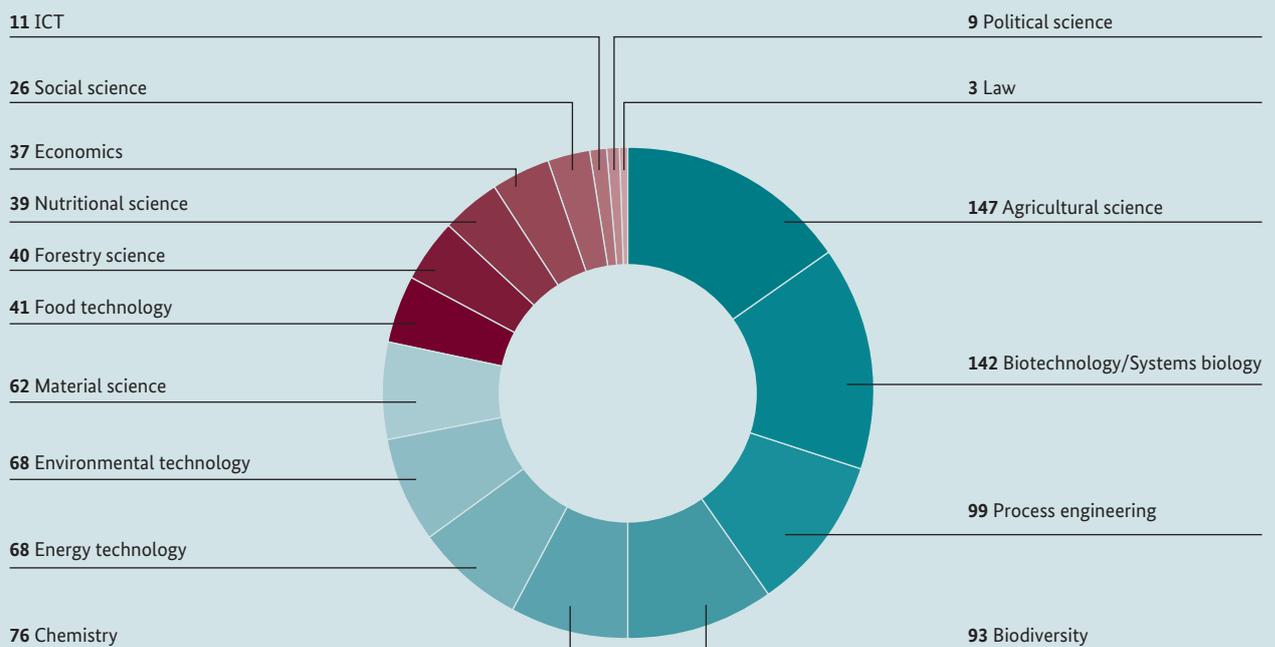
The bioeconomy involves the selective use of biological resources for economic purposes, be they plants, animals, waste products or natural organisms, or components thereof such as enzymes, proteins or other biological molecules. The bioeconomy offers an opportunity to profit from nature’s efficiency and apply those benefits to products, processes and services. In practice, the bioeconomy can be quite diverse and include all industries, e.g. agriculture and forestry, mechanical engineering, chemistry, pharmaceuticals, energy, foodstuffs, textiles, consumer goods and construction. This part of the economy will involve

completely new products and services that will become a reality for the first time through the application of knowledge-based technology, but on the other hand current processes, products and services will be adapted to meet the requirements of sustainable economic activity.

The bioeconomy as a driver of innovation

The bioeconomy is for the most part spurred on by innovation in the life sciences. Yet it is also sustained by its connection to a wealth of other research disciplines within the natural sciences. That is the message contained in the survey of bioeconomy research commissioned by the BMBF in 2016, which was published on the information portal *bioökonomie.de*. Approximately 750 university institutes, technical universities

Overview of the orientation of research institutes relevant to the bioeconomy in Germany*



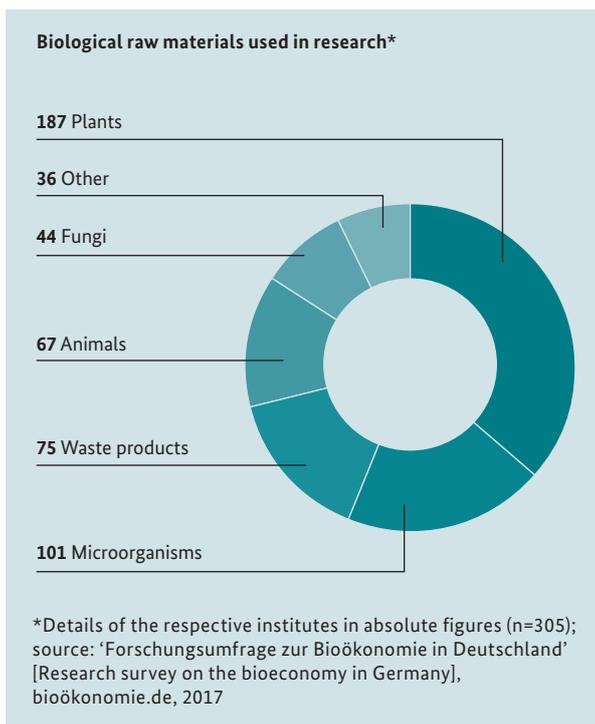
* Details of the respective institutes in absolute figures (n=305); source: 'Forschungsumfrage zur Bioökonomie in Deutschland' [Research survey of the bioeconomy in Germany], bioökonomie.de, 2017



and other organisations were asked about their activities in the bioeconomy field. The research focuses not only on renewable raw materials, but also on biobased solutions for processes spanning the entire range of biological resources right down to microorganisms, cells and single biological components (see diagram below). It can thus be said that bioeconomy research is highly relevant for various industries (see section on “Innovations for a biobased economy”, page 12).

Biobased innovations are already revolutionising entire industrial sectors. The concept of the biorefinery has been used regularly not only in the production processes of the chemical and energy industries, but also in those of the food sector. Biobased raw materials are increasingly being used industry-wide, building value chains in recycling or the industrial processing of waste products. Textile manufacturers are placing their trust in fibres generated from food industry waste. Coffee grounds or wood are used as the raw material for bioplastic, while olive leaf extract can be used in place of conventional chemicals to tan leather in an environmentally friendly manner.

Experts believe that the bioeconomy has the ability to innovate and revolutionise on a scale comparable with digitisation today. Digitisation also necessitated a shift in economic thinking and an open mind. A similarly profound transformation is anticipated in the bioeconomy – as a holistic approach, it can combine economic growth with sustainability. On a political level, the bioeconomy is therefore understood as a broad concept that involves research, energy, industry, agriculture, forestry and fisheries, as well as climate, environmental and development policy.







The policy and research context of the bioeconomy

The bioeconomy has the potential to bring about a thorough structural change in the economy and drive it towards sustainability. In 2010, with the adoption of the 'National Research Strategy BioEconomy 2030', the Federal Government became one of the world's first to put the bioeconomy on the agenda of research and innovation policy. Two years later, that development was continued in the form of a cross-departmental policy strategy. The bioeconomy also plays a role within Germany's National Sustainable Development strategy.

How do we envisage a sustainable future? Are sustainability and economic growth a contradiction in terms, or can they complement each other? Can the growing need for biomass be combined with the responsible use of available resources? How can we ensure our prosperity while also accepting responsibility on a global scale? Research and development provide the key to answering those questions. On a national and international level, however, these require a suitable framework within which the relevant social players can come together and bring about the structural change needed for biobased and sustainable economic activity.

Clear visions for a cross-departmental strategy

The German government agreed at an early stage how research policies can drive the development of a sustainable bioeconomy. At the end of 2010, Germany became one of the first countries to publish a long-term, cross-departmental 'National Research Strategy BioEconomy 2030', thus taking concrete steps towards a biobased economy in Germany.

The strategy was drafted under the aegis of the Federal Government's Ministry of Education and Research (BMBF) in collaboration with six other ministries. Around 2.4 billion euros in funding have been provided for research and development (R&D) under the auspices of the BMBF. The 'National Research Strategy BioEconomy 2030' firmed up all the targets and visions relevant at the time of publication and set a high standard, even on an international level. Hardly any other country decided at such an early stage to engage so intensively with the bioeconomy, including its importance for structural change in industry, and

for climate and environmental protection, with the goal of achieving sustainable economic growth. Five fields of action have been defined within the context of initial research policy regarding the bioeconomy:

- **Securing global nutrition**
- **Ensuring sustainable agricultural production**
- **Producing healthy and safe foods**
- **Using renewable resources for industry**
- **Developing biomass-based energy carriers**

Building on those, another four cross-section activities have been agreed:

- **Speeding up transfer into practice**
- **Exploiting the potential of international cooperation and sharing knowledge**
- **Interdisciplinary expanding competencies for a knowledge-based bioeconomy**
- **Intensifying dialogue with society**

The following guidelines have been established:

- **Food security shall invariably enjoy precedence over other uses of biomass.**
- **Linking up value chains intelligently will ease competition between the various biomass applications e.g. through joint or cascading use.**
- **The bioeconomy must use environmentally and resource-friendly production that is kind to nature and animals, while also considered ethically acceptable, as a benchmark for evaluation.**

In summer 2013, the Federal Government marked another milestone in the move to a sustainable, biobased economy with 'Nationale Politikstrategie Bioökonomie' [National Policy Strategy on Bioeconomy], a publication agreed at cabinet level (see box on page 10). The strategy, which is effective across Government Ministries, was drafted under the aegis of the Federal Ministry of Food and Agriculture (BMEL) and is aimed at facilitating more coherent policy-making. Relevant government activities in the bioeconomy field have been co-ordinated and promoted by a joint ministerial task force (IMAG). IMAG published its first progress report in the summer of 2016. Experts have found that the guiding ideas behind the policy strategy have been factored into the policies of Federal Ministries and the design of funding programmes and measures.



Further development of the research agenda in the bioeconomy

In 2016, the Fraunhofer Institute for Systems and Innovation Research (ISI) assessed BMBF project funding under the 'National Research Strategy BioEconomy 2030'. This brochure builds on the knowledge gained in that evaluation, providing an overview of the key activities carried out under the 'National Research Strategy BioEconomy 2030' – based on the fields of action and cross-section activities outlined above. The report focuses on BMBF research funding programmes; funding measures for other Ministries are mentioned where appropriate.

The evaluation serves as a focal point from which to develop the bioeconomy research agenda and to ensure that the 'National Research Strategy BioEconomy 2030' is kept up to date. Recommendations for action made by the Bioeconomy Council (see also box on page 33) and the expert community are also drawn on here. The objective is better linkage of bioeconomy activities with other areas of emphasis in research funding programmes. To that end, thanks to its uni-

versal and innovative nature, the bioeconomy has already been included in the 2014 version of the Federal Government's High-Tech Strategy. The bioeconomy is particularly relevant with regard to future priorities such as 'sustainable economic activity', as outlined in this document.

The bioeconomy's contribution to global sustainable development goals

The bioeconomy is of particular importance when it comes to the implementation of the global Sustainable Development Goals (SDGs) adopted by the international community in 2015. A total of 193 countries across the globe agreed to 17 SDGs as part of "2030 Agenda for Sustainable Development", highlighting the key importance of using natural resources responsibly. More than half of the SDGs tie in with the bioeconomy. Whether it is the issue of global food security, access to clean water, biodiversity protection or sustainability strategies in relation to cities, consumption or economic growth – the ambitious sustainable development goals can only be achieved through resource-efficient processes based on natural material cycles and biobased technology. The demand for innovative solutions to bring about sustainable

Bioeconomy Policy Strategy – an overview

In the 'National Policy Strategy on Bioeconomy', the Federal Government sketches out targets, strategic approaches and measures to exploit the potential for action and development of value chains in line with sustainable economic practices and to encourage structural change leading to a biobased economy. The cross-departmental strategy drafted under the leadership of the Federal Government's Ministry of Food and Agriculture (BMEL) aims to facilitate more coherent policy-making.

Recommendations for action in relation to an internationally competitive and sustainable bioeconomy have been developed for all areas of policy: not only for research and innovation policy, but also for industrial, energy and agricultural policy, climate and

environmental policy, and development policy. Three cross-section activities and five fields of action are based on the key principles guiding the bioeconomy: (A) Coherent policy framework (B) Information and dialogue with society (C) Education and apprenticeship (D) Sustainable production and provision of renewable resources (E) Growth markets, innovative technologies and products (F) Processes and value-adding networks (G) Competition among uses of land (H) International context. A progress report on the policy strategy was published in the summer of 2016.

Further information:

www.bmel.de/EN/Agriculture/RenewableResources/renewable-resources_node.html

economic practices is thus higher than ever. Those solutions must satisfy the growing need for renewable raw materials, without compromising food security or our natural livelihood. Targeted innovation and research policy can boost such developments enormously. For that reason, bioeconomy research policy is increasingly being linked with other areas of sustainability policy. We see this at Government level in the National Sustainable Development Strategy, the National Strategy on Biological Diversity, the Green Economy Research Agenda, the third framework programme for sustainability research and the German Resource Efficiency Programme.

Dovetailing bioeconomy and digitisation

Developments in key technologies associated with the bioeconomy are important for its future growth. That applies above all to digitisation and the Industry 4.0 trend. Many experts believe that those technological advancements have paved the way for structural change, something also of great relevance for a bio-based economy. Against that backdrop, it is advisable that the many parallel developments in the fields of science and economics should be brought together in future and used to benefit Germany as a whole.





Innovations for a biobased economy

Under the auspices of the ‘National Research Strategy BioEconomy 2030’, since 2010 participating ministries have implemented a host of measures to bring about innovation for a biobased economy. By the end of 2016, approximately 1 billion euros had been made available by the Federal Ministry of Education and Research (BMBF) alone through 36 funding initiatives.

A sustainable bioeconomy can be achieved only if all parties along the value chain are involved – beginning with research-and-development teams and continuing with producers and industrial users, right down to the customer. The ‘National Research Strategy BioEconomy 2030’ is aimed, in particular, at expediting the change to a sustainable economy, resulting not only in more biobased products, services and manufacturing processes, but also in their being brought to market. It is hoped that they will offer solutions to the social challenges facing the 21st century. The process is guided and broken down into five fields of action and four cross-section activities (See section on “The policy and research context of the bioeconomy”, page 8). As opposed to the preced-

ing ‘Rahmenprogramm Biotechnologie – Chancen nutzen und gestalten’ [Biotechnology Framework Programme – Using and Shaping Opportunities], the push for purely technological developments has been cast aside in favour of a perspective based on application and problem-solving. That re-conceptualisation has gone hand in hand with the opening up of the topic – no longer confined to the narrow idea of biotechnology, it has instead been extended to embrace biobased innovations, which are part and parcel of a modern bioeconomy based on the diversity of biological resources, methods and procedures. To that end, it develops applications and products for the economy: from agriculture and the food industry to the chemical, pharmaceutical, automotive and textile sectors.

Growing relevance for industry

The growing importance of applied research on the boundaries between science and the economy was identified in the appraisal of research institutes commissioned by the BMBF and carried out in the autumn of 2016 by the information portal biooekonomie.de. It concluded that the activities carried out by approxi-

mately 750 research institutes identified as working on the bioeconomy are of particular relevance to industry (see diagram below).

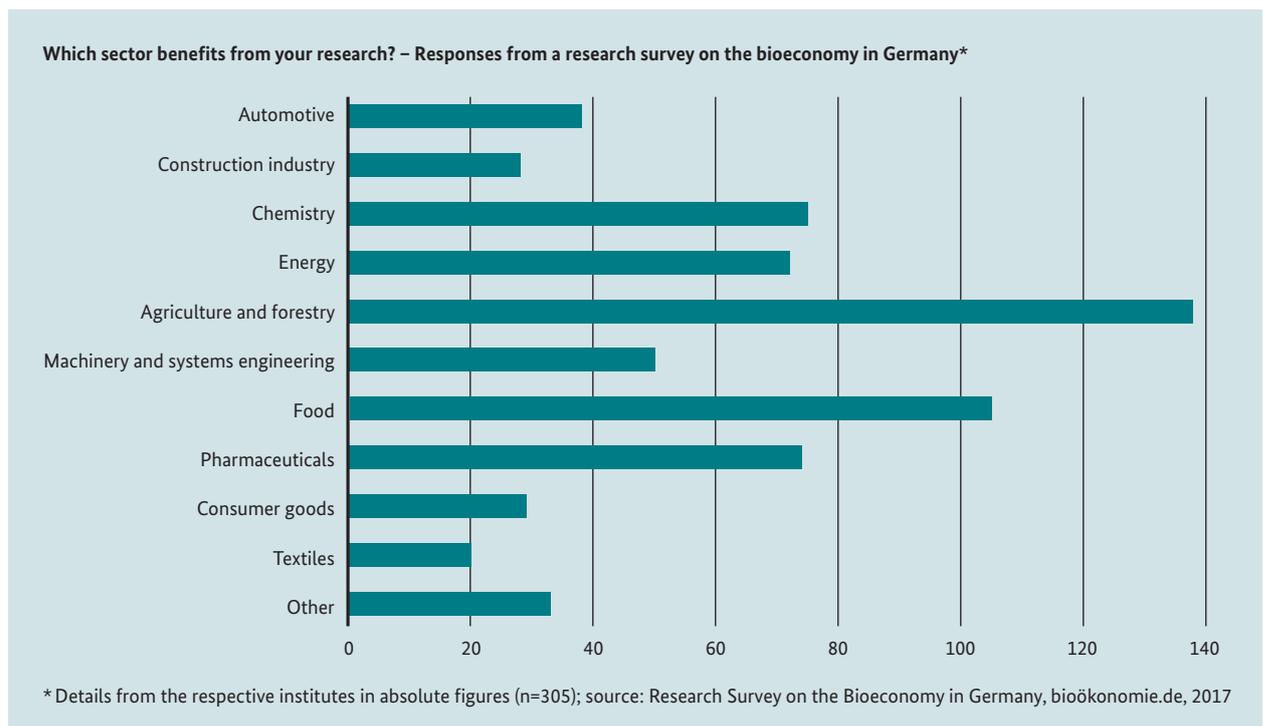
Investment in applied research and innovative SMEs

In that vein, the ‘National Research Strategy BioEconomy 2030’ has targeted a diverse group in the fields of science and industry, encompassing research disciplines in the natural and social sciences, and companies operating across various sectors. The activities of the participating ministries are correspondingly multifaceted. The BMBF alone, in its role as strategy forerunner, has set up more than 30 funding measures across the various fields of action and cross-section activities, 12 of which were continued or further developed from the predecessor programme. The measures have resulted in about 1,800 individual and joint projects receiving funding totalling 876 million euros, according to the evaluation by the Fraunhofer Institute for System and Innovation Research (ISI). The assessment, carried out in 2016, captured all of the bioeconomy activities performed by the BMBF between May 2009 and January 2016 as part of the ‘National Research Strategy BioEconomy 2030’. A

further 281 million euros of allocated funds have been mobilised for bioeconomy research by participating research institutes and companies. The analysis found that the majority of BMBF funding recipients were operating in science rather than industry. Almost two-thirds of funded projects were conducted by university research institutes or other research organisations. SMEs, on the other hand, received a third of the funding.

Key areas receiving funding

Fraunhofer ISI organised the 28 funding measures relevant for the period 2009 to 2016 into groups of topics and, where possible, classified them according to their field of action, thus allowing it to gain an insight into the content of the BMBF funding portfolio. The institute was thus able to identify that the main focus during that period was on plant breeding and agricultural research, industrial biotechnology and the promotion of SMEs and start-ups. Arranged by field of action, particular support was granted to numerous projects in the agricultural and food industries. Three fields of action, “Securing global nutrition”, “Ensuring sustainable agricultural production” and “Producing



healthy and safe foods”, alone received investments of up to 268 million euros from the BMBF. That figure represents 31% of total funding (see diagram below).

The BMBF also focused on “Using renewable resources for industry” field of action, granting it 205 million euros (23.7% of total funding). The BMBF invested only around 31 million euros (3.7%) in the “Developing biomass-based energy carriers” field of action and associated activities in order to investigate the possibilities of cascading use of biomass. The Federal Ministry of Food and Agriculture (BMEL) is the main body responsible for that area under the ‘National Research Strategy BioEconomy 2030’. The evaluation also found that cross-section activities figured greatly in the BMBF’s bioeconomy funding. That applies in particular to developing interdisciplinary competencies and technology transfer. The Fraunhofer ISI’s portfolio analysis also discovered that a total of 157 million euros (18.1%) of BMBF funding was made available for ‘platform technologies/analysis techniques’ and a

further 113 million euros was granted for SMEs and the development of start-ups (13.1%), an area spanning diverse fields. According to the analysis, an additional 89 million euros (10.4%) of funding could either not be allocated to a specific field of action or were assigned to projects spanning more than one area. At least half of the distributed funds also enabled international cooperation or opened it up as a possibility. A total of 138.6 million euros (14.4%) was used for internationally networked projects (see ‘Driving international collaboration’ on page 34).

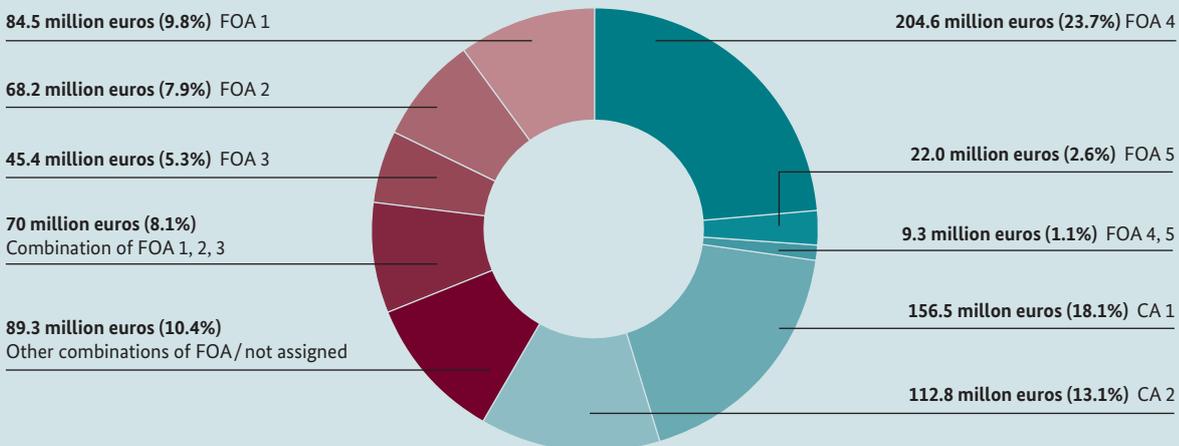
Distribution of BMBF funds under the ‘National Research Strategy BioEconomy 2030’

Fields of Action (FOA)

- 1 Securing global nutrition
- 2 Ensuring sustainable agricultural production
- 3 Producing healthy and safe foods
- 4 Using renewable resources for industry
- 5 Developing biomass-based energy carriers

Cross-Section Activities (CA)

- 1 Platform technologies/analysis techniques
- 2 SMEs and start-up funding



Source: Evaluation of the National Research Strategy BioEconomy 2030, portfolio analysis, Fraunhofer ISI, 2017
 *includes funds granted through 28 BMBF funding measures (period from 5/2009 until 1/2016)



Field of action: Securing global nutrition

Despite the increase in global wealth over the past few decades, a good half of the world's population continues to suffer from hunger and malnutrition. Finding a long-term solution to this issue is one of the major challenges facing the international community. On a political level, global food security has been recognised as a complex challenge. The production, processing, storage, trade and consumption of food plays a vital role, as do health, societal, economic, ecological and political factors.

In the 'National Research Strategy BioEconomy 2030', considering the diverse routes by which biological resources are used, the urgent need for food security was defined as top priority. The National Policy Strategy on Bioeconomy [Nationale Politikstrategie Bioökonomie] has taken a similar approach to food security. In addition, it has been reaffirmed on an international scale, for example, at the agricultural ministers' conferences that take place annually on the fringes of the Global Forum for Food and Agriculture (GFFA) in Berlin.

Building bridges between Africa and Germany

One focus of the research projects funded by the 'National Research Strategy BioEconomy 2030' has been relieving the situation facing emerging and developing countries, above all those in Africa. That task is particularly challenging, since more and more people need to be properly nourished, while the availability of farmland cannot be stretched much

further. The following questions need to be answered in this context: How can we increase yields sustainably using existing arable land? How can we reduce wastage after harvesting? How can the agricultural and food industries meet humanity's need for food? With the aim of employing relevant approaches on the ground, the BMBF, together with the Federal Ministry for Economic Cooperation and Development (BMZ), set up the Globale Ernährungssicherung [Global Food Security] – GlobE funding initiative. Up to 42 million euros are being invested in six joint German-African research networks. The objective here is to build bridges between African countries and Germany to reconcile the benefits of not only traditional cultivation techniques, but also highly developed processes. For it is sustainable productivity growth, improved organisational infrastructure such as that offered by producer associations, and developments in marketing and processing along the entire agricultural value chain that are key to increasing income and production in agricultural sectors characterised by small

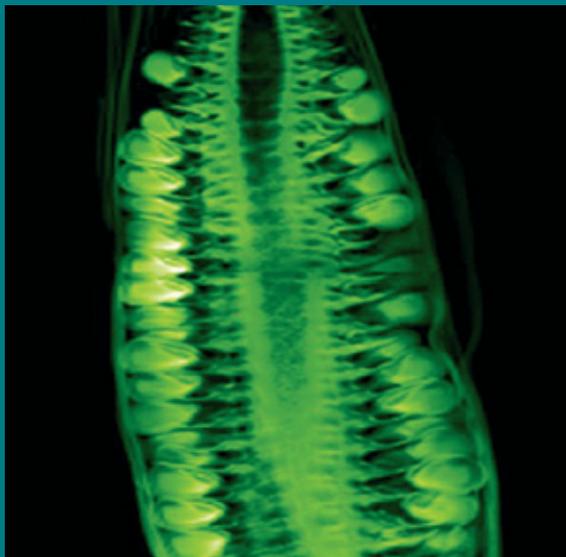
farmers. There is particular demand for innovations tailored to the local economy and capable of bringing sustainable development to the entire agri-food sector.

That approach has also been factored into Germany's development work with such nations. The BMZ focused on improving global food security in a special initiative called 'EINEWELT ohne Hunger' [One World – No Hunger], leading to an annual investment of 1.5 billion euros in rural development, agriculture and food security in 2014 and 2015. Another highlight of the initiative was the establishment of 'green innovation centres', which make it easier for small

farm enterprises in parts of Africa and India to access innovative agricultural methods while also supporting sustainable agricultural production. The above measures were also supported by the BMBF's Africa strategy, published in 2014. The bioeconomy is at the core of Germany's development cooperation. Soil research also plays a vital role in food security. When the quality of soil deteriorates and it becomes less fertile, so too does the land's productivity – a trend that can currently be observed in many regions across the world. Comprehensive soil analysis is thus as essential to global food security as it is to sustainable agricultural production (see page 18).

Improving crops for the future

Whether high-yield grain, robust sugar beet or fast-growing poplar: The development of crops to meet future demands requires innovative approaches to research. 'PLANT 2030' pools the BMBF's comprehensive funded research activities for applied plant research. PLANT 2030 currently includes the funding initiatives 'Pflanzenzüchtungsforschung für die Bioökonomie' [Plant Breeding Research for the Bioeconomy] and 'Pflanzenbiotechnologie der Zukunft' [Plant Biotechnology of the Future],



View of a corn cob using magnetic resonance imaging.

as well as funding projects under the transnational 'PLANT-KBBE' programme. It allows for cooperation between public research institutes and companies in the plant breeding sector and related areas of the bioeconomy. Private partners bear part of the cost of their projects themselves. Private sector companies are organised in the Gemeinschaft zur Förderung von Pflanzeninnovation e. V. (GFPI) [German Federation for Plant Innovation (GFPI)]. Projects on applied plant research draw particularly on knowledge unearthed in recent years as a result of genome research. The findings gained through such research are of interest to the entire farming industry. German plant researchers have received international attention thanks to their efforts in decoding the genome for sugar beet. German researchers have also been frontrunners in an international consortium tasked with compiling the most detailed gene catalogue for barley known to man, paving the way for the complete sequencing of complex genomes. These findings can now be put to good use in the development of new types of barley and in the optimisation of cultivation methods.

For further information see:
www.pflanzenforschung.de (in German only)

Strengthening innovative plant breeding on a national and international level

The 'National Research Strategy BioEconomy 2030' also places importance on its ability to identify ways to diversify agricultural crops and use more innovative new breeds. Such breeds are more resistant to pests and can withstand certain kinds of environmental conditions such as drought and high levels of salinity. One focus of the strategy is the analysis of economically relevant plant genomes. Knowledge gained on plants' genetic adaptation strategies for different environmental conditions and locations sets the foundation for the development of modern, robust crop types. Relevant data gathered as part of the 'Genomanalyse im biologischen System Pflanze – GABI' [Genome Analysis of the Plant Biological System] funding measure were developed further in 2010 through a follow-up measure called 'Pflanzenbiotechnologie der Zukunft' [Plant Biotechnology of the Future].

Other key activities, launched in 2012 and 2013 respectively, were the Innovative Pflanzenzüchtung im Anbausystem (IPAS) [Innovative Plant Breeding within the Cultivation System] funding measure and work with the German Plant Phenotyping Network (DPPN). The focus of IPAS is on methods and approaches for examining the effects of plant-breeding innovations in their respective cultivation systems and also in regard to their influence on society, the economy and ecology. The DPPN was set up to develop a high-throughput technology platform for the automatic non-invasive measurement of entire plants, including their roots. In mid-2015, the BMBF published funding guidelines, 'Pflanzenzüchtungsforschung für die Bioökonomie' [Plant Breeding Research for the Bioeconomy] as part of a joint initiative with the Ministry of Food and Agriculture (BMEL). Applied, interdisciplinary research proposals are supported on topics such as functional biodiversity, plants as meta-organisms, predictive breeding, resource efficiency and 'green' bioinformatics for applied research on agricultural crops. Such activities are supplemented by the BMEL's drive for innovation, which among other benefits acts as an impetus for the breeding of high-performing wheat strains. The BMEL also supports German scientists participating in the International Wheat Initiative (WHEATSEQ).



Linking up international plant research

Domestic measures for plant research are backed by international activities. 'Transnational Plant Alliance for Novel Technologies – towards implementing the Knowledge-Based Bioeconomy in Europe' (PLANT-KBBE) is one such European initiative lending its support. As part of the 37 public-private partnerships funded, approaches to yield stability have been tested, along with crop adaptation strategies where there are environmental stress factors in play.

Field of action: Ensuring sustainable agricultural production

Today's agricultural sector faces the challenge of contributing towards global food security while simultaneously avoiding damage to nature and the environment in the longer term (see page 15 for the 'Securing global nutrition' field of action). For that challenge to be overcome, we need not only highly productive strategies, but also ecological and resource-efficient ones. The problem with the above is that the huge need for food in most developing countries often comes up against local agriculture's limited ability to produce crops. On the other hand, highly mechanised agriculture in industrial countries generates extensive yields, but often to the detriment of the environment and climate protection. Modern bioeconomy research can help find sustainable, tailor-made solutions to meet local demands.

One of the central measures contained in the 'National Research Strategy BioEconomy 2030' in regard to Germany was to pool the expertise of each of Germany's best agri-food research institutes and bring their skills to industry networks. That has been realised through the Kompetenznetze in der Agrar- und Ernährungsforschung – AgroclustEr [Competence Networks in Agricultural and Nutrition Research] initiative (see page 19). Such measures lay the foundation for excellent agri-food research capable of taking on international competition. They allow for research results to be applied in practice quickly across the agricultural value chain, from the initial production of natural resources to the completion of high-quality raw materials ready for processing such as biomass, animal feed or food. Agriculture and food research and education have also been strengthened thanks to those initiatives.



Soil: an important resource

Soil management practices need to be adapted to the local environment in order for agriculture to be sustainable. As part of the BMBF's 'Boden als nachhaltige Ressource für die Bioökonomie' – BonaRes [Soil as a Sustainable Resource for the Bioeconomy] funding measure, an investigation is being carried out to determine which strategies may be used to protect and maintain soil, one of agriculture's most important resources. Since 2015, ten project networks have been developing new approaches to such questions as how water and nutrients might be used more efficiently and how cultivation strategies and ground management can be improved. The BonaRes-Zentrum für Bodenforschung [BonaRes Centre for Soil Research] was also established under that funding measure. The platform aims to effect a substantial improvement in opportunities for relevant German players to exchange scientific knowledge. The centre seeks key outcomes such as the formulation of evidence-based options to improve soil management and aims to es-

establish a central database on soil science. The database is, inter alia, intended to form a basis for validated prognostic soil ecosystem models.

The application of digital technologies is another trend in modern agricultural production. Nowadays, intelligent tractors and harvesters are already a reality: fitted with sensor technology, on-board computers and satellite navigation, the tractors can gather information on the quality of plants as they travel across the field, make adaptations in line with programmed fertiliser requirements, reconcile geo-data and fertilise exactly as needed based on the soil and nutrients present in the crops. Such precise agricultural practices help to ensure that agricultural land is cultivated in an ecologically friendly manner, saving energy and reducing greenhouse gas emissions and the consumption of fuel, crop-protection chemicals and fertilisers. The BMEL also encourages relevant developments in agricultural technology as part of its drive for innovation. On the other hand, it also supports projects developing integrated procedures for plant protection, from infestation diagnosis to decision-making aids based on computer and geo-informational data.

Biodiversity research and preservation

With so much of the world's land being used for intensive agriculture, experts have observed a lasting deterioration in natural and semi-natural habitats and a concomitant loss of biodiversity. Yet many of the biotopes and cultivated landscapes worth protecting today first came into being through agricultural use. It is not only economic and technological developments that have determined the intensity of agricultural production and influenced rural biodiversity; the European Union's 'Common Agricultural Policy' has also had a hand. The latest reports on implementation of the Habitat and Birds Directives show that in general biodiversity continues to decline, notwithstanding regional differences. Against that backdrop, there is also an impetus to drive biodiversity research under the 'National Research Strategy BioEconomy 2030'. One such area of research has been the genetic cataloguing of species diversity. Such databases have gained importance as tools for breeders of plants and animals. On a national and international level, BMBF and BMEL have initiated investigations into topics

Pooling agricultural research competencies

Since 2009, in order to better link supra-regional expertise, the BMBF has funded several 'Kompetenznetze in der Agrar- und Ernährungsforschung' [Competence Networks in Agricultural and Nutrition Research] that have the potential to solve social problems by applying knowledge from agricultural science. A network co-ordinated by the University of Kiel is involved in milk research. The scientists put the entire value chain of milk under the microscope, from the influence of food on animal health to milk processing and consumer health. They focus in particular on the identification of ingredients in milk that are beneficial to health and their use in dairy products. In turn, agricultural scientists from a leading network in Rostock focus on researching the properties of beef and pork relevant to breeding – here they opt for a combination of functional genome analysis, behavioural research and bioinformatics. The Synbreed cluster coordinated by the Technical University (TU) of Munich brought together plant and livestock breeders, molecular biologists and bioinformaticians to establish genome-based strategies for plant and animal breeding.

such as resource-based plant, animal and forest genetics, as well as aquatic resources. As part of the initiative, BMEL also supports projects for the development and implementation of innovative concepts that pave the way for the preservation of biodiversity and its sustainable use through pilot and demonstration projects.

Reconciling greater yields with environmental and climate protection

On the level of Joint programming in the context of the EU framework programme "Horizon 2020" BMBF contributes to dedicated research on sustainable agriculture. In particular, it addresses the growing need for food (see page 15 for the 'Securing global nutrition' field of action) and other criteria for environmental and climate protection. The joint programming

initiative 'Food, Security, Agriculture and Climate Change' (FACCE-JPI), for example, funds collaborative international work on solutions for an adequate food supply in the light of climate change, globalisation, declining natural resources, and demographic change. 'FACCE SURPLUS' is the outcome of the co-operative, multi-faceted research programme FACCE-JPI. Several member states came together under the ERA-Net umbrella to create these guidelines for the promotion of research projects to implement concepts for environmentally friendly and sustainable agricultural growth and productivity. Fourteen projects were selected in the first call for proposals, nine of them including German partners. A new call for proposals on small, decentralised and multi-functional biorefineries was made at the beginning of 2017.

Agricultural systems of tomorrow

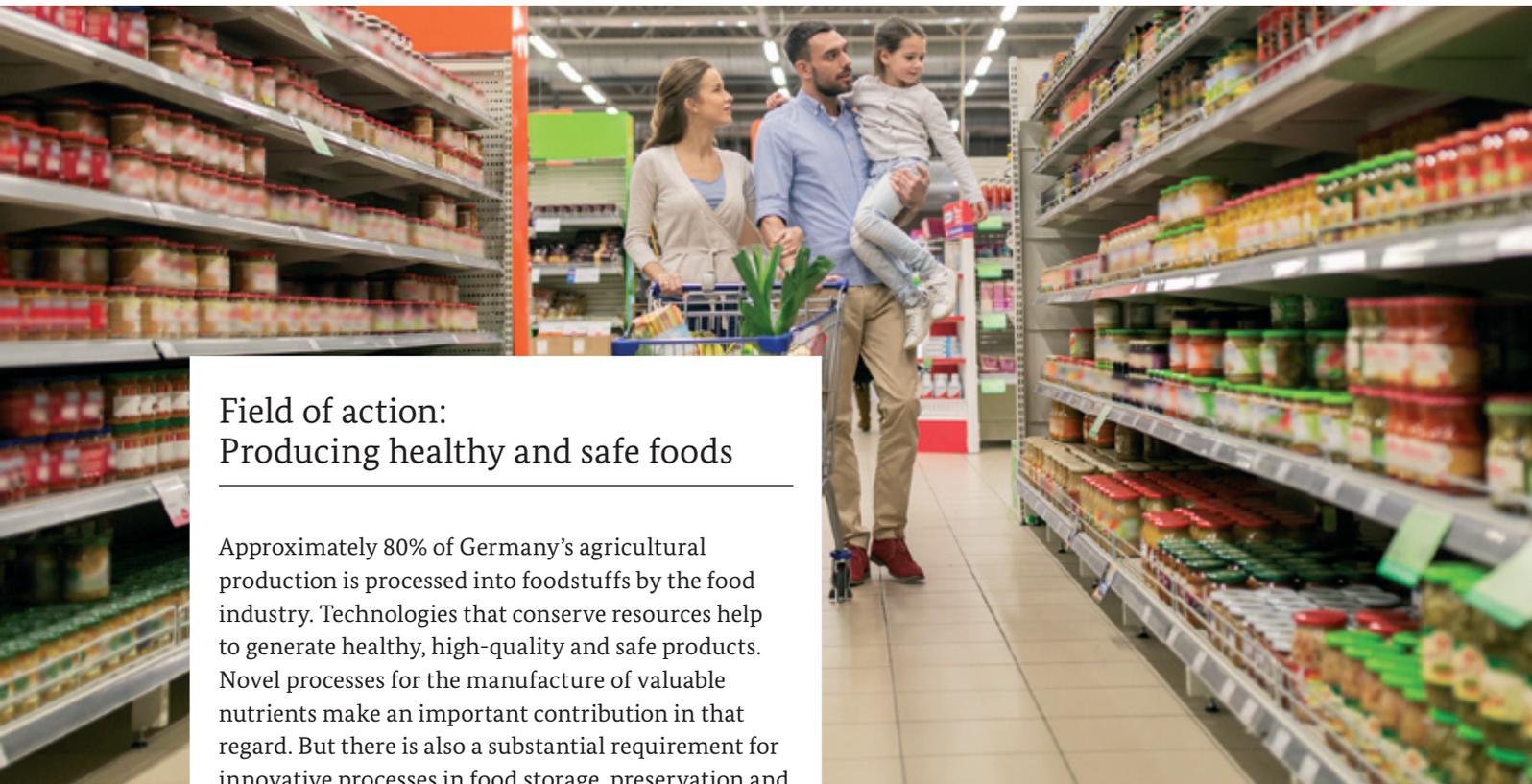
In 2014, the BMBF launched the 'Agrarsysteme der Zukunft' [Agricultural Systems of the Future] strategy process in parallel with its ongoing funding initiatives. An open competition for ideas, a creative workshop and an expert advisory committee laid the cornerstones for future funding measures. It calls for the development of long-term agricultural research, spanning many different fields, and higher-quality collaboration. That should create linkages between the broadest possible spectrum of research approaches relevant to agricultural production. Key modern technologies have been allocated a prominent role in agricultural science, particularly at the interfaces of different scientific fields and in the innovative information and communication technology sectors. A funding measure for future-oriented agricultural systems was publicised in the summer of 2016.

Combining animal welfare expertise

Ensuring the well-being of livestock is a fundamental part of sustainable agricultural production, as well as being crucial to healthy food (see page 21). Different factors such as illness and epidemics, treatment regimens and standards of animal husbandry can all have an effect on animal health. The 'National Research Strategy BioEconomy 2030' drives research into animal welfare. Under the auspices of the ERA-Net 'Animal Health and Welfare' (ANIHWA), the Federal Government, working with partners from 19 differ-

ent countries, has brought together technological and scientific expertise on livestock health and welfare. Here it was able to build on its experience of infectious diseases from a past initiative (Emerging and Major Infectious Diseases of Livestock, EMIDA).

The cross-border European ERA-Net ANIWHWA projects focused on developing innovative livestock husbandry techniques capable of underpinning safe, progressive and animal-friendly approaches to disease prevention and management in the longer term. Efficient and sustainable methods for the improved handling of antibiotics and treatments lie at the heart of those projects. Three transnational calls for proposals have been issued since ANIWHWA was launched in 2011. The funded consortia aimed to put innovative animal welfare approaches at the centre of agricultural production, the meat industry and food retail, across the board.



Field of action:
Producing healthy and safe foods

Approximately 80% of Germany’s agricultural production is processed into foodstuffs by the food industry. Technologies that conserve resources help to generate healthy, high-quality and safe products. Novel processes for the manufacture of valuable nutrients make an important contribution in that regard. But there is also a substantial requirement for innovative processes in food storage, preservation and transport. Much bioeconomy research is, therefore, important for the food sector (see diagram on page 13). The ‘National Research Strategy BioEconomy 2030’ has developed relevant research competencies in Germany.

In Europe, the BMBF participates in the ERA-Net initiative SUsustainable FOOD production and consumption (SUSFOOD). The initiative backs research projects aiming at sustainable food production, reduced environmental damage and the avoidance of food waste. Further aims include a secure food supply and high-quality food. The European programme granted funding to 12 international joint research projects involving German participants until the end of 2014. Those joint projects include research on topics such as increased resource efficiency in food handling and processing, innovative technological approaches, and consumer behaviour.

Biobased ingredients

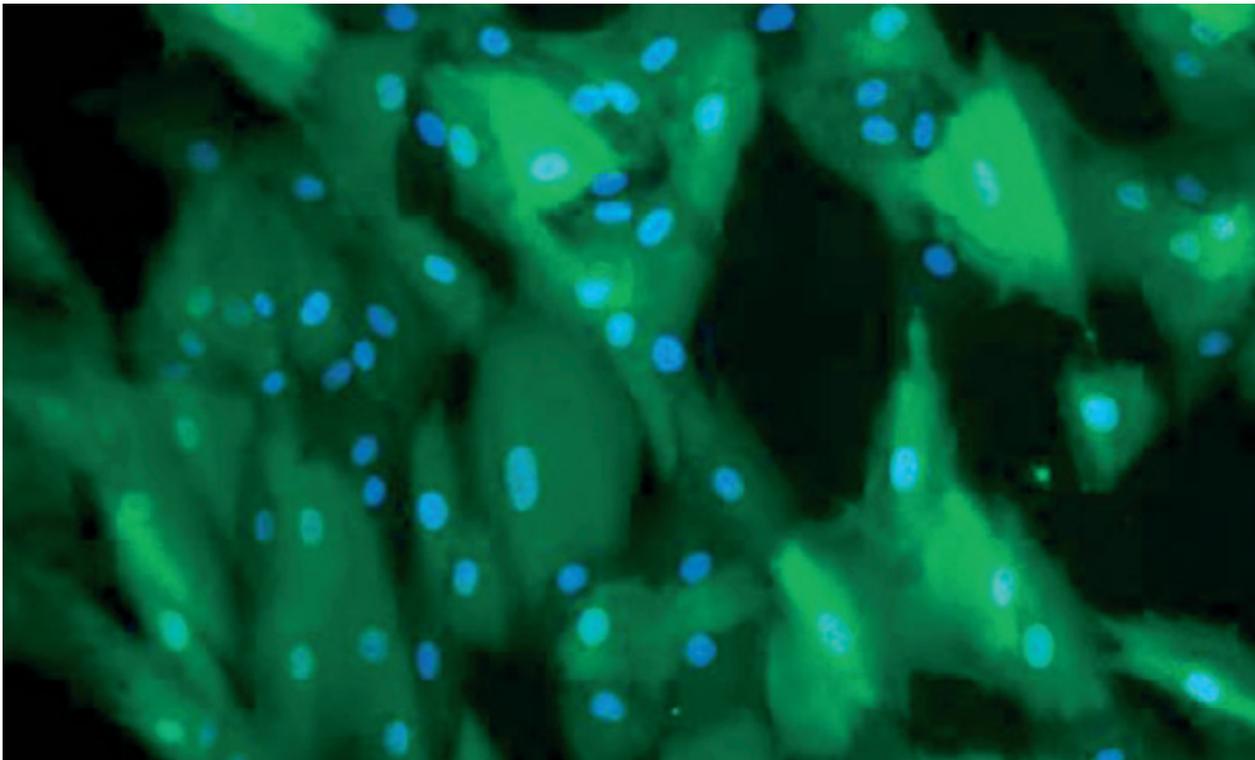
Technological and scientific advances in the biosciences, particularly in molecular biology and bioanalysis

processes, have enabled researchers to identify and understand complex biological networks and systems. Biological production systems characterised by a new substrate spectrum, increased diversity of products, or greater production efficiency can be developed on the back of such research. Biological resources can thus be considered biochemical ‘factories’ generating high-quality, tailored ingredients. That principle is applied extensively to the production of food ingredients. To that end, microorganisms help brew beer or make wine or cheese. Microbes are also used to produce many flavourings. The same applies to useful molecules such as enzymes. They are used in the baking industry, for example, for the production of durable crusts. Thanks to increased knowledge in the molecular biology field, these multi-skilled, biobased molecules are now manufactured in large quantities inside steel fermentation vessels. The more complex and elaborate the syntheses and process steps involved in biobased production become, the more valuable ingredients can be produced, for food, for example, and

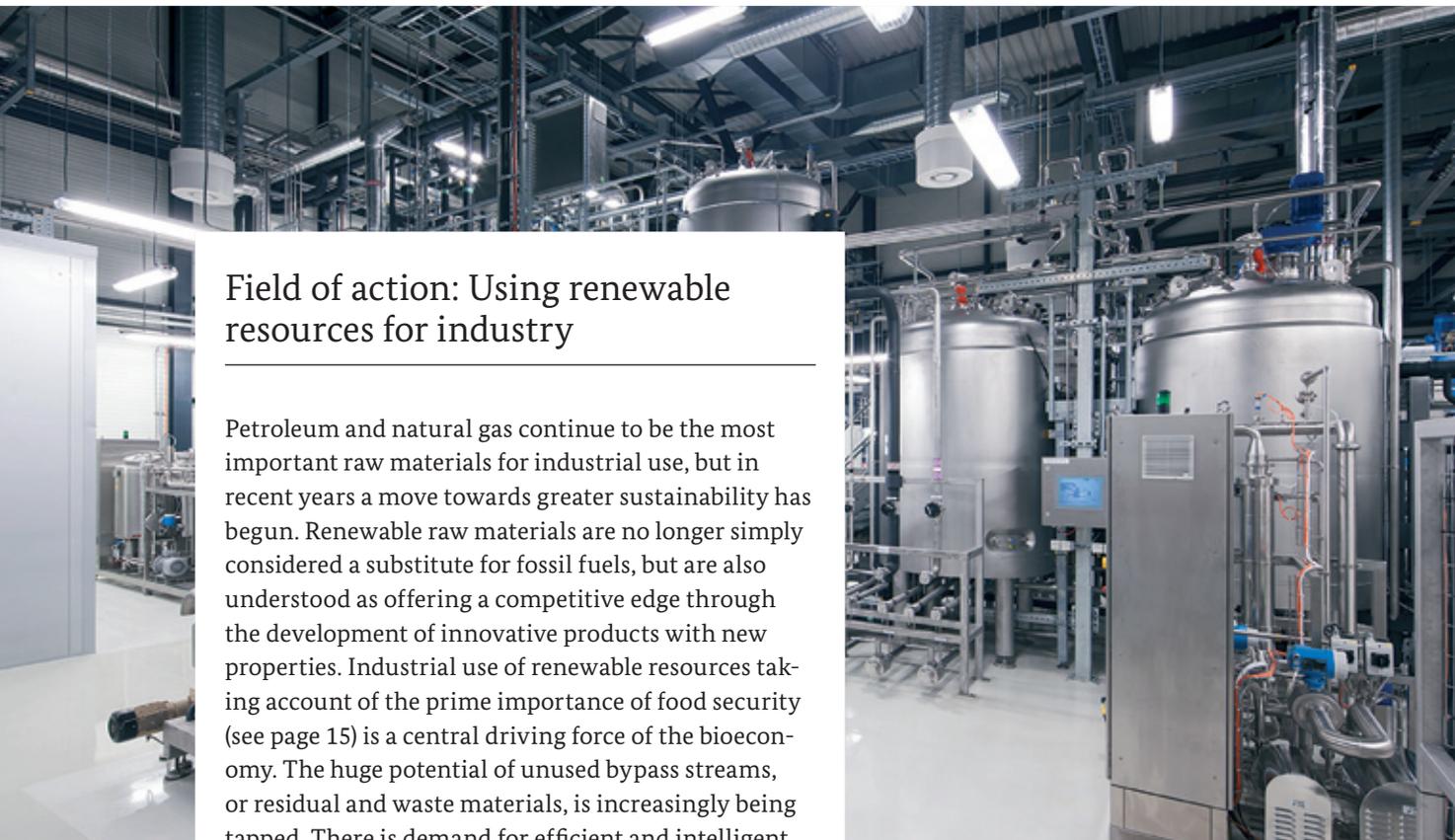
more economically. The same is also true of products made from plants, algae or microorganisms. They can offer benefits to the environment that far outstrip those of their precursor substances. In 2016, with the goal of advancing such developments, the BMBF introduced the funding measure 'Maßgeschneiderte biobasierte Inhaltsstoffe für eine wettbewerbsfähige Bioökonomie' [Tailor-made, biobased ingredients for a competitive bioeconomy]. The measure does not target the food sector alone. Rather, it is important to other industries too. It was designed with several sectors in mind, as certain technologies and procedures can be applied to other purposes in addition to the food sector. Thus, foodstuff innovations also touch on 'Using renewable resources for industry', a field of action outlined on page 23. For example, the Natural Life Excellence Network 2020 – Natlife 2020 focuses on the development of new kinds of natural food ingredients. This strategic alliance has received funding as part of the Innovationsinitiative industrielle Biotechnologie [Innovation Initiative Industrial Biotechnology]. See the box on page 25 for more details.

An overview of alternative protein sources

The search for alternative sources of protein is a major area of research in the light of increased demand for vegetarian and vegan food. In order to reduce the consumption of animal-based protein and to put sustainable structures in place for domestic agriculture, protein from plant sources including lupins, soya, or home-grown legumes such as peas or broad beans, are coming into focus. The Bundesprogramm Ökologischer Landbau (BÖLN) [Federal Organic Farming Programme] tests strategies to improve the cultivation of such plants. In 2012, the BMEL also set up the Protein Crop Strategy to fund further projects.



Taste cells under the microscope: Researchers of the BMBF-funded innovation alliance „NatLife“ are looking for new food ingredients.



Field of action: Using renewable resources for industry

Petroleum and natural gas continue to be the most important raw materials for industrial use, but in recent years a move towards greater sustainability has begun. Renewable raw materials are no longer simply considered a substitute for fossil fuels, but are also understood as offering a competitive edge through the development of innovative products with new properties. Industrial use of renewable resources taking account of the prime importance of food security (see page 15) is a central driving force of the bioeconomy. The huge potential of unused bypass streams, or residual and waste materials, is increasingly being tapped. There is demand for efficient and intelligent procedures and technologies to harness biomass as a raw material in a sustainable natural element cycle, from cascade utilisation through to recycling processes, while simultaneously adding value.

Diverse uses for biomass

Targeted support is required to use biological resources in such a comprehensive manner and to construct high-tech plants to recycle biomass in diverse ways. Although such approaches can usually make a substantial contribution towards reducing CO₂-emissions that damage the environment, they are often also more elaborate and expensive than conventional processes. From an economic perspective, it is much more sensible to link process and product innovations. The 'National Research Strategy BioEconomy 2030' has targeted such developments. In that context, it has offered support to the 'Spitzencluster BioEconomy' [Leading Edge Cluster BioEconomy] (see page 24) in order to effect the construction of new biorefineries in Leuna, a hub of the chemical industry in central Germany. The site has received funding from the

Federal Government, the state of Saxony-Anhalt and the Fraunhofer Society. The BMBF made available 40 million euros as part of its funding for the cluster of excellence. The BMEL and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) also channelled significant funds into the Fraunhofer Centre for Chemical-Biotechnology Processes (CBP). The CBP focuses on the use of wood as a raw material for various sectors. It aims to develop an economically viable concept for a plant to produce beech and poplar pulp, as well as the joint and cascading use of beech waste. The research activities within the Cluster of Excellence involve the innovative use of materials, the manufacture of chemical feedstock and innovative biomass materials, and the use of waste in energy generation.

Cross-sectoral utilisation of resources

Funding under the 'National Research Strategy BioEconomy 2030' was targeted in particular towards the

Leading Edge Cluster BioEconomy bolsters bioeconomy in central Germany



The Leading Edge Cluster BioEconomy aims to advance industrial development in central Germany within the context of the bioeconomy and to create new opportunities for growth. To that end, biomass must be utilised as intelligently as possible, particularly in regards to resources such as wood which face no competition for use in the food and animal feed industries. The cluster aims to build new links between key sectors in the region such as the forestry and wood processing industries, but also the chemical and plastics industries as well as bioenergy. A total of 60 partners in central Germany are pooling their expertise to develop an optimal, commercial value chain for local beech wood. The cluster includes industry partners from large corporations such as Linde and Schüco, but also SMEs like Tecnaro and research organisations such as the German Biomass Research Centre (DBFZ). The French company Global Bioenergies has also established itself in central Germany to develop a pilot plant for the production of the coveted gaseous carbon isobutene as a chemical raw material made from biological resources. At the same time, the pool of experts on the bioeconomy has been strengthened in the region. It is anticipated that the cluster will result in central Germany becoming more competitive in the long term.

utilisation of biological resources, preferably from residual or waste materials, in a cross-sectoral manner. In 2011, the BMBF launched the ‘Innovationsinitiative industrielle Biotechnologie’ [Innovation Initiative Industrial Biotechnology], which provided up to 100 million euros for several strategic alliances along value chains to initiate projects in that field (see box on page 25). The initiative builds on its predecessor, the nationwide ‘BioIndustrie2021’ BioIndustry2021 funding measure, which prioritised the development of regional structures and competencies in industrial biotechnology.

High-tech tools for tomorrow’s biobased production

A wide array of high-tech tools is key to incorporating biological resources in industrial processes. They can originate in the engineering science fields of process engineering, and systems and mechanical engineering, or in the life sciences, such as molecular biology and biotechnology. In addition to today’s existing methods and procedures, researchers are also working on new ideas for ways to strengthen links between biology and technology for the biobased production of tomorrow. Launched in 2010, the BMBF’s ‘Nächste Generation biotechnologischer Verfahren – Biotechnologie 2020+’ [Next Generation of Biotechnological Processes – Biotechnology 2020+] initiative, has, for example, tried to emulate biological processes found in material and energy conversion by bringing together engineering and food science. Whether it is microbial fuel cells, artificial photosynthesis or a universal production organism – there are already many ideas for future industrial production. To date, BMBF has already invested approximately 97 million euros in just shy of 50 projects on enabling technologies. That figure also includes large-scale projects run by research organisations in receipt of partial funding from the BMBF. Not only that: every two years since 2012, a research prize has been awarded to scientists with projects that are particularly promising or visionary. Winners can use the funding to finance their own research group.

From the laboratory to industry

In order to bring excellent ideas to market, targeted funding measures are required that support technol-

ogy transfer from the scientific field while retaining close links to academia. The 'Ideenwettbewerb Neue Produkte für die Bioökonomie' [Ideas contest new products for the bioeconomy] has enabled the BMBF to develop a funding option for researchers with minimal entry requirements, aimed in particular at novel and original ideas for industrial biotechnology. The ideas contest can include visions for products that have been or will be developed as part of the 'Nächste Generation biotechnologischer Verfahren – Biotechnologie 2020+' [Next Generation Biotechnological Processes – Biotechnology 2020+] initiative or from other creative activities organised by the BMBF such as the 'Innovationsakademie Biotechnologie' [Biotechnology Innovation Academy]. The 'GO-Bio Gründungsoffensive Biotechnologie' campaign for start-ups also targets technology transfer as part of its cross-section activities under the 'National Research Strategy BioEconomy 2030'. It is aimed at advanced teams of researchers wishing to develop a life-science idea into a start-up project, however.

Alongside domestic measures, the 'National Research Strategy BioEconomy 2030' also promotes networking between players on an international level. Collaborative science-and-industry projects have been funded since 2006 under the 'ERA-Net Industrial Biotechnology' initiative – a joint European initiative of 19 research funding organisations in 13 countries working on industrial biotechnology. There has been a total of seven calls for proposals since.

Driving applications with greater value

Renewable resources are also a key aspect of the BMEL agenda. It has developed its own funding programme specifically for that topic, with the latest iteration was published in 2015. The programme targets funding at applied research and development projects focussing on new applications with greater potential to add value. The projects should go beyond environmental, resource and climate protection, and the strengthening of agriculture and forestry, by encouraging a socially responsible biobased economy and the preservation of biodiversity. As well as greater efficiency and cost-effectiveness, the programme emphasises projects involving recycling, cascading use and integrated utilisation concepts such as biorefineries.

Innovation Initiative Industrial Biotechnology



The 'Innovationsinitiative industrielle Biotechnologie' [Innovation Initiative Industrial Biotechnology] was launched in 2011. The initiative is centred on strategic alliances guided by companies that aim to tap into the potential of industrial biotechnology for climate and resource protection. A budget of up to 100 million euros funds seven consortia. It covers a broad array of topics, demonstrating the diverse innovations in the bioeconomy. The 'Wissensbasierte Prozessintelligenz' [Knowledge-Based Process Intelligence] alliance examines new online-based methods to monitor process quality. Another alliance, 'TeFuProt', seeks to generate high-quality, technical protein blocks from rapeseed meal for use in the manufacture of paints and dyes. The 'Zero-Carb FP' alliance concentrates on harnessing carbohydrates from residual material and waste streams which can be used to produce additives for high-tech oils. The 'Funktionalisierung von Polymeren' (FuPol) [Functionalisation of Polymers] is an alliance that aims to further draw on the potential of enzymes aimed at moulding innovative products for the textile sector and construction chemicals. Finally, companies in the GOBI alliance are on the lookout for beneficial bacteria to produce bioactive products in the animal feed, health and pharmaceutical industries. Here they work together to find biobased alternatives to conventional antibiotics.

Among other activities, it focuses on the sustainable management of materials streams, special consideration of water as a resource, and the decentralised generation of resources in aquatic systems.

Raw-material suppliers need to get on board

Current developments underline the fact that the cross-sectoral industrial utilisation of renewable raw materials has particular influence on how an industry such as agriculture, as a future supplier of raw materials, should develop in future. In 2015, BMBF launched the 'Agrarsysteme der Zukunft' [Agricultural Systems of the Future] strategy process to overcome those challenges (see the field of action 'Developing sustainable agricultural production' on page 18).

Call for innovative alliances

In the autumn of 2016, the BMBF also organised the competition 'Innovationsräume Bioökonomie' [Bioeconomy Innovation Spaces]. They hope to identify innovative alliances where partners from science, industry and society can come together to develop and implement ideas for the bioeconomy in a cross-

sectoral manner. A budget of up to 20 million euros has been made available over a five-year period for innovative concepts to be selected in a multi-step process. The new funding format aims to create a culture of innovation to define, map out and grow new forms of cooperation in biobased industry. The innovation areas have been designed to create space to make it easier for players to implement and breathe life into ideas and projects. It allows partners from universities to establish contact with industry representatives in order to present their ideas. In turn, companies gain an early insight into new scientific and technological developments.



With the new Fraunhofer Center for Chemical-Biotechnological Processes (CBP) a biorefinery has established at the former chemical industry site Leuna. Here, the resource wood is converted via different routes into biobased building blocks.

Field of action: Developing biomass-based energy carriers

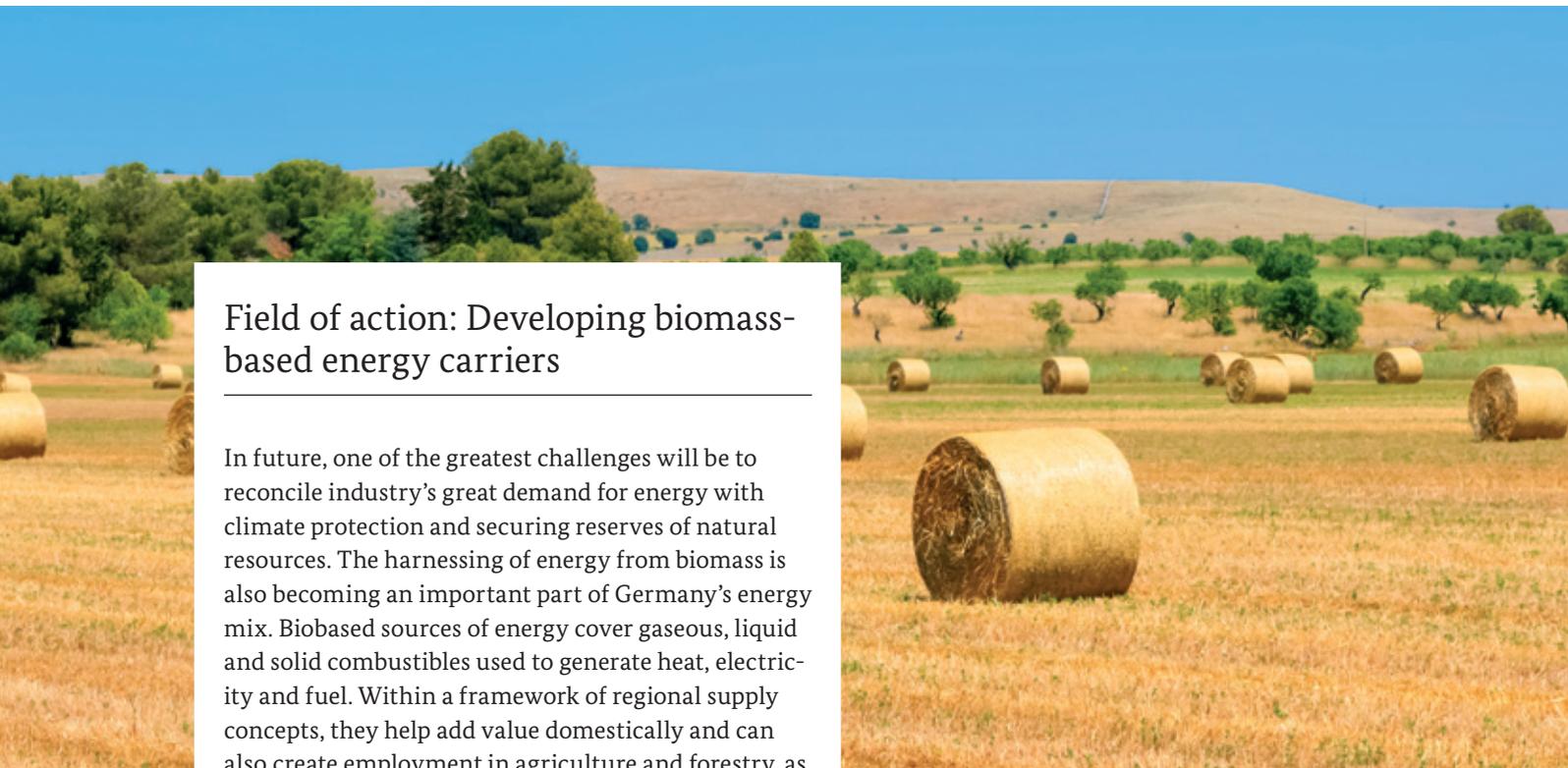
In future, one of the greatest challenges will be to reconcile industry's great demand for energy with climate protection and securing reserves of natural resources. The harnessing of energy from biomass is also becoming an important part of Germany's energy mix. Biobased sources of energy cover gaseous, liquid and solid combustibles used to generate heat, electricity and fuel. Within a framework of regional supply concepts, they help add value domestically and can also create employment in agriculture and forestry, as well as industry. Based on the field of action 'Developing biomass-based energy carriers', the 'National Research Strategy BioEconomy 2030' is promoting the generation of bioenergy in an internationally more competitive and eco-friendly manner that is kinder to the climate, nature and the environment.

Making domestic biomass more competitive

Great research challenges lie ahead if we aim to utilise the potential of biomass further. Raw materials from agriculture can be used more efficiently only through our exploiting the latest technology and insights, particularly those originating in fields such as systems biology, genome research and biotechnology. Such resources are fundamental for the generation of energy from biomass in an internationally competitive, sustainable and large-scale manner. The need for further research and development was incorporated into the 'BioEnergie 2021 – Forschung für die Nutzung pflanzlicher Biomasse' [BioEnergy 2021 – Research for the use of biomass] funding measure. It was aimed at maintaining, developing and growing Germany's technical lead in various value chains relevant to the generation of bioenergy. Diverse cross-sectoral

concepts for utilisation were called for (e.g. energy, transport and chemistry). Closer interdisciplinary links between plant breeding and plant biotechnology on the one hand, and industrial biotechnology, chemical-physical conversion processes, processing technologies and downstream user sectors on the other, should improve technology transfer, extend application options, and expedite increases in efficiency.

In order to achieve those goals, the three modules comprising the measure were conceived as a joint activity of the 'Energy Research Programme' and the 'National Research Strategy BioEconomy 2030'. The project funding from the Energy Research programme prioritised bioenergy conversion, particularly the production of biogas. A total of 48 projects with funding in excess of 25 million euros were grant-funded before the measure closed in May 2015. The utilisation of non-specific biomass, including residual and waste material, for the production of biofuels may help to reduce competition between its use as food and as a source of raw materials or energy.



Utilisation of energy crops and residual material

One of the modules also targeted research on the utilisation and improvement of energy crops capable of being cultivated in areas that generally present difficulties for them. The module additionally supported young scientists in their development of holistic concepts for the future use of bioenergy. From 2010 to 2015, a further 25 million euros or so of funding was made available for those research areas. The findings from those projects were also applied to the BMBF's 'BioProFi – Bioenergie – Prozess-orientierte Forschung und Innovation' [BioProFi – BioEnergy – Process-oriented Research and Innovation] initiative, which runs until 2017. The initiative deals with topics such as how to optimise the utilisation of waste and develop processes in biogas plants to improve load-dependent feed-in to the grid.

Advancing efficient cascade use

The BMEL also supports bioenergy through its 'Förderprogramm Nachhaltende Rohstoffe' [Renewable Resources Funding Programme] funding pro-

gramme, which aims to support the energy switch-over as it affects electricity, heat and fuel conversion pathways. The programme's main focus is on improved efficiency in biogenic value chains, technical applications, and viable cascade use. Funding also particularly targets research and development involving, for example, increased links between use for energy generation and raw materials, and detailed studies of the utilisation of by-products and residual material. In the longer term, the BMEL also aims to bring about even better integration of bioenergy in regional and supra-regional energy (infrastructure) systems.



In the biorefinery in Straubing ethanol is obtained from straw for usage as biofuel and for other industrial purposes.

Expediting the move from theory into practice

German industry must aim high in research terms and continue to invest in the development of new processes, technologies and products if it is to remain competitive. Innovative SMEs continue to drive the R&D phenomenon. Small and medium-sized enterprises (SMEs) are leaders of technological progress in advanced biological research. They lay the foundation for sustainable economic activity through their biobased processes and innovative products and services. Funds targeted at SME research play a key role in the 'National Research Strategy BioEconomy 2030' as a cross-section activity involving several areas and also support the BMBF's ten-point programme 'Vorfahrt für den Mittelstand' [Priority for SMEs], published in 2016.

Paving the way for start-ups

A reduction in start-ups in the high-tech sector and reduced access to private venture capital spurred the BMBF to launch the GO-Bio campaign in 2005. The campaign focus is on research teams from universities, non-university research institutes, businesses and clinics ready to establish a start-up. It gives them the chance to develop technically demanding bioscience research topics that demonstrate good potential for innovation and commercial uses. It is hoped that the measure will result in the establishment of viable start-ups. There have been seven selection rounds since GO-Bio was launched, with 50 teams receiving support. The eighth GO-Bio selection round began in December 2016. A total of 150 million euros have been invested.

Investing in innovative SMEs

Executing cost-intensive, high-risk research and development projects is not only a challenge for young



entrepreneurs, but also for SMEs. 'KMU-innovativ: Biotechnologie – BioChance' [SME-innovative: Biotechnology – Biochance] addresses innovative small and medium-sized enterprises in the biotechnology sector – which play a key role in driving the bioeconomy. The measure offers companies an opportunity to develop a high-risk R&D project with the aim of bringing it to market. This is particularly attractive to new companies. In turn, the funding measure creates the necessary space for older businesses to establish themselves in new markets and areas. 'KMU-innovativ' can also be thought of as a tool to bring together SMEs from different sectors or develop entirely new products. Since 2007, 19 calls for proposals have been announced. Approximately 260 projects have been supported with 230 million euros in funds over a ten-year period. The 'European program for Transnational R&D&I cooperations of SMEs in the field of Biotechnology – EuroTransBio' is the transnational counterpart of 'KMU-innovativ: Biotechnologie – BioChance' [SME-innovative: Biotechnology – BioChance].



Understanding societal change

The bioeconomy makes an important contribution to food security, climate protection, and the sustainable use of natural resources. Owing to its complexity, it makes an appearance in almost all areas of life and the economy. For society to change as a whole, political, social and economic factors must be considered alongside innovations in technology and natural science. A biobased, sustainable economy can only become a reality when all of society's groups can come together to agree on the different perspectives and interests.

Society is already beginning to see the shift towards a sustainable bioeconomy and it continues to gain momentum. The general research and development tasks associated with such progress have been determined in the 'National Research Strategy BioEconomy 2030' (see page 12, 'Innovations for a biobased economy'). Over the past six years, we have seen that the support of all parties involved in the bioeconomy is necessary in order for its ambitious plans to be achieved. Integration is particularly important here as such a profound transformation is not so much

an abstract, theoretical process, as it is a procedure involving all social participants. For Germany's bioeconomy to really take off, a range of social players must be willing to commit to the changes which have been initiated. It is against this backdrop that it is vital for the bioeconomy to be in the public eye more than it has been so far to date, allowing for fact-based dialogue.

Examining the effects of the change towards a bioeconomy

The 'National Research Strategy BioEconomy 2030' is a groundbreaking achievement that has already proven important for the bioeconomy. Through funding for numerous natural science projects from agricultural research to chemistry and process engineering, it has initiated expert debates on technical solutions for many of the key challenges facing society. This strategy has also been fundamental in instigating much-needed debate in the social sciences. Thus, research to examine the socio-economic issues surrounding the transformation to a biobased economy from a social, economic and political perspective has gotten under way. The success of the bioeconomy

depends on a comprehensive understanding of the interactions between society, technology, the economy and ecology. Such complex interplay must be understood before an appropriate political course can be set.

Discussing conflicts of interest

In this context, the concept 'Bioökonomie als gesellschaftlicher Wandel' [Bioeconomy as Societal Change] is a key funding activity. It was first introduced at the 'Bioeconomy Mid-Term Conference' in 2014. The BMBF uses this concept to support research in the social, political and economic sciences that highlights the social effects of the shift to a bioeconomy which until now were only beginning to emerge. It also aims to develop practical holistic concepts to accompany and guide the transformation process. Research projects funded by the BMBF focus on issues such as conflicts of interest and social distribution resulting from biobased structural changes. Conflicts around land use can arise, for example, once increased demand for biomass leads to more opportunities for the use of land, but existing farmland remains limited. That challenge must be considered not only from a technological point of view, but also from ecological and social perspectives. Although the 'National Research Strategy BioEconomy

2030' clearly prioritises food security, there are still recurring conflicts about the actual management of farmland and the importance of individual renewable raw materials. At an international level, such as in the case of emerging and developing countries, the cause of conflict is often much more complex. Here local, regional and global factors often go hand in hand and must be considered as a whole.

Bringing about informed public debate

Reliable data that provides information on the current status of the bioeconomy and involves as many relevant participants and developments as possible is one of the essential requirements for the growth of a biobased economy. Such research from the fields of social and economic science contributes important data for the bioeconomy monitoring which commenced in 2016 under the umbrella of the 'National Policy Strategy Bioeconomy 2030', for instance, when compiling the direct and indirect effects of the bioeconomy in the context of its impact on sustainability. Accordingly, the BMBF has put a funding measure into place. The BMEL and BMWi also finance studies as part of the bioeconomy-monitoring.



Conflicts around land use can arise, for example, once increased demand for biomass leads to more opportunities for the use of land. For the German government, securing global nutrition is a priority.

Encouraging social participation

Despite the huge political support which has set the foundations for a German biobased economy, the bioeconomy, as well as its methods and sub-areas remain unknown to vast sections of society. The vision for a biobased economy is complex and often requires explanation. The Bioeconomy Council, an interdisciplinary expert board, advises the Federal Government (see box on page 33). Its own series of events initiate social dialogue, compile policy recommendations and drive international networking (see 'Driving international networking' on page 34). One thing is clear: Social dialogue and an understanding of the challenges facing the bioeconomy play a decisive factor in the demand for new products and services and the associated technological developments. The biobased economy only stands a chance if citizens actively participate in designing social change.

The 'Bioeconomy Mid-Term Conference' organised by the BMBF in the summer of 2014 allowed it to take

stock of the 'National Research Strategy BioEconomy 2030' together with players from the worlds of science, economy and politics. The BMBF used the event as an opportunity to introduce its 'Wegweiser Bioökonomie' [Destination Bioeconomy] in which it elaborated on its funding policy. The event also offered others a forum in which to discuss the current challenges posed by a German biobased economy.

Developing new forms of communication

In 2016, the BMBF launched 'Neue Formate der Kommunikation und Partizipation in der Bioökonomie' [New Formats of Communication and Participation in the Bioeconomy], a measure aimed at providing the foundations to initiate social debate about the actual design of the bioeconomy. It takes a scientific approach to the development and testing of novel formats, instruments and methods for communication that help to involve as many sections of society as possible and/or to strengthen social engagement. One of the particular challenges in that regard is the multi-



During the International Green Week 2017 the Bioeconomy Council informed about sustainable products in everyday life.

dimensional and abstract nature of the bioeconomy, which is open to developments and can often be contentious. Any actions taken should be subject to scientific evaluation as they progress, beginning with the bioeconomy sector, to deduce the factors for the success of innovative communication and participation concepts. In the long-term, it is hoped that the knowledge from such evaluation procedures can also be applied to other scientific sectors.

The BMEL's 'Förderprogramm Nachwachsende Rohstoffe' [Renewable Resources Funding Programme] specifically aims at improving social dialogue on the opportunities of a sustainable bioeconomy as a whole. The programme intends to initiate long-term discussion and critical assessment of not only the opportunities, but also the strengths and weaknesses of biobased products and energy sources together with representatives from economics, science and civil society. At the top of the list are measures to inform and encourage acceptance of the bioeconomy amongst the public, as well as scientific tests and strategy developments which offer a practical accompaniment to the growth of a sustainable bioeconomy. In October 2015, the BMEL convened an expert board to discuss the topic of 'Gesellschaftlicher Dialog Bioökonomie' [Social Dialogue on Bioeconomy]. The board was designed to assist BMEL by providing expertise on social dialogues which it can draw upon to appraise communication projects.

Latest developments and news

In addition to the communication activities performed by governmental ministries, the *bioökonomie.de* internet portal acts as a supplementary source of comprehensive information that works on behalf of the BMBF to provide interesting daily updates for those in the science and economic sector, as well as interested members of the public. It reports the latest trends via news, interviews, profiles and films. Funding case studies and success stories offer an insight into the Federal Government's political activities. Numerous databases enable researchers to keep up-to-date on the latest calls for proposals. The website also makes the entire bioeconomy accessible for lay people – through factsheets on available biobased products and overviews of bioeconomy trends in distinct sectors.

The Bioeconomy Council

The Bioeconomy Council, an independent advisory board to the Federal Government, was first established in 2009 by the BMBF (Federal Ministry of Education and Research) and the former BMELV (Federal Ministry of Food, Agriculture and Consumer Protection). The 17 members of the Bioeconomy Council provide expertise across the entire bioeconomy spectrum. In 2012, they held their second term in office. The experts seek approaches to sustainable solutions and put their knowledge to use in a global context. The council leads an open dialogue with society. Furthermore, it gives recommendations for the optimisation of funding in terms of training, continuous development, research and development. The council focuses on long-term goals, but also current political demands. In the autumn of 2016, the board published recommendations for action to develop the long-term bioeconomy research strategy.

For further information see:
www.biooekonomierat.de/en

Additionally, it provides an introduction to bioeconomy activities in other countries. Students and their teachers can find many helpful videos to allow them to explore the world of bioeconomy.



Driving international networking

The development of a sustainable bioeconomy is a global challenge that requires close and efficient international cooperation. That applies especially in view of the ambitious objectives set out for food security. Germany set new international standards with its 'National Research Strategy BioEconomy 2030'. In the long term, the Federal Government has taken the important step of integrating the bioeconomy, nationally and internationally, into its innovation, sustainability and climate policies.

Germany has also been able to make a difference at an international level thanks to its implementation of the 'National Research Strategy BioEconomy 2030'. The next step is to find the best possible method to combine its national activities with those of other countries. According to a study by the Bioeconomy Council, a Federal Government advisory board (see box on page 33), a total of 45 countries worldwide have already built the bioeconomy into their political strategies and have set up corresponding programmes. That only serves to convince us of one thing: Politicians and entrepreneurs all over

the world are investing in green growth, resource-efficiency and a sustainable, biobased economy – each focussing on different aspects. Industrialised countries in Europe and North America view the bioeconomy mainly as an opportunity to develop innovative biobased products and processes and to open up new markets. Emerging countries such as Brazil are investing in the growth of entire sectors based on renewable raw materials. Developing countries, in turn, are given opportunities for cooperation on technology transfer and economic involvement in international fair trade.

International research partnerships

In recent years, the BMBF has advanced international networking in research and development for German participants – not only at a European level, but worldwide. The 'Bioökonomie International' [Bioeconomy International] funding measure supports exemplary projects involving international partnerships in the field of research and development – spanning all fields of action and areas under the 'National Research Strategy for the BioEconomy 2030', with an emphasis on Argentina, Brazil, Chile, China, India, Canada, Malay-

sia, Russia, and Vietnam. In addition to technological issues and development goals, socio-economic aspects of the bioeconomy are also considered important.

Fostering European economic growth

For many years, politicians within Europe have communicated closely on the bioeconomy. The European Union supports a resource-efficient, competitive, biobased economy through its strategy 'Innovating for Sustainable Growth: A Bioeconomy for Europe', adopted in 2012, and the associated action plan. In 2013, a public-private partnership called 'Biobased Industries' (BBI) was put in place, to which the European Commission and numerous representatives from European firms have lent their support. A total of 3.7 billion euros – of which just under a billion euros were granted by the European Commission – has been made available for a period of seven years (2013–2020)

for research projects and pilot plants. Approximately 140 partners from all over Europe are involved in Biobased Industries, including German corporations, SMEs, clusters and associations. The partnership aims to grow value chains which go beyond the traditional routes and to develop recycling concepts for today's natural resources such as wood, or waste and residual material. The European Commission is currently overhauling its activities in regard to the bioeconomy. Particular focus is being placed on maintaining competitiveness and the strengthening of expertise within Europe – particularly vis-à-vis the growing competition from other countries such as the USA or China. It also advises on how to better network and co-ordinate the various activities scattered around the globe. The diversity seen in the strategies for the bioeconomy mirror the multitude of ways it is understood worldwide. The next step is to bring together all of the individual measures and national strategies as a whole, to discuss them on a global platform, and adapt them to meet local requirements.



The international Steering Committee at the Global Bioeconomy Summit 2015 laid down the priorities for an international bioeconomy policy; see: http://gbs2018.com/fileadmin/gbs2015/Downloads/Communique_final_neu.pdf



More than 700 experts came together at the Global Bioeconomy Summit to discuss the conditions necessary for the growth of a global bioeconomy.

Anchoring bioeconomy at an international level

In the autumn of 2015, approximately 700 participants from 82 nations met in Berlin at the first 'Global Bioeconomy Summit' to exchange ideas on how the bioeconomy can play a more important role at an international level, and how existing processes of negotiation for sustainability and climate protection can be incorporated into their national agendas. In response to an invitation from

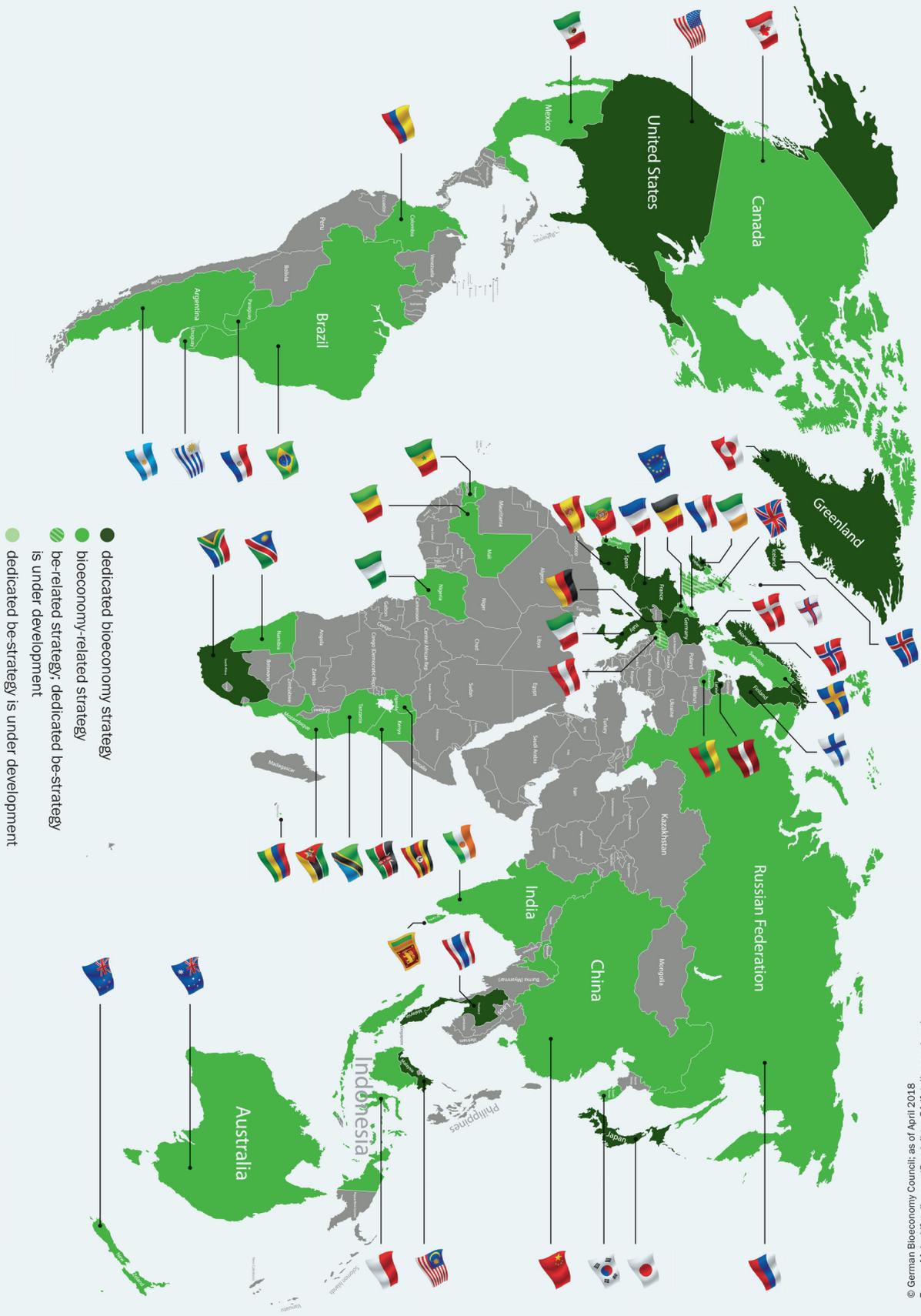
the Bioeconomy Council, supported by the BMBF, key international and national representatives from policy and the industry came together for the first time. The Food and Agriculture Organization (FAO), the Organisation for Economic Cooperation and Development (OECD), the European Commission and the International Energy Agency participated in the summit by holding their own workshops. At the end of the two-day conference, a final communiqué was presented which laid down five priorities for an international political agenda towards a biobased economy:

- **International cross-discipline and cross-sectoral cooperation aimed firstly at the efficient use of natural resources in global value networks, and secondly to protect nature**
- **The development of a collaborative approach for measuring the bioeconomy's contribution to the sustainable development goals**
- **Fostering the exchange of experiences and co-ordination of funding for innovation, the application of local expertise as well as for industry and trade politics**
- **More efforts to guide bioeconomy funding towards the agendas of international organisations and to incorporate it into multi-lateral political processes and governmental negotiations, such as negotiations for the implementation of Agenda 2030, the climate agreement or international trade talks**
- **Bolster cooperation in terms of education, joint learning and dialogue**

Based on those key points, the Bioeconomy Council is currently planning the second Global Bioeconomy Summit scheduled for 2018.



One of the summit's most important goals was to encourage networking amongst the international participants. Over a period of two days, a wealth of participants from 82 countries exchanged ideas on how best to co-ordinate the bioeconomy at an international level.



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Raman Maise/fotolia.com (flags), Jktu_21/fotolia.com (map)

The Bioeconomy Council reported in an international study that 45 countries have included bioeconomy in its governmental programmes.

Further information

Bioeconomy facts on the Internet

BMBF information on the bioeconomy

www.bmbf.de/en/bioeconomy---new-concepts-for-the-utilization-of-natural-resources-4543.html

The BMBF's bioeconomy information portal

www.biooekonomie.de/en

Project Management Jülich – Information on BMBF-project funding

www.ptj.de/biooekonomie

BMBF-funded website on plant research (in German only)

www.pflanzenforschung.de

BMEL information on the bioeconomy

www.bmel.de/EN/Agriculture/RenewableResources/renewable-resources_node.html

BMWi information on innovation policies

www.bmwi.de/Redaktion/EN/Dossier/innovation-policy.html

BMZ information on Agenda 2030

www.bmz.de/en/ministry/principles/2030_agenda/index.html

BMUB information on the economy and environment

www.bmub.bund.de/en/topics/economy-products-resources-tourism/

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