# Innovation

## Around 10,000

Employees in research and development worldwide

Spent on research and development

€1,888 million

Around 3,000 Projects in research pipeline

A growing need for food, energy and clean water, limited resources and a booming world population – reconciling all these factors is the greatest challenge of our time. Innovations based on chemistry play a key role here, as they contribute decisively to new solutions. Effective and efficient research and development is a prerequisite for innovation as well as an important growth engine for BASF. We develop innovative processes and products for a sustainable future and drive forward digitalization in research worldwide. This is how we ensure our longterm business success with chemistry-based solutions for almost all sectors of industry.

For BASF, innovation is the key to successfully standing out from the crowd in a challenging market environment. Our innovative strength is based on a global team of highly qualified employees with various specializations. We had around 10,000 employees involved in research and development in 2017. Our three global technology platforms are run from our key regions – Europe, Asia Pacific and North America: Process Research & Chemical Engineering (Ludwigshafen, Germany), Advanced Materials & Systems Research (Shanghai, China) and Bioscience Research (Research Triangle Park, North Carolina). Together with the development units in our operating divisions, they form the core of our global Know-How Verbund. BASF New Business GmbH and BASF Venture Capital GmbH supplement this network with the task of using new technologies to tap into attractive markets and new business models for BASF.

In 2017, we generated sales of over €9 billion with products launched on the market in the past five years that stemmed from research and development activities. In the long term, we aim to continue significantly increasing sales and earnings with new and improved products.

### **Global network**

#### Network with around 600 universities, research institutes and companies

Our global network of about 600 universities, research institutes and companies forms an important part of our Know-How Verbund. We collaborate with them in many different

disciplines. The direct access to external scientific expertise, new technologies and talented minds from various disciplines helps us to strengthen our portfolio with creative new projects. For instance, we are working on innovative materials for electrochemical energy storage with the Karlsruhe Institute of Technology (KIT) at the BELLA (Battery and Electrochemistry

Laboratory) joint laboratory.

We use the Creator Space<sup>®</sup> approach developed by BASF to generate innovative ideas and continuously promote dialog with customers, partners and suppliers. We draw on cutting-edge innovation methods here.

In our excellence program UNIQUE – The BASF Academic Partnership Program, we are working with fifteen leading universities around the world. BASF also runs four postdoctoral centers that pool collaborations with several research groups on a regional level.

The North American Center for Research on Advanced Materials (NORA) and the California Research Alliance (CARA) postdoctoral centers are located in the United States. In 2017, BASF extended the cooperation between NORA and its academic partners by another five years and celebrated the 10-year anniversary of the partnership with Harvard University. Focus areas include materials science, bioscience, catalysis research, digitalization and cooperation with start-ups. The CARA multidisciplinary collaboration has been work-ing on new functional materials and in the area of biosciences for three years now. It has established more than 25 research projects, which have resulted in many scientific discoveries and patent applications. In 2017, we announced that the collaboration between CARA researchers and BASF experts will continue for another five years.

The Joint Research Network on Advanced Materials and Systems (JONAS) postdoctoral center is active in Europe, while the Network for Asian Open Research (NAO) covers the Asia Pacific region. The Network for Advanced Materials Open Research was renamed the Network for Asian Open Research in 2017 after NAO's research projects were expanded to include process research, chemical engineering and biosciences.

#### Strategic focus

- Innovation approach with strong focus on customers and markets
- Globalizing research and strengthening regional competencies

In 2017, our **research pipeline** comprised approximately 3,000 projects. **Expenses** for research and development amounted to around  $\in$ 1,888 million, just above the prior-year level ( $\in$ 1,863 million). The operating divisions accounted for 80% of total research and development expenses in 2017. The remaining 20% related to cross-divisional corporate research focusing on long-term topics of strategic importance to the BASF Group. We strive to maintain a high level of spending on research and development.

The needs of our customers are the starting point for chemistry-based innovations, requiring market-driven research and development. Creativity, efficiency and collaboration with external partners are among the most important success factors. In order to bring promising ideas to market as quickly as possible, we regularly assess our research projects using a multistep process and align our focus areas accordingly. The aim of our **innovation approach** is to increase our company's power of innovation and to secure our long-term competitiveness. We aim to achieve this by concentrating our research focus on topics that are strategically relevant for our business, strengthening our existing scientific processes and increasingly using new scientific methods and digital tools, and optimizing our organizational structures.

Our cross-divisional corporate research is closely aligned with the requirements of our operating divisions and allows considerable space to quickly review creative research approaches. We strengthen existing and continually develop new key technologies that are of central significance for our operating divisions. Examples include polymer technologies, catalyst processes or biotechnological methods.

We continued to refine our innovation approach in 2017 and have identified additional, far-sighted topics that go above and beyond the current focus areas of our divisions to drive innovation in new business fields and with new technologies. The aim is to use these to exploit new business opportunities within the next few years. We are also working on overarching projects that are highly relevant from a technological, societal or regulatory point of view.

In 2017, we continued to work on the systematic application of digital technologies in research and development. In the



#### Global network: postdoc centers and UNIQUE excellence program

Also a partner of the UNIQUE program

years ahead, we plan to consistently expand existing expertise in fields like modeling and simulation and to develop new digital applications.

Our **global research and development presence** is vital to our success. We want to continue advancing our research and development activities, particularly in Asia as well as in North America, and are adapting this to growth in regional markets. A stronger presence outside Europe creates new opportunities for developing and expanding customer relationships and scientific collaborations as well as for gaining access to talented employees. This strengthens our Research and Development Verbund and makes BASF an even more attractive partner and employer.

In addition to the Innovation Campus Shanghai (previously Innovation Campus Asia Pacific) which opened in 2015, we inaugurated the Innovation Campus Mumbai in 2017 to further increase our research capacity in Asia. The new Campus brings together existing and new research and development activities in Mumbai, India, under one roof, where up to 300 scientists focus on crop protection and process development.

Ludwigshafen remains the largest site in our Research Verbund. This is underscored by the investment in the world's largest supercomputer for research in the chemical industry, which was put into operation in 2017. With a computing power of 1.75 petaflops,<sup>1</sup> Quriosity offers around 10 times the computing power previously available to BASF researchers worldwide. In collaboration with the Hewlett Packard Enterprise group, the new supercomputer was custom designed for chemical research and will drive forward the digitalization of BASF research globally.

The number and quality of our patents also attest to our power of innovation and long-term competitiveness. We filed around 800 new patents worldwide in 2017. In 2017, we once again ranked among the leading companies in the Patent Asset Index, a method that compares patent portfolios industry-wide.

 $\bigcap$  For a multiyear overview of research and development expenditures, see the Ten-year summary on page 247

### **Research focus areas – examples**

- Increased use of digital technologies
- Expansion of business activities in 3D printing

Our focus areas in research are derived from the three major areas in which chemistry-based innovations will play a key role in the future: resources, environment and climate; food and nutrition; and quality of life. In 2017, BASF researchers from the Process Research & Chemical Engineering technology platform demonstrated the enormous potential of **digitalization** in research. For the first time, researchers were able to systematically analyze the existing data on catalysts used in the production of the intermediate product ethylene oxide, leading to valuable insights. The correlations between the formulations and the application properties of the catalysts allow their performance and lifetime to be predicted more accurately and faster.

A further example is the data-based optimization for the production of dirt-resistant, water-based coatings used in the furniture industry, for instance. Using electronic data from previous experiments, researchers from the Advanced Materials & Systems Research technology platform were able to quickly determine a successful formulation. Through the combination of laboratory work and virtual experiments, they were able to create new coatings that meet customer demands in a very short time.

We also use data mining methods to gain new insights from very large quantities of existing data. In biotechnology, for example, data mining helps to identify promising enzymes or suitable bacteria more quickly as part of product or process development. This work comes under our Bioscience Research technology platform.

**3D** printing involves the development of innovative materials. In the chemical industry, BASF already has a broad portfolio with materials, system solutions, components and services. In 2017, BASF New Business GmbH established BASF 3D Printing Solutions GmbH in Heidelberg, Germany, to continue the targeted expansion of the business. As a wholly owned subsidiary of BASF, it works closely together with researchers and application engineers from BASF as well as external partners, such as universities and customers.

In addition, BASF New Business GmbH acquired the filament producer Innofil3D B.V. headquartered in Emmen, Netherlands, in 2017. We can now provide both plastic granulates and filaments for 3D printing. These long, thin plastic fibers are used in fused filament fabrication, a special 3D printing process that manufactures items layer by layer from meltable plastic.

Our competence in the area of material development for 3D processes is demonstrated by the filament Ultrafuse 316LX. It was specially developed for a new process on the market for metal printing and has been in use since 2017. The product makes it easier to print 3D metal parts inexpensively and reliably.

For more information on research and development, see basf.com/innovations

Research and development expenses by segment 2017



**Chemicals:** Our specialty monomers enable innovation in our customers' downstream applications. These include a new application with **tertiary butylacrylate (tBA) in decorative paints**. tBA is primarily used as a functional component in water-based exterior paints. Our customers can use tBA to fomulate dispersions that improve the specific properties of their exterior paints – such as weathering and surface adhesion – without increasing production costs.

BASF's constant stream of new ideas has secured its position as the technology leader and largest supplier of hydrosulfites for over 100 years. These bleaching and reducing agents are used in paper production, for example. The new **Adlite**<sup>®</sup>, a hydrosulfite for the paper industry, testifies to our innovative strength. Adlite<sup>®</sup> improves the entire paper production process and makes it more flexible. It enables our customers to achieve a higher degree of whiteness with the same raw materials and in this way, manufacture higher quality paper. At the same time, Adlite<sup>®</sup> saves energy and mitigates the impact on the environment, resulting in lower wastewater residues.

BASF is one of the leading global providers in the field of gas treatment. Our OASE<sup>®</sup> brand portfolio ranges from gas treatment agents to licenses for gas treatment processes and the planning of plants. We have further developed our business model and systematically expanded our service offering with the new **OASE<sup>®</sup> connect** online platform, which is particularly attractive for customers at remote locations. Special software enables them to find the optimum technical settings for their plants and manage them more efficiently, achieving energy savings of up to 20% in the form of electricity and steam and significantly reducing operating costs at the same plant output.

**Performance Products: Acronal® 6292** is a new styrene acrylic binder that enables the production of more environmentally friendly scrub resistant interior wall paints. The polymer's high pigment binding power also means that less binder is required to produce a scrub resistant paint. This offers a cost advantage for paint manufacturers. Acronal® 6292 can also be used to produce low-emission paints without biocides

- preservatives needed to prevent bacterial growth in traditional water-based paints.

Fibroblasts are important cells in the skin, which contribute to skin regeneration. When they lose their vitality, the skin loses its resilience and elasticity. **Dermagenist**<sup>®</sup>, a marjoram leaf extract developed by BASF, restores the skin's density and firmness. It inhibits the fibroblast ageing process and stimulates the cells to produce structural proteins in the connective tissue.

**Pronovum** is a new BASF technology in the area of omega-3 food supplements. Intake of Omega 3 can help improve consumers' coronary and cognitive health. Independent studies have shown that the body processes omega-3 fatty acids formulated with Pronovum four times better than conventional, highly concentrated omega-3 fatty acids in the form of the chemical compound ethyl ester. Pronovum is a patented mixture of omega-3 oils in a new formulation that can be accessed much better by digestive enzymes.

"Cool roofs" are more reflective and so do not heat up as much in direct sunlight. Roofing membranes made from thermoplastic polyolefins (TPO) are an energy-saving and cost-efficient solution here. BASF now offers new **plastic additive systems** that are customized for such TPO roof membrane applications. Combinations of the light stabilizers Chimassorb<sup>®</sup> and Tinuvin<sup>®</sup>, the antioxidants Irganox<sup>®</sup> and Irgafos<sup>®</sup> as well as customer-specific plastic additive mixtures with minimal dust formation protect TPO membranes from the damaging effects of sunlight, extending their lifetime by up to 30 years.

**Functional Materials & Solutions: Formaldpure**<sup>®</sup> is a new catalyst from BASF, which removes the pollutant formaldehyde at room temperature with high conversion efficiency. It is suitable for use in a wide range of portable and large-scale air purification equipment. Formaldehyde is used in the manufacture of building materials and household products, so it is found in homes and buildings as an indoor pollutant. BASF's Formaldpure<sup>®</sup> is a thorough, long-life technology that removes formaldehyde from indoor environments and reduces the costs otherwise associated with frequent filter changes.

BASF's **MasterSeal 7000 CR** waterproofing system protects concrete structures in wastewater and biogas plants exposed to high concentrations of chemicals such as sulfuric acid. MasterSeal 7000 CR bridges cracks in concrete to prevent penetration by aggressive substances. This prolongs the lifetime of concrete structures, contributes to sustainable water management and simultaneously reduces maintenance costs. MasterSeal 7000 CR is easy to work with and even adheres to humid substrates. The quick hardening time allows water contact only 24 hours after application, reducing downtimes – an important factor in wastewater management. Thanks to the biomass balance method developed by BASF, we are able to flexibly replace fossil resources in our current Verbund system with sustainably generated bio-based raw materials by feeding biogas and bionaphtha directly into the value chain at the very beginning. The first **biomass-balanced products** have now been introduced in the area of **automotive refinish coatings**. The share of raw materials replaced by renewable raw materials in the Production Verbund is allocated to certain refinish coating products according to certified methods. Coatings in this category add ecological value by saving on fossil-based raw materials while maintaining their usual qualities.

The specialty polyamide **Ultramid® Deep Gloss** picks up on the trend toward higher quality and functionalized surfaces in car interiors. Ultramid® Deep Gloss is suitable for high gloss yet resistant components without the need for coating. It offers excellent resistance to scratching along with high chemical and good UV resistance. The material reproduces even the smallest structures true to detail, making haptic design elements and intuitive user interfaces possible – similar to a touchscreen. Demand for new operating concepts like this will continue to grow in the transition to autonomous driving. Ultramid® Deep Gloss also takes into account the automotive industry's demands with respect to emissions and odor.

Agricultural Solutions: We are working with farmers around the globe to improve the quality and yield of their agricultural production while taking societal expectations and requirements into consideration. To achieve this, we constantly invest in our development pipeline in order to expand our portfolio both in and beyond conventional crop protection – such as in biological solutions. In 2017, we invested €507 million in research and development in the Crop Protection division, representing around 9% of sales for the segment.

Our well-stocked **innovation pipeline** comprises products with a launch date between 2017 and 2027. With a peak sales potential<sup>1</sup> of  $\in$ 3.5 billion, the pipeline includes innovations from all business areas. The first market launches of **Revysol**<sup>®</sup>, our new fungicide, are scheduled for the 2019 growing season following registration with the relevant authorities. A new herbicide with a unique mode of action to control key weeds in

cereal should come on the market in 2019. The market introduction of the new insecticide **Inscalis**<sup>®</sup> to combat piercingsucking pests is planned for 2018. Another new insecticide, **Broflanilide**, which helps farmers control chewing insects like potato beetles and caterpillars in specialty and field crops, should be on the market from 2020. In Functional Crop Care, we are pushing ahead with the market introduction of **Velondis**<sup>®</sup>, for example, a biological fungicide for seed treatment. This is planned for 2018.

Digital innovations are also a key focus in the Crop Protection division. One example from digital agriculture is the online platform **Maglis®** that was launched in 2016, which offers farmers agronomic information and combines this with IT solutions and expertise from BASF. Maglis® is used by farmers worldwide – and we are constantly enhancing it. We are already testing new applications such as the automated diagnosis of plant diseases based on photo analysis.

□ For more information on Revysol<sup>®</sup>, see page 82

**Oil & Gas:** The Wintershall Group concentrates its innovationrelated activities on improving the success rate of exploration, developing technologies for reservoirs with challenging development and production conditions, and increasing the recovery factor of reservoirs.

Wintershall is working on the development of heatresistant and salt-tolerant surfactants together with the Performance Chemicals division. These substances are used in enhanced oil recovery to mobilize the oil trapped in the pores of the rock. Conventional surfactants often cannot be used because of the high temperatures and high salt concentrations of many reservoirs, especially in regions such as the Middle East, North Africa or in the North Sea. The research project is currently in the laboratory phase.