Innovation

A growing need for food, clean water and energy, 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 are a prerequisite for innovations as well as an important growth engine for BASF. We work in interdisciplinary teams on innovative processes and products for a sustainable future. This is how we ensure our long-term 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 our global team of highly qualified employees with various specializations. We had around 10,000 employees involved in research and development in 2016. Our three global technology platforms are each run from one of the regions particularly significant for us – 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 2016, we generated sales of over €10 billion with products launched on the market since 2011 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 strengthens our portfolio with creative new projects.

In our excellence program “UNIQUE – The BASF Academic Partnership Program,” we are working intensively with fifteen leading universities around the world. BASF also runs four postdoc 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) are located in North America. The Joint Research Network on Advanced Materials and Systems (JONAS) is active in Europe, while the Network for Advanced Materials Open Research (NAO) covers the Asia Pacific region.

In order to continuously promote exchange with external customers and partners, we have integrated the Creator Space® approach from our 2015 anniversary year into our regular research activities. We use this program to develop innovative ideas.

Strategic focus

- Enhanced innovation approach with strong focus on customers and markets
- Increased use of digital technologies
- Globalizing research and strengthening regional competencies

Our research pipeline comprised approximately 3,000 projects in 2016. Expenses for research and development amounted to around €1,863 million, slightly below the prior year’s level (€1,953 million). This was particularly attributable to the rearrangement of research activities in plant biotechnology and the corresponding adjustment of site structure in North America and Europe. Operating divisions were responsible for 79% of total research and development expenses in 2016. The remaining 21% was allocated to cross-divisional corporate research focusing on long-term topics of strategic importance to the BASF Group. We strive to maintain the recent years’ high level of spending on research and development.

Innovations based on chemistry require market-oriented research and development focused on the needs of our customers. That is why our cross-divisional corporate research is closely aligned with the requirements of our operating
In order to bring promising ideas to market as quickly as possible, we regularly assess our research projects using a multistep process and focus our topics accordingly. Creativity, efficiency and collaboration with external partners are among the most important success factors.

We enhanced our innovation approach in 2016 with the aim of increasing our company’s power of innovation and securing long-term competitive ability. We aim to achieve this by honing our research focus on topics that are strategically relevant for our business, strengthening our existing scientific processes and methods and introducing new ones, and optimizing organizational structures.

In so doing, we restructured cross-divisional corporate research in 2016 to create more space for the quick review of creative research approaches. At the same time, we tailored our previous technology fields even more toward the needs of the BASF Group. They have been rearranged into multiple, strategic key technologies that are constantly being further developed. We also place our focus on the innovative application of specific key technologies that are of central significance for our operating divisions. Examples include polymer technologies, catalyst processes and strategies for the development of biodegradable and bio-based materials.

In order to develop future business fields with high sales potential for BASF, we develop specific growth fields. These are regularly reviewed in terms of their attractiveness for BASF. When they mature, we transfer them to the operating divisions and promote the development of new approaches with high market potential. In addition, we have set a course for systematically using digital technologies in research and development. In the years ahead, existing expertise in fields like modeling and simulation will be consistently expanded and new digital work areas will be developed.

After rearranging our research activities in plant biotechnology, we undertook further organizational adjustments to our global R+D structures at the end of 2016. Research activities in Singapore were discontinued toward the end of the year due to market developments. We are pursuing the research topics located there at other sites. Research and development activities at the European research sites in Basel and Düsseldorf were restructured in order to be able to support the operating divisions more effectively.

Our global research and development presence is vital to our success. In 2015, we had completed the expansion of the Innovation Campus Asia Pacific in Shanghai, China. A second Innovation Campus Asia Pacific is now being set up in Mumbai, India, in order to continue strengthening our regional research capacities. There, the focus areas in research will be on crop protection and method development.
We want to continue advancing our research and development activities in Asia especially, as well as in North America, and are adapting this to the growth in regional markets. This increased presence outside Europe creates new opportunities for fortifying and expanding customer relations and scientific collaborations and for gaining access to talented employees. The result will be to strengthen our Research and Development Verbund and make BASF an even more attractive partner and employer, both on a global level and in the regions.

Ludwigshafen remains the largest site in our Research Verbund. In the nearby BASF agricultural center of Limburgerhof – headquarters of the Crop Protection division – a new research and development center for biological crop protection and seed solutions was opened in April 2016.

The number and quality of our patents also attest to our power of innovation and long-term competitiveness. We filed around 850 new patents worldwide in 2016. For the eighth time in succession, we headed the rankings in the Patent Asset Index in 2016 – a method which compares patent portfolios industry-wide. For a multiyear overview of research and development expenditures, see the Ten-Year Summary on page 233.

Research focus areas – examples

- Innovations based in chemistry to answer important questions of the future

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.

The field of efficient energy systems reveals high innovation and market potential. In this context, BASF is working on such topics as the development of high-temperature superconductors based on yttrium barium copper oxide, which transmits electricity at low temperatures with negligible loss and enables savings potential in generating and transporting power. Its current-carrying capacity is twenty times greater than that of copper, the most commonly used material in electrical lines. Two milestones have been achieved on the path toward a market launch: BASF and the global energy company American Superconductor Corp. (AMSC) announced a licensing agreement and research cooperation together in March 2016. Furthermore, Deutsche Nanoschicht GmbH, a 100% subsidiary of BASF New Business GmbH, started up a pilot plant for manufacturing high-temperature superconductors in May 2016.

As the market leader in chemicals, BASF holds a special responsibility toward people and the environment. Accordingly, new products undergo comprehensive environmental and toxicological testing before being brought to market. These tasks are appointed to the Bioscience Research technology platform and include the search for new methods to reduce, improve or replace the animal testing required by law. We are the global forerunner in the chemical industry in developing such alternative methods. In May 2016, LuSens, an alternative method developed by BASF, was validated by the European Union. LuSens is one component of a three-part testing strategy that enables reliable screening for allergic skin reactions on contact with chemicals.

3-D printing involves the development of innovative materials. Compared with injection molding, 3-D printing offers advantages such as lower costs in small-series production, more time efficiency, and the realization of complex structural elements in a single manufacturing process. In the chemical industry, BASF has a broad material portfolio for 3-D printing at its disposal. BASF New Business GmbH is constructing a development center in Heidelberg, Germany, to develop improved materials and optimize the interplay between materials and 3-D printers, together with partners like printer manufacturer Farsoon Technologies. Furthermore, our Advanced Materials & Systems Research technology platform is active in this field at the sites in Ludwigshafen, Germany; Basel, Switzerland; Wyandotte, Michigan; and Shanghai, China. One attest to BASF’s competencies in material development is Ultrasint PA6 X028, launched in April 2016. This powder, based on polyamide 6, is geared toward use in the laser sintering technique widely used in 3-D printing. Compared with conventional polyamides, it provides superior mechanical stability and higher heat resistance. Furthermore, BASF announced its intention in November 2016 to expand its cooperation with American printer manufacturer HP in order to move forward with the development of new 3-D print materials.

In the E.U.-supported PRODIAS1 project, researchers and developers of our Process Research & Chemical Engineering technology platform are working together with partners from industry and academia on methods and processes that allow products based on renewable raw materials to be produced efficiently and with fewer resources, while simultaneously increasing the competitiveness of these products. The biotechnological processes used, like fermentation, mostly take place in diluted aqueous systems that demand energy-intensive steps for separation and purification. Through the use of freeze concentration – a technique typical in the food industry – we managed to concentrate biotechnologically produced products in an especially gentle manner with negligible losses for the first time in 2016.

1 PRODIAS stands for Processing Diluted Aqueous Systems.
Innovations in the segments – examples

Research and development expenses by segment

<table>
<thead>
<tr>
<th>Segment</th>
<th>Expenses</th>
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<tbody>
<tr>
<td>Chemicals</td>
<td>10%</td>
</tr>
<tr>
<td>Performance Products</td>
<td>20%</td>
</tr>
<tr>
<td>Functional Materials &amp; Solutions</td>
<td>21%</td>
</tr>
<tr>
<td>Agricultural Solutions</td>
<td>26%</td>
</tr>
<tr>
<td>Oil &amp; Gas</td>
<td>22%</td>
</tr>
<tr>
<td>Corporate research, Other</td>
<td>21%</td>
</tr>
</tbody>
</table>

Chemicals: In 2016, we established the Amsterdam-based Synvina C.V. joint venture with Avantium to produce and market furandicarboxylic acid (FDCA) from renewable resources on an industrial scale. The most significant use of FDCA is the production of polyethylene furanoate (PEF), a new polymer used for applications such as food and beverage packaging. Compared with conventional plastics, PEF demonstrates higher barrier properties for gases like carbon dioxide and oxygen, leading to a longer shelf life for packaged products. In addition, its higher mechanical strength allows for thinner – and therefore lighter – packaging.

Our new HydroBlue®90 demonstrates that innovation and enhancement are even possible for products that were patented over 100 years ago. The product originally went to market as an auxiliary agent in dyeing textiles with indigo. Today, HydroBlue®90 ensures consistent high quality in the dyeing process. This stability is important for textile producers, as signs of faulty coloring in denim do not usually appear until after the garment is already finished. New HydroBlue®90 is especially highly concentrated, shelf-stable, odorless and dust-free.

With Ultramid® C37LC, BASF launched a new, high-quality copolyamide on the market in 2016. It ensures a stabler and more efficient production process for shrink films used in food packaging. Films produced with Ultramid® C37LC are considerably softer and more transparent than those made from conventional materials. Manufacturers of fishing nets and lines can also further increase the quality of their products using the new plastic.

Performance Products: Flexible food packaging must fulfill the highest functional requirements; at the same time, interest and delivery.

Lavergy® Pro 104 L is a newly developed protease – or protein-splitting enzyme. Liquid detergents formulated with this enzyme are already powerfully effective at low washing temperatures, removing certain tough stains considerably better than the established market standards. Lavergy® Pro 104 L is even more powerful when combined with our high-performance detergent polymer Sokalan® HP 20. Expertise in both biology and chemistry allows us to offer customers even more opportunities to precisely customize liquid detergent formulations.

Farmers require high-quality feed for their animals. Yet preserved feed, typically in the form of silage, and water are both susceptible to pathogenic microorganisms. Adding our Lupro-Mix® NA organic acid mixture inhibits the growth of harmful bacteria and mold, allowing livestock to receive silage and water of the highest quality. Farmers also benefit from the fact that Lupro-Mix® NA is easier and safer to use than comparable products, while remaining nevertheless economical.

Plastic components offer possibilities to make vehicles lighter, more comfortable, and more aesthetically pleasing. Additives like light stabilizers are used to maintain the original properties and appearance of materials and surfaces for as long as possible. Tinuvin® 880 is a novel light stabilizer that significantly increases the durability of plastic parts exposed to UV radiation and heat, making it suitable for automotive applications that require plastics to stand up to high levels of stress. Tinuvin® 880 can also be used in the construction, agricultural and packaging industries.

Functional Materials & Solutions: To meet ever-tightening exhaust regulations for diesel vehicles, manufacturers employ special catalysts for nitrogen oxides (NOx) such as lean NOx trap (LNT) technology, that is, NOx adsorbers. With EMPRO® LNT, BASF has launched a new generation of these catalysts that are especially robust and powerful, even under widely various driving conditions, like city traffic, country roads, or interstate highways.

MasterSuna SBS is a new concrete additive that allows previously unsuitable types of sand to be processed into high-grade concrete. Clay minerals in sand usually prevent concrete superplasticizers from doing their job. With MasterSuna SBS, even sand containing high levels of clay can be used in the production of consistently high-quality concrete. Concrete producers save considerable costs, as they no longer need to pay for the transport of more suitable sands from distant sand pits. Fewer sand pits need to be opened, as well, which helps protect the environment and landscape.
Our **Cool Coatings** automotive coating technology combines innovative functional properties with a sophisticated design that allows for a broad color palette. The coating formulation reflects infrared light, reducing the vehicle’s surface temperature by up to 20°C. This passive temperature management reduces the inside temperature by up to 4°C. Cool Coatings thus enables our customers to save on air conditioning, which decreases fuel consumption or, in the case of electric vehicles, increases range.

**Ultramid® Advanced N**, our new portfolio of heat-resistant polyamides, gives customers in different industries greater freedom for innovation, such as when it comes to developing technically sophisticated end-user products. It allows for the construction of lighter, smaller and more high-performance plastic components for demanding operating conditions, such as in automotive construction, household appliances or entertainment electronics. With **Ecovio® EA**, BASF has developed a high-performance foam that is bio-based and compostable. Its excellent properties make it especially suitable for the transport packaging of valuable, heavy or fragile goods that require high shock resistance and durability.

**Agricultural Solutions**: We are working with farmers around the globe to improve the quality and yield of their agricultural production while taking into account societal expectations and requirements. To achieve this, we constantly invest in our development pipeline in order to developing technically sophisticated end-user products. It allows for the construction of lighter, smaller and more high-performance plastic components for demanding operating conditions, such as in automotive construction, household appliances or entertainment electronics. With **Ecovio® EA**, BASF has developed a high-performance foam that is bio-based and compostable. Its excellent properties make it especially suitable for the transport packaging of valuable, heavy or fragile goods that require high shock resistance and durability.

Our well-stocked **innovation pipeline** comprises products with a launch date between 2016 and 2026. With a peak sales potential of €3 billion, the pipeline comprises innovations from all business areas. The herbicide **Engenia®** is being introduced to the North American market for the 2017 growing season. It serves as a key component of dicamba and glyphosate-tolerant cropping systems for soy and cotton. We are also planning the launch of the new insecticides **Inscalis®** and **broflanilide**. **Inscalis®** combats piercing-sucking pests like aphids and whiteflies. An application for approval was submitted in 2016. **Broflanilide** is effective against chewing insects, like potato beetles and caterpillars, in specialty and field crops; use is also planned in professional pest control. With its novel mode of action, it is highly effective in low doses and will play an important role in resistance management.

We submitted the first approval applications for our new fungicide, **Revyso®,** in 2016. The active ingredient **Revyso®** is highly effective in combating a number of hard-to-control fungal infections, like Septoria tritici, an agent that causes leaf blotch in wheat. It will be offered in regionally and customer-specific product formulations and used in all important field and specialty crops worldwide. The first market launches are scheduled for the 2019 growing season upon registration with the relevant authorities.

**Oil & Gas**: The Wintershall Group concentrates its innovation-related 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.

In the Düste crude oilfield in Germany, we tested an innovative and environmentally friendly method for increasing the reservoir’s recovery factor and have achieved positive initial results. Wintershall developed a concept within the BASF Verbund for **microbial enhanced oil recovery (MEOR)**: We aim to use tiny life forms found in the reservoir, like microbes and microorganisms, to produce more crude oil. Fed nutrients, these multiply and produce various natural substances as metabolic products that can increase the oil recovery factor. Unlike other enhanced oil recovery (EOR) technologies, the use of microbes in MEOR can have several production-increasing effects at the same time. We also successfully managed, for the first time, to model these effects outside of the reservoir, allowing for more efficient use. A larger field test is scheduled to begin in 2017.

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1 Peak sales describes the highest sales value to be expected in one year. For more, see the Glossary on page 239.