Innovations based on effective and efficient research and development are 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.

A growing need for energy, food 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.

We set ourselves ambitious goals: In 2015, we wanted to achieve sales of around €10 billion with new and improved products or applications that had been on the market since 2011. Despite the challenging market environment, we have achieved this sales goal. EBITDA from innovative products and processes on the market since 2011 was below the targeted amount of €2.5 billion in 2015, according to current estimates. Yet we nevertheless reached our associated goal, which was to achieve margins with innovations that exceeded those of the rest of the product portfolio. In the long term, we aim to continue significantly increasing sales and earnings with new and improved products.

Our innovative strength is based on our global team of highly qualified employees with various disciplines. We had around 10,000 employees involved in research and development in 2015. At the beginning of 2015, we arranged the central research units Process Research & Chemical Engineering, Advanced Materials & Systems Research, and Bioscience Research into three global platforms each headquartered in one of the regions particularly significant for us: Europe, Asia Pacific and North America. As knowledge and competence centers, they form the core of our global Know-How Verbund, joined by the development units in our operating divisions. BASF New Business and BASF Venture Capital supplement this network. Their task is to develop attractive new markets and new business models for BASF based on new technologies.

Global network in science and industry

- Network with over 600 universities, research institutes and companies
- Successful collaboration with leading universities within UNIQUE excellence program

Our global network with more than 600 excellent universities, research institutes and companies is an important part of our Know-How Verbund. We collaborate with them in many different disciplines in order to achieve our growth targets. In our excellence program UNIQUE, we are working particularly intensively with fifteen leading universities around the world. This program will strengthen and expand our portfolio with creative new projects by giving us even more direct access to scientific expertise, new technologies and talented minds from various disciplines. Also involved in UNIQUE is Heidelberg University, with whom we signed a collaboration agreement for our joint “Catalysis Research Laboratory” (CaRLa) in the spring of 2015. The research cooperation, which began in 2006, addresses current issues in homogeneous catalysis and was extended to October 2017.

Together with researchers from Harvard University – also a member of UNIQUE, as well as of our North American Center for Research on Advanced Materials (NORA) – BASF researchers developed a new method for making amorphous nanoparticles with increased solubility. This property improves the efficient uptake of, for example, vitamins and drugs in the human body. The new process is well suited to a number of different pharmaceutical, food and crop protection applications.
Strategic focus – examples

- Forward-looking project portfolio
- Strong customer and market orientation
- Worldwide presence and expansion of research and development centers

Our research pipeline comprised approximately 3,000 projects in 2015. We increased our spending on research and development by €69 million to €1,953 million (2014: €1,884 million); the operating divisions were responsible for 79% of total research and development expenditures. The remaining 21% was allocated to cross-divisional corporate research focusing on long-term topics of strategic importance to the BASF Group. Innovations based on chemistry require market-oriented research and development that is sharply focused on the needs of our customers. In order to bring promising ideas even faster to market, we regularly assess our research projects using a multistep process and focus our topics accordingly.

Another vital factor for our success is a global research and development presence. We continued to broaden our activities in 2015, especially in Asia. In May, we opened a new agricultural research station in Pune, India. The new facility focuses on global research in the areas of herbicides, fungicides and insecticides, as well as on solutions going beyond classic crop protection. In addition, we are also addressing topics there that are especially relevant for India.

The extension of our Innovation Campus Asia Pacific in Shanghai, China, was inaugurated in November, strengthening regional research capacity for new materials and systems, as well as our power of innovation for both the region and the world.

We aim to keep strengthening our research and development activities in Asia as well as in North and South America. Our plan is to conduct half of our research and development activities outside of Europe in the long term. We 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, shoring up our Research and Development Verbund and making BASF an even more attractive partner and employer in the regions. Ludwigshafen remains the largest site in our Research Verbund. This was emphasized by the investment we made in a new research building opened in July. It creates modern workspaces and ideal cooperation conditions for around 200 employees in the platform Advanced Materials & Systems Research.

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The number and quality of our patents attest to our power of innovation and long-term competitiveness. We filed around 1,000 new patents worldwide in 2015. For the seventh time in succession, we headed the rankings in the Patent Asset Index in 2015 – a method which compares patent portfolios industry-wide. This once again underscores BASF’s power of innovation.

For a multiyear overview of research and development expenditures, see the Ten-Year Summary on page 235

UNIQUE – global partnership program with leading universities

United States
- University of California Berkeley, California
- Stanford University Stanford, California
- Harvard University Cambridge, Massachusetts
- Massachusetts Institute of Technology Cambridge, Massachusetts
- University of Massachusetts Amherst, Massachusetts
- Texas A&M University College Station, Texas

Europe
- UNICAT Berlin Berlin, Germany
- Heidelberg University Heidelberg, Germany
- KIT Karlsruhe Institute of Technology Karlsruhe, Germany
- Imperial College London, England
- ETH Zürich Zurich, Switzerland

Asia
- Dalian Institute of Chemical Physics Chinese Academy of Science Dalian, China
- Fudan University Shanghai, China
- Institute of Chemistry Chinese Academy of Science Beijing, China
- Kyoto University Kyoto, Japan
Research focus areas – examples

- Chemistry-based innovations play important role in answering questions of the future
- Growth fields with attractive sales potential
- Science symposia strengthen university network

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 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, they are transferred to the operating divisions and new ones are promoted. We will tailor our technology fields even more closely to the needs of the BASF Group and rearrange them into key technologies. Key technologies pool competencies in order to uphold the long-term competitiveness of our businesses and products.

We held three interdisciplinary science symposia in the year of our 150th anniversary: in Ludwigshafen, Germany; Chicago, Illinois; and Shanghai, China. There, a total of 1,500 renowned experts from more than 37 countries engaged with each other on the topics “smart energy,” “food” and “urban living,” developing concrete approaches for interdisciplinary solutions. Nobel laureates Steven Chu of Stanford University in California and Jean-Marie Lehn of the University of Strasbourg in France contributed with keynote speeches. The symposia strengthened our academic network and marked the highlights among the co-creation activities we used to link people and ideas around the globe in order to find new solutions together for global challenges. We plan symposia in the future, as well, in order to foster scientific exchange.

We also successfully maintain close cooperations with others in the area of energy. For example, we have developed new materials for energy-saving cooling together with leading universities and partners from industry around the world. Thanks to their special properties, these magnetocaloric materials warm up when introduced to a magnetic field and cool off again when the field is removed. Compared with today’s usual compressor technology, cooling systems based on these widely available and affordable materials have the potential to reduce energy consumption by up to 35%. They are also quieter and operate without gaseous coolants. Together with the U.S. technology company Astronautics and others in the area of energy. For example, we have developed new materials for energy-saving cooling together with leading universities and partners from industry around the world. Thanks to their special properties, these magnetocaloric materials warm up when introduced to a magnetic field and cool off again when the field is removed. Compared with today’s usual compressor technology, cooling systems based on these widely available and affordable materials have the potential to reduce energy consumption by up to 35%. They are also quieter and operate without gaseous coolants. Together with the U.S. technology company Astronautics and the Chinese appliance manufacturer Haier, we introduced the first prototype of a magnetocaloric wine cooler and are now developing it jointly to achieve commercial readiness. We offer our customers magnetocaloric products for their cooling applications under the brand name Quice.

For us, the development of innovative materials also involves 3-D printing – that is, additive manufacturing. Many complex plastic components have been made using injection molding. By contrast, 3-D printing offers distinct advantages: lower small-batch production costs and considerably less time, since no mold is necessary. Complex structural elements can be built in a single step, allowing for completely new design options like branching internal cavities. And yet the materials currently available on the market often do not meet the high demands of functional components for industrial applications. This is especially true of components optimized for shape and weight, like those in the aviation, automotive, and consumer goods industries. We are therefore developing improved materials together with partners, such as plastics and resins, and optimizing the interplay between the material and 3-D printer.

Process optimization is our goal in the E.U.-supported projects PRODIAS¹ and RECOBA², in which we have been closely collaborating with partners from industry, academia and research institutions since the spring of 2015. With PRODIAS, we intend to further unlock the potential of products in white biotechnology. This involves methods and processes that allow products based on renewable raw materials to be produced efficiently and with fewer resources. The project focuses particularly on processing diluted aqueous systems, which are generated in large quantities by the manufacture of such products and which demand energy-intensive steps for separation and purification. In PRODIAS, we are developing methods and process steps optimally suited for biotechnological processes, increasing the competitive ability of these products.

The RECOBA research project pursues the goal of improving product quality, efficiency, and flexibility in complex batch processes – such as for emulsion polymerizations – thus saving energy and raw materials. Typically, the process control runs through repetitions according to a fixed schedule. We want to replace this by developing a model-based online control system that can adjust to current conditions and calculate the optimal trajectory for any point in time. Product properties, such as the texture of product particles, can therefore be better controlled, and the reactor’s productivity and energy consumption optimized.

¹ The acronym PRODIAS stands for Processing Diluted Aqueous Systems.
² The acronym RECOBA stands for Real-time sensing, advanced Control and Optimization of Batch processes, saving energy and raw materials.
Innovation in the segments – examples

Innovations are an important success factor for BASF’s long-term growth. In developing new products, we look at the needs of our customers as well as at market trends, and take advantage of the opportunities arising from value chains in the BASF Verbund. We want to become even more competitive through innovative production methods. We never stop improving our existing products, applications and processes. With chemistry, we can sustainably create value for customers and society.

Research and development expenses by segment

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<th>3</th>
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<tr>
<td><strong>Chemicals</strong></td>
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<td></td>
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<td>€1,953 million</td>
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<tr>
<td><strong>Performance Products</strong></td>
<td>11%</td>
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<tr>
<td><strong>Functional Materials &amp; Solutions</strong></td>
<td>20%</td>
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<tr>
<td><strong>Agricultural Solutions</strong></td>
<td>20%</td>
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<tr>
<td><strong>Oil &amp; Gas</strong></td>
<td>26%</td>
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<tr>
<td><strong>Corporate research, Other</strong></td>
<td>2%</td>
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Chemicals: Over the last few years, we have been constantly improving our production process for isononanol (INA), an important precursor for products like plasticizers. We have been able to raise the production and energy efficiency of this process and expand its raw material base, so that in addition to steam cracker products, side streams from refineries can also be used as a raw material. This increases our supply security and improves our cost structure. Together with our partner Sinopec, we started up a new INA production plant in October 2015 in Maoming, China, in which the new process has already been successfully implemented.

In the Monomers division, we are constantly on the lookout for innovative and large-volume applications for our existing products. An example of this is the successful introduction of polymer MDI as a binding agent for various wood-based products. Laminate flooring especially benefits from improved performance properties, with increased moisture resistance. Our globally active team of specialists proved a key success factor for this new application, as they supported customers in North America and Asia in converting their production.

In 2015, we supplied the first PolyTHF® 1000 produced using renewable raw materials to selected partners for testing purposes in various applications. This precursor is made using a license from Genomatica, and its quality is on a level with conventionally produced PolyTHF® 1000 based on petrochemicals. It can therefore be employed as a chemical component in thermoplastic polyurethane (TPU), which is used to make such products as ski boots, shoe soles, films, hoses and cable jacketing. This enables our customers to develop innovative products based on renewable raw materials.

Performance Products: Paint manufacturers want to offer products that can be applied in a short amount of time without compromising on high quality and attractive appearance. Our Acronal® EDGE 4750 dispersion in the North American decorative paint portfolio allows our customers to combine the demands of both primer and top coat into a single paint: Acronal® EDGE 4750 adheres well and prevents stains from penetrating the paint while providing coverage, durability and stain resistance. Painters can therefore dispense with a whole process step and still achieve the highest-quality results.

The minty taste of menthol, the world’s top-selling flavor, can be found in countless everyday products. Unlike other flavorings that remain in liquid form, menthol crystallizes to a solid at room temperature. Customers first have to melt it again before using it. Yet we already supply our menthol in liquid form by transporting and storing the still-hot menthol from the production facility in containers with a mobile heating element. This saves our customers several processing steps along the value chain, allowing them to put it to direct use: a sustainable business model with both economic and environmental benefits.

The high-performance polymer Sokalan® HP 20 gets laundry clean with fewer resources. It can be used in both conventional and highly concentrated liquid laundry detergents, removing stains from textiles even at low washing temperatures. Sokalan® HP 20 also prevents the redeposition of removed soil onto the washed fabric, keeping colors bright and white laundry from turning grey.

Since 2014, the United States has had very stringent regulations for the environmental friendliness of certain lubricants in the shipping industry – such as those used for marine propulsion and steering systems. Our Synative® ES TMP ester base stocks contain a large amount of renewable raw materials, are biodegradable, and are nontoxic to marine organisms. Because they work effectively and yet also in a more environmentally friendly manner than many comparable products in the marine industry, they help protect marine life and are employed in many applications subject to especially strict regulations.
Functional Materials & Solutions: BASF has developed a catalyst technology that allows refineries to increase yields of valuable products like gasoline, diesel and other fuels from crude oil. The nickel contained in crude oil presents a particular challenge to further processing, as it significantly increases the generation of undesirable by-products like petroleum coke and hydrogen. Combined with an optimized pore structure, our new catalyst based on the metalloid boron intercepts nickel in processing, thus preventing undesirable chemical reactions.

The MasterEase range of concrete additives greatly improves the flow properties of the building material. This is especially true of modern high-performance concrete. Its lower water and cement content improves stability and increases buildings’ longevity, but also makes the material sticky and harder to pump. Developed by BASF, polymers contained in MasterEase products reduce the concrete’s viscosity by up to 30%. From mixing and pumping to sealing and smoothing, processing therefore becomes easier, quicker and more economical.

With XSpark®, we have developed an exclusive color effect for automotive OEM coatings that sparkles with particular brilliance in direct sunlight. Tiny glass particles that reflect light more precisely than other effect pigments are applied together with the paint layer in a single step. The resulting homogeneous surface provides a pure, solid-color reflection with particular depth, a complex paint effect that creates a high-quality, elegant-looking coating without being intrusive. This innovative product has already won several international awards.

Together with our partner ContiTech Vibration Control, we have developed the world’s first plastic transmission crossbeam in the rear axle subframe of vehicles for the S-Class from Mercedes-Benz. Made of Ultramid® engineering plastic, the component reduces noise and is 25% lighter than typical models made of aluminum, which means a reduction in vehicle fuel consumption. Thanks to our Elastollan® thermoplastic polyurethane, the company Schwalbe has been able to reduce weight in its “Evo Tube” inner tube designed for mountain bikes by up to 65% compared with conventional, butyl-based inner tubes.

Agricultural Solutions: We work together with farmers to keep their farmland arable for future generations and to accommodate society’s rising expectations. To do so, 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 2015, we invested €514 million in research and development in the Crop Protection division, representing around 9% of sales for the segment.

Our innovation pipeline comprises products launched between 2015 and 2025. With a current peak sales potential of €3 billion, the pipeline comprises innovations from all business areas. The herbicide Engenia®, for example, is being introduced in the United States as a key component of dicamba- and glyphosate-tolerant cropping systems. In 2016, we will apply for approval of a new fungicide that can be used in many crops around the world. We are also bolstering our insecticide portfolio with novel high-performance ingredients.

Our Settima® formulation from the Functional Crop Care portfolio offers farmers an efficient, yet environmentally friendly, solution for guarding rice crops against fungal infections. The special encapsulation technology developed in the BASF Verbund ensures the precise release of its active ingredient exclusively on the rice leaf’s surface, enabling better protection of both plant and environment.

BASF Plant Science: We collaborate with numerous biotechnology and seed companies, research institutes, and universities worldwide on developing crops with higher yields and improved resistance to unfavorable environmental factors, such as drought. We also work closely together with the Crop Protection division to research and bring to market innovative herbicide tolerance solutions. In 2015, we launched the Cultivance® production system, a combination of genetically modified soybeans and the corresponding herbicide. Cultivance® therefore provides farmers with a complete solution for weed control in soybean cultivation.

Oil & Gas: Our research and development activities focus on improving the discovery rate of oil and gas reservoirs, developing technologies for reservoirs with challenging development and production conditions, and increasing the recovery factor of reservoirs.

Together with an external partner, we have employed a new and efficient method in the Staffhorst natural gas field in Germany for recovering remaining potential in an economical manner. The conventional drilling rig that would have been used to extend the well by the necessary 170 meters would have been too time and cost-intensive; in addition, production would need to have been halted while the work was in progress. Instead, the drilling was accomplished through the existing production tubing, using flexible steel coiled tubing and the world’s smallest drilling turbine to drive the drill head. We were thus able to deepen the well at low cost and without stopping production.