BASF R&D Webcast: Driving sustainability with microorganisms – Speech

November 17, 2022

Dr. Melanie Maas-Brunner
Member of the Board of Executive Directors
and Chief Technology Officer of BASF SE

[Title Slide]

Thank you ladies and gentlemen, for joining today's R&D Webcast for investors and analysts.

[Slide 2: Multiple challenges ahead]

Our actions revolve around sustainability. It is at the core of our strategy. Sustainability and innovation go hand in hand at BASF. The picture you see here shows what we are facing in the chemical industry: rough seas. The crew must give its all. We must stay on course.

This means: Energy-intensive companies such as BASF must reconfigure their energy supplies and respond to soaring energy costs. In addition, governments worldwide have adopted ambitious climate targets and the European Union is setting a new framework for chemicals with its Chemicals Strategy for Sustainability. BASF is facing many challenges at once: Our production must become climate-neutral; we must create a circular economy, scrutinize many of our products and achieve the digital transformation. And all of this in the middle of an unprecedented energy crisis and soaring inflation in Europe.

Yet, I also want to state very clearly: Our company is taking on this enormous task. And, though there is cause for concern, we also see enormous opportunities for a sustainable future. It is clear what is needed: Only with innovations and a competitive industry can we stay on course in these stormy times.

[Slide 3: Continuous commitment to sustainability]

We are well equipped to navigate safely in these conditions. We know our strengths, and we have the ability to transform. It helps us that sustainability has been a topic for BASF since long before the European Green Deal.

Sustainability has been our guiding principle for 27 years. Since 2011, it has been anchored in our corporate purpose: “We create chemistry for a sustainable future.”

Let me prove that with some figures: Between 1990 and 2018, we reduced our greenhouse gas emissions by half, while our production doubled. And we continue to be ambitious: We are firmly committed to being a pioneer in the chemical industry. By the year 2030, we want to reduce our global CO_2 emissions by 25 percent compared to 2018. By 2050, our goal is net zero emissions. We are in the process of transitioning to renewable energy sources. As one of our first steps, we are building a 1.5-gigawatt wind farm in the North Sea off the coast of the Netherlands together with Vattenfall and Allianz. It is slated to fully start up in 2023 and will be the world’s largest offshore wind farm. We need huge amounts of renewable energy to electrify our energy-intensive processes, for example. I will come back to this later.

Our circular economy program is also ambitious. By 2025, we want to process around 250,000 metric tons of recycled raw materials annually. And we want to double our sales generated with circular economy solutions by 2030. One contributor to this will be the ChemCycling™ method. As you can see, we have big plans – and we are already making good progress.

[Slide 4: Our global innovation setup benefits our customers and supports the transformation towards sustainability]

For these challenging tasks, we need the best team. In the past few years, we brought our research and development units closer together so that we are even better able to adapt to the market. We concluded this process this year and realigned our global research activities.

Ladies and gentlemen, I would like to mention three key elements of this realignment:

First: Business- and application-oriented research units are now embedded in the operating divisions. They are closer to our customers and thus even better able to cater to their needs. This further shortens the time to market for new products and accelerates BASF's organic growth.

Second: Research activities that are relevant for multiple operating divisions have been bundled into a central research division. This unit remains globally organized, with research centers in Europe, North America and Asia Pacific. Together with the development units in our operating divisions, it forms the core of our global Know-How Verbund.

And third: The central research unit brings external knowledge into BASF. Our global network of top universities, research institutes and partner companies gives us direct access to external scientific expertise, talented people and new technologies.

The transformation of our research structure is now complete. With its innovative strength, our new setup supports us on our journey to even greater sustainability.

[Slide 5: We operate the industry-leading innovation platform: Facts and figures 2021]

We are proud of our R&D platform. Let me give you a few figures for 2021. Worldwide, we have around 10,000 employees in research and development. As in the past few years, we invested somewhat more than €2 billion. We invest to develop new sustainable products but also to enter new fields of technology, such as the recycling of battery materials. Developing our competencies is an ongoing task for us. For example, when it comes to generating CO_2-free hydrogen or using digital tools more effectively.

And our work pays off: We generated sales of over €11 billion with BASF products launched on the market in the past five years that stemmed from R&D activities. Within the chemical industry, we have a leading position in terms of the number and the quality of our patents. I am especially happy that in 2021, 45 percent of our patent applications were related to inventions with a special focus on sustainability – and this trend is growing. And in the long term, too, we want to increase our sales and earnings in particular with new and improved products that make a significant contribution to sustainability.

[Slide 6: Driving sustainability – a value chain perspective]

But there is more than just our new products: The research projects our global R&D team is working on today affect all steps of our value chain. We are also thinking about new raw materials and new processes. With the resulting advantages, we want to support and strengthen our customers. I will give you a concrete example in a moment.

[Slide 7: A conventional chemical value chain…]

In the chemical industry, we need raw materials – and a lot of energy! Let’s look at the traditional linear value chain, as we know it today. Our raw materials are largely fossil-based. The main ones are naphtha – a crude oil distillate – and natural gas. We use them to produce chemical products in our Production Verbund. In the first stage of the value chain, we form small and simple chemical molecules from these feedstocks, primarily ethylene, propylene and acetylene. These are like a set of building blocks, which we use to produce various and increasingly complex derivatives for our customers.

Today, recycling of our products is not widely used, it is mainly limited to mechanical recycling of plastic waste. In this case, though, the structure of

the polymers remains intact and cannot be used in our building-block principle.

[Slide 8: ... and the result of a sustainable transformation]

So how do we tackle the desired transformation? Where do we get the large volumes of renewable energy necessary for climate-friendly chemistry? How do we replace fossil feedstock with renewable raw materials? These are critical questions.

We cannot entirely predict what our raw material mix will look like in 2050. However, one thing is already clear: Our raw material base will still contain carbon – because our world and our products are based on carbon. So, while decarbonizing energy inputs is possible in principle – with wind or solar energy – it is impossible to fully decarbonize products.

But we can replace some of the fossil feedstock with renewable raw materials. So-called bio-naphtha is produced, for example, by converting renewable raw materials such as native plant oils or used cooking oil.

We want to source another portion of our feedstock by closing material loops. To do this, we need partners to supply us with sustainable sources of hydrocarbon compounds. Waste is transformed into valuable raw materials, which must be collected by the waste industry and sorted. This will also require that consumers become more aware of the value of waste separation. Products must have the right properties to be suitable for chemical recycling.

Many of the technologies that will enable a climate-neutral society in 2050 have not yet been invented. When we make decisions today about the best technology currently available in order to make rapid progress, we should never completely rule out alternative technology concepts. Being open to

and supportive of innovations and technologies are essential for a successful transformation.

[Slide 9: Feedstock: Battery recycling]

Ladies and gentlemen, let us move from the future to the present: I would now like to show you a specific example of how we will soon be able to supplement our raw material mix thanks to recycling. I am talking about cathode active materials for batteries. In this area, BASF has built up a strong market position with a broad portfolio of cathode materials for the automotive industry.

Now, our researchers have developed a process to recover lithium, nickel, cobalt and manganese with high yield from end-of-life lithium-ion batteries or production scrap. We can thus further reduce the carbon footprint of electric vehicles and meet the strict requirements of the EU's Batteries Regulation.

To transition this process from the lab to the factory and to optimize the technology, we are currently building a prototype plant at our Schwarzheide site in Germany. The metals we recover via battery recycling will be used to produce new cathode materials. This circular model will support our customers throughout the entire value chain and will reduce the need for primary metal from mining operations.

[Slide 10: Process: From idea to commercialization]

I just showed you how we can expand our raw material base with recycling. Here is another lever for greater sustainability – at the process level. I talked about how our products are developed using a building-block principle. Our steam crackers play an important role here. Inside these crackers, naphtha is heated to 850 degrees Celsius in the presence of steam. This breaks down the long carbon chains into smaller components for our chemical

value chains. Until now, we have been heating our cracker furnaces with gas, which produces around 1 metric ton of CO_2 per ton of olefin.

In the future, we want to heat the furnaces with renewable electricity. With our development partners SABIC and Linde, we have developed the world's first electrical heating concept for steam crackers. We thus have the potential to reduce the CO_2 emissions of one of the chemical industry's most energy-intensive production processes – by at least 90 percent compared to traditional processes! This is a true technological leap. Our eFurnace demonstration plant in Ludwigshafen will start up already next year. It will be fully integrated into one of the existing steam crackers at our Verbund site.

Policymakers also support our approach to climate neutrality, as evidenced by the project funding provided by the German Ministry for Economic Affairs and Climate Action.

However, as you can imagine, we will need to bring a huge volume of renewable electricity to Ludwigshafen for this new technology – reliably and at competitive prices. We are laying the groundwork with our investment in wind farms. However, much will depend on the speed of the energy transformation in Germany and in particular on the rapid expansion of the electricity grid.

[Slide 11: Product: Create additional value for our customers]

Now let's look at the product level, and at how we are proceeding on our path towards lower emissions. If we use green electricity, low-carbon generated steam and renewable raw materials, and our processes are highly efficient, we can offer our customers net-zero products and products with a smaller product carbon footprint (PCF).

I would like to highlight the mass balance approach. We cannot trace every single carbon atom in our complex Production Verbund. However, with this approach, we can allocate the share of bio-based raw materials or of those from ChemCycling™ processes to specific sales products according to a certified method. It is already being used for many BASF products. What does this mean for our customers? They can stand out from the competition by improving their carbon footprints or by conserving fossil resources. We expect that consumers will drive growing demand for such products because they want to make a personal contribution to lowering emissions. Therefore, we want to be one of the first companies to offer industrial-scale volumes of as many products as possible with a reduced carbon footprint.

The scope of this concept already includes everything from insulation materials to sneakers, from appliances to textiles. In these cases, the reduction of the carbon footprint and thus the benefit for our customers and end consumers is already significant – as you can see from the numbers.

[Slide 12: Driving sustainability with microorganisms]

And we have not yet fully exploited our potential. Thanks to white biotechnology, we have another tool that enables us to become even more sustainable at the three levels of our value chain that I mentioned earlier. White biotechnology is nature's toolbox: Just think about the centuries-old processes to make bread, cheese, wine and beer – all of which use the power of microorganisms. Louis Pasteur once said: "The role of the infinitely small in nature is infinitely great." With this finding, he paved the way for modern biotechnology. We say: Small but powerful!

And our researchers are taking advantage of this. When it comes to raw material sources, white biotechnology gives us maximum flexibility. Our tailor-made microorganisms can handle fossil, renewable or recycled material streams, either pure or mixed. They allow us to produce some

products in a much gentler and more environmentally friendly way than traditional chemical processes – at room temperature and at normal pressure, often in an aqueous medium. Using fermentation or bio-catalysis, we also have access to entirely new products that otherwise would not be simple to synthesize.

[Slide 13: Microorganisms produce molecules]

Ladies and gentlemen, let's go into more detail. Perhaps you remember the concept of anabolism from your school biology lessons. It is the metabolic process that builds larger molecules. The opposite process is catabolism, which breaks down molecules. Microorganisms help us in both respects. Let's start with the anabolic, or building process: In nature, with the help of their enzymes, microorganisms catalyze the formation of a large number of molecules. We can use this ability to produce a wide variety of products: from simpler structures such as ethanol and lactic acid to very complex structures such as vitamin B_2, aroma chemicals or crop protection products. Microbes can use a large number of starting materials to do this, ranging from glucose to carbon monoxide or carbon dioxide.

[Slide 14: Microorganisms digest molecules]

In catabolic processes, microorganisms break down complex organic compounds into simple molecules. In nature, they are responsible for degrading dead material, such as the leaves on trees. Nature's cycle is nearly perfect. It produces energy, water, CO_2 and biomass. How can we take advantage of this? By offering synthetic substrates and copying the natural process of biodegradation. If polymers and functional materials have the right structure for biodegradation, microbes can also digest them and turn them into energy, water, CO_2 and biomass. Microbes live in communities, either in natural habitats such as soil or in "technical systems" such as compost or wastewater treatment facilities. For us, it is essential

to understand both the natural and technical systems in order to design new chemical structures that are completely biodegradable in a short period of time.

[Slide 15: Biotechnology and biodegradability broaden BASF's capability to shape a sustainable future]

For us as a chemical company, there are therefore many good reasons to expand our competencies in the field of biotechnology. I also want to illustrate this with a few figures. In five of our six BASF segments – Chemicals, Materials, Industrial Solutions, Nutrition & Care and Agricultural Solutions – we already produce more than 3,000 products that we associate with biotechnology or biodegradability. For today's event, we calculated that we generated more than €3.5 billion in sales with these products in 2021. And the trend is rising. We expect that growth in the coming years will be above that of the chemical market – a good reason to strengthen our R&D activities in this area!

[Chart 16: Three facets of today's topic]

At our Research Press Conference earlier today, we showed in detail how white biotechnology is becoming an increasingly important piece of the puzzle for the chemical industry. How BASF and its partner company LanzaTech are working together to produce chemicals from alternative carbon sources. And how basic research and thus newly gained knowledge in the field of biodegradability are making important contributions to developing sustainable products. I would now like to present a few specific examples from this event.

[Chart 17: White biotech enables a plethora of different products]

Over the past 20 years, BASF has brought to market numerous innovations based on white biotech for a wide variety of customer industries. Technical disruptions in recent years, such as genome editing, metabolic engineering,

directed evolution and bioinformatics allow us to gain significant speed and power in developing competitive production processes and shortening time to market.

White biotech is an enabling technology. It contributes to formulated performance products or leads to intermediates that are further processed by means of classical chemistry. White biotech thus plays a central role in terms of technology diversification.

We are also seeing rising demand for “green” solutions and biodegradable products. The trend towards more sustainable products of biobased, renewable, recycled or circular origin offers huge opportunities. An optimal combination of biotechnology, engineering and classical chemistry enables processes that are very efficient but also economically and ecologically sustainable. This will play a role in helping BASF to achieve its sustainability goals.

Biotechnology is opening up many new opportunities for us. For example, it allows us to manufacture certain products from a broader range of raw materials and in a more energy-efficient way than with chemical processes. Biotechnology also enables BASF to develop completely new products and value chains. With conventional synthesis approaches, we would not be able to produce them, or only at great effort.

[Chart 18: BioSolutions by BASF: A complement to conventional crop protection]

This slide shows products we have developed in response to rising demand for alternatives to conventional crop protection products. Biologicals are more target-specific and have less or no impact on other beneficial insects. Biologicals are safe for users and consumers, and there are no residues left after their use. Here, you can see a variety of such products offered by our Agricultural Solutions division.

Velifer® is one of BASF's biological insecticides. As an active ingredient, it contains a strain of *Beauveria bassiana*. This is a beneficial fungus that grows naturally in the soil and acts as a parasite to target insects such as whiteflies, aphids and mites. Velifer works through direct contact. Once the pest comes in contact, the fungus multiplies in the insect's body, providing insect control within 48 to 72 hours.

Beneficial nematodes are a further example of products for biological insect control. The product ranges marketed under the BASF brands Nemaslug® and Nemasys® consist of microscopic worms that attack, invade and kill targeted pests. They are easy to apply and can be used either alone or in partnership with other biological or conventional pest management programs.

[Chart 19: Isobionics: Fermentative production of flavors and fragrances]

Let's now move on to an example from our Nutrition & Health division.

In 2019, BASF acquired Isobionics, an aroma ingredients company located in the Netherlands. Isobionics uses a unique fermentation technology based on renewable resources to produce a wide range of natural ingredients for the flavors and fragrances market.

Isobionics Santalol was the first product launched jointly by Isobionics and BASF in 2020. Santalol is one of the key components of sandalwood oil, which is traditionally extracted from the wood and roots of the white sandalwood tree. The trees are not ready for harvesting until they are about 30 years old, and their existence is highly endangered by overexploitation.

The starting material for the Isobionics process is corn starch obtained from corn grown in Europe, which is then fermented using the bacterium *Rhodobacter sphaeorides*. The result is a high-quality product for the perfume industry that conserves natural resources.

[Chart 20: Detergent enzymes: Excellent washing performers, even at low temperatures]

In our Care Chemicals division, the detergent enzymes in the Lavergy® product line are a further example of how white biotech can contribute to sustainability. These enzymes are produced by bacteria or fungi. When incorporated into detergent formulations, they offer excellent washing efficiency and are effective at low temperatures, thus saving both water and energy.

Our efforts to ensure fully biodegradable detergent formulations are supported by our research activities: BASF is a pioneer and leader in digital modeling of predictive biodegradation. We understand in detail how and why materials and molecules are degraded in various environments. As a result, we are able to predict their properties and degradation behavior at an early stage of product development and adapt their structures accordingly.

[Chart 21: Classical and alternative fermentation platforms: Integrating alternative carbon sources into chemical value chains]

Let’s now move from specific product examples to a disruptive technology. Gas fermentation has the potential to revolutionize the production of small molecules like ethanol by turning emissions, residues and wastes into valuable chemical precursors.

Classical fermentation processes already enable the integration of alternative carbon sources into chemical value chains. By using carbohydrates, it is possible to produce complex molecules like enzymes, biologicals and polymers as well as small molecules like ethanol.

Parallel to classical fermentation technologies, alternative fermentation platforms can use non-food-relevant carbon sources that are often waste-based.

BASF and LanzaTech have joined forces to explore the potential of gas fermentation and the use of its products to feed BASF's value chains. The LanzaTech gas fermentation platform is the only at-scale commercialized alternative fermentation platform worldwide. There are already LanzaTech production plants in China that produce ethanol using this technology. The first European plant at ArcelorMittal in Belgium will go on stream in December this year. Now, BASF and LanzaTech want to further develop gas fermentation to produce higher alcohols and other intermediates.

The beauty of this approach is that there is more than enough alternative carbon that can be used. Furthermore, there is no competition with food or land resources. Another advantage is that a large part of the existing infrastructure and assets can be used, which is the basis for economically viable production.

[Chart 22: Combining competences and capabilities leads to success!]

The cooperation between LanzaTech and BASF is complementary. LanzaTech contributes its innovative gas fermentation technology and its unique competence and capabilities in synthetic biology. BASF provides its outstanding know-how and expertise in the design, development, operation and optimization of chemical and bio-chemical processes and production plants. Derived via fermentative synthesis, the target molecule is always a component of an aqueous system, the fermentation broth. This mixture needs to be downstreamed. In other words, the target molecule needs to be separated and purified to meet the required specifications. This is BASF's home turf.

The concept of the gas fermentation platform is to combine versatile reactor vessels with on-demand designed microbes – the "hardware" and the "software," if you like. By tailoring the microorganism, it is possible to

produce diverse target molecules based on the same feedstock, thus allowing a rapid response to market dynamics.

Combining gasification and gas fermentation is one option to integrate alternative carbon sources into existing chemical value chains. Greater use of alternative carbon sources will mean less need for virgin fossil feedstocks to produce chemicals and will drive the move towards carbon cycling. Nevertheless, investment is needed, and, in many cases, a change of mindset. This will encourage cross-sectoral projects and link the chemical industry with steel mills or waste recyclers.

In addition, we would like to see a regulatory framework that fosters the use of waste and gaseous emissions as sustainable carbon sources for the chemical industry.

[Chart 23: To successfully meet the challenges of today's world … we rely on innovative minds, partnerships and cooperation]

To close, ladies and gentlemen, I would like to repeat the message I started out with: The chemical industry is facing unprecedented challenges. But in our long history at BASF, we have proven again and again that we emerge even stronger from challenging times. The key to this is our innovative strength.

Society will only achieve the transformation to climate neutrality with innovative solutions based on chemistry and neighboring disciplines. The transformation will be impossible without our industry. And I know we can count on our creative and dedicated BASF team.

However, we also need alliances. We must work together – with all players in industry, science, politics and society. And across all borders – in Germany, Europe and the world. Alliances between companies and legislators are especially important because we need good framework

conditions underpinning our actions. It is essential that we all work together to remain competitive, strong and successful.

And now I’m looking forward to your questions.