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Research Press Conference 2023

Speech

P374/23e
December 1, 2023

Chemistry and Sustainability: A Perfect Match

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The spoken word applies.

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Ladies and gentlemen,

A warm welcome from me as well. I am very pleased that we can present a broad spectrum of BASF's R&D to you today. Our event is titled Chemistry and Sustainability: A Perfect Match. And at BASF, we have been bringing together chemistry and sustainability for many years. Today, our team will show you some of our innovation highlights, the particularly effective bridges like in this DNA structure.

[Slide 2: July 2023 was the hottest month ever measured on earth]

We live in an era of superlatives. However, many of these superlatives are not positive; in fact, they are very concerning to us. I would like to remind you what we have experienced in the past half-year: the hottest global temperatures ever recorded, extreme rainfall and flooding in various regions of the globe, forest fires – and the list goes on. United Nations Secretary General Antonio Guterres issued a wake-up call with his words "global boiling." The impact of climate change is real. We feel it and we suffer from it. And climate change is progressing. What does this mean for society? What does it mean for us?

[Slide 3: Sustainability at BASF – our central goal]

At BASF, we are not wasting any time. On the contrary, we are active and making a significant contribution to the sustainable transformation of our society. This means we are offering our customers the best and simultaneously most sustainable products and solutions. But not only that! We are also working flat out on transforming our own processes and activities to make them even more sustainable. Our ambitious global target is net zero emissions by 2050.

As the CTO of the world's leading chemical company – and as a chemist myself – I am convinced that chemistry is the key to fighting climate change and optimally using our limited resources. With innovative solutions for our customers and our company. Now I'd like to sketch out the paths we are taking and where our innovation power comes from.

[Slide 4: BASF contributes to the global sustainability development]

As early as 1994, BASF committed to the concept of sustainability – at the time as part of our Vision 2010. Since then, we have used a variety of methods to regularly evaluate the sustainability of our portfolio. As a result, we have adapted processes and raw material usage. Our success shows we are on the right path: In the 30

years after 1990, we reduced our global greenhouse gas emissions by 48 percent – even though our production doubled in the same time period.

Over time, we have established eight important sustainability categories that shape our actions – I will come back to these in a minute. And we contributed in 2016, when the United Nations developed its 17 Sustainable Development Goals.

But this is not enough for us. Our portfolio evaluation methods are becoming increasingly sophisticated and are evolving to meet the requirements of our world, our customers and our company. The latest iteration is Sustainable Solution Steering, also known as TripleS.

[Slide 5: Our path to success: measurability and transparency]

With this evaluation method, we analyze the contribution of our products to our eight sustainability categories. The aim is to increase the share of innovative and sustainable products. This applies to the entire BASF portfolio, meaning we analyze around 45,000 products and classify them into five segments: Pioneer, Contributor, Standard, Monitored and Challenged. Doing this enables us to recognize weaknesses at an early stage and take measures to find solutions. Products with a significant sustainability deficit – the Challenged category – will be taken off the market by BASF within five years.

We refined the method this year to steer our portfolio even more toward climate protection, resource efficiency and the circular economy. The next BASF Report will specify the share of sales generated in these five TripleS segments. And we will set a new target for the proportion of sales generated by all Pioneer and Contributor products. As you can see: TripleS enables us to transparently measure how sustainably we act and improve.

A bit later in today's event, we will show you specific products and their classifications.

[Slide 6: Our path to success: research and product portfolio]

To develop our product portfolio, we therefore continuously need new and even more sustainable products and solutions. These do not fall from the sky. They are the result of our innovation power. And this, too, can be measured. With great pride, I can say: Our work is paying off! We generated sales of around €12 billion in 2022 with BASF products launched on the market in the past five years that stemmed

from R&D activities. Over the past five years, we have significantly increased this figure.

Products that make a major contribution here include Infinergy® – you might know this particle foam from sport shoes or cycling. A further example is our nickel-cobalt-aluminum cathode active material for batteries. Or Revysol®, a fungicide that farmers worldwide use to protect their crops very effectively against fungal infection.

One reason for these successful innovations is that we invest continuously and considerably in research and development. Our ongoing high level of expenditure is even more valuable in relation to our sales during the same period. With annual research expenditures of €2.3 billion, we are the leader in our industry. So, there is a lot of financial tailwind for innovation. But money alone is not enough.

[Slide 7: Our path to success: key enablers]

There are many more essential prerequisites for our success:

- A team of extremely qualified scientists with high-level networks in the academic world that enters into strong partnerships
- Cutting-edge technology for digitalization
- A unique set of scientific enablers
- And the Net Zero Accelerator unit. It has strong links with R&D and has been a major driver of innovative sustainable projects for nearly two years now.

Let’s take a look in greater detail:

[Slide 8: Highly skilled scientists]

I am immensely proud of our global R&D team – around 10,000 highly qualified employees. I would like to highlight our Senior Experts. They have chosen to pursue a career in R&D, where they contribute in-depth knowledge and expertise in their specialist areas. Many of them are simultaneously professors and teach at universities. They receive international awards and work on important scientific committees, also outside of the company. They are outstanding drivers of innovation. I’d like to take this opportunity to express my heartfelt thanks to all of them as well as our entire research team!

Our innovative power can also be seen, for example, in the more than 500 scientific publications. And – this is especially significant – in the number of patents. Both

figures are from last year. With more than 1,000 patents, we are once again in the absolute top ranks of the industry. As we continuously adapt our portfolio, as I just talked about, we have also changed our approach to patents. I am happy to report that around 40 percent of our patent applications in 2022 had a particular focus on sustainability. A further 20 percent were related to digitalization. We want to resolutely continue on this path.

[Slide 9: Connected research through outstanding academic partnerships]

Even the strongest R&D team needs additional scientific expertise and access to talent and new technologies. This is why we have been working with the world's best universities for many years and we continuously intensify our collaboration. In the past 12 months, we have entered into around 400 new agreements with academic partners. We have particularly close partnerships with the academic research alliances shown on this slide. In these alliances, we are simultaneously pursuing several projects in different fields – 215 at the moment. In this way, we bring together the best scientific resources from industry and academia. To illustrate how fruitful these partnerships are, I want to tell you about an extremely interesting project with the California Research Alliance (CARA).

[Slide 10: Project with academic partners: high entropy alloys]

Precious metals such as iridium or platinum are rare and expensive. But in catalysts, they ensure especially high activity and efficiency. For example, in two catalysis-supported applications that we are working on with our partners at UC Berkeley and Stanford University as part of the CARA collaboration. These two applications are: cracking ammonia into nitrogen and hydrogen and water electrolysis to produce CO_2-free hydrogen.

Can the precious metals be replaced? No, but they can be diluted. Here, a special material class comes into play: high entropy alloys, or HEA for short. These are alloys made of five or more metallic elements, in contrast to conventional alloys. Due to the numerous elements with a random configuration – this means high entropy – the alloys have special properties.

Together with our partners in CARA, we were not only able to show that the use of HEA can reduce precious metal volumes with no adverse impact on the performance of the catalyst. We also developed a robust and diverse synthesis

method with which we can synthesize many different compositions on an industrial scale.

Theoretically, there are almost unlimited possibilities for the structure of such materials. Not even a supercomputer can evaluate all of them. But with the help of quantum mechanical calculations and machine learning, we have dramatically accelerated the search for the most promising and stable compounds. In a close collaboration between our experts in the Digitalization and Automation unit and EPFL, the Swiss Federal Institute of Technology in Lausanne, the modeling speed was increased by a factor of more than 1,000 and we can now focus on just five lead compositions.

These research projects are making promising progress because we continuously build up our own scientific modeling capacities while also working closely with academic partners around the world. And thanks to Quriosity, our supercomputer.

[Slide 11: Quriosity enables fundamentally new research approaches]

Since 2017, Quriosity has carried out an average of 20,000 tasks per day and has been used by more than 400 employees worldwide. Calculations that would have once taken a year can now be accomplished in just a few days. This year we started up a new version of Quriosity. It is the most powerful computer for research in the chemical industry and a perfect tool for simulations, as I just described. It has a computing power of three petaflops, equal to roughly 10,000 laptops. However, it is also clear that we can only utilize this potential when we also have close interaction between technicians and scientists as well as their know-how.

[Chart 12: Cutting-edge digitalization]

Almost all of our research projects today rely on the support of artificial intelligence and digital solutions. One good example is research on battery materials. You will hear even more about this later.

Our researchers want to know at an early stage how well the cathode active material they have produced performs in terms of charging behavior, lifetime and battery capacity. With the help of electron microscopy images, we can study the morphologic properties of our materials, such as the particle shape and size, its distribution or material defects. Manually reviewing such images is extremely laborious. Machine learning can provide incredible added value here because

computers are able to analyze countless images very quickly and systematically. Algorithms learn from example images. This knowledge is saved as a statistical model.

Such models help us in various projects: We identify relationships between morphology and performance, and we optimize materials more systematically, for example, through the addition of dopants. We can make predictions about how a new cathode active material will influence the lifetime of a battery. Complex charge/discharge tests for batteries can take several weeks or months. Now we can focus on the promising materials and therefore significantly shorten the development phase. And everyone in our team worldwide can access our internal database and compare an enormous trove of data regarding those projects. This also saves a lot of time.

[Slide 13: Unique set of scientific enablers]

Digitalization and automation are indispensable. But we also need other disciplines, known as enablers, which are essential for our R&D activities.

Toxicology is crucial for the safety of our products. For many years, we have also been successfully developing alternative methods to animal studies. With our modern **analytics methods**, we dramatically accelerate our innovation cycles. Our **formulation experts** are particularly indispensable for the markets we serve with high value-added products. And last but not least, the development, synthesis and application of new **catalysts** significantly improve our processes, as they help to save energy, raw materials, emissions and waste.

There is another key pillar of our transition to sustainability: Net Zero Accelerator.

[Slide 14: Net Zero Accelerator – strongly connected to R&D]

I previously mentioned our global sustainability goal: net zero emissions by 2050. How can we achieve this as focused and quickly as possible? We have created an entire unit tasked with accelerating the global transformation in collaboration with R&D and all corporate divisions. This is not just about using renewable raw materials or energy sources. We want to develop entirely new technologies to reduce our carbon footprint. This is a much more complex undertaking: From calculations and laboratory tests, we progress to demonstration plants and eventually we revamp entire production facilities.

[Slide 15: BASF's Hy4Chem-EI: PEM water electrolysis in Ludwigshafen]

For example, we are working with our partner Siemens Energy to build an electrolyzer with a capacity of 54 MW here in Ludwigshafen. As you know, electrolysis uses electricity to split water into its components: hydrogen and oxygen. With green electricity, this process is emission-free. It is planned that the plant will produce up to 8,000 metric tons of hydrogen per year and start up in 2025.

Last week, we were presented with the official notification of funding for this project from the Federal Ministry for Economic Affairs and Climate Action and the state of Rhineland-Palatinate. Here you can see pictures from the ceremony and how the electrolyzer will be integrated into the Verbund. It is good and necessary that policymakers and industry are joining forces here to shape the energy transition in industry. After all, the transformation of our company and the entire industry is closely linked to the availability of low-emission or emission-free hydrogen. With this future hydrogen output, we will be able to make products with a reduced carbon footprint, which will also benefit the region.

Therefore, we can only encourage our political partners: Please, let's have more of these lighthouse projects to implement innovations for a faster transformation. We need targeted investments in research and development as well as regulations that encourage innovation in order to strengthen our competitiveness. Moreover, we need to rapidly tap sources of green electricity, as the electrolysis process is very power-intensive.

[Slide 16: BASF's Hy4Chem-NG: next-generation material and product development]

To make this process even more efficient and sustainable, our R&D is working on important improvements. We are focusing on three key elements. You can see here how the various parts of an electrolysis cell – membrane, catalyst and the porous transport layers – are arranged with one another.

In catalyst research, we are testing new materials and a sophisticated coating to increase the performance and durability of the cell and reduce costs, especially for iridium.

For the membrane, we are working on substituting per- and polyfluorinated compounds in the long term with new fluorine-free materials.

And we are optimizing the porous transport layers, for example, in their structure. This will enable us to achieve a more efficient water supply and better oxygen transport. Contact with the spent catalyst should also be improved by changes to the surface structure.

[Slide 17: Carbon abatement in syngas production]

Another research project – also with the goal of CO_2 reduction – concentrates on the production of syngas, a mixture of carbon monoxide and hydrogen. This is a fundamental process in the chemical industry that we need for the production of numerous chemical products – from basic products, such as methanol, to plastics, dyes and coatings. However, it currently results in significant CO_2 emissions.

Through partial oxidation, we convert hydrocarbons such as natural gas or refinery residues with oxygen into carbon monoxide (CO), hydrogen (H_2) and as a by-product carbon dioxide (CO_2). BASF operates several syngas production facilities. Similar plants can be found at many large chemical sites worldwide.

With TU Bergakademie Freiberg, another university partner, we have now analyzed how we can retrofit our existing production plants so that the production of syngas can even use CO_2 – in other words: CO_2 recycling. Because the addition of CO_2 changes many of the process parameters, calculations help to maintain the quality of the syngas in the new process.

In the mid-term, we will also be able to use CO_2 emissions from the BASF Verbund, according to the principle of carbon capture and utilization (CCU). And we are thinking even further ahead. We also want to replace natural gas as a feedstock, initially with alternative sources of carbon, and in the long term with CO_2 itself and CO_2-free hydrogen. This will mean even more efficient use of carbon dioxide. And this is where water electrolysis comes into play again. This illustrates yet again how vital emission-free hydrogen is for the transformation of the chemical industry.

[Slide 18: Contribution to sustainability: many examples at BASF]

These last examples in particular demonstrate once more how we are rigorously pursuing solutions for sustainable processes and products. And that brings me back to my opening words: We are making significant contributions toward the sustainable transformation of our industry and society – because chemistry is the start of most value chains. And the CO_2 savings we achieve carry through processes

in all other industries and all the way to end consumers. The following film will show you more.

[Chart 19: Contribution to sustainability: highlights presented today]

The last examples in the film were already a teaser for the next part of today's program. Presenting these five innovations from very different industries, my colleagues will now show you our specific sustainability contributions. Earlier, I told you about our transparent measurements using the TripleS method. Now you will find out about some of our Pioneer products. So far, our battery materials are classified as Monitored. This is due to the procurement of the raw materials. But this example in particular shows how important recycling concepts are for our efforts – and that recycling offers great potential to make our materials even more sustainable. I hope you enjoy these presentations!

And now I'm looking forward to your questions.