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Growing with hydrogen

Dr. Stefan Hartung,

chairman of the board of management, Robert Bosch GmbH,

and Dr. Markus Heyn,

chairman of the Mobility business sector,

at the Bosch Tech Day on July 13, 2023,

in Stuttgart-Feuerbach

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Ladies and gentlemen,

Geographically, Auto Shanghai and Hannover Messe may be a long way apart, but they've never been as interrelated as they were this year. At the Bosch booths in China and in Germany, there was one subject that dominated discussion: hydrogen. We are among the few companies that people expect to come up with solutions – solutions for the generation and application of H_2 that can quickly go into volume production. This is precisely what we are working on – worldwide, and in the heart of Europe. Here in Stuttgart-Feuerbach as well, in our oldest manufacturing plant, the hydrogen future is about to happen. Today, it will see the symbolic start of volume production of our fuel-cell powertrain system. This is why we have called today's media event, to which I would like to offer you a warm welcome. We want to show that Bosch knows its way around hydrogen, and Bosch is growing with hydrogen. With our H_2 technologies, we want to generate sales of some 5 billion euros by 2030.

We are developing our solutions along the entire H_2 value chain. Before we go any further, we want to give you a quick explanation of the technology. But don't worry, this won't be a science lesson. To put it briefly: in a fuel cell, we generate electricity from hydrogen – in the mobile version with proton exchange membranes, and in the stationary version using solid-oxide technology. The mobile versions are used above all in trucks, while the stationary versions can supply power to computing centers or even urban districts. What's so special about this? Both processes can be reversed, and in their reversed roles they are suitable for electrolysis: in other words, they can produce hydrogen using electricity. And Bosch is involved in this as well. There is

obviously a lot of synergy between the respective fuel-cell and electrolysis technologies. We want to exploit this synergy.

Bosch is helping to shape the hydrogen economy, but policymakers need to be faster in four respects

Whether with fuel cells or electrolysis, Bosch is helping to shape the hydrogen economy. That will help us develop new business worldwide, and also to secure jobs in our plants – we always have both things in mind. For example, the production of mobile fuel-cell systems is getting underway both in Chongqing and here in Feuerbach. Bosch is the first company to produce these systems in both China and Germany. And the components it needs come from Bamberg, Homburg, and Wuxi. When it comes to hydrogen as well, we are opting for a global manufacturing network right from the start. We are planning to include our Anderson plant in South Carolina as well in the future. Especially in the initial phases, the prowess of our German locations will be vital in this network. But what is the long-term outlook? How good a chance do we have of not just kick-starting hydrogen in Germany und Europe, but also of creating enduring growth with hydrogen? The answer to this depends on whether the political conditions are right. I want to elaborate on this in more detail, since it is these conditions that enable the success of hydrogen technologies in Germany and in global competition in the first place.

In principle, all of us want to be climate neutral – but this won't be possible without hydrogen. True, the main thrust of the energy transition is in the electrification of vehicles and heating systems, and Bosch is playing a role here as well. But renewable power can be generated especially efficiently in the world's sunniest and windiest regions, not

where its industrial centers are to be found. So how can we get green energy from where it is generated to where it is used? Not by means of transmission, but by using chemical carriers, and in particular hydrogen and its derivatives. Worldwide, the move from the carbon to the hydrogen economy will be decisive in the fight against climate change. This fight is a historic task. Yet we have to shift up a gear, here and now, also in Germany. We are glad to have very recently received notification of funding for our stationary fuel-cell technology. But when it comes to hydrogen, we still haven't got up to the new "German speed" in every area.

The United States is getting on with things faster. There, the Inflation Reduction Act is heavily subsidizing the resources for ramping up the hydrogen economy. Leaving China aside, interest in H_2 technologies is growing by leaps and bounds outside Europe. Europe itself has great ambitions, but we can observe worrying contradictions between ideals and reality. Four points are important for us.

- First, we have to step up the pace of hydrogen production in Europe. This is being hampered at present – above all by strict criteria for electricity procurement. Neither China nor the U.S. have such criteria. One example is the principle of additionality that allows green electricity for electrolyzers to be procured solely from additional wind and solar power plants. Clearly, the priority for the EU is for electricity from renewables to be used directly in applications such as cars or heating systems. But here we have to ask why electrolyzers even have to furnish proof of origin of the green electricity they use, while it is of no concern at all where the electricity for electric cars and heat pumps comes from. Such treatment is anything but equal. Above all, a regulation like this won't stimulate

hydrogen production. The EU is not doing itself any favors here. To go at least some way toward offsetting this competitive advantage, investment and operating costs need to be heavily subsidized, at least in the ramp-up phase.

- Second, international hydrogen supply chains need to be set up. Here as well, there are still obstacles to be overcome. Worldwide, hydrogen can best be transported using derivatives such as methanol, which is created by synthesizing hydrogen and carbon. But when importing these derivatives, the EU calls for effective carbon pricing in the countries of origin – without having defined the criteria more closely. This is an important point, as only very few countries have so far introduced such a pricing system. Under conditions such as these, there is one thing potential investors will be reluctant to do – and that is invest. This is worrying, since Europe wants to cover half its hydrogen requirements through partnerships with other world regions by 2030. The International Energy Agency estimates that African countries can produce 5,000 megatons of H_2 annually – as much as the world's current total energy supply. The EU has to do all it can to establish hydrogen partnerships with other continents. That is astute energy policy – and astute development policy as well.

- My third point is an appeal to use hydrogen in all sectors of the economy. While it is true that H_2 is indispensable for climate-neutral chemical and steel plants, purely electrical solutions also come up against their limits in the transportation and building sectors. The older the building, the less economic sense a heat pump makes. The longer the route to be driven, the less sense a battery-only powertrain makes. It is not just ships and airplanes, but also trucks

that need H_2-based fuels. In transportation and buildings, therefore, our maxim when it comes to electrification and hydrogen solutions is not either/or, but both/and.

- Last not least, infrastructure for distributing hydrogen has to be created in Europe. There are many ways to transport green molecules: by pipeline, by truck, by ship. In the EU as well, we need to interconnect our centers of energy supply and energy consumption better. This is necessary for things such as the H_2 operation of stationary fuel cells in micropower plants. And not least, we need a network of hydrogen filling stations, oriented to the needs of trucks.

This will not come about without a supportive framework. Whether in Europe or the U.S., it is up to the government to take us toward the hydrogen economy by resolving the "chicken-and-egg problem" of infrastructure and market development. Without H_2 trucks there can be no H_2 pumps, and without H_2 pumps, no H_2 trucks – it is blindingly obvious that governments have to take the initiative here.

All in all, Europe has to do much more in order to become not just "H_2 ready," but also "H_2 competitive." That said, there are some positive signs, such as the promotion of research – the support granted for our stationary fuel-cell technology as part of the IPCEI program aims to do precisely this. And in its regulations for hydrogen production, the EU Commission has made some concessions to industry by relaxing a few rules. However, the planned review clause is crucial. As quickly as possible, we need a review of how electricity-procurement criteria affect H_2 production costs, and thus Europe's competitiveness. Worldwide, the level playing field for the hydrogen economy is being staked out, and here as well, Europe has to create a counterweight to the

dynamic developments in the United States. It's high time we started to sprint.

But in all this, what is Bosch doing? For the answer to that question, I'll hand over to my colleague Markus Heyn...

Bosch is commercializing hydrogen technologies,
the fuel-cell powertrain system is now going into production

...many thanks Stefan! My message is clear: Bosch is entering the hydrogen economy in earnest. The clearest sign of this is our upfront investments. Between 2021 and 2026, we will have invested a total of nearly 2.5 billion euros in the development and manufacturing of our H_2 technologies. Of this amount, nearly two thirds will have gone into the fuel-cell powertrain. By as early as 2030, it is expected that one in five new trucks weighing six tons or more will feature such a powertrain. In addition, we are working on a hydrogen engine that will be suitable above all for agricultural and construction machinery, but also for heavy long-haul trucks. As Stefan Hartung has already underlined, we are occupying many fields along the entire H_2 value chain. This also means that we will supply stacks for hydrogen production, and in doing so enter the electrolysis market, which is expected to have a global volume of 26 billion euros by 2030. And we also want to use stationary fuel-cell technology for distributed energy systems, where the global market volume is expected to be 20 billion euros by 2030.

So our business opportunities are enormous, and the effects of this entry into the hydrogen economy on jobs are no less important. Even now, we have more than 3,000 people at Bosch working on hydrogen technologies, more than half of them in Europe. And whether this figure rises depends in its turn on the political conditions Stefan Hartung just outlined. The important thing here is that our commitment to electrolysis and fuel cells is helping us transform our core business. We can fill most of the vacancies arising in the emerging hydrogen business from within the company, and especially with people who have so far worked in our powertrain business. More than that, we can transfer expertise from the one area to the other.

Whether diesel or hydrogen technology, Bosch can rely in both instances on two essential core competencies.

- On the one hand, there is our systems know-how – our ability to control many components with sensor technology and complex electronics.
- On the other hand, there is commercialization – the ability to scale up a new development quickly into volume production.

Fundamentally speaking, Bosch can apply unrivalled automotive experience to the hydrogen economy. This is why we are also in demand in H_2 production, where we are new to the market. Plenty of companies can build electrolysis stacks in the laboratory. But only very few are capable of mass producing such stacks.

Specifically, we can use and modify processes from the manufacture of diesel and gasoline systems for the production of fuel cells. For example, laser welding is something we are familiar with from injector production. And whether in coating technology or leak testing, a technology transfer is possible. But none of this is any use unless complex processes can be controlled. This is the reason why we manufacture so much in-house. Over the long term as well, we expect that more than half the value generated by our fuel cell power module to be created within the company. Not least, this also involves our traditional strength in making special-purpose machinery. This means we can cover some 50 percent of the manufacturing equipment we need.

Our capabilities are also in evidence in the finer details. Let me give you two outstanding examples.

- This first is high-speed laser welding. We use it to make 1,200 meters of welds in each stack of our mobile fuel-cell systems hydrogen-tight. This is a process that only exists at Bosch.
- Then there is laser drilling. We use it to make more than 200 million holes – 6,000 a second – in each stack of a stationary fuel-cell system.

In the transition to the hydrogen economy as well, we can see that the concrete solutions developed to mitigate global warming depend on thorough technological knowledge. And it is this knowledge that Bosch can contribute. On a final note, I would like to give you a rundown of where we stand at present.

- First, as concerns hydrogen production. At the start of the year, Bosch started constructing prototypes for electrolysis using proton exchange membranes – in other words, the reverse of the energy conversion method used in mobile fuel cells. In a first step, we have produced 150 kilowatt stacks, and from the fall we will supply 1.25 megawatt prototypes for pilot applications. This means we are on course to start production in 2025. We are entering the market as a supplier of stacks, but will also supply sensors, controls, and the necessary services. Our lead plant is Bamberg, yet especially in electrolysis, global supply chains are crucial. What customers want is clear: they want to see the economies of scale that come from high-volume production – and this is what Bosch stands for. Moreover, hydrogen production is an important area of study for our R&D teams. In 2024, together with our partners Ceres Power and Linde, we will also trial solid-oxide electrolysis in a demonstrator project.

- And that brings me to the subject of stationary fuel cells, which are also based on solid-oxide technology. They can be used in distributed energy supplies – not just in the form of electricity, but also as heat. For example, in a pilot project at the hospital in Erkelenz, near Cologne in Germany, we will achieve overall efficiency of 90 percent. A micropower plant like this starts off with natural gas, but can be converted to green hydrogen. This will take us gradually toward climate neutrality. We want to start volume production of this technology in the middle of this decade. Not least, we can use our expertise in functional ceramics when manufacturing these stationary fuel-cell stacks. We developed this expertise when manufacturing lambda sensors for vehicles.

- On the subject of mobile applications, we can not only convert hydrogen into electricity using the fuel-cell powertrain, but also use hydrogen directly as a fuel. Such a hydrogen engine can do everything a diesel engine does, but on top of that, it is practically carbon neutral. This is a quick and cost-efficient way into the mobile use of hydrogen, since we can use more than 90 percent of our existing engineering and manufacturing technologies. Hydrogen engines are particularly suitable for heavy vehicles on long hauls with especially heavy payloads. Bosch is developing two systems for these engines: port and direct injection of hydrogen. The biggest technological challenge is the injector for direct injection. Unlike in a diesel engine, it has to work without any lubrication from the fuel, and yet, just like in a diesel engine, still be capable of opening and closing billions of times over. Our engineers are in the process of solving this problem without any additional oil being emitted. Nobody else in the world has managed this so far. The H_2 engine is expected to be launched starting in 2024. Even now, Bosch has four orders for production projects from all the major economic regions. By the end of the decade, production may run into the hundreds of thousands.

- Finally, ladies and gentlemen, there is the fuel-cell powertrain. Here, we are starting volume production. We can deliver the powertrain system as well as important components, whether the stack, the hydrogen metering valve, or the electric air compressor. We have four production orders for the complete system, and further orders for our components. In our exhibition, you can take a look at the truck of our customer Nikola Iveco. All in all, we are supplying truck makers in China, the U.S., and Europe. Our system has already clocked 2 million kilometers in pilot operation at our customers'. In addition, we have established an international

manufacturing network. Back in 2022, for example, stacks went into production in Bamberg and Wuxi. In both plants, we will have manufactured stacks with a total output of one gigawatt by the middle of the decade. Moreover, the production of complete powertrain systems is now getting underway, both here in Feuerbach and in Chongqing. In the initial stages, we will manufacture several thousand systems in total each year. We believe that the market will initially show the strongest development in China. But regardless of this, we are officially beginning volume production of our fuel-cell powertrain system here today.

Together with Stefan Hartung and Thomas Pauer, the president of our powertrain division, I would now like to symbolically get production started. Please join me here on stage. It's only a flick of a switch, but for us it's the start of a new and exciting area of business. Bosch will now be synonymous with hydrogen!