On the path to a digital car company with smart production

- **Audi using digital solutions to make production more flexible and efficient**
- **Audi Production Lab and Automotive Initiative 2025 integral part of the group's digital strategy**
- **Audi's global production network will be part of Industrial Cloud in the future**
- **5G, 3D printing, RFID, machine learning, and AI – cutting-edge technologies leading the way to the smart factory**

Ingolstadt, August 26, 2021 – Audi is working at full speed to digitalize its production and, as a result, the working environment in areas such as planning, assembly, logistics, maintenance, and quality assurance at the five production facilities the company operates itself around the world. A number of groundbreaking projects with technologies such as 3D printing, 5G, apps, and virtual reality are already revolutionizing operational processes and creating synergies and new forms of global networking. Read on for an overview.

What is Audi doing to digitalize its global production?
Efficient systems and new high-tech solutions are the basis for fully connected, digitalized production operations. With this clear vision in mind, Audi is strategically aligning its processes with the future. The Audi Production Lab is instrumental in the development of many forward-looking projects. The P-Lab, as it is known at the company, was set up by Audi in 2012 and is a kind of think tank for all topics related to production. Here, a core team of 30 employees develops ideas and tests new approaches together with their coworkers from production and logistics in order to further optimize efficiency, precision, and quality at the plants. The P-Lab has played a key role in helping technologies such as 3Dprinting, human-robot collaboration, automated guided vehicles, and augmented and virtual reality make their way into large-scale production at Audi.

Another element of the company's digitalization efforts is the Automotive Initiative 2025 – AI25 for short – which was launched in early 2021. The goal of the initiative is to create a global network of expertise for digital factory transformation and sustainable innovation. To this end, Audi Neckarsulm will play a pivotal role as a pilot factory and real-world laboratory. The long-established site already has extensive expertise in production IT for both high-volume and small-scale production. In addition, the initiative is intended to serve as a source of ideas and inspiration for the transformation of production and logistics throughout the Volkswagen Group. Over the next five years, digital solutions for vehicle production and the supply chain will increasingly be tested and developed through to full-scale production via AI25. The development of IT solutions for the smart factory is being supported by academic institutions such as the Fraunhofer Institute for Industrial Engineering and the Technical University of Munich, as well as

technology partners Amazon Web Services (AWS) and SAP. Custom-developed solutions and ideas are also expected to come from the joint venture “XL2” based in Heilbronn, which was founded last year together with Capgemini. This independent unit is focusing on SAP projects for production, master data management, and the development of cloud-based applications.

Speaking of Volkswagen – what role does Audi play in the group’s digital production?
The company with the four rings is part of the Volkswagen Group’s digital strategy. Volkswagen is currently building one of the world’s largest cloud projects of its kind: the Industrial Cloud. The technological heart of this system is the Digital Production Platform – or DPP for short. In the future, the platform will be used to bring together and analyze the data from all of the machines, production lines, and systems in use at the group’s factories around the world. In its final stage of development, the amount of data that will be analyzed on the platform every day is likely to be in the order of magnitude of the quantity of data generated by a small German town. It is being built on technologies from fields such as the Internet of Things (IoT), machine learning, data analytics, and computing services that have been developed to meet the specific needs of the automotive industry. Each site will be able to download applications for its machines, tools, and systems directly from the Industrial Cloud and thereby produce even more efficiently (i.e., an “app store approach”). Neckarsulm and Ingolstadt are the first two Audi sites already connected; the remaining three will follow by the end of 2021. As a result, the sites will become part of an open platform that will also gradually integrate the global supply chain and industrial partners. Furthermore, Volkswagen is also working with partners to create a marketplace for industrial applications. This would allow all of the participants to share applications with each other as well as purchase and use the applications they need. Audi can then share best practices and deploy them itself.

What opportunities does 5G technology hold for production?
A high-performance network infrastructure that can respond in real time plays a critical role in the agile and flexible production environment of the future. Audi is therefore focusing on the use of 5G technology in smart production processes. Network operators promise fast data speeds of more than ten gigabits per second and minimal latency rates of no more than one millisecond. The cellular connections are considered robust, they consume very little power, and reliability stands at nearly 100 percent. In addition, 5G offers the ability to wirelessly connect a large number of industrial devices. A machine connected via 5G can respond in real time to inputs from the control system. The company recognized these advantages early on and has already launched several pilot projects. Automated guided vehicles are already in use, which deliver materials and components for production just in time and exactly where they are needed.

This is just one example of what high-speed 5G technology will make possible at Audi in the future. In the Audi Production Lab (P-Lab), several applications are currently being tested under real production conditions in order to formulate the requirements that 5G technology will have to meet in Audi’s production environment. An exclusive frequency spectrum – a 5G campus network within the factory – has been in use in Ingolstadt since mid-2020. This local frequency is an important condition for successful 5G deployment in production.

How is Audi using 3D printing in production?
Audi has been using digital 3D printing in production processes for more than 20 years. Originally, the process was mainly used to produce visual models. In recent years, the share of components created using the technology for the company's own production tools and vehicle models has increased significantly. In the meantime, plastic and metal 3D printing is capable of producing larger and larger parts. A number of different competencies and resources for Technical Development and Production are pooled at the Ingolstadt site. This is where technology scouting and the development of new applications with various departments takes place. The metal 3D printing center located in Ingolstadt specializes in producing complex steel and aluminum parts as well as tool inserts for forming tools weighing several tons, for example for pressing car body parts or for die casting, which are manufactured from metal powder using the laser melting process. This makes it easier to implement unusual designs because 3D printing supports open shapes, i.e., all conceivable organic forms. This is a major advantage for tool inserts with cooling channels close to the edge, for example.

A second center of excellence for 3D printing using plastics is located at the Neckarsulm site. In close collaboration with coworkers from Production, 3D printing specialists there design customized assembly aids that make work more ergonomic. If employees have optimization ideas, they can simply contact the in-house 3D printing center. Together with a start-up from Berlin, Audi has developed software that reduces the time required to design preassembly devices by 80 percent. A sketch is usually all that is needed, and the desired part is available in just a few hours. 3D printing was first incorporated into the preparations for the high-volume production of* the Audi e-tron GT. More than 160 different printed aids are now in use at the location today. One of these, for example, is used in the preassembly of air-conditioning compressors as well as cooling lines. The assembly aid with a built-in clamp was designed in-house and holds all of the components in the exact position.

How are sensors and apps revolutionizing maintenance at Audi?
The company-wide "Predictive Maintenance" flagship project makes the maintenance of production equipment at the Neckarsulm site in the body shop more efficient, thereby minimizing downtime. Special sensor technology in a joining system that rivets various car body components together uses data, algorithms, and measured values to detect traces of wear in plastic hoses. Sudden system failures have been virtually eliminated as a result, and maintenance work can be carried out during non-production time. This makes maintenance work easier and production more efficient. Processes are currently being standardized in order to connect multiple systems and machines to databases. After a successful pilot phase, Predictive Maintenance is set to enter high-volume production and will also be used in other areas.

Audi's maintenance staff receive further support from the "iMaintenance" app. This app contains a knowledge database with around 5,000 pages on materials science and recommended actions. If a machine displays an error code, the user simply enters the code into a tablet and then receives step-by-step instructions. Via another app, "Audi Mobile Maintenance," experts in assembly at the Ingolstadt site and in the paint shop at the Neckarsulm plant receive immediate

information about system errors. The app displays all of the relevant information via a push notification – which system in which hall is affected? Which warehouse has a replacement available? Are coworkers possibly already taking care of the situation? This increases transparency, reduces trips, speeds up processes, and enhances data quality. Everything is documented digitally and can be accessed by the entire team from anywhere using a mobile device. Audi plans to roll the app out to other factories in the near future.

What are the benefits of RFID for production and logistics?
The Audi Neckarsulm site was the first automotive plant in the VW Group to use radio-frequency identification (RFID) technology for digital vehicle identification – throughout the entire production process. To this end, every Audi manufactured at the plant receives an RFID tag consisting of a chip and an antenna during the very first production step in the body shop. This tag then accompanies each vehicle from there to the paint shop, to assembly, and all the way to delivery. The chips contain a unique identification number. With the help of a reader, important vehicle information such as body design, paint finish, engine, and features of the respective car can be accessed in the various production areas.

Among other benefits, this guarantees that every single Audi rolls off the production line exactly as it was configured. Since the start of production of the all-electric Audi e-tron GT* at the end of 2020, Audi has also been using “RFID on metal” tags. This innovative data storage device uses direct contact between the vehicle and the tag to the benefit of transmission quality by using the body of the e-tron GT* itself as an extended antenna. In addition to the production areas, other areas also benefit from the use of this technology. For example, vehicle logistics uses the RFID tag to track individual vehicles moving around the factory premises. Likewise, future loading records, such as those used when loading vehicles onto cargo trains, will be processed via dedicated reading stations by simply scanning the tag. RFID technology is set to become the standard in all areas of Audi’s global production network in the coming years.

How can machine learning and AI improve production quality?
Increasing demands in terms of design, lightweight construction, and functionality are constantly presenting the press shop with new challenges. Sharper lines for the exterior as well as the increasing complexity of the components lead to narrow process windows that can occasionally result in cracks during the production of body components. In order to keep product quality as high as possible, a cross-functional team at Audi is developing a solution to visually detect quality defects with the help of artificial intelligence.

The methods used mimic the human ability to reliably detect cracks in sheet metal parts. An algorithm based on deep neural networks, also known as deep learning, operates in the background. This enables it to reliably detect defective parts automatically, in seconds, and with maximum precision. To this end, the software is continuously trained and improved with sample images. For this purpose, experts from production marked cracks by hand and photographed them.

The process is carried out at the Ingolstadt press shop with the help of several cameras in the system that take photos of newly produced deep-drawn parts. The images are then evaluated in real time by the algorithm. If a crack has been identified, a visual signal alerts the employees. The pilot solution from 2019 is currently being refined and enhanced for use in high-volume production, including at other sites, and is gradually being implemented with the group's partners. A key technology in this context is the VW Vision Workbench (VW²) group platform, which lays the technical foundation for and expands the use of new AI-based approaches at all plants worldwide. This is also intended to intensify cross-location collaboration, which can lead to further synergy effects. By working together more closely, several locations have already been identified for possible roll-out projects.

How does virtual reality support digital production planning?
The Audi e-tron GT* is the first model from the brand with the four rings whose assembly and logistics processes were tested entirely virtually and without physical prototypes.
This was made possible by innovations such as three-dimensional building scans, machine learning, and virtual reality. All of the assembly sequences and the associated logistics processes were tested and optimized in virtual rooms, such as the exact arrangement of machines, racks, and components along the assembly line or ergonomic aspects. To achieve this, the conditions in the production hall had to be precisely reproduced to scale. This is where 3D scans came into play. They create a virtual image of the production facility including all of the systems, tools, and shelves.

At the same time, the scanning process generates a three-dimensional point cloud that can be used to virtually recreate machines and infrastructure. Audi employees can digitally update their layout and planning systems, thereby saving time and cutting costs. Thanks to the digital likeness and a VR solution developed by Audi, coworkers from all over the world now meet in virtual rooms. Here they can look over the shoulders of computer-generated workers as they carry out the planned workflows and experience and optimize the planned processes for any component versions in the application itself. Audi developed the software based on artificial intelligence and machine learning in-house. Virtual planning and production preparation is now used across locations and allows employees to work digitally and collaboratively with far fewer business trips – and not just during the coronavirus pandemic.

How important is training in the course of this transformation?
Audi will not rely only on technologies alone in the future. Instead, the company understands Vorsprung durch Technik to also mean connecting people and machines in the factory of the future in the best possible way. Innovative technologies support Audi employees in production, relieving them of strenuous physical tasks or monotonous manual labor. As a result, employees can better focus on value-adding activities. Within the framework of various programs, Audi is therefore training its workforce for digital tasks. For example, in order to make 3D printing better known and to teach relevant basic and expert knowledge, Audi has been promoting the topic in training for several years. Among other qualifications, aspiring mechatronics engineers can complete additional training in 3D printing. Trainees and employees from plant logistics

learn how to carry out what is known as the pick-by-light process using VR headsets and controllers. For this purpose, a typical workplace was recreated virtually and accurate down to the last detail. In it, the trainees practice various work routines. This gamified approach is designed to make the training fun. The basis of this solution is a modular VR system that can be used to create training programs for all operational and process-oriented workflows in production. At a higher level, the Audi Academy offers a wide range of training courses in the future field of digitalization, thereby preparing employees for the future. All of these examples clearly show that Audi's transformation into a digital car company is in full swing.

Location Communications
Sabine Taner
Spokesperson Production and Logistics
Phone: +49-841-89-42505
Email: sabine.taner@audi.de
www.audi-mediacenter.com/en

Location Communications
Maximilian Kranl
Spokesperson Production and Logistics Phone:
+49-152-5881-2306
Email: maximilian.kranl@audi.de
www.audi-mediacenter.com/en

Fuel consumption of the models named above
Information on fuel/electricity consumption and CO_2 emissions in ranges depending on the tires and alloy wheel rims used and on the equipment and accessories of the car.

***Audi e-tron GT quattro**

Combined electric power consumption in kWh/100 km (62.1 mi): 21.8–19.9 (WLTP); 19.6–18.8 (NEDC); combined CO2 emissions in g/km (g/mi): 0 (0)

The indicated consumption and emissions values were determined according to the legally specified measuring methods. Since September 1, 2017, type approval for certain new vehicles has been performed in accordance with the Worldwide Harmonized Light Vehicles Test Procedure (WLTP), a more realistic test procedure for measuring fuel consumption and CO_2 emissions. Since September 1, 2018, the WLTP has gradually replaced the New European Driving Cycle (NEDC). Due to the realistic test conditions, the fuel consumption and CO_2 emission values measured are in many cases higher than the values measured according to the NEDC. Vehicle taxation could change accordingly as of September 1, 2018. Additional information about the differences between WLTP and NEDC is available at www.audi.de/wltp.

At the moment, it is still mandatory to communicate the NEDC values. In the case of new vehicles for which type approval was performed using WLTP, the NEDC values are derived from the WLTP values. WLTP values can be provided voluntarily until their use becomes mandatory. If NEDC values are indicated as a range, they do not refer to one, specific vehicle and are not an integral element of the offer. They are provided only for the purpose of comparison between the various vehicle types. Additional equipment and accessories (attachment parts, tire size, etc.) can change relevant vehicle parameters, such as weight, rolling resistance and aerodynamics and, like weather and traffic conditions as well as individual driving style, influence a vehicle's electrical consumption, CO_2 emissions and performance figures.

Further information on official fuel consumption figures and the official specific CO_2 emissions of new passenger cars can be found in the "Guide on the fuel economy, CO_2 emissions and power consumption of all new passenger car models," which is available free of charge at all sales dealerships and from DAT Deutsche Automobil Treuhand GmbH, Hellmuth-Hirth-Str. 1, 73760 Ostfildern-Scharnhausen, Germany (www.dat.de).