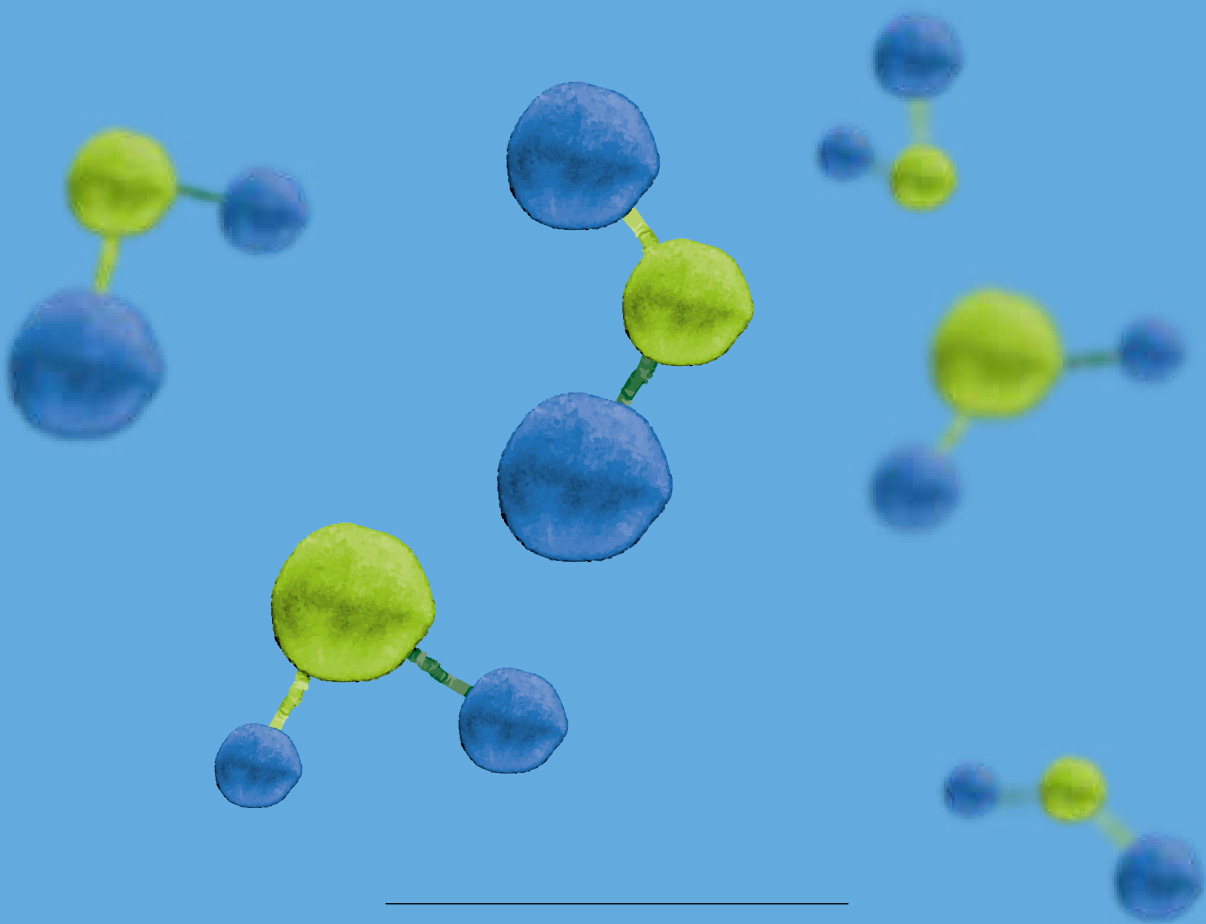
THE MAGAZINE OF THE **PRODUCTION TECHNOLOGY CENTER BERLIN**

# futur

VISION | INNOVATION | REALIZATION



## CARBON-NEUTRAL PRODUCTION

### Climate-neutral – But How?

Climate change presents industry with a major challenge: How can greenhouse gases be reduced in an economically viable way?

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### Hybrid High-flyers

The future of mobility is (hybrid-) electric – and the aviation sector is no exception. The digital path now needs to be defined in order to fulfill new requirements.

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### Material Matters

Welding is becoming more sustainable: by means of material selection, lightweight construction methods and, not least, Industry 4.0 processes.

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Fraunhofer IPK

INSTITUTE
PRODUCTION SYSTEMS AND
DESIGN TECHNOLOGY

IWF

INSTITUTE MACHINE TOOLS
AND FACTORY MANAGEMENT
TECHNISCHE UNIVERSITÄT BERLIN



**This little cloud
was once industrial waste.**

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## Production Technology Center (PTZ) Berlin

**PROFILE** The Production Technology Center (PTZ) Berlin houses two research institutes: the Institute for Machine Tools and Factory Management IWF of the TU Berlin and the Fraunhofer Institute for Production Systems and Design Technology IPK. As production-related research and development partners with a distinctive IT competence, both institutes are in international demand. Their close cooperation in the PTZ puts them in the unique position of being able to completely cover the scientific innovation chain from fundamental research to application-oriented expertise and readiness for use.

We provide comprehensive support to companies along the entire process of value creation: Together with industrial customers and public-sector clients, we develop system solutions, individual technologies and services for the process chain of manufacturing companies – from product development, planning and control of machines and systems, including technologies for parts manufacturing, to comprehensive automation and management of factory operations. We also transfer production engineering solutions to areas of application outside industry, such as traffic and safety.

# DEAR READERS,

Carbon-neutral, climate-friendly, emission-free. These terms describe measures that all contribute to the same goal: A way of doing business that does not advance global warming. Political institutions such as the EU Commission, but also responsible companies and of course social movements such as Fridays for Future are working to ensure that these words will be filled with meaning and actions will follow suit accordingly.

Particularly in the manufacturing industry, a great deal of inventiveness is required, if the idea of carbon neutrality is to be put into practice. As they say, you can't make an omelet without breaking eggs, and manufacturing will always mean consuming resources and energy. The common goal of our researchers at PTZ Berlin is therefore to design all processes associated with the production of goods in such a way that consumer demands can be met at the same time as long-term environmental interests are preserved.

We are currently refining classic manufacturing processes in the course of several R&D projects to make them more climate-friendly. For example, scientists at IWF TU Berlin have discovered that during honing processes, the clogging of the honing layer by removed material can be significantly reduced with the aid of low-frequency vibrations. This allows for metals to be processed without environmentally problematic and climate-damaging cooling lubricants.

Significant potential for emissions savings can also be leveraged in welding processes by means of material selection, lightweight construction methods and, not least, Industry 4.0 processes. The article »Material Matters« summarizes the results of several Fraunhofer IPK projects on that subject.

In the area of product development, our scientists are investigating how emissions can be reduced before production even begins. They are developing integrated data strategies for greenhouse gas-intensive industries such as aerospace and automotive engineering, thanks to which the most important carbon drivers can be identified and eliminated.

The guest articles in this issue show that our customers and partners are on the same page as us when it comes to this important topic. We spoke with Gudrun Sack, Managing Director of the Berlin Tegel Projekt GmbH, about the city of the future. In his guest column, our alumnus Benjamin Graf draws parallels between production science and the generation of mobility at Deutsche Bahn. And a panel of experts from the »BioFusion 4.0« project discusses the question of what manufacturing companies can learn from nature.

Please enjoy reading this issue.

**Yours**

Eckart Uhlmann

**Eckart Uhlmann**

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Sustainable and socially diverse: the city of the future
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© Tegel Projekt GmbH



Full speed ahead toward climate-friendly rockets
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© ArianeGroup Holding / Master Image



Does metalworking have to be this wet?
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**From drawing board to disassembly: data from the entire life cycle help to optimize products in terms of their carbon footprint.**

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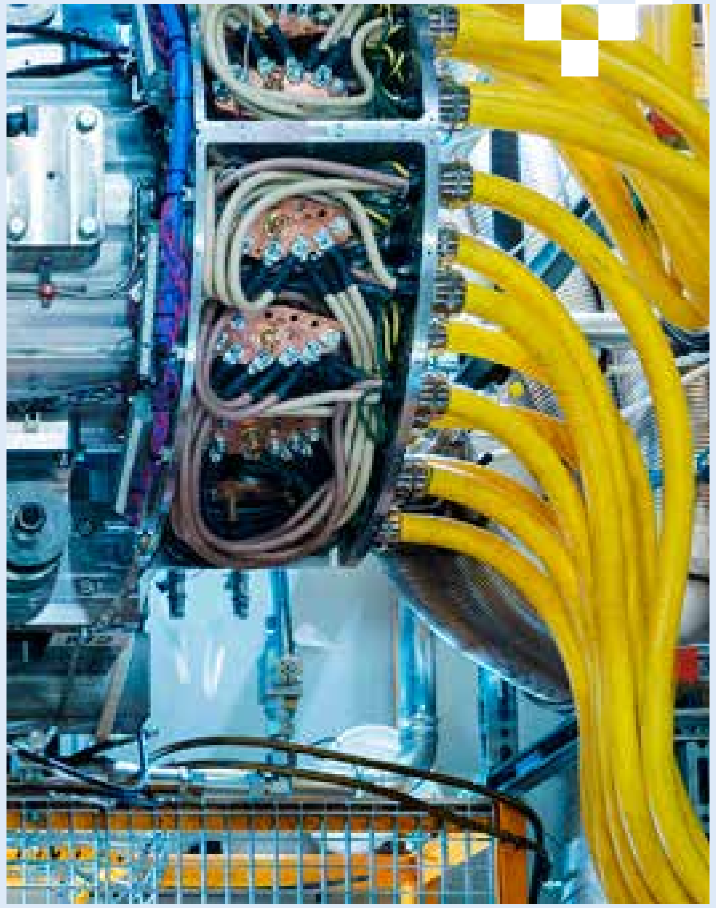
# SHORTCUTS | futur

## IN DETAIL



**Find out which complex technology you are looking at!**
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## MODELING AND SIMULATION DEMANDS OF THE SMART FACTORY

In the new expertise of the Research Advisory Board of the Industry 4.0 Platform, Fraunhofer IPK highlights current approaches to the use of modeling and simulation in the smart factory. For Industry 4.0 capabilities with varying degrees of complexity, the study determined which research and development needs must be addressed in the future to enable a smart factory.

↳ **Further information and download of the study [German only] at** www.ipk.fraunhofer.de/expertise-modellierung-simulation

## ALL-ROUND PACKAGE FOR CORPORATE CLIMATE PROTECTION

Climate protection is becoming increasingly critical to the success of all companies as a joint task. The KliMaWirtschaft project provides companies of all sizes and from all sectors with practical and individual support in measurably reducing their greenhouse gas emissions. All services are free of charge. You will be supported in the development, implementation and evaluation of your own climate protection measures with a three-part workshop series, webinars and checklists as well as a telephone consultation.

*The project »KliMaWirtschaft – Nationwide Climate Protection Management for the Economy« (67KF0166A) is funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) as part of the funding call for innovative climate protection projects of the National Climate Initiative (NKI).*

↳ **Registration and further information [German only] at** www.klimaschutz-wirtschaft.de

## WELL SAID

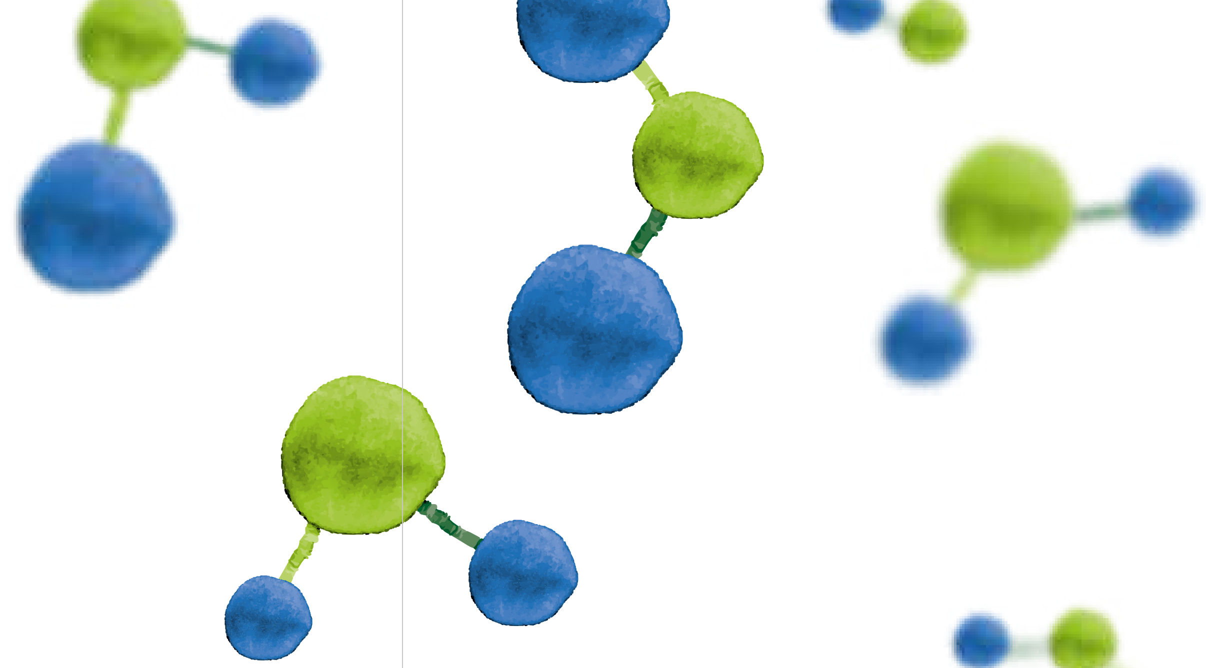
**»Our vision is to scale timber construction to an industrial level and thus help climate-friendly construction achieve a breakthrough.«**

Gudrun Sack, Managing Director of Tegel Projekt GmbH in Berlin
↳ Read more starting on page 16.

## NUMBER OF THE ISSUE

# 800 000 000 000 000 kg

or 800 gigatons of $CO_2$ equivalents will be consumed by the production of steel, aluminum, plastics, and cement with the current state of production technology in the 21st century. To find out how we can counteract this, read our lead article on climate-neutral production. ↳ page 10



# Climate-neutral – But How?

**Climate change presents industry with a major challenge: How can greenhouse gases be reduced in an economically viable way?**

The German manufacturing industry is responsible for around 20 percent of $CO_2$ emissions in this country, making it the second largest emitter of greenhouse gases behind the energy industry and ahead of transport, buildings, agriculture, and the waste sector. According to current calculations, industrial production recorded around 181 million metric tons of $CO_2$ equivalents in 2021 – almost back to the level of 2019 after a decline in 2020. According to the German Federal Ministry for Economic Affairs and Climate Action, this was due to »economic catch-up effects in the wake of the Corona crisis and the increased use of fossil fuels.«

Most emissions in the industrial sector occur in the steel industry, in the chemical industry and in the manufacture of mineral products such as cement. The manufacturing sector, including the industries with traditionally the highest gross value added, namely vehicle manufacturing, mechanical engineering and metal production and processing, account for around 120 million metric tons of $CO_2$ equivalents in 2020. According to forecasts, the production of steel, aluminum, plastics and cement alone will generate around 800 gigatons of $CO_2$ in the 21st century, based on the the current state of production technology. This would mean missing the target to limit global warming to below two degrees Celsius compared to the pre-industrial era, set at the 2015 UN Climate Change Conference in Paris.

Climate researchers, business associations and politicians therefore agree that in order to achieve the German government's goal of making Germany greenhouse gas-neutral by 2045, it is not only necessary to increase the use of renewable energies and boost energy efficiency, but also to switch to climate-neutral production. But what does it mean in concrete terms for companies to produce in a $CO_2$-neutral way? And how can $CO_2$ neutrality be achieved in global manufacturing and value creation systems?

**ALL EMISSIONS AT A GLANCE**

Calculating, reducing and offsetting emissions – these are the basic steps that manufacturing companies can take on the way to a climate-neutral production. Some German manufacturers are already following the Greenhouse Gas Protocol (GHGP), an internationally recognized standard that divides the options for companies to reduce emissions into three categories – known as »scopes«.



Scope 1 addresses all direct emissions that a company causes itself when manufacturing its products – for example, in its own production facilities and processes or through its own company vehicles. Scope 2 takes into account all indirect emissions caused by a company's production-related consumption of electricity, steam or heating and cooling agents. Scope 3 also includes all indirect emissions from upstream and downstream value creation and the life cycle of a product. This includes materials and components from suppliers, the associated logistics, and the use of the products produced up to the end of their life cycle. Business travel by company personnel is also included here.

**COMPANIES HAVE LEVERAGE**

Companies can directly influence the reduction of Scope 1 and 2 emissions with energy-related measures focused on their own production, development and organization. These include, for example, investing in renewable energies such as wind, photovoltaics, or using waste process heat to generate their own electricity. Bosch, one of the major automotive suppliers in Germany, states that it has already been climate-neutral in this way since 2020 with its more than 400 locations worldwide. In order to further minimize its ecological footprint in regards to Scope 3, the company also intends to reduce upstream and

Minimum price per ton of $CO_2$ from 2025

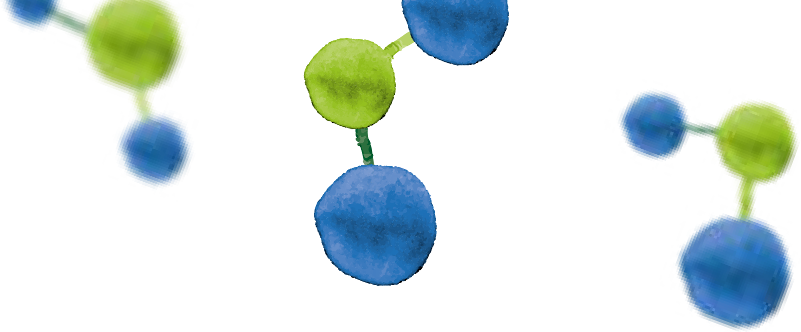
55 €

The German manufacturing sector's share of energy consumption out of all production sectors

42 percent

Germany's energy prices compared globally

15th rank (out of 133)



downstream emissions by 15 percent by 2030, relying not only on an increasing circular economy and careful use of water but also on offsetting unavoidable carbon emissions with compensation measures.

The car manufacturer Audi wants to produce carbon-neutrally by 2025, at least in balance sheet terms. This is an ambitious plan in view of the assumption that $CO_2$ emissions will tend to rise in the future as a result of increasing electromobility – because even though electric cars are much more climate-friendly while in use, their production is associated with higher energy consumption than conventional gasoline-powered cars, according to a study by Fraunhofer ISI. Audi intends to achieve its goal by making the entire value chain,

**Image:**
Dürr's EcoDryScrubber is based on dry separation and does not require water and coagulation chemicals. The result: energy savings and conservation of resources in painting, the most energy-intensive process in vehicle production. © *Dürr*

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**Images 1 and 2:**
As part of the aluminum Closed Loop, Audi returns aluminum waste generated during production to the supplier, who uses it to produce new aluminum coils in original quality and delivers them back to Audi. © *AUDI AG*

including the production supply chains, climate-neutral. The first step is to save energy in its own plants, the second is to use green energy, and only the third step is to offset unavoidable emissions. With its »Aluminum Closed Loop« initiative, Audi has also been recycling the traditional but highly energy-intensive lightweight material since 2017. In doing so, the manufacturer is saving primary raw materials and improving the environmental performance of its vehicles even before they enter the use phase. According to Audi, the measures, which also include suppliers, harbor a reduction potential of 1.2 metric tons of $CO_2$ on average per car by 2025.

## RESOURCE EFFICIENCY IS KEY

The examples show that, in addition to energy consumption, efficient use of resources and consistent recycling management are the keys to climate-neutral production. This also applies to mechanical and plant engineering. Said sector is considered to be material-intensive, rather than energy-intensive, and faces challenges particularly with regard to Scope 3 emissions in its supply chains.

»That is why it is important for globally active companies, as well as small and medium-sized enterprises, to collect data along their entire value chain,« says Prof. Dr. Holger Kohl, Deputy Director of Fraunhofer IPK and an expert in sustainable corporate management. He and his research team use the life cycle assessment method, amongst others, to investigate which points in the product life cycle have the biggest potential for $CO_2$ savings. This enables companies to determine where the greatest impact can be generated, identify the major $CO_2$ drivers in a targeted manner and derive economical and efficient measures. According to Kohl, the greatest opportunities lie in reducing energy consumption and using renewable energy sources, but above all in closed material cycles and increased use of recycled materials or products and components that have undergone remanufacturing. »In many cases, about 80 percent of carbon emissions can be reduced through energy savings,« says Holger Kohl. »The last 20 percent are more difficult and must also be tackled using long term strategies.« In the end, this can only be achieved through production technology and consistent resource conservation not only in a company's own value chain, but also upstream and downstream.

## CHANGE IS POSSIBLE

Best practices from the mechanical engineering and metalworking sectors underscore this: With modern heating, air and cooling concepts, consumption-optimized components and intelligent aggregate controls, for example, plant manufacturer DMG MORI is improving the energy and emissions efficiency of its machines. In addition, the company is following a global sustainability strategy and reducing $CO_2$ emissions at all its sites worldwide. Dürr, a systems supplier for exhaust air purification and paint finishing technology, is modernizing existing systems by converting them from wet separation to dry separation, thus helping car manufacturers to reduce the energy required for the overall production of a vehicle by ten percent. When it comes to conserving resources, clamping equipment manufacturer Hainbuch focuses on durable products and offers modular solutions that enable customers from the aerospace and medical technology sectors to adapt machine tools to different production jobs without additional expense.

Prof. Dr. Dr. Eckart Uhlmann, Director of Fraunhofer IPK, also sees potential for all-round climate-neutral production primarily in the optimization of manufacturing processes and plants, the heart of manufacturing companies. »We need to enable manufacturers to design all manufacturing steps in a way that conserves energy and resources,« the production systems expert emphasizes. To this end, he and his team are developing technologies for high-performance machining that meet the highest requirements for productivity, reliability and resource efficiency. Among other things, research focuses on the optimization of machining processes. Some plant manufacturers, as Dürr's example shows, are already switching from wet to dry machining and dispensing with cutting fluids in many machining processes. Where their use remains absolutely necessary, Fraunhofer IPK experts are supplying solutions with essential oils that can avoid toxic substances and even achieve antimicrobial effects.

Fraunhofer IPK scientists are also developing strategies and technologies for maintenance, repair and overhaul of components, machines and production systems, as well as for the recycling of components and products. This includes solutions for the remanufacturing of used parts. With the help of AI, used vehicle components such as starters or alternators can thus not only be recycled, but also remanufactured and given a further life cycle in use. According to a study by the VDI Center for Resource


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**Images:**
**1**
Since January 2021, customers worldwide are receiving completely climate-neutral machines from all DMG MORI production plants.
© *DMG MORI*
**2**
Cryogenic cooling with $CO_2$ makes cost-effective and energy-efficient high-performance machining possible, entirely without environmentally harmful lubricants.

»We need to enable manufacturers to design all manufacturing steps in a way that conserves energy and resources.«

Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann

Efficiency, such remanufacturing of old parts could save up to 80 percent of manufacturing costs and reduce material consumption by up to around 90 percent.

Uhlmann is certain: »Only when considering the use and end-of-life phases of their products in terms of their climate neutrality from the very beginning of the product development and production process can companies keep the ecological footprint of their products and services as small as possible.« Economic efficiency and sustainability must go hand in hand – because with a consistent circular economy, manufacturing companies could ultimately not only reduce their $CO_2$ emissions and increase resource efficiency, but also sustainably increase their competitiveness. ◆

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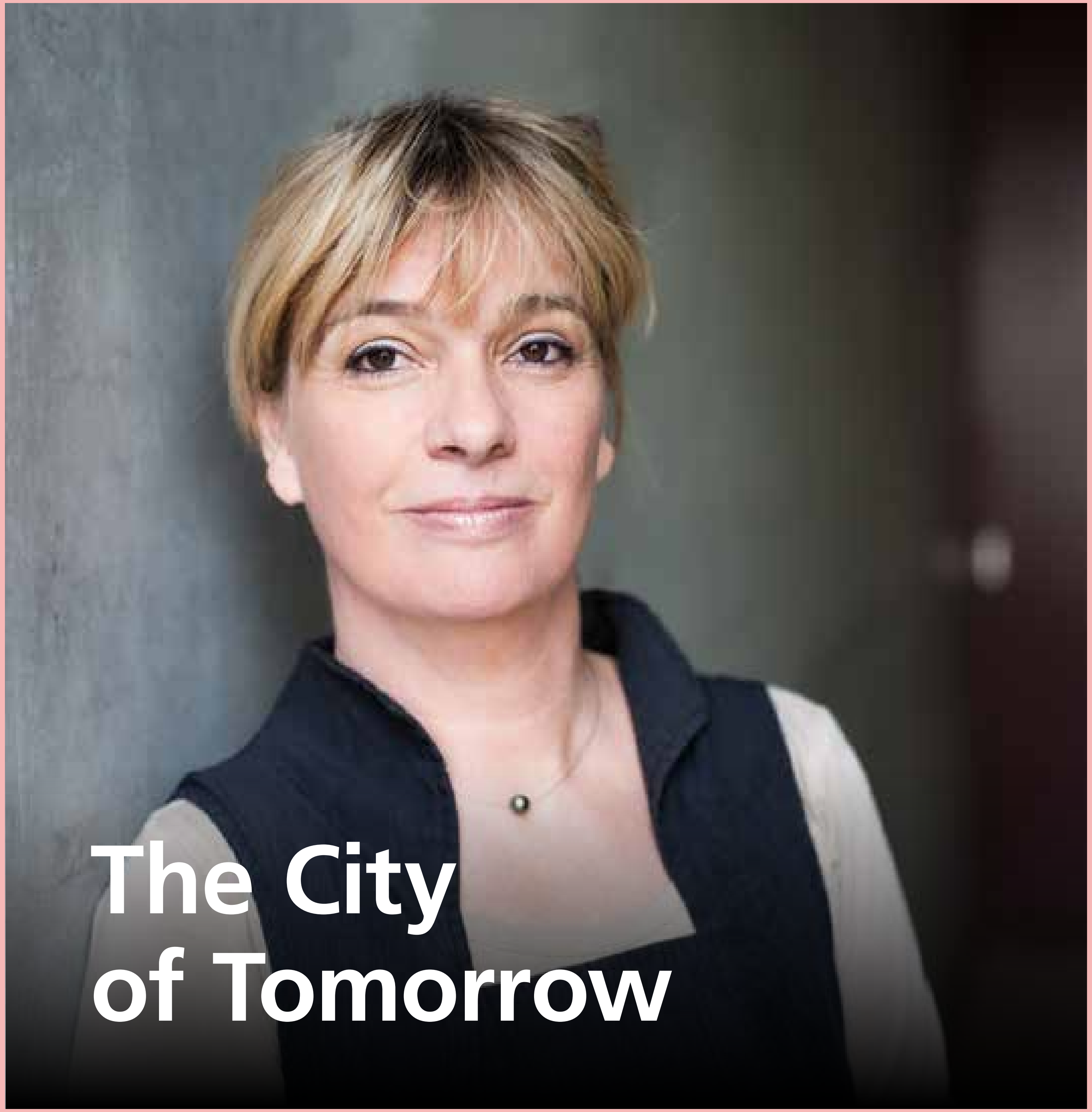

# The City of Tomorrow

*© Jonas Maron*

Following the closure of Tegel Airport, a new residential district is arising on its former site among other things: The Schumacher Quartier is to become a sustainable, smart and social home for more than 10,000 people. We spoke with Gudrun Sack, Managing Director of Tegel Projekt GmbH, about Berlin's ambitious showcase project.



**Interview with Gudrun Sack, Tegel Projekt GmbH**

**Image:** »Berlin TXL – The Urban Tech Republic« is an innovation park for urban technologies. *© Tegel Projekt GmbH*

**| futur |** Ms. Sack, you have been Managing Director at Tegel Projekt GmbH since May 2021 and are responsible for both the residential quarter and the Innovation Park. What is the current planning status?

**/ Sack /** The plans for both projects are well advanced and are based on ten years of intensive work on the question of how we want to live in our cities in the future. In the process, exemplary and innovative concepts have emerged for the Urban Tech Republic and the Schumacher Quartier. The task at hand is to implement these concepts now, and for us this is a process that is as exciting as it is challenging.

The core of the Urban Tech Republic, namely the former main terminal, will be home to a university. Around it, we will create space for up to 1,000 start-ups and companies working on innovative technologies for our cities. Ideally, they will be applied right next door in the Schumacher Quartier. It will be a smart, $CO_2$-neutral urban district, ultra-modern, socially mixed, with affordable rents. What both projects have in common is their model character with a large number of individual innovations. Concepts such as the Car-free Neighborhood or the 15-Minute City are applied here, as is a new type of energy system, the Sponge-City principle or Animal-Aided Design.

**| futur |** What are you specifically engaged in at the moment?

**/ Sack /** In August 2021, we took over the project site of the former airport and since then the first steps of implementation have been running parallel to the planning. In concrete terms, we are currently clearing explosive ordnance and preparing for civil engineering. The first development plans have been drawn up, the land allocation process can start this year and we are pleased to have the first companies on site. 1,600 m² in offices and workshops

## GUDRUN SACK

MANAGING DIRECTOR OF TEGEL PROJEKT GMBH IN BERLIN

Gudrun Sack's focus is on sustainable planning and building, anchoring qualities and new standards in construction, and implementing forward-looking and pragmatic urban planning solutions. After studying architecture at the Technical University of Berlin and the University of Applied Arts Vienna, the trained restorer began her professional career with Norman Foster in London. After a stopover at Alsop Störmer Architekten in Hamburg, she worked as a research assistant in the Department of Architecture at the Berlin University of the Arts. For more than 20 years Gudrun Sack was managing director at NÄGELIARCHITEKTEN with offices in Berlin and Karlsruhe. Among other things, she was a board member of the Berlin Chamber of Architects as well as of the Netzwerk Berliner Baugruppen Architekten and is a member of the housing working group at the BDA – Bund Deutscher Architektinnen und Architekten.

and 6,000 m² of experimental space are already being used in the future research and industrial park, which is a great success. Parallel to the renovations of the listed airport buildings, the first major construction phase will begin in 2024. The plan is for the first construction phase in the Urban Tech Republic to be completed in 2027 and for the first wooden buildings to be in place in the Schumacher Quartier.

**| futur |** The Schumacher Quartier is regarded as a model project for neighborhood development adapted to the effects of climate change. What are you doing specifically to make the new district climate-neutral?

**/ Sack /** In the Schumacher Quartier, various building blocks come into play that are aimed not only at climate neutrality but also at climate resilience. For example, we focus on sustainable raw materials, renewable energies, the sensible use of resources, and a conscious look at the $CO_2$ footprint we leave behind – in everything we do. Our big issue is the circular economy. We don't think in terms of consumption, but in terms of reusing and recycling raw materials within a closed-loop system. This applies to the Schumacher Quartier, but also to the Urban Tech Republic, where we hardly ever demolish buildings, for example, but instead convert them or recycle the concrete from the many sealed surfaces.

**| futur |** To what extent will the Schumacher Quartier benefit from the neighboring Innovation Park?

**/ Sack /** Very directly. The Schumacher Quartier is considered a model quarter for the »city of tomorrow« and new forms of construction. The technological foundations for this are being researched, tested, produced and transferred into marketable solutions in the Urban Tech Republic. Starting with the efficient use of energy, sustainable construction, environmentally friendly mobility, recycling and the networked control of systems, through to clean water and the use of new materials. If we look at our project area, research, development, production and application take place in a 500-hectare microcosm in which the »system city« with all its facets can be rethought and designed for the future.

**| futur |** What role does wood play as a raw material in the urban planning concept of the Schumacher Quartier?

**/ Sack /** A very big one. Nothing less than the largest urban timber construction quarter in the world is to be built here. Our vision is to scale timber construction to an industrial level and thus help climate-friendly construction achieve a breakthrough. We want to make timber construction attractive and competitive while saving 80 percent of climate-damaging emissions. In view of the fact that the building sector is responsible for almost 40 percent of all $CO_2$ emissions, there is no alternative to a building turnaround. With the Schumacher Quartier, we can showcase the sustainable innovations that are possible in neighborhood development.

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## »Our vision is to scale timber construction to an industrial level and thus help climate-friendly construction achieve a breakthrough.«

Gudrun Sack

**| futur |** Experts at Fraunhofer IPK have investigated how architecture in timber construction can succeed on such a scale. Industry 4.0 technologies can make a significant contribution to this. What advantages do you expect from digitalization and automation in timber construction?

**/ Sack /** Digitalization is a common thread running through the after-use of Tegel Airport. We are not only planning digitally, but are also building a digital infrastructure with our own data platform. And of course, the advantages of digitalization and automation are also obvious for timber construction. They make prefabrication faster, more efficient, more controllable, and it is impossible to imagine serial production without them. The construction volume that we have in front of us with the Schumacher Quartier is simply not feasible without digitalized planning and production processes. Wood construction is already very digitalized anyway. For the requirements of climate-positive construction, the degree of prefabrication in timber construction is a significant advantage, if you think of the blower door test, for example. With a very high degree of prefabrication, it is much easier to manufacture components precisely.

**| futur |** If you look ten years into the future, …

**/ Sack /** … the construction turnaround will have been completed. We will be building less, but in a more climate-friendly and qualitatively better way. Berlin TXL will have set an example in this respect. Here, the first 3D-printed wooden facades will have been manufactured, residential blocks with integrated, self-sufficient vegetable cultivation areas realized, and much more. In the Schumacher Quartier, socially responsible residential construction with an interesting mix of players will have been realized; a lively, colorful and nature-loving residential district will have been created. And the clever solutions for such livable neighborhoods – those will be created in the growing Urban Tech Republic, Berlin's innovation hub for urban technologies. ◆

**Images:**
**1**
Neighborhood street in the future Schumacher Quartier
**2**
A bird's-eye view of the future: On the former site of Tegel Airport, a research and industrial park for urban technologies and a new residential district are being built.
**3**
Environmentally friendly mobility is being taken into account in neighborhood planning.
*all images © Tegel Projekt GmbH*

# The Digital Thread into Space

Staying competitive in space is only possible with sustainable and economical launch vehicles.

© ArianeGroup Holding / Master Image

Traffic density in space has increased dramatically since the second half of the 20th century. While back then it was state actors that conquered space with the help of launch vehicles, nowadays it is private companies that set the tone – such as Tesla founder Elon Musk's Space X or Peter Beck's Rocket Lab. As a result, European companies in particular are coming under increasing competitive pressure from a more cost-intensive and essentially institutional rocket program, particularly in terms of sustainability. In addition, the European Space Agency (ESA), which has so far relied on their cooperation with NASA to carry out manned flights into space, now wants to take the step toward an independent access to space. Only in this way can Europe independently research issues of climate and ecology and achieve strategic and military sovereignty.

To serve these interests, the sustainability and competitiveness of ESA's launch vehicles, which are developed and produced by ArianeGroup, must be further strengthened. In this context, not only must the entire development, production and operational phases of launch vehicles be digitized, but a consistent and reliable information strategy is required. This also involves interconnecting the information-providing systems from product development with production and operations.

## DIGITAL CONSISTENCY

In the course of this transformation, mechanisms for evaluating the performance of information-bearing systems must be developed and introduced. These mechanisms must be consciously designed for the changing product and infrastructure systems. It is no longer the IT systems alone that are decisive for information and quality assurance, but rather the entire development, production and operating process. The systems concerned can be digitized end-to-end and thus networked consistently. The term »digital thread« is often used for this, which in turn can positively influence the circular economy strategies (e. g. predictive maintenance, reusability and recycling) of launch vehicles.

In the »POLAR« research project, a Fraunhofer IPK research team, together with a team from ArianeGroup, is using the real example of launch vehicle development and production in Germany to investigate how coupled information-providing systems can be applied and improved. In a holistic view of the value chain, they do not only have to consider the data and information technology solution elements, but also evaluate the process-related and organizational implications. In this context, the DMAIC methodology, the core process of Six Sigma, is intended to meaningfully complement the product life cycle-based data flow architecture. The planned tasks are divided into three main areas:

1. **Status quo analysis:** In the development and production environment, the orchestration of processes, organizations, IT systems and models will be determined and evaluated based on the results of the data flow. For this purpose, both existing and future performance requirements are taken into account.

2. **Performance evaluation system:** The user-critical functions of central IT systems in the development environment are presented. The goal is to provide a prototype that ensures that the development environment continuously meets expectations.

3. **Sustainability analysis:** Trends in the context of the actors in the development environment will be systematically identified and tested in future scenarios to identify necessary key factors.

These scientific insights enable engineers to work more efficiently. The complex product development process can thus be shortened, making it much easier to develop more climate-friendly launch vehicle models. With this in mind, future research projects should also address the use of climate-neutral energy sources within the entire product life cycle, according to Thomas Kruschke, research engineer at Fraunhofer IPK: »Only through climate-neutral solutions can space travel contribute in the future to achieving the Paris climate protection goals and act as a role model for other industrial sectors.« •

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

# ArianeGroup – Europe’s Threshold to Space

As the world market leader in space transportation, ArianeGroup not only serves institutional and commercial customers, but also guarantees Europe's strategic independence in space.

ArianeGroup is the prime contractor for Europe's Ariane launch vehicles for space travel. The company manages launch vehicles throughout their entire life cycle – from design and development through production to utilization and marketing by its subsidiary Arianespace. It also manufactures and operates Ariane 5, the most reliable commercial launch vehicle on the market, and is managing the development and design of the future Ariane 6.

ArianeGroup was founded by the Airbus and Safran groups in an effort to lead European space industry to new heights. It is owned equally by the two groups and combines all their activities and competencies in the field of civil and military launch vehicles. ArianeGroup consists of eleven subsidiaries and majority holdings, with more than 7,000 highly qualified employees in Germany and France. While it was only founded in 2016, its origins date back 70 years in the history of European spaceflight.

The company’s broad European positioning places an emphasis on simplifying and streamlining engineering processes using the results of many years of research and state-of-the-art development tools and processes, such as the digital modeling tool for simultaneous engineering. This is complemented by new, more efficient, value-adding organizational concepts and operating principles. This is why the company is also focusing on manufacturing technologies and digitization: using virtual reality to increase the efficiency of production facilities, accelerating development and subsequent manufacturing through the use of 3D printing, and digitizing all areas and data throughout the entire life cycle. Read the previous article on our joint »POLAR« project to find out more about the key role of digitization in contributing to the sustainable development of the space industry. ◆

CONTACT
**ArianeGroup**
www.ariane.group/en

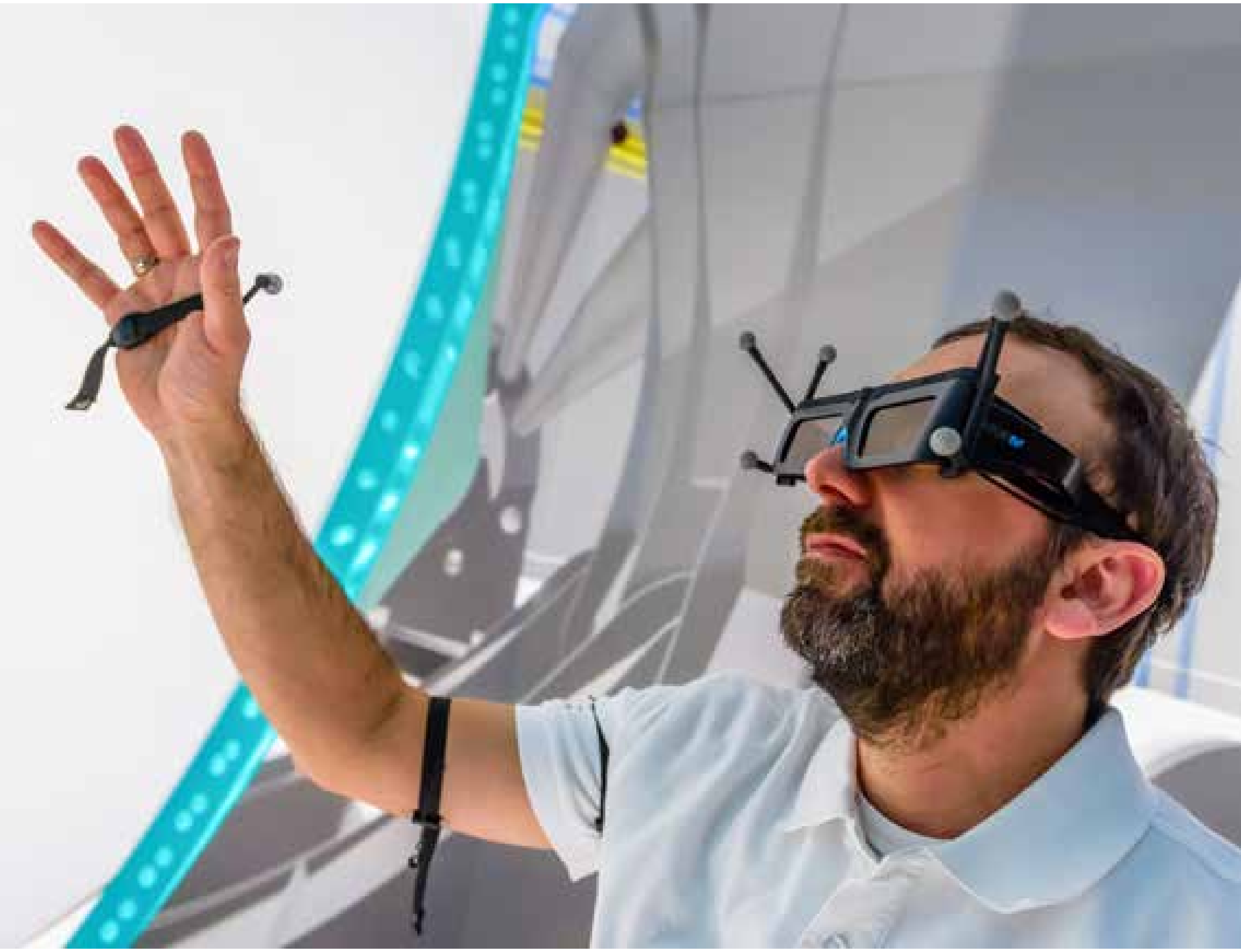


**Image:**
At ArianeGroup the latest development methods are used.
© *ArianeGroup Holding / Master Image*


© Pixel B / Shutterstock



# On the Dry

**The use of cooling lubricants is the standard in metalworking. A team at IWF TU Berlin is looking for more environmentally friendly alternatives.**

Cutting fluids are widely used in industrial metalworking, and with good reason. Through their cooling, lubricating and flushing effects, they fulfill three important functions at once for efficient and economical machining processes. Their use reduces tool wear, improves surface finish and minimizes thermally induced defects. But there is a catch: The lubricants, often mineral oil-based liquids or oil-water emulsions, have an extremely poor eco balance.

The negative ecological impacts extend over the entire life cycle of a cutting fluid, starting with the extraction and production of the necessary components such as fossil mineral oils and synthetic chemicals. These are prepared for the manufacturing process using pumps, as well as heating and cooling units. Once the cutting fluid has served its purpose, it is usually burned, releasing pollutants such as nitrogen oxides, sulfur dioxide, hydrogen fluoride, and hydrogen chloride.

**LESS IS MORE**

Minimizing or even eliminating the use of cutting fluids can therefore make manufacturing processes much more sustainable. In times of increasing environmental awareness among consumers, forward-looking and responsible companies have recognized this as a competitive advantage. In recent years, there has been a trend toward dry machining processes and intermediate steps such as the use of minimum quantity lubrication, or MQL for short. The latter is already being used successfully in widespread processes such as milling and turning. MQL consumes only a few milliliters of oil per hour for the same process compared to the hundreds or even thousands of liters of cutting fluid per minute that would otherwise be used.

Minimizing the use of cutting fluids can make manufacturing processes much more sustainable.

**Images:**
**1**
Honing tool
**2 and 3**
Comparison of honing stone surfaces after honing in one pass;
2: Without superimposed low-frequency vibrations, the circles show clogged work-workpiece material.
3: With superimposed low-frequency vibrations, the circles show hardly any clogged workpiece material.

1

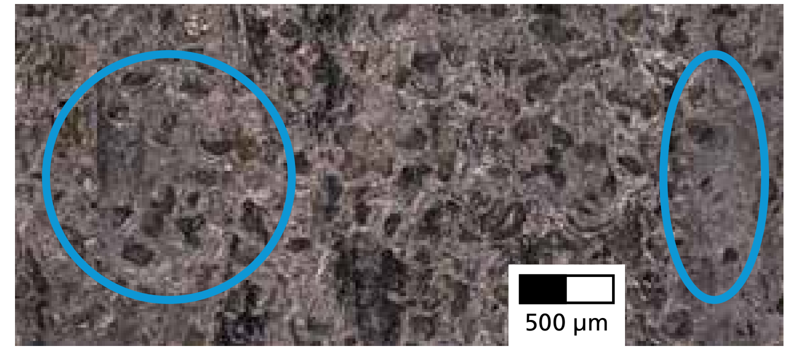
However, processes such as conventional honing do not appear to be suitable for dry or MQL-guided machining due to the process characteristics. These key process features are the use of a multi-bladed, bore-filling tool with a two-dimensional separation of material over a large contact area between the honing stones and the workpiece. In particular, flushing out the separated material requires a lot of cutting fluid in order to avoid clogging of the honing stones and subsequent increased tool wear or damage to the tool and workpiece.

In processes such as honing, where the use of cutting fluids appears to be indispensable, new ecological, mostly vegetable-based cutting fluids are therefore increasingly being utilized. These have both a much smaller ecological footprint during production and disposal, and a longer service life than conventional agents. At first glance, this would seem to exhaust all possibilities for reducing greenhouse gas emissions in processes such as honing. However, if one considers the complete life cycle already mentioned, hidden potentials can be found. In particular, the energy required for conditioning the cutting fluid, especially heating and cooling, is an often underestimated source of greenhouse gas emissions. For example, an average honing process consumes 180 – 3,000 liters of cutting fluid per hour, which must be cooled with an average energy requirement of 30 kilowatts. In a cylinder liner manufacturing plant where honing processes are used on a large scale, for example, 33.54 tons of $CO_2$ equivalents are emitted as a result of the energy consumption for cooling the cutting fluids alone.

**RETHINKING HONING**

A scientific team at the Institute for Machine Tools and Factory Management of the Technical University of Berlin (IWF TU Berlin) has now devised a completely new approach to realize cutting fluid-free machining during mandrel honing. The researchers were able to



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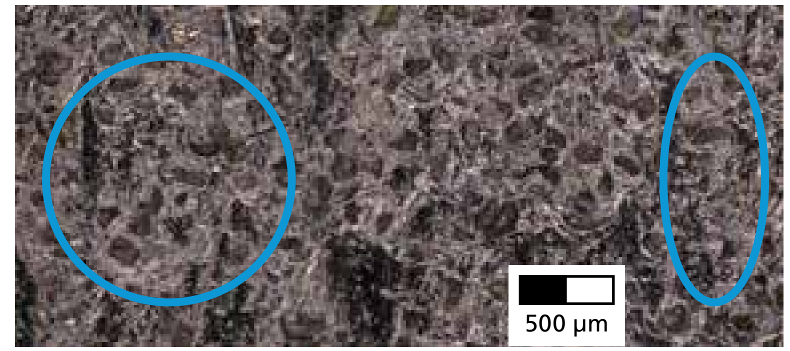


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show that by superimposing low-frequency vibrations, the clogging of the honing layer by separated material can be significantly reduced. As project manager André Rozek explains, this lowers the process forces and torques by a lot: »This effect is due to a specific variation in the force vectors acting on the grains used during honing. We assume that this principle can also be transferred to other common honing processes.«

The new process variant helps to solve ecological problems, but it also brings new challenges. Although the honing layer is no longer clogged by separated material, the dust-grain-sized chips are no longer bound in the cutting fluid, which flushes them out of the machining area. A new project with two different approaches is therefore planned at IWF TU Berlin to develop new tools for dry honing. The first concept is to develop a honing tool for use with MQL that has internal feed channels similar to a conventional tool, but in which the usage of cutting fluids is significantly reduced. The second approach employs magnets between the honing bars to collect the separated material during the dry honing process. In addition to these design measures, a viable extension is being implemented to control the low-frequency vibrations. By developing these new tools, the researchers hope to help save even the last latent greenhouse gas emissions from honing in the future. ◆

The researchers hope to help save even the last latent greenhouse gas emissions from honing in the future.

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# All Aboard for Carbon Neutrality

**At Deutsche Bahn, we produce mobility. Particularly when it comes to $CO_2$-neutral production, a surprising number of parallels can be found with Fraunhofer IPK's production research.**

**A guest article by Dr.-Ing. Benjamin Graf, Senior Officer at the Executive Board of Deutsche Bahn AG in the area of quality assurance and excellence assessment**

Two topics that, at first glance, are completely different: producing mobility and producing material goods. But the same procedures for $CO_2$-neutral value creation and associated findings from research also apply to the production of mobility.

First of all resource usage has to be designed to be $CO_2$-neutral. Production research teaches us a precise understanding of the $CO_2$ expenditure associated with the use of materials. This is equally true for the use of resources when mobility is your product, as is the case for Deutsche Bahn. The most important resource here is energy. Deutsche Bahn is using more and more green electricity for this purpose. Long-distance trains are already running on 100 percent green electricity. By 2025, all stationary facilities, i.e., train stations, maintenance plants and office buildings, will be converted. And, as with the use of materials for the production of tangible goods, it is crucial to always keep sufficient resources on hand, even for increasing demand. To meet the greater demand for green power, DB recently signed its first transnational green power contract. Starting in 2023, hydroelectric power from Norway will help the company achieve annual $CO_2$ savings of 146,000 metric tons. Green electricity from Germany will also be sourced from hydropower plants. The Saalach power plant in Bad Reichenhall is operated by DB Energie itself. Increasing energy efficiency is also a key factor in both production targets. To this end, modern trains use systems that recover braking energy and feed it back into the overhead line.

A challenge for $CO_2$-neutral value creation: Increasing demand requires scaling during ongoing production. Quality management has an important contribution to make here.

Delays occur in particular at points where the existing infrastructure is heavily utilized or the usual capacities on the line are restricted by necessary construction work. In the area of quality auditing at Deutsche Bahn, we assess the resulting risks to operations in preventive audits. We then derive measures to minimize the risks. These include, for example, strengthening the fallback levels and the robustness of the infrastructure on diversion routes. We are working closely together within the Integrated Rail System to implement the measures. The aim is to provide mobility for our customers in the highest possible quality while scaling our production system to meet the high demand for $CO_2$-neutral mobility.

**Dr.-Ing. Benjamin Graf**

... has been working for the Corporate Management of Deutsche Bahn AG in the area of quality testing and excellence assessment since 2020. He deals with construction sites, punctuality and the optimization of operational processes. At Fraunhofer IPK, Graf earned his doctorate in the subject of laser metal deposition and headed the Joining and Coating Technology department. »I have been benefiting greatly from the experience gained from production-oriented research at Fraunhofer IPK in my current work on the production of mobility. It is always important to focus on customer benefits and adapt the technical solutions accordingly.«

# Machines Meet Manual Sorting

**An AI-based assistance system can make the identification of old parts more robust and profitable. This leads to more parts being repaired instead of new parts having to be produced. Using starters as a real-world calculation example from the automotive industry, let us show you the amount of emissions that can be saved as a result.**

Using the automatic identification technology developed in the »EIBA« project, only one percent of used starters are rejected by mistake, compared to around six percent when they are sorted manually. This means that five percent more parts can be remanufactured. Compared with new production, the emissions saved per remanufactured component amount to 8.8 kg $CO_2$e. In our example calculation with 63,000 sorted parts per year, we thus arrive at a total of 27,558 kg $CO_2$e. After subtracting the emissions generated during training and operation of the AI, this results in

**net savings of 27.5 tons of $CO_2$e per year through the use of the AI solution.**

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Traditional manual sorting process

sorted

Incorrectly sorted parts approx. 6 % (3,765)

Training of the AI 130.18 kWh

Total energy or $CO_2$e consumption of the AI solution

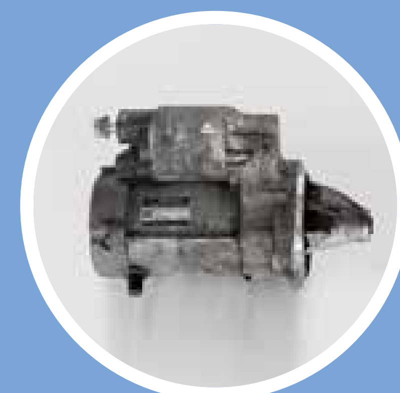
196,11 kWh ≙ 111,39 kg $CO_2$e

Business data evaluation 0.13 kWh

Operation of the workstation 65.2 kWh

Automatic identification with the AI solution

sorted



63,000 starters / year sorted

Incorrectly sorted parts approx. 1 % (634)

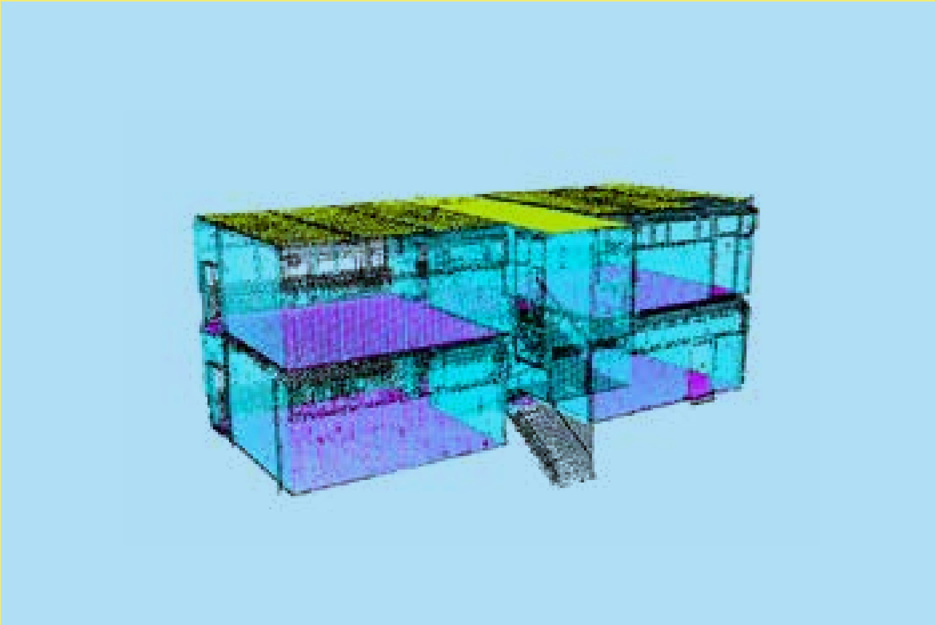
**ANNOTATIONS:**

**$CO_2$e**
$CO_2$ equivalents: unit that makes the climate impact of different greenhouse gases comparable

**Energy mix**
The conversion of energy consumption into $CO_2$ consumption was based on the average German grid mix: 0.568 kg $CO_2$e / kWh electricity

**More Information**
www.ipk.fraunhofer.de/automaticidentificationofoldparts

The EIBA project is funded by the German Federal Ministry of Education and Research under the funding program »ReziProK« with the funding code 033R226.



**Existing buildings are responsible for one third of all carbon emissions in Germany. In order to renovate them efficiently on the basis of 3D models, the Scangineering process is being adapted.**

# Innovate to Renovate

The odds have never been more favorable for energy refurbishments of existing buildings: Since February 2022, the application process for funds from the Federal Support for Efficient Buildings (BEG) has once again been opened. There is a reason why the new federal government implemented this so soon after taking office: The refurbishment of existing buildings is possibly the area with the greatest potential for $CO_2$ savings, as almost a third of all German greenhouse gas emissions are attributable to this sector.

**EASIER SAID THAN DONE**

Today, new virtual technologies such as Building Information Modeling (BIM) support architects and civil engineers from the outset. Buildings are planned and constructed virtually in the form of digital 3D models. During and after the construction phase, real data can be used to validate the building's condition and check it against the planning data. In 2017, dena (German Energy Agency), a think tank of the Federal Republic of Germany and the KfW banking group, already noted that thanks to BIM, »renovation costs could be cut almost in half« in a pilot project.

However, BIM modeling today faces a major challenge: It must be possible to represent existing buildings virtually in order to benefit from the advantages mentioned above. In Germany, the majority of these structures was built over 40 years ago and was thus designed and documented entirely on paper. Digital data on such buildings is, therefore, rare.

The transfer of analog data into virtual formats usually has to be carried out manually by skilled personnel. But the construction industry is also affected by the general shortage of skilled workers. The Federation of German Industries (BDI) therefore concludes in its guidance on the Climate Paths 2.0 study: »Capacity shortages among skilled craftsmen, architects […] are standing in the way of the urgently needed wave of renovations.«

Meanwhile, measures are imperative in order to still be able to meet the European energy and climate targets in the construction sector: »The number of energy-related renovation of buildings must double,« according to BDI. Achieving such a quota while facing a shortage of skilled workers will only be possible if professionals are supported in modeling the building stock with the help of automated software technologies. Researchers at Fraunhofer IPK have therefore teamed up with the start-up pointreef to further develop their technology for automated processing and feedback of point clouds to CAD models into a marketable product for the construction sector.

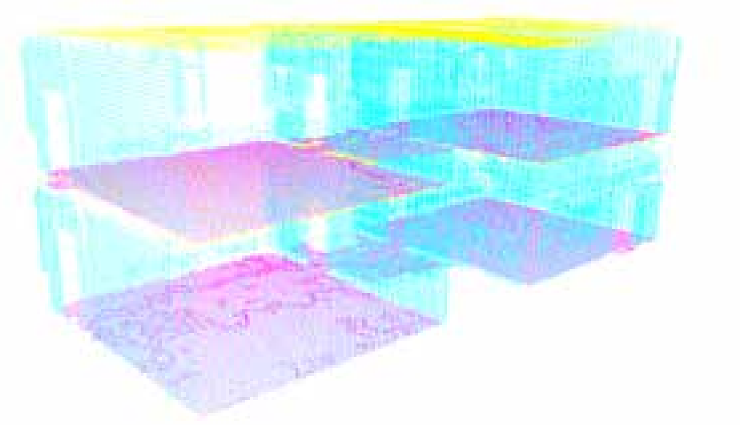
**FROM SCANGINEERING TO ARGOS**

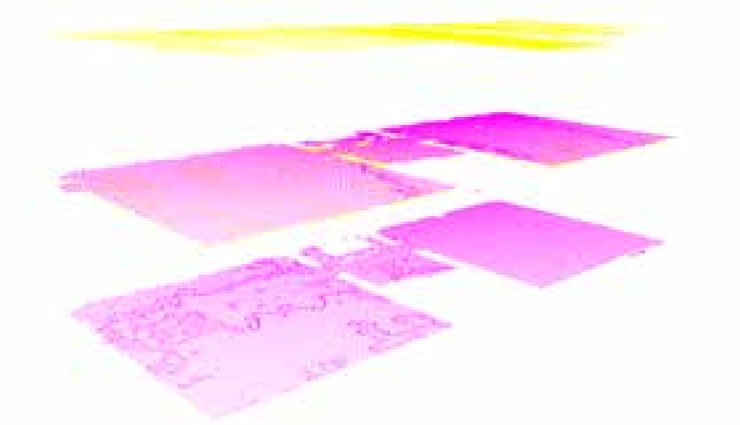
The collaborative project »ARGOS – Automated Feedback of Building Models from Optical Scan Data« is funded by Fraunhofer's internal funding program AHEAD and is based on a software prototype called Scangineering.

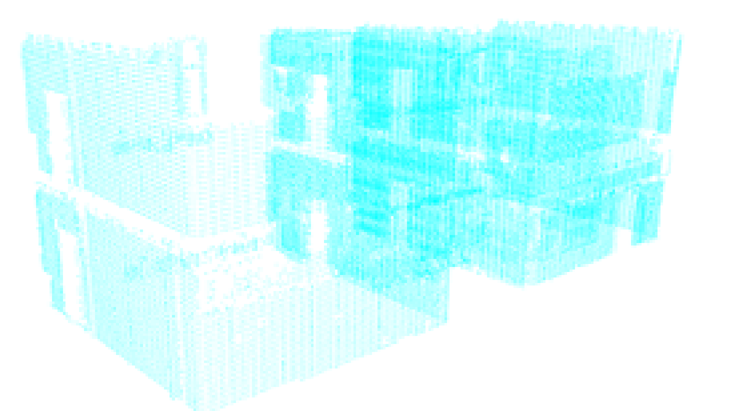
The latter was originally developed to reposition given CAD models from an assembly group (»as-designed« state) using the underlying 3D scan data (»as-built« state). The original use case was the internal structural elements of an aircraft, where parts such as furniture (seats, floor) and other components attached to the aircraft structure were disassembled. The real components were thus placed differently (»as built«) than originally planned virtually (»as designed«). This changed position had to be reflected back into the digital models. The scan data was available as a tesselated point cloud. They were of comparatively poor quality, i.e. the point density was coarse and details smaller than 10 mm were not mapped. Noise artifacts distorted the true representation of the geometry. To achieve this repositioning, the researchers used a software architecture that masters the most advanced tools in the reverse engineering process chain.

The Scangineering software's programming is based on open-source code. The Scangineering framework can be integrated into existing software environments using optional interfaces to external software API's. Depending on the technical use case, the software can be either open-source based or implemented in proprietary software in a suitable programming language. For use in the building sector, for example, interfaces to the proprietary software products Revit and ArchiCAD, which are widely used in architecture, are required to provide the desired front end for the end user.

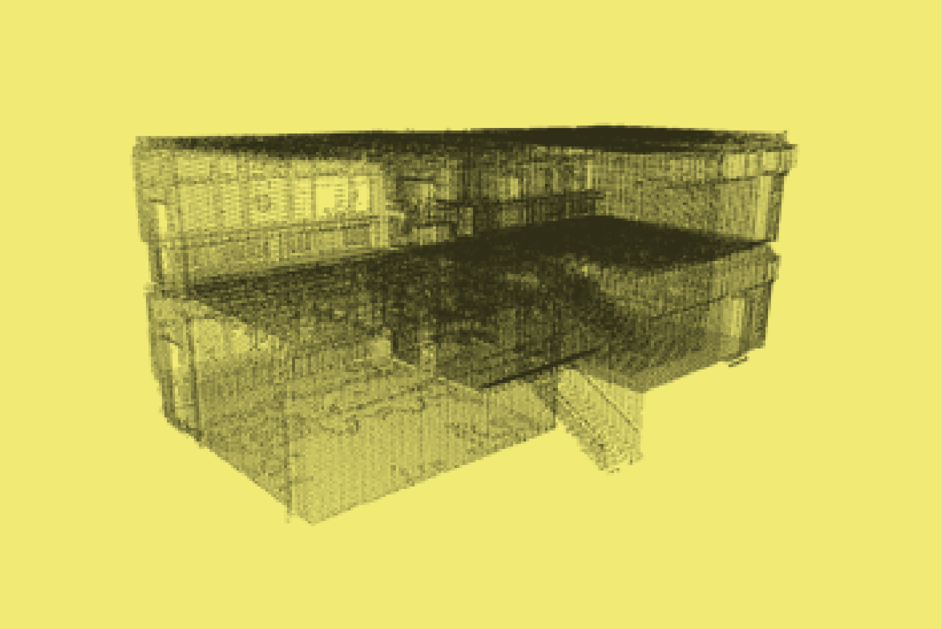
The development GUI of the prototype shows what the Scangineering of buildings looks like in the application. The simple, functional user interface enables the inter-







**Images:**
Screenshots from the software make it easy to see what the 3D building scans will look like later, and how they can be broken down into their individual parts and classified. From top to bottom can be seen: the complete data set, the classification of floors (purple) and ceilings (yellow), and walls (turquoise).



active control of all required development and test functionalities. Operations for data manipulation are called up via the buttons in the upper area, after which further windows open for process control and parameter input. The structure tree displays all existing entities. The central visualizer displays 3D data graphically. Further windows for text output are used to display process information and metadata.

**FROM THEORY TO PRACTICE**

The unique, hybrid approach of the project combines geometry property-based algorithms established in mechanical engineering and novel artificial intelligence (AI) algorithms. In keeping with the Fraunhofer founding spirit, the inventors of Scangineering now intend to spin off with the ARGOS project. »The approach promises enormous efficiency gains for our future customers. A big advantage here is that our partner pointreef is an established start-up and, as such, already active in the market, with an existing customer base we can draw from. In addition, we have broad backing from Fraunhofer IPK, which is actively supporting us and our spin-off plans,« says Stephan Mönchinger, who heads the project at Fraunhofer IPK.

Incidentally, those interested in mythology may already have noticed that the researchers included an allusion in the naming of the project: Argos, in Greek mythology, is a hundred-eyed giant who could look in all directions at once at any given time. Now THAT is a fitting name. ◆

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The Scangineering hardware was co-financed by the European Regional Development Fund (ERDF).

EUROPEAN UNION
European Regional Development Fund

# Material Matters

Sustainability is as important as efficiency in welding today. Both can be increased through material selection, lightweight construction methods and, not least, Industry 4.0 processes.

Whether medical technology, automotive industry, or shipbuilding, no industry can do without welding. Meanwhile, many metallic components are manufactured additively – which is also a welding manufacturing process. In addition to maximizing efficiency, efforts have also been focusing on environmental protection. Resource-saving production, sustainable carbon footprints and recyclable long-term solutions are demanded from all directions – including from the manufacturing companies themselves. Fortunately, welding technology in particular offers many opportunities to optimize processes toward greater climate neutrality. Initiatives that use state-of-the-art high-strength steels by means of lightweight construction methods and transform manufacturing processes with digital approaches to simulation not only save resources, but also costs.

**THE MATERIAL MAKES THE DIFFERENCE**

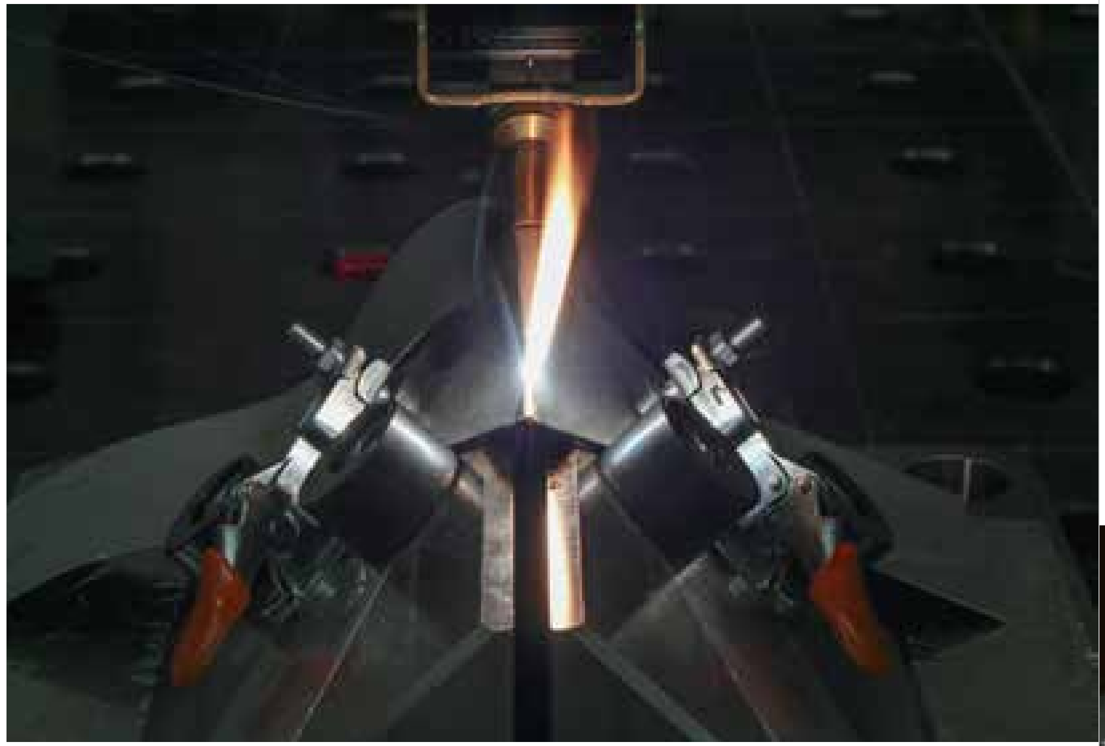
For example, in the automotive industry there are a variety of ways to make welding processes more profitable and sustainable. For the latter in particular, electromobility is considered a key factor, as electric vehicles cause comparatively fewer carbon emissions along their product life cycle. Despite strong subsidies from German policymakers, only 0.6 percent of all registered passenger cars are electric. Above all, the high purchase costs prevent people from switching from passenger cars to electric vehicles. The development of a novel concept for the production of battery housings made entirely of steel is intended to contribute to the realization of a more economical and climate-friendly alternative to the conventional aluminum housing.

The demands on battery housings are high: They must be able to withstand corrosion and also guarantee high crash safety and leak tightness. Battery housings made of galvanized multiphase steel meet these requirements and offer the opportunity to reduce production costs, optimize performance and improve the carbon footprint. To take full advantage of the exceptional material properties of these steels, it is necessary to select suitable joining processes.

Researchers at Fraunhofer IPK are working on making the processes for linear joining of steel battery housings as sustainable as possible. In addition to laser beam welding, laser beam brazing is also being considered as a potential joining process. Laser beam brazing, in which the brazing alloy serves as the joining agent, meets the requirement for high gas-tightness in particular. In addition to the advantages in terms of process technology, the two laser beam joining processes also show high potential with regard to the requirements for a climate-friendly production process. Little research has been done to date into the effects of welding processes on the environment. This makes it difficult for manufacturing companies to take environmental protection considerations into account in the process of creating a product. To evaluate the process, a so-called life cycle analysis is applied to the manufacturing processes.

A life cycle analysis provides important conclusions about the environmental impact of a product or process. Useful indications for a variety of decision-making processes can be determined this way. The core element of any life cycle assessment is the life cycle inventory. It records all relevant inputs and outputs relating to the »welding process« system. The environmental impact of the process is derived from the accumulated values using categories such as $CO_2$ equivalent, acidification potential or photo-oxidants.

In practice, it gets interesting and particularly relevant when comparing different welding processes with regard to their environmental impact. It turns out that two input factors often have a particularly large influence on the life cycle assessment of a process: the need for filler material and energy. Thanks to this insight, the researchers were able to limit the influencing variables to be recorded to these two factors. In practice, this reduces the effort for companies that want to carry out a life cycle assessment of their welding processes.



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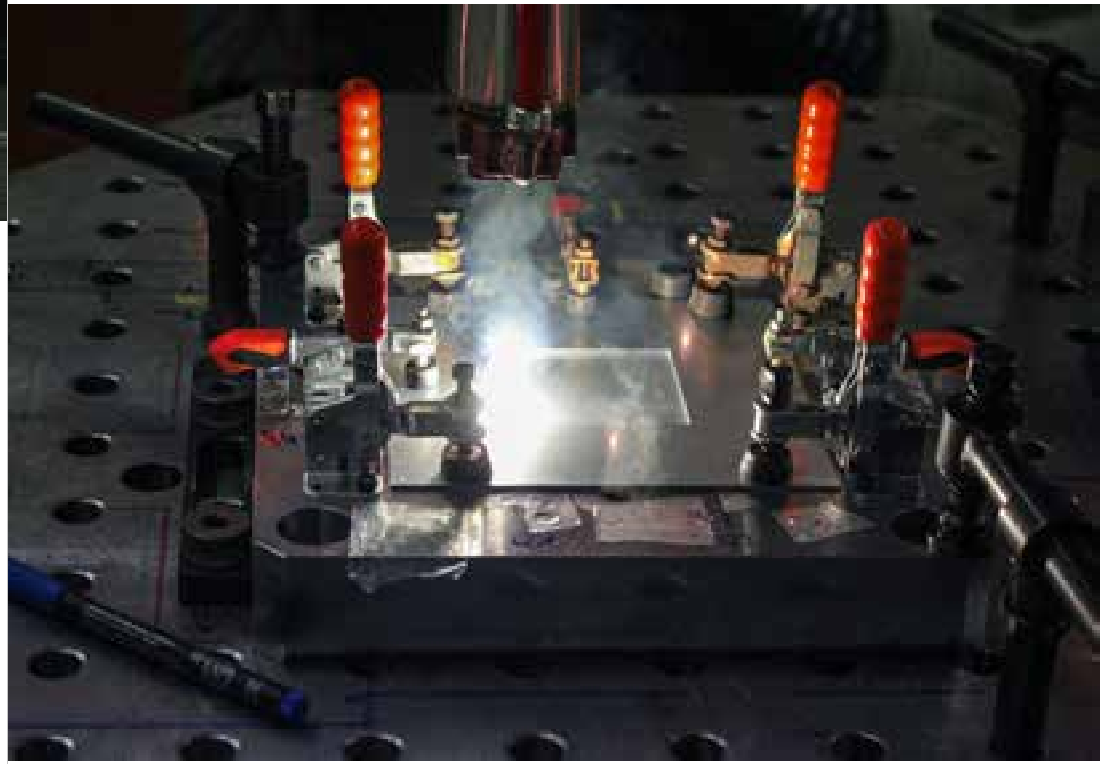

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**Images: 1 and 2**
Laser beam brazing (left) and laser beam welding (right) of automotive sheet metal, more precisely: a battery box

In a direct comparison, steel and aluminum casings lead to similar carbon emissions when in use. However, up to two thirds of greenhouse gas emissions can be saved in the production of steel battery housings. In addition, steel-based battery housings can be recycled virtually endlessly.

## Steel-based battery housings can be recycled virtually endlessly.

### STEEL GOES DIGITAL

Additionally, the carbon footprint can be actively reduced using lightweight construction approaches. The automotive industry is increasingly looking to high-strength and ultrahigh-strength dual- and complex-phase steels for this. These steels can provide the same crash safety as conventional steel designs, while at the same time requiring less material to be used.

One example of such construction methods are so-called Tailor Welded Blanks (TWB): semi-finished products in which steels of different tensile strengths are welded together. They thus provide different strength zones in a component. This means that high-quality material only has to be used at the crash-relevant point, such as the B-pillar. At two million vehicles produced per year, installing TWB can save around 32,000 tons of $CO_2$ in the course of production. The reduced weight leads to additional savings. Overall, a savings potential of 85,000 tons of $CO_2$ per year can be assumed.

The TWB's individual sheets are joined by laser beam welding and then given their final shape by deep-drawing. This is currently still a challenge for high strength classes (> 1,000 MPa). The areas in and around the weld seam are particularly susceptible to cracking. Changes in hardness occur due to the high heat input during welding.

After all, Industry 4.0 has long since arrived in the welding sector. Welding power sources are digitized and computers and microprocessors are integrated into modern equipment that can communicate with other devices. This provides the basis for »smart production«. The intelligent periphery of welding equipment makes it possible to continuously improve and optimize applications and processes.

The application of weld structure simulation extends the scope for optimized product development processes. Various result parameters can be read as output: distortion, residual stresses, temperature curves and phase transformations.

Digital methods not only help companies to save resources, but also to reduce the carbon footprint of the entire process chain. With the help of simulation findings, life cycle assessments and detailed process understanding, they can map and analyze entire process chains as digital twins. In this way, time-consuming prototype construction is reduced to a minimum and product creation is digitally optimized even before the first welding. ◆

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# The Earlier, the Better

**Digital twins can help track and reduce the carbon footprint of products along their life cycle. The data shows: The biggest leverage can be achieved at the very start.**

When all you have is a hammer, everything looks like a nail. In other words, when assessing and solving problems, it always depends on one's own perspective – and when working in science, that is something that must be taken into account. So when researchers in production science consider how to influence the sustainability of a product, they have to look beyond the natural scope of the mere production. This is exactly what scientists at Fraunhofer IPK do by observing sustainability indicators such as the carbon footprint over the entire life cycle of a product.

**CONSIDERING THE ENTIRE LIFE CYCLE**

From raw material procurement to disposal, reuse, remanufacturing or recycling – data about emissions are recorded and evaluated everywhere. These data can be used to determine the points in the product life cycle where it is possible to influence a product's carbon footprint. It shows that particularly important decisions are made long before production. The climate friendliness and also the circular economy capability of a product – and everything that belongs to its ecosystem – are determined by, for example:

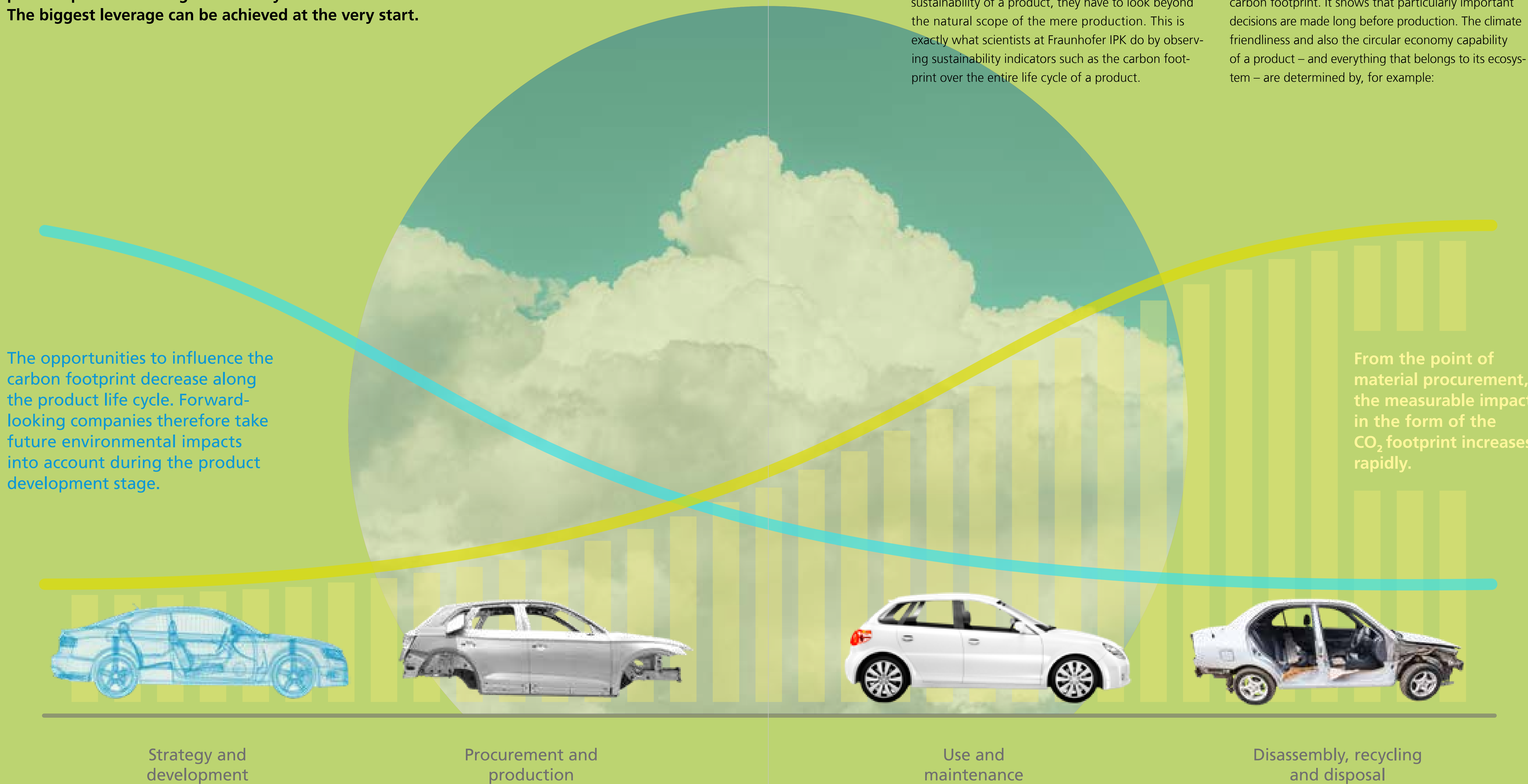


**Image:** With the help of data from the entire life cycle, developers can test products in terms of their $CO_2$ balance sheet.

**1. the optimal design of the product itself.**
This includes

- product design that aims for a low carbon footprint in the use phase (for example, through efficient engine types),
- the choice of materials that ensure a low carbon footprint in material procurement and required transport routes, production processes, recycling and disposal, as well as a long service life, and
- optimizing the geometry and joining methods of the product to facilitate repairs, disassembly and reuse, thus enabling circular economy strategies.

**2. planning the manufacture of the product in terms of resource-efficient production strategies,** intralogistics technologies and manufacturing processes, as well as the machinery and equipment used – but also planning energy-efficient processes accompanying production, for example for lighting, heat, ventilation or exhaust air. In production itself, potential for improvement can be leveraged by regulating machines and systems to run at their optimum in an energy-efficient manner. Product developers use the information gathered during production and in the further life cycle to adapt subsequent product generations in the long term and optimize them in terms of their carbon footprint (feedback to design).

So how does one get from data about a product and its production to its carbon footprint? In this context, the method of life cycle assessment provides a standardized procedure for evaluating the sustainability of products on the basis of various impact categories, in accordance with ISO standard 14044. All material



and energy flows in the course of the product life cycle are recorded and standardized in indicators, for example in $CO_2$ equivalents. This creates an extensive body of data for each individual product that must be stored and evaluated in a meaningful way – and this is where the digital twin comes into play.

**DIGITAL TWINS FOR SUSTAINABILITY**

Digital twins provide product-specific insights, for example in the form of a carbon footprint, which can be used to understand how sustainable the respective product is. They support product developers in making decisions during product design and production planners in designing production processes. In the after-sales area or during system maintenance, they help with monitoring and point out possible optimization measures. At the end of the product life cycle, they provide product-specific information on its disassembly and reuse potential, thus contributing to reuse, remanufacturing or recycling. Digital twins can even make decisions themselves with the help of suitable data analytics – as autonomous digital twins, so to speak. Researchers at Fraunhofer IPK are harnessing the ecological potential of digital twins on the behalf of the manufacturing industry. To this end, they have developed a concrete concept, including system models, the necessary infrastructure, information logistics and development methodology: The »Digital Twin for Sustainability«.

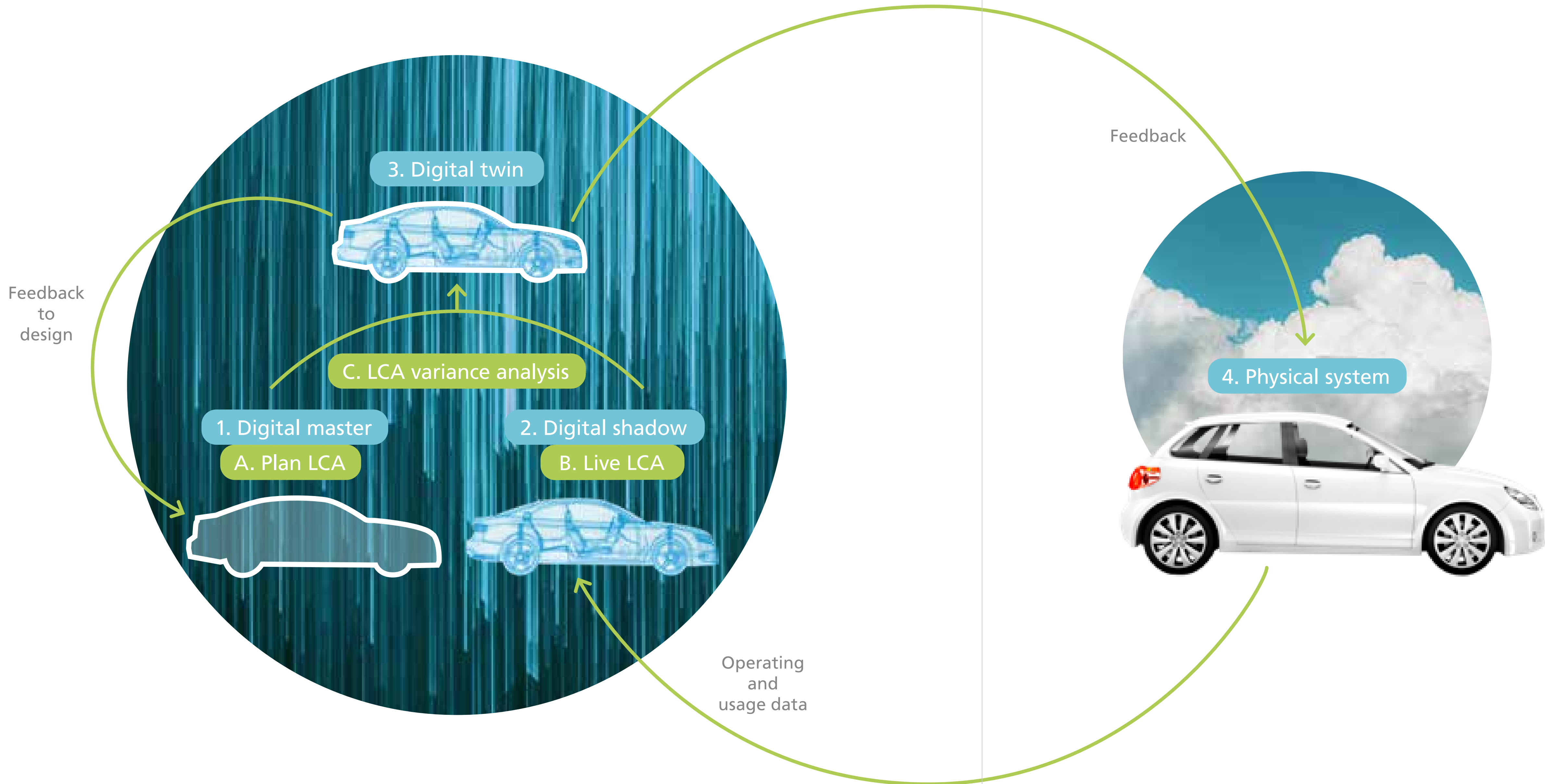
> Digital twins provide product-specific insights.

For this purpose, the central steps of data collection and evaluation of a life cycle assessment are performed several times over a product's lifetime. A distinction is made between the three central steps: the early LCA during the planning phase, the so-called »plan LCA« (A), the regular update based on operational data, also known as »live LCA« (B), as well as the comparison of these two as the core function of the digital twin (C).

**DEFINITION**

A digital twin is a digital representation of an active unique product – real device, object, machine, service or intangible asset – or product-service system, i.e. a system consisting of a product and an associated service. The digital twin encompasses its selected characteristics, properties, conditions, and behaviors by means of models, information …

… and data within a single life cycle phase or even across multiple ones. In this context, planning data (digital master) are linked with operational data or usage data (digital shadow) and, based on this, data analytics are implemented, digital services are offered, or optimization of specific indicators is realized, depending on the use case.




These are shown in *our illustration* in the context of the components of the digital twin.

**A.** As early as in the development phase, an initial life cycle assessment based on assumptions and plan data (»plan LCA«) is performed for different variants of product design and corresponding process alternatives. These LCA results are stored in a so-called **digital master** (1), which can be the same for several product instances.

**B.** As soon as the manufacturing phase begins, the product generates an individual carbon footprint, which is now recorded over all phases of the product life as a **digital shadow** (2). Data is also collected from suppliers for all procured parts to determine the most accurate carbon footprint possible. The carbon footprint is constantly recalculated during production based on energy and resource consumption data as well as emissions. For this reason, this digital shadow can also be referred to as a status quo life cycle assessment or, in the case of very real-time data, as a »live LCA«. A unique identification number of the digital twin is used to link these data together and make them traceable over the life cycle. Depending on the use case, the carbon footprint is updated at certain fixed points in time or continuously and calculated and stored for each individual product instance – or even for an entire product group or fleet.

**C.** In order to not only calculate a realistic carbon footprint for verification purposes, but also to be able to effectively reduce said footprint, the digital master and shadow are intelligently linked in the core of the **digital twin** (3). Deviations to the plan are automatically detected and evaluations are performed to identify the most critical polluters and derive optimization measures. Control commands can also be derived from evaluations within the digital twin via a direct feedback loop to the **physical system** (4), for example to optimize product behavior with regard to carbon emissions.

The BMBF-funded »BioFusion 4.0« research project shows the implications of this method in concrete terms. A digital twin with integrated LCA is being implemented using the example of an automotive component – the valve housing – which is manufactured at the Mercedes-Benz plant in Berlin. The component's carbon footprint is recorded from the procurement to the production phase and stored in a digital twin. The entire process is being implemented by Fraunhofer IPK, together with its technology partners CONTACT Software and Green Delta.

If the component in question is then installed in a car, its carbon footprint can be considered a component of the vehicle's overall footprint. BMW, ZF Friedrichshafen, BASF, Henkel and LRP – Autorecycling Leipzig, among others, are investigating how digital twins can be designed at the vehicle level as part of the major »Catena-X« research project. Fraunhofer IPK researchers are involved in designing digital twins in order to implement circular economy principles such as reuse, recover, remanufacturing or recycling: The architecture, services and data models required for this are being researched and implemented in the automotive value chain. However, the focus here is explicitly on a – Gaia-X compliant – cross-company data exchange. ◆

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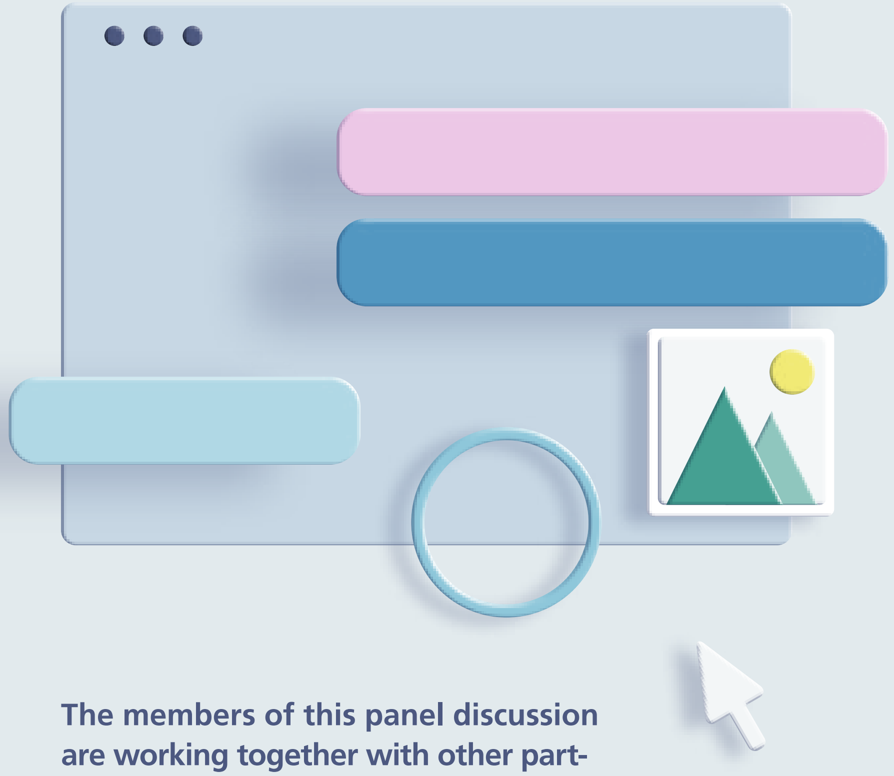
In a study published in 2022 by Fraunhofer IPK on the topic of digital twins, 63 % of the companies surveyed saw a very high potential for digital twins to be used for sustainability assessment in the future.

**More Information**
www.ipk.fraunhofer.de/readiness-en

# Industry Imitates Nature



**The members of this panel discussion are working together with other partners – including research institutions, corporations and start-ups – on the Biological Transformation of industrial manufacturing in the large-scale project »BioFusion 4.0«. Read their thoughts about how environmental impacts are operationalized and measured in the project and how people can be made aware of the issue .***

* Based on the panel discussion at the »BioFusion 4.0« kick-off event.



> »Biological principles are not sustainable per se.«

Theresa Riedelsheimer

**Theresa Riedelsheimer**

Deputy head of department

in the Virtual Product Creation division at Fraunhofer IPK

| futur | **Dr. Ciroth, how do you measure sustainability in production?**

**/ CIROTH /** In this project, we are using a method called life cycle assessment, or LCA. This is a reference method that is accepted worldwide for recording the environmental impact of products over their life cycle, i.e. from resource extraction and production through the use phase all the way to disposal or recycling. Data is collected everywhere to neutrally and objectively assess various environmental impacts of the individual phases. The »BioFusion 4.0« project is very interesting for us because biotransformation is a colorful bouquet of different methods and measures for the individual phases. The task at hand is to look at which of these are actually better for the environment, for example, by leading to fewer greenhouse gas emissions.

| futur | **You are raising the question of whether Biological Transformation is good for the environment per se. Ms. Riedelsheimer, at Fraunhofer IPK you and your team are researching the transfer from science to industry, what can you tell us about this very relevant question?**

**/ RIEDELSHEIMER /** There is a great deal of preliminary theoretical work and many research results in the area of sustainability assessment. But there are also numerous aspects that we cannot clarify on our own in terms of research. That is why a project like »BioFusion 4.0« is so important. We need the user side with problems and requirements that stem directly from industrial production to show how complex biological principles can be transferred in such a way that they really bear fruit. There are still many unanswered research questions here, including the environmental impact. Because, as Mr. Ciroth has already hinted at, biological principles are not sustainable per se. At Fraunhofer IPK, we are therefore researching how production engineering technologies can be combined with natural principles and with sustainability aspects. For example, we are looking at human-robot collaboration, 3D printing of biogenic polymers, but also digital solutions such as digital twins. Here in particular, the question arises: What exactly are the changes that come about as a result of Biological Transformation, when products and processes but also operating principles change? And what concrete potentials arise in their application? This is also something we cannot answer from research alone.

| futur | **Speaking of operating principles: Within the consortium, these are the expertise of 5thIndustry's Dr. Harms. What can we learn from biological principles in terms of organizational management?**

Dr. Robert Harms

Co-founder of 5thIndustry GmbH

»If you compare traditional organizational management to an orchestra with a conductor, today we have to think more in terms of free jazz.«

Dr. Robert Harms

**/ HARMS /** If you compare traditional organizational management to an orchestra with a conductor, today we have to think more in terms of free jazz. We build the stage on which the band can play. This system of high degrees of freedom resembles a »natural« ecological situation – which explains why biological principles such as emergence, self-organization and evolution are important for successful management today. What can IT and organizational infrastructures look like, and how do they fit together? Do you need this or that value creation process, this or that business model today? Companies need to be able to change and adapt quickly. You also need some structures that help you coordinate and work with other, sometimes unknown, players. Like with free jazz: How do I communicate that it's your turn to get involved? Bringing all this together organizationally and IT-wise is our field of research.

| futur | **The »BioFusion 4.0« project also seems to fit very well into the era of Fridays For Future and the like. Nevertheless, many people are still unfamiliar with the term »Biological Transformation«. How do you intend to publicize the concept?**

**/ RIEDELSHEIMER /** We emphasize that our work is based on the principle of harmony with nature. We all know that we are already very late in prioritizing nature, i.e. our planet, and protecting it. This line of argumentation is a way to get a lot of people to take interest in the topic. We're not starting from scratch; society is definitely open to the issue. Especially if we prove in practice that our solutions are not just innovative, but also sustainable.

| futur | **Climate protection has also reached the top of the political agenda, as witnessed by the fact that it is under the responsibility of the Ministry of Economics under the current German government. What role do economic and political considerations play for »BioFusion 4.0«?**

**/ RIEDELSHEIMER /** Of course, regulations and laws are an important factor. We can't solve all problems technologically; that's a task for society as a whole. Laws are important drivers here, the Supply Chain Act, for example. Of course, something like this promotes investment in socially responsible solutions and environmentally friendly technologies and companies.

**/ CIROTH /** The European Commission's Green Deal has made a huge difference in this area. Today, every renowned company invests in climate protection, regardless of economic considerations. In this respect, politics can really make a big difference.

| futur | **Let's look to the future. Where do you see yourself in three years? Because that is the planned duration of the research project.**

**/ CIROTH /** For us, one interesting outcome of the project is a classification and pattern detection in sustainability models. The difficulty in communication on Biological Transformation is that the possible measures are so varied and, at first glance, disorganized. By applying pattern recognition to LCA, we hope that we can then structure the different biotransformation principles. Working not with 75 individual examples, but rather with three or four on each of the basic principles – that would really be helpful in terms of communicating project outcomes.

**/ HARMS /** We are looking at a future where we can tell the whole story of Biological Transformation. Not just through the individual aspects of applications, people, organization and infrastructure, but in a wholistic overall context: how will the transformation work from today's machine age as we know it to the biological age? Of course it's nice to have recyclable packaging material. And of course it's nice to have lean IT infrastructure. But what does that mean in terms of eco-balance? If we can tell that as an inspiring story, we will have fulfilled our goal. ◆

**More Information**
www.ipk.fraunhofer.de/en/references/biofusion40.html

Sponsored by the Federal Ministry of Education and Research

Founder and CEO

of the engineering consulting and software company GreenDelta GmbH

Dr. Andreas Ciroth

# Additive, Creative, Alternative

**Processing biopolymers for industrial purposes is a demanding task. Fraunhofer IPK has the necessary equipment.**


1

2



**PROFILE**

**Usable installation space:**
max. 234 x 134 x 230 mm
–
**Component carrier:**
3-axis with positioning accuracy of +/- 0.022 mm
–
**Installation space temperature:**
max. 120 °C
–
**Discharge units:**
2 – 3
–
**Layer thickness:**
0.2 mm
–
**Absolute component accuracy (x- and y) according to VDI guideline 3405:**
+/- 0.1 mm

**Images:**
**1, 2**
The freeformer 300-3X brings the advantages of injection moulding to additive manufacturing.
© *ARBURG*
**3**
Biopolymers in different processing states.

In search for sustainable plastic alternatives to be used in industrial manufacturing, it is not only crucial how they are produced, but also how they are processed. Researchers in the »BioFusion 4.0« project want to find creative solutions for technical problems like these by using principles of natural systems. To this end, researchers at the Application Center for Microproduction Technology AMP are producing replacement or functional components from biogenic and degradable polymers by additive manufacturing. These are formed from waste materials with the help of bacteria, whereby the researchers make use of the natural property of microorganisms in deficient environments to form reserve deposits in the form of small plastic particles. Using additive manufacturing technologies, they can produce short-lived spare parts on-demand from this biodegradable plastic.

These parts are printed mechanically using the freeformer 300-3X 3D printer by the company Arburg, which has its roots in injection molding. Accordingly, the printing technique starts off similarly to injection molding with the melting of the granulate in a heated plasticizing cylinder with a screw. A high-frequency, rigid nozzle closure then discharges up to 330 drops per second. The smaller the droplets, the finer the surface structure, while larger diameters allow faster working progress. In the process, the droplets bond with the material already surrounding them, so that layer by layer, three-dimensional components of high mechanical durability can be created.

In processing their biopolymer, the Fraunhofer IPK team takes advantage of a special feature of the printer: the ability to print three materials simultaneously. This allows for industrial additive manufacturing of complex functional components in a resilient hard-soft compound with a support structure. In addition to their own material, the scientists can also access Arburg's material database.

Moreover, it is possible to automate additive manufacturing and integrate the freeformer 300-3X into IT-networked production lines. In the course of the »Biofusion 4.0« project, the researchers can thus

3

integrate microservices for print initiation to create a decentralized system. This means less planning effort and quick adaptation to changing conditions.

For example, if the need for a gripper is communicated from the workshop, the pressure triggering of a corresponding component made of bioplastic can be controlled in a decentralized manner. After its use phase, the gripper is compostable and can be disposed of without hesitation. This enables manufacturing companies to make their contribution to a sustainable, carbon-neutral production. ◆

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**Image:**
With outputs in the megawatt range, PGS1 is currently the most powerful hybrid-electric system in aviation and could power regional aircrafts in the future.
*© Rolls-Royce plc*

# Hybrid High-flyers

The future of mobility is (hybrid-)electric – and the aviation sector is no exception. The digital path now needs to be defined in order to fulfill new requirements.

Less air travel – this is often the slogan when it comes to acting in a climate-responsible manner. It is clear that the aviation sector must take accountability, as air travel currently contributes around two to three percent to all global $CO_2$ emissions. However, due to the lack of suitable alternatives and the great importance of the aviation industry for the global economy and mobility, abandoning air travel is not a real option. So what other ways are there to reduce $CO_2$ so that neither the industry will have to lose out nor private individuals have to restrict their mobility? For manufacturing companies in the aviation sector, the answer is simple: sustainable alternatives must be found, including electric or hybrid-electric drives. These concepts bring with them new requirements. For example, how can electrical energy be efficiently stored and distributed? And how can corresponding battery systems be integrated or lower noise operation be achieved by using a variety of electric drives?

**DIGITAL TWIN FOR THE DRIVE**

A research project at Fraunhofer IPK, together with industry partner Rolls-Royce


1

Deutschland, aims to set the course for the resource-efficient hybrid-electric flights of the future. To this end, the research team developed a cross life cycle information concept for aircraft development and production. This is intended to enable digital interconnection of all value creation steps in order to prepare for the efficient implementation of the new propulsion concept.

Based on the various processes of the product development phases, the researchers designed a process model, which also includes a digital twin. This captures all activities, the roles of the people involved, and the tools used in different models during the individual process phases in the development of an engine. Within these process phases (requirements management, functional flow modeling, design and development, safety, simulation, production planning, manufacturing and quality assurance), possible changes and enhancements are identified and can be implemented in the digital twin. In the future, the digital twin can also help predict, for example, whether a planned change in product properties is feasible.

**FROM PLAN TO ACTION**

But how do companies benefit specifically from the newly developed process model when converting to hybrid-electric drives? Heiko Witte, Business Development Consultant Digital at Rolls-Royce, explains that the development of digital twins has significantly deepened the understanding of system dependencies, especially at the interfaces of different functions. »The process model is fundamentally important here in order to identify interfaces and dependencies and to be able to set priorities in development and system description. With the help of a cyber-physical system based on various digital twins, we want to achieve a holistic understanding of the



system in order to be able to describe the entire life cycle of hybrid-electric engines and develop corresponding business models.« Witte and his team at Rolls-Royce Deutschland are currently implementing the newly gained insights in the development cycle for new types of hybrid-electric engines in order to achieve the development goal cost-effectively and, above all, through rapid iterations. Above all, the project is a milestone for a climate-neutral future of aviation, as it can provide real data on the feasibility of reducing greenhouse gas emissions in propulsion systems. For example, in the Tecnam P2010, the use of a hybrid-electric engine to power the aircraft has significantly reduced the size of the internal combustion engine: the standard 180-hp engine could be replaced by a smaller one of just 141 hp. This results in a potential reduction in fuel consumption of up to 20 percent, which significantly reduces $CO_2$ emissions. If the new requirement, as in this case, is to reduce the use of fossil fuels, is captured in the system, the effects on crucial process phases such as function and system modeling can be simulated and integrated accordingly in the digital twin.

Overall, electric drives will noticeably reduce emissions in air traffic, says Heiko Witte: »A quantum leap will be achieved here that cannot be achieved by increasing the efficiency of the gas turbine alone. Since 80 percent of all flights serve short- and medium-haul routes, emissions in these segments in particular will be decreased dramatically. Hybrid and battery electric engines are a game changer on these route profiles.« Companies that want to optimize their business model in terms of sustainable and emission-reduced management can benefit from the use of the process analysis tool to identify and implement potential changes in the product creation phases through digital twins. ◆

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**Images:**
**1**
In the future, the apus i-5 aircraft will be used as a flying test bed for fully electric and hybrid drive systems.
© *Rolls-Royce plc*
**2**
The Power Generation System PGS1 was tested thoroughly at the Bristol and Trondheim sites.
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# 18th Global Conference on Sustainable Manufacturing
October 5–7, 2022, Berlin

GCSM
18th Global Conference on Sustainable Manufacturing

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