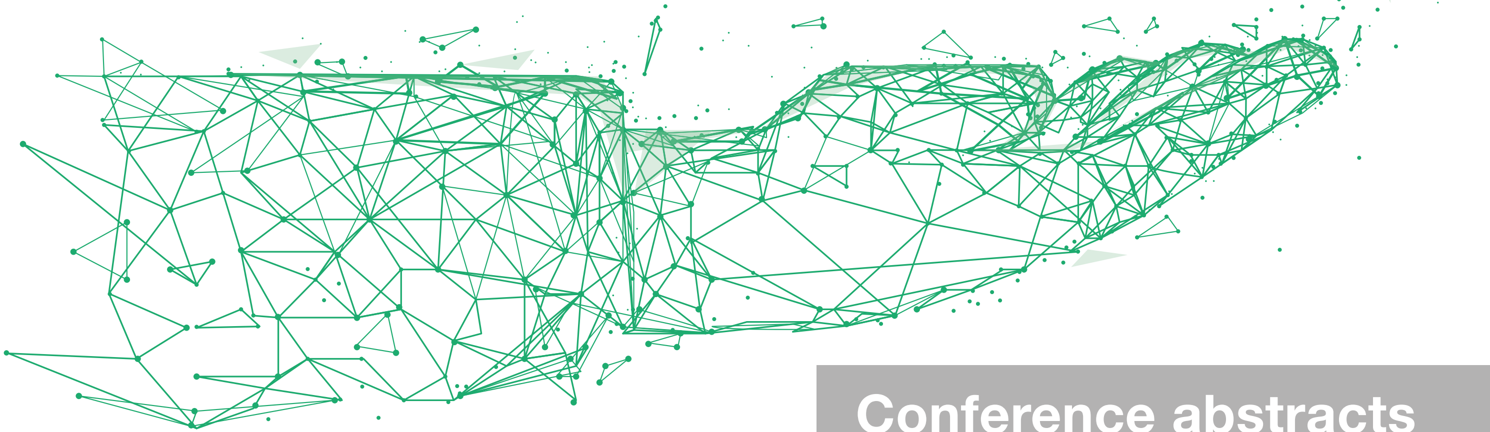
AWK'23

May 11-12, 2023

Empower Green Production



Conference abstracts

WZL | RWTH AACHEN UNIVERSITY

Fraunhofer IPT

AWK'23

May 11–12, 2023

Empower Green Production

Empower Green Production

Prof. Dr.-Ing. Thomas Bergs MBA, Prof. Dr.-Ing. Christian Brecher,
Prof. Dr.-Ing. Robert H. Schmitt, Prof. Dr.-Ing. Dipl. Wirt.-Ing. Günther Schuh

Not only higher energy efficiency, CO_2 savings and less scrap characterize sustainable production. If we want to "Empower Green Production", the paradigm shift is to extend the use cycle by transferring products or assets beyond their original life cycle into a multiple life cycle by adding a perceptible extension of functionality. Life-extending measures such as the timely replacement of existing components or assets with refurbished ones or those that can offer upgrades with completely new functions to end customers exemplify our understanding of a value-added circular economy. It differs from the generally intuitive understanding of "circular economy" in that not only are raw materials and energy recovered from used products, but used products and machines are specifically refurbished, industrially upgraded and used for a significantly longer period of time and potentially in a different context.

The digital shadow, along with specific technological and technical solutions, which were researched in the Aachen Cluster of Excellence "Internet of Production", creates the conditions for exploiting this – by far the greatest – sustainability potential of industrial production. In the future, new connectivity and data technologies will help companies save up to 50 percent of their industrially used resources and emissions, while at the same time enabling them to manufacture and offer complex series products up to 30 percent more cost-effectively than before. Household appliances, cars, machinery and plants can thus be systematically upgraded for a second, third or fourth life, without customers having to forego the added performance and appeal of new products created in parallel.

Ensuring the future viability of manufacturing companies against the backdrop of growing global challenges posed by climate change and the associated political and economic measures is the goal of the 31st AWK, the international Aachen Conference for Production Technology. The guiding theme of this year's AWK – "Empower Green Production" – represents the joint efforts of science and industry to achieve the urgently needed transformation towards green production.

In past editions of our conference series, we already used examples of successful research and industrial projects in the 2010s to show the opportunities offered by the comprehensive networking of machines and plants. Whereas AWK'21 dealt in detail with how the database obtained can serve as the basis for an "Internet of Sustainability", the next logical step for us is now to use these resources not only to increase productivity, as in the past, but above all for the transformation towards circular production. With this concept of a value-adding circular economy, for example, the (F-)ESG criteria could also be achieved many times better than with the classic, limited approach to the circular economy. The expansion of production boundaries beyond the factory gates and the inclusion of the information gained in the user cycle enables higher industrial value creation and at the same time increases the control options in the direction of increased resilience.

Using initial concrete examples from current industry and research projects, this year's AWK'23 would like to show which technologies and strategies will promote this transformation, how companies can select their individual tools for the change from the wealth of methods available, and with which challenges proximate production research can provide targeted support. The four central thematic blocks of the AWK include contributions on high-performance, storage-optimized and resilient data infrastructures, on technologies and processes for a properly functioning circular economy, on modeling and analyzes aimed at more resource-efficient manufacturing, and on scenarios and business models for sustainable value creation.

Under the guiding theme "Empower Green Production", we are taking up the complex challenge of the transformation to a value-adding circular economy, and have discussed our ideas and concepts with top-class teams of experts from industry and science at the 31st AWK. Together we want to set impulses and enable companies in the best tradition of the Aachen Machine Tool Colloquium to make their production equally more efficient and more sustainable.

Together we want to set impulses and enable companies in the best tradition of the Aachen Machine Tool Colloquium to make their production equally more efficient and more sustainable.

AWK'23 is a renowned network meeting and hybrid information hub at the same time. Accompanied by the international top-class lecture program and with thematic tours of the host research facilities – on site in Aachen as well as digitally – the conference offers a comprehensive insight into the trends of applied research and development for specialists and executives from industry and science.

These conference abstracts, which take up and reflects the contents of the event program, can serve as an incentive to initiate a conversation with us, with the expert teams and with the speakers, and to become an active protagonist of a value-enhancing circular economy yourself. We are pleased to make our research results available to a wide circle of interested parties and would like to thank all those who have contributed with great personal commitment to the discussion and the preparation of the presentations and the contributions in this book.

Hosts of AWK23

Prof. Dr.-Ing. Thomas Bergs MBA

Holder of the Chair of Manufacturing Technology,
WZL | RWTH Aachen University and
Head of Process Technology, Fraunhofer IPT

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WZL | RWTH Aachen University and
Head of Production Quality and Metrology, Fraunhofer IPT

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Holder of the Chair of Production Engineering,
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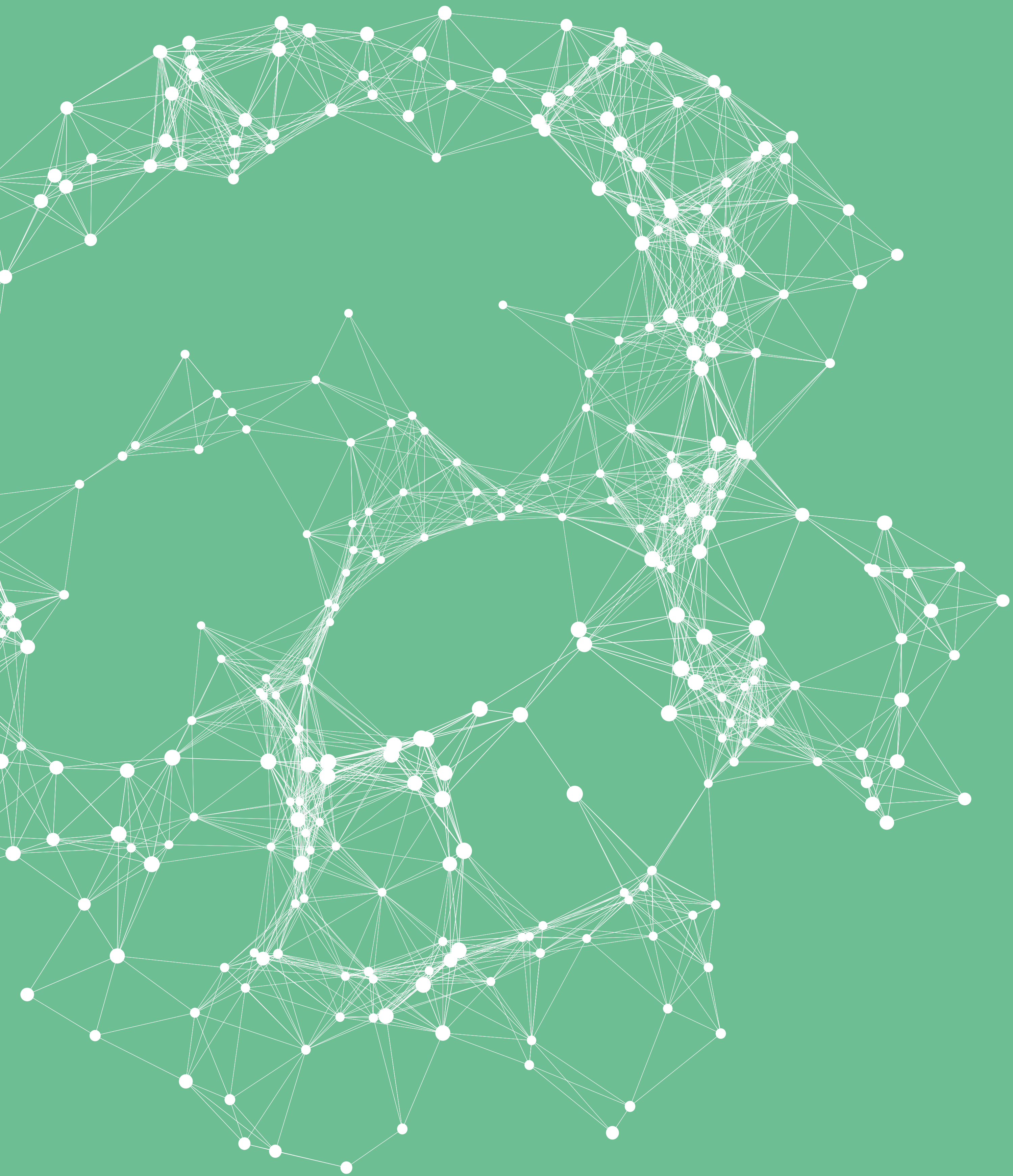
Head of Technology Management, Fraunhofer IPT

Table of Contents



Greeting

Production technology of the future – resilient, intelligent and sustainable

Lutz Eckstein
President of VDI Verein Deutscher Ingenieure e.V.

Current crises such as pandemics and wars, but also ongoing climate change, show us how necessary it is for companies and society to be able to adapt to changes in product availability and supply chains.

In the coming years there will be further disruptive changes. In Germany, we have to adapt to scarce and expensive energy, and to adapt our production systems in such a way that we work with the raw materials that we import as carefully as possible and in closed value-added cycles. Our goal must be a sustainable circular economy – as independent as possible from fossil fuels – which meets the global emissions- and climate-targets and is simultaneously resilient and adaptable.

In all sectors in Germany, it is important to implement processes that make production more sustainable. We have to decarbonize, recycle and reuse all materials, recycle waste immediately, and avoid waste over the entire production life cycle, as well as to generate, distribute and use energy intelligently. With the heading "Empower Green Production", it is clear that we are still in a global competition in which the best solution counts to make production truly green. The goal must be to think and act in a circular manner and to implement changes as quickly as possible.

According to the four "Rs" – Rethink, Reuse, Reduce, Recycle – it is important to consider the entire product life cycle. Since recycling usually only works as downcycling, reuse in combination with refurbishment should also play a major role in order to generate maximum effects.

According to the four "Rs" – Rethink, Reuse, Reduce, Recycle – it is important to consider the entire product life cycle.

Specifically, it is important to consider two footprints of a means of production: the manufacture of the machine; and the use and disposal of the machine. So here, too, a consideration of the entire life cycle – from cradle to grave – is required!

I am convinced that, based on your excellent research and systematic development, you will succeed in creating a resilient, intelligent and sustainable production technology which will help ensure the future of our manufacturing industry as a pillar of Europe.

Responsibility for social and economic climate protection

Sibylle Keupen
Lord Mayor of Aachen

Multiple crises such as natural events and the war of aggression on Ukraine are challenging companies in a way never seen before. Nevertheless, it is important to think ahead together and shape our future. The current challenges are also an opportunity.

The transformation to a more sustainable, energy- and resource-efficient industry and economy must succeed. We have a responsibility to make climate protection socially and economically sustainable for future generations. To do this, we need to develop even more momentum.

The transformation to a more sustainable, energy- and resource-efficient industry and economy must succeed.

The manufacturing industry is still highly dependent on global logistics chains, fossil energy, and rare raw materials. A circular economy that is less dependent on fossil fuels can help create greater resilience and security while helping to meet global emissions and climate targets.

How to overcome dependence on conventional energy suppliers is the topic of the 31st Aachen Machine Tool Colloquium (AWK). Internationally renowned experts from industry, politics and science will discuss new technologies and concepts for a more crisis-resistant and at the same time greener production in the future under the motto "Empower Green Production".

The colloquium is a unique flagship for our city of Aachen and highlights the interdisciplinarity and industrial relevance of this location. I wish all participants an interesting exchange about opportunities, experiences and ideas.

Sustainable innovative production technologies

Prof. Dr.-Ing. Reimund Neugebauer
President of Fraunhofer-Gesellschaft

Sustainable, innovative production technologies are essential for increasing productivity while maintaining climate targets, reducing dependence on fossil fuels, and, thus, securing Germany's long-term competitiveness as a technology location.

Digital transformation in particular provides numerous opportunities for sustainable and circular industrial production by networking people and machines in an intelligent system with real-time control. The successful implementation of a circular economy comprizes three elements: first, resource-efficient products, processes, and production systems; second, circular product lifecycles, i.e., circulation of products and resource-efficient (re)manufacturing; and, finally, the circular materials lifecycle with renewable raw materials. All of these measures must be supplemented and flanked by digitalization, AI, and robotics.

Digital transformation in particular provides numerous opportunities for sustainable and circular industrial production by networking people and machines in an intelligent system with real-time control.

Sustainable and circular production also plays an important role in gaining independence from volatile raw material markets and in saving costs by improving material use. Against this background, the circulation "Empower Green Production" focus of the Aachen Machine Tool Colloquium 2023 perfectly addresses the current times. Both a fundamental openness to technology and close cooperation between industry, science, and politics are essential for a successful transformation and for securing our international competitiveness. Let us set the course for a successful future together.

Top-level research up close – experience the virtual 3D campus

At the campus Digital Twins are not only used in research. In the 3D environment of the machine halls and laboratories of the WZL | RWTH Aachen University and Fraunhofer IPT, the nine thematic tours can be visited and experienced virtually. In this way, targeted information on the rich diversity of research and development topics of the two host institutes can be provided to complement the AWK. All with the focus on sustainable production.

Digital lab tours:

1. Data-driven sustainable manufacturing
2. Sustainable manufacturing through data-driven optimization of process chains
3. Sense - think - act: closed-loop data for closed-loop lifecycles
4. Production analytics in machine tools
5. Innovative gear analysis for a green production
6. Smart automation lab
7. Next generation propulsion systems
8. Digitization as an enabler for green production
9. Enablers for sustainable production systems

Plenary Talk 01

Manufacture #LikeABosch – producing technology invented for life

Dr. Stefan Hartung
Chairman, Board of Management, Robert Bosch GmbH

Year of birth
1966

Current position:
since 2022 Chairman of the Board of Management, Robert Bosch GmbH

Previous positions:
2019-2021 Chairman of the Mobility Solutions business sector, Robert Bosch GmbH
2013-2019 Member of the board of management, Robert Bosch GmbH
2009-2013 President, Power Tools division

Studies:
1993 PhD at RWTH Aachen University
until 1990 Studies of Mechanical engineering, specializing in production engineering at RWTH Aachen University

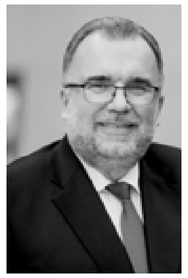
Advanced and high-volume production is at the heart of our economies turning ideas and digital designs into tangible goods for the masses. For us, this ranges from the creation of tiny structures in specialized semi-conductors, to fabricating power tools for millions of users and automotive products for millions of drivers, as well as to the provision of manufacturing technology and services themselves. With the implementation of advanced green technologies, sustainable, circular approaches, and resilience measures, modern production facilities offer great opportunities to achieve these goals for supply chains and economies at large. Thus, for us, high-quality manufacturing is a cornerstone in achieving the goal of our technology, which is invented for life, too.

With the implementation of advanced green technologies, sustainable, circular approaches, and resilience measures, modern production facilities offer great opportunities...

Plenary Talk 02

Circular economy as an industry strategy for sustainable value creation made in Europe

Prof. Dr.-Ing. Dr.-Ing. E. h. Siegfried Russwurm
President, Federation of German Industries BDI e.V.



Year of birth:
1963

Current positions:
since 2021 President, Federation of German Industries (BDI e.V.)
since 2019 Chairman of the Supervisory Board, thyssenkrupp AG
since 2019 Chairman of the Shareholders' Committee and the Supervisory Board, Voith GmbH & Co. KGaA

Previous positions:
2008-2017 Member of the Managing Board & Chief Technology Officer, Siemens AG
1992-2007 various management positions, Siemens AG

Studies:
1983-1988 Production Technologies
1988-1991 Computational Mechanics (PhD)

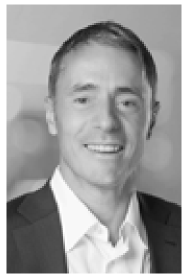
We need a circular economy to achieve our climate goals and secure our raw material supply. According to the Circularity Gap Report, only 7.2 percent of the global economy is currently circular. However, companies can design products in such a way that as few – and, above all, sustainable – materials are used. Sustainable business models need to focus on longevity, repairability, and recyclability. Not considering a product's recovery potential means not understanding its full value potential.

We need a circular economy to achieve our climate goals and secure our raw material supply. According to the Circu-larity Gap Report, only 7.2 percent of the global economy is currently circular.

Plenary Talk Co-Host 01

Autonomous manufacturing for a sustainable future

Paolo Guglielmini
President and CEO, Hexagon AB



Year of birth:
1977

Current position:
since 2023 President and CEO, Hexagon

Previous positions:
2022-2023 Chief Operating Officer, Hexagon AB
2020-2022 Manufacturing Intelligence Division President, Hexagon AB
2017-2020 President and CEO, MSC Software (part of Hexagon AB)
2010-2017 Business Development, Manufacturing Intelligence Division, Hexagon AB
2004-2008 Project Lead, Engineering Department, CERN
2003-2008 Business Analyst, Accenture

Studies:
2009 Master of Business Administration
2002 Master of Science in Engineering

Our world is composed of finite resources. To conserve the environment, it is vital to reshape product lifecycles and create a value-added circular economy. When products reach end of life, we can do much more than recover the materials – we can refurbish and upgrade them to extend the product lifecycle and maximize the energy used to manufacture goods in the first place. But how can we ensure products are designed with end-of-life in mind, made to last, fit for reuse and ready for upgrade? This presentation will explore the complex equation of people, technology and process in the pursuit of greener production.

Driving optimization and innovation

Addressing key sustainability challenges such as decarbonization, waste reduction and resource protection requires a focus on productivity, quality and efficiency at every stage of the product lifecycle. To make manufacturing as planet-friendly as possible we need to ask questions about everything – from the products we create, to the way they are designed, the way they look, the materials we use, the way they are created, and the way they are used and serviced.
Optimizing product design and production processes can help reduce waste, energy usage, and emissions. But optimization alone cannot stop climate change – we must also accelerate innovation. Manufacturers need to innovate and bring sustainable product innovations to market – for example by making better-performing products, using the best available materials in the most efficient ways, and developing more sustainable production processes.

Taking a data-driven approach throughout the product lifecycle offers a blueprint for greener production.

Empowering people with technology

Leveraging data to its full potential, digital reality solutions empower makers with insight to make better products in better ways. They bring together innovation and optimization so that sustainability concerns can be addressed more holistically. Deployed effectively, this technology can be enhanced with advanced automation and autonomous technologies to unlock the power of human ingenuity, enabling cross-functional teams to collaborate, solve problems, iterate faster, and address complex but urgent sustainability challenges sooner. This is the time for new ideas and greater ambition. To achieve scalable sustainability, manufacturers must empower people with the data they need to make informed decisions throughout the product lifecycle.

Digitalizing the product lifecycle

Taking a data-driven approach throughout the product lifecycle offers a blueprint for greener production. Using digital tools to break down siloes and drive collaboration enables product developers to take a more holistic view of sustainability issues from design concept to delivery and make better decisions that will, in time, lead to a more sustainable manufacturing ecosystem.
In design – With an estimated 80% of a product's environmental impacts locked in at the design stage, it is important that development teams have as much information as possible to inform decisions about materials, processes and the product's purpose and required performance. Understanding the usage cycle and consumer behaviour provides valuable insight, as does data from the production and quality assurance processes of previous iterations. The ability to understand the consequences of decisions in digital reality and test ideas can reduce prototyping, and ensure manufacturability and quality. Effectively leveraging data in the design process also opens the door to design for sustainability and eco-design approaches, supporting predictive maintenance, value-added upgrades, simple dismantling, re-manufacturing, and recycling.
In production – Digital reality solutions enable process simulation and validation and optimise production to save resources and cut waste by reducing rework and scrap. Bringing the process of manufacturing closer to the design phase through continuous digital feedback helps to create optimized products in optimized ways that maintain design intent. Increasingly closed-loop automation helps to remove the potential of human error in processes, and mitigate common issues such as tool wear, moving production closer to "first time right".
In quality control and service life – Metrology solutions capture real-world data typically used for quality assurance, but its potential is much greater. Feeding measured data back into design simulations can improve a designer's understanding of the impact of the manufacturing process, or of the behaviour of the part during service – thus helping to provide usage cycle insights that raise the bar for future developments.
Digitalizing products throughout the lifecycle also offers the potential to introduce digital product passports. With digital information embedded in products, manufacturers will gain transparency to improve the lifecycle sustainability of products by gathering and sharing information on how they can be repaired, broken down, or recycled.

Harnessing the power of data

Data is the key to scalable sustainability, but it will only supercharge the march to greener product production when it is fully accessible to the right people at the right time. Siloed tools and rigid systems are hampering innovation. To change this, manufacturers need to connect data from different applications to form workflows and solve problems. Connecting this data centrally via cloud technology can provide advanced insight and power intelligent automation, while applying AI and machine learning techniques to autonomously make vast quantities of data usable and actionable to human experts. Only then can cross-functional teams fully leverage data, interact and share as never before, bring their ideas to life faster, and produce better products in new innovative ways.

Make the difference

Let’s rethink making. Let’s shape a better future.

Securing the future for people and planet requires more than a rethink – we need to reinvent making.

This isn’t about improving what exists, it’s about rethinking everything we know about products and production. Hexagon technology empowers makers with the tools to create optimised products in new innovative ways – from concept design and material selection to simulation and production.

Dream the impossible and redefine what’s real. Let’s create the change we need to see. Together.

Empowering green production

Let’s shape tomorrow, today

Makers shape our world. Define the way we live. Constantly strive for improvement. With a climate emergency staring humanity in the face – makers can make the difference.

Hexagon exists to empower makers to shape a better future – collaborating with designers, inventors, engineers, researchers and manufacturers, and providing the tools to unlock innovation and solve challenges.

Through efficient design, material selection, process, production and end-of-life planning, we can conserve energy, resources, money and time – taking manufacturing from problem to solution.

The innovation imperative

An opportunity exists, not simply to slow climate change, but to turn the tide. It is time for new ideas and bigger ambition.

Makers that place their focus on optimising what exists will lose out to innovators who rethink every aspect of products and production – disrupting the status quo with solutions that realign people with planet.

It’s time to swap resources, energy and consumption for data, technology and innovation. It’s time to give wings to your ideas.

Visit **hexagon.com/mi**

#empoweringmakers

Session 01

Data structures for resilience

Sustainable product and material life cycles require equally long-lasting data cycles: The continuous availability of resilient, historical, and current information is necessary to exploit the sustainability potential of production technology.

Examples include automated disassembly in the course of recycling and remanufacturing, or data-driven approaches to strategic and long-term decision-making. Without ubiquitous, resilient information availability, fragile systems emerge that are a contradiction to the necessary resilience of production systems. Data must be reliably discoverable, accessible, interoperable, and reusable over a long period of time and for many stakeholders, even if there are multiple decades, multiple data owners, and multiple system breaks between data collection and data use. This raises elementary organizational, regulatory, and technical questions: What do appropriate, long-lived data structures look like? Which technologies can be used to design a powerful, resilient data infrastructure? How can data quality be ensured? How do current digitization efforts converge to create sustainable production data management?

Data structures for resilience in life cycle sustainability

R. H. Schmitt, M. Bodenbenner, H. Brings, B. Montavon

Tomorrow's Green Production exceeds, but still includes reduction of input and increase of efficiency, the usage of re-cycled resources and the sustainment of installed assets. It aims at a wider understanding of life cycle sustainability (LCS) as the fulfilment of defined sustainability criteria by a product or its components over its actual lifetime, and builds on information on the entire – as well as preceding or following – life cycles. In this way, the perspective of tomorrow's LCS complements the megatrends of sustainability, digitalization, and resilience under the frame of responsible resource usage. Effectively using existing building blocks – such as smart sensors, digital twins, cyber physical systems, and intelligent algorithms for pattern recognition and decision making – can leverage these megatrends when backed by advanced communication in terms of speed, latency, and jitter. Data management, as figuratively spoken cement between these blocks, enables generation of knowledge and broadens the apparent horizon beyond production towards user cycles. Connecting to established 9R-Strategies, data management, technological design scope, and objective assessment form a containment framework to afford or sustain economically successful operations. These sustainable operations enable circular value creation containing products or assets in different life cycles that are founded in their obsolescence reduction or function enrichment (Figure 1.1). Considering the complexity of modern products and manufacturing systems, as well as the longevity aspect of sustainability, the need for resilience emerges and its benefits become obvious. For LCS, resilience is defined as capability to maintain the fulfilment of sustainability criteria in the long term with a limited take-up of additional footprint when facing external stimuli or disruptions.

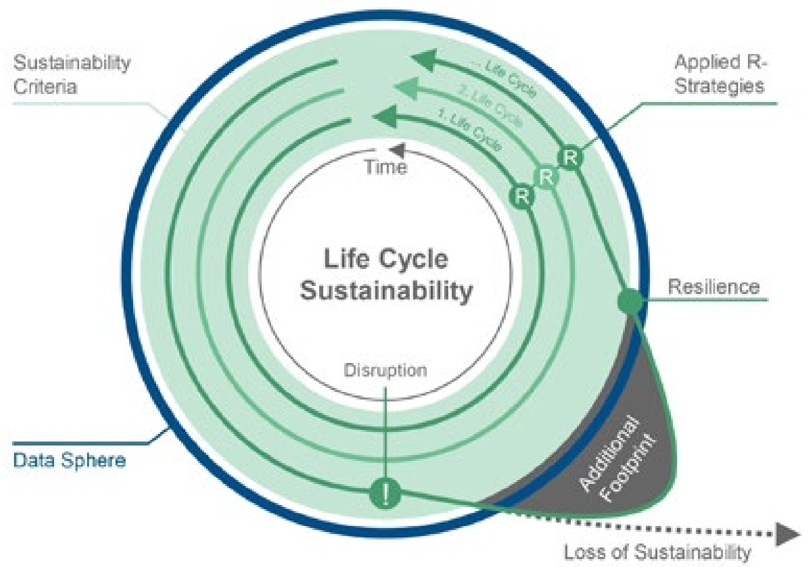


Figure 1.1: Resilient life cycle sustainablity

Data as foundation of life cycle sustainability
Industry, politics, and science have highlighted the necessity of data in the form of digital twins for the successful transition towards green production. This relationship and the role of data in explicit technical materializations are illustrated more concisely, adopting the framework of the knowledge pyramid (Figure 1.2). Most data-driven sustainability strategies can only deliver full impact if data is contextualized to information, aggregated to knowledge, and ultimately used as a basis for action. As a prerequisite, relevant resources must be connected to collect relevant data in the first place. The same holds for objective assessment: To make decisions that contribute to broad sustainability criteria, such as ESG, the latter must be decomposed to indicators and specific information along the life cycle which determines the scope of required data with regards to measurable quantities. It is thus not only the data itself, but also its ubiquitous findability, (long-term) availability, accessibility, continuity, reliability, exchangeability, and reusability that are decisive, even if there are multiple decades, data owners and IT systems between data acquisition and usage.

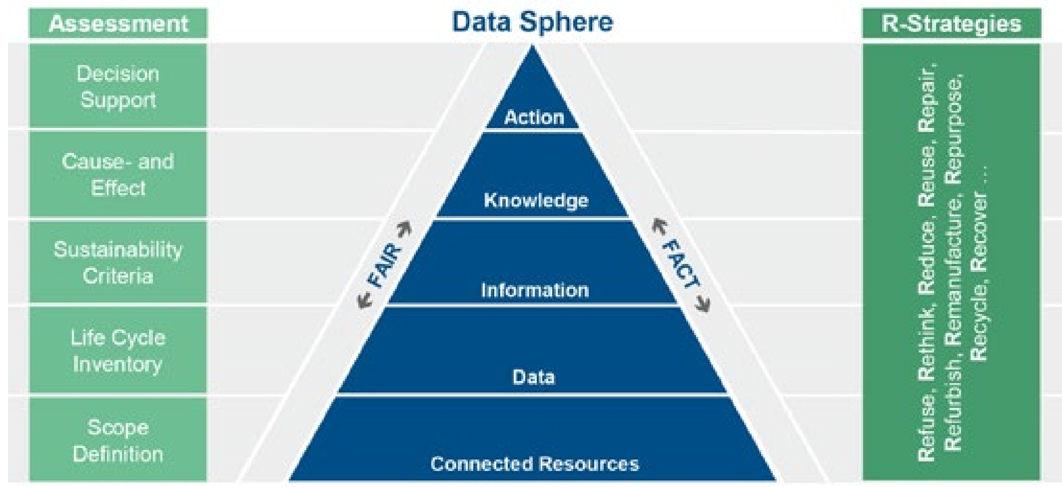


Figure 1.2: Sustainability assessment and strategies in the framework of the knowledge pyramid

FAIR data and FACT algorithms
In data management, the requirements and corresponding efforts are guided by the principles of FAIR data and FACT algorithms. They set a framework for production data management, but must be adapted to the needs of complex business relations (e.g., open market competition or customer-supplier relationships). This is neither a singular field of action, nor can a single, universally valid implementation be expected. Rather, it is the integration of interdisciplinary, data-driven technologies and methods in the dimensions of people, organization, and technology in several fields. For quality and information management, metrology and sensing, communication technology, automation, and employee qualification, successful implementations across all levels of the knowledge pyramid have already been undertaken. Model-based techniques address the needs of short-term industrial communication, long-term data management, and human involvement. This has been demonstrated, e.g., with the sensor interfacing language SOIL, which combines low-level sensor interfaces with a FAIRification layer for metadata enrichment and communication via standard protocols such as MQTT and OPC UA. In industrial assembly, SOIL's principles are integrated into a digital twin pipeline reaching from ontology definition and expert input to automation deployment.

Production data management as essential for green production
Data structures are fundamental to the transition towards green production. Research outcomes consistently outline that the domain-specific adaptation of widely used standards is more beneficial than initiating many individual, niched approaches. The more the technological and organizational scopes of production data management form the system boundaries of life cycle sustainability, the more application of base services (such as for terminology, ontologies, knowledge graphs, memory organization or legal questions) are required to handle digital objects. They pave the way to achievement of green production and to recognition of its potential as outstanding synergy along the megatrends digitalization, resilience, and sustainability.

Download full conference paper
Keynote Session 01

Closing the loop with automated adaptive disassembly

R. H. Schmitt, A. Göppert, F. Sohnius, M. Frye, J. Elsner, K. Briele, L. Bergs, F. Balzereit, J. Bitter-Krahe, M. Drechsel, I. Geyer, T. Greshake, T. Häring, D. Mishra, C. Kokott, G. Nilgen, S. Schmitt

One of the main strategies to achieve sustainable, green production is a circular economy. To close material life cycles, the EU is currently passing multiple legislations that regulate reparability, recycling quotas, and digital product passes for a range of products. Strategies to close the material loops, however, are currently only feasible to a limited extent. Complex products are typically either destroyed to recover valuable materials, or manually refurbished and reused. Since the activities in assembly mark the decisive step of value creation in manufacturing, its ability to adapt to higher input diversity and resilience to variability is crucial. Data-driven advancement of assembly, both co-ordination and technical solutions, can achieved this – beyond the synchronization in time and space that Toyota attains with its synchronous production system. A possibility is to implement dis-assembly abilities. The implementation of automated disassembly systems will enhance conventional manual systems and enable a wider range of strategies, such as remanufacturing, to scale it into a profitable business case. This article discusses the characteristics of disassembly systems based on three use cases, the need for adaptive automated systems, and the main challenges for the industry.

Vision of an industrial disassembly system

The lifespan of products can be extended through circular economy by determining the best strategy to close material loops for each component. Disassembly systems help by breaking down products to the necessary disassembly depth while still preserving its components. As products are now highly individualized and exhibit diverse signs of usage, the disassembly system must be flexible and able to handle different product varieties. Conventional assembly lines are highly specialized and repeatable processes, which allows for rigid automation. A disassembly system, however, must combine process adaptability – the ability of the system to change the disassembly process to account for product design or conditions – and system adaptability – the ability of the system to be adjusted to external conditions, e. g., market demand or resource availability. The main enablers to handle variety and scaling needs are sensory capabilities, intelligent support systems, and an organizational structure geared to disassembly, e. g., line-less disassembly. As for a high disassembly depth and low degree of destruction, the primary enabler is design for disassembly.

Use cases

Their advantages being transferable for many use cases, the three following use cases which embed automated disassembly systems highlight their benefits including resilience in terms of material strategies.

Miele & Cie. KG has implemented the refurbishment of washing machines in a regional business unit. The goal of the system is to refurbish and, if necessary, replace parts within the individual washing machine so that the product remains intact for a significantly extended lifespan. The main challenge is to convert the manual disassembly line to an automated one while keeping the same level of adaptability. Key enabling technologies include automated testing and accessibility of the components.

Ford Werke GmbH is conducting research on the disassembly of car batteries. Due to EU regulations, manufacturers must assume responsibility for car batteries. The goal is to recover the valuable battery modules for reuse or recycling, which requires high disassembly depth down to battery modules. Since the battery is a static element embedded in a rigid box, there is no mechanical damage to the battery itself only the electrical condition of the battery changes, which does not influence the disassembly process. The key enablers are design for disassembly, such as advances in cell chemistry and vehicle design. In the current phase, work is being done primarily on the logistics of returning batteries that have reached the end of their first life cycle.

PCH Innovations is investigating the feasibility of an automated shoe disassembly to allow repair components like the sole or the funneling of each material back to an individual material stream through complete disassembly. The use case requires a high level of adaptability to account for the high variety of shoe models, materials, and wear conditions. The integration of sensory capabilities is the most important enabler for automation and creation of a viable business case.

The three use cases show the broad range of products that benefits from suitable disassembly systems to enable circular material streams. Although they differ in their intended material strategies and requirements for disassembly depths, degree of destruction, and adaptability, all utilize the same technological enablers: a product design that enables disassembly; and an adaptive system that integrates sensory capabilities and robotics in a line-less organization.

Next steps towards adaptive automated disassembly

The need for disassembly systems is slowly emerging in the industry through legislative and customer pressure. Currently, companies are evaluating legal questions regarding liability for logistics of product returns and strategies to implement manual disassembly lines. However, for profitable, large-scale business cases, adaptive automation is necessary. This requires focusing on technological challenges. The implementation of adaptive automation involves three main tasks: reducing product variety, reliably identifying product properties and conditions, and automating handling operations.

Initially, the variety; must be reduced by standardization in industry and amonglegislators. This concerns, for example, standardized product modules, recyclable material mixes, or battery chemistry. Secondly, the product properties and condition must be identified by using both data and sensors. Product and usage data help to categorize the product and its condition before the actual disassembly. During disassembly, computer vision systems and automated condition testing determine the exact product condition to decide on the best material loop and disassembly strategy. Lastly, the disassembly system must integrate sensory capabilities with AI and robotics to handle the variety of products and conditions. The robot system must be capable of managing a variety of materials, product conditions and disassembly techniques, while simultaneously reacting to changing external circumstances.

In conclusion, adaptive, automated disassembly is one of the key technological enablers for circular economy. It expands the scope from conventional material loops such as reuse and recycling to remanufacturing of complex products as a profitable business case on an industrial scale.

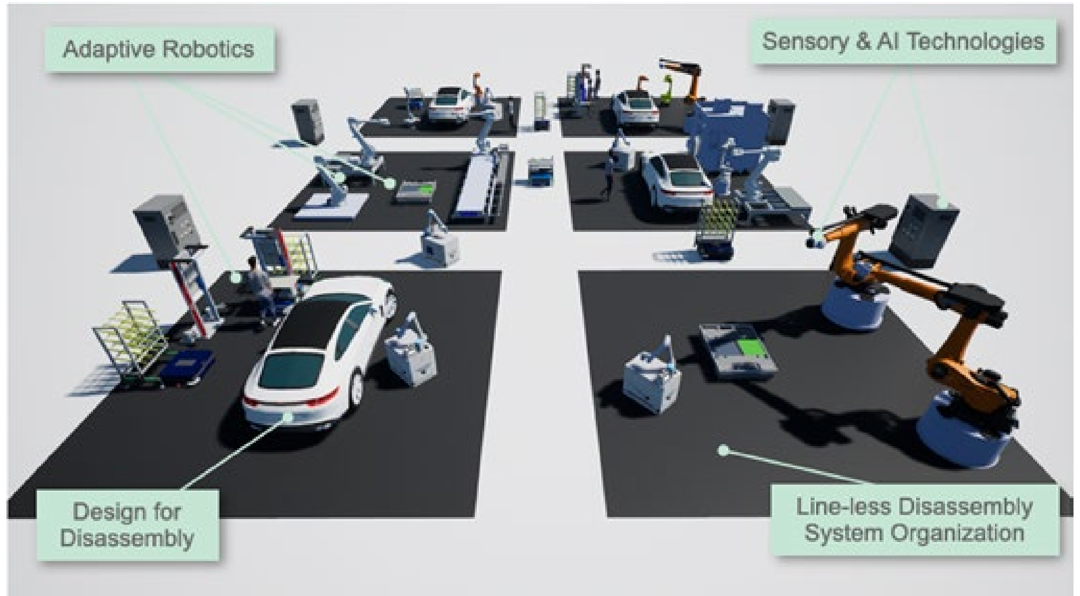


Figure 1.3: Adaptive automated disassembly system facilitated by technological enablers

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Expert Session 01

New modularity and technology roadmapping

G. Schuh, M. Kuhn, A. Keuper, M. Patzwald, L. Schenk, M. Feucht, J. Kantelberg, G. Rossmair, H. Schroth, U. Viethen, P. Zeller

Over the past decades, industrialization has led to a significant increase in productivity, which has resulted in overproduction of goods through the reduction of production costs. This approach favored a linear model of value creation. Considering not only the economic but also the ecological effects of this linear value creation, a fundamental change is necessary. By focusing on recycling, lower energy consumption, and reduced use of environmentally harmful (raw) materials, sustainability can only be increased to a certain extent and usually requires compensation for the associated costs. In contrast, a change in thinking and a radical transformation of value creation towards a circular economy offer superior ecological and economic potential.

The transformation of the manufacturing industry towards circular economy

A successful circular economy in the context of the manufacturing industry is characterized by the concurrent and simultaneous realization of ecological and economic benefits, and requires the alignment of corporate activities towards the circular economy as the north star and overarching goal. To effectively leverage this potential, companies have to synchronously develop and conflate their capabilities within the four dimensions of modularity, technology, value creation, and revenue. To illustrate the path to this goal, the transformation trajectory cutting through the four dimensions is illustrated in Figure 1.4.

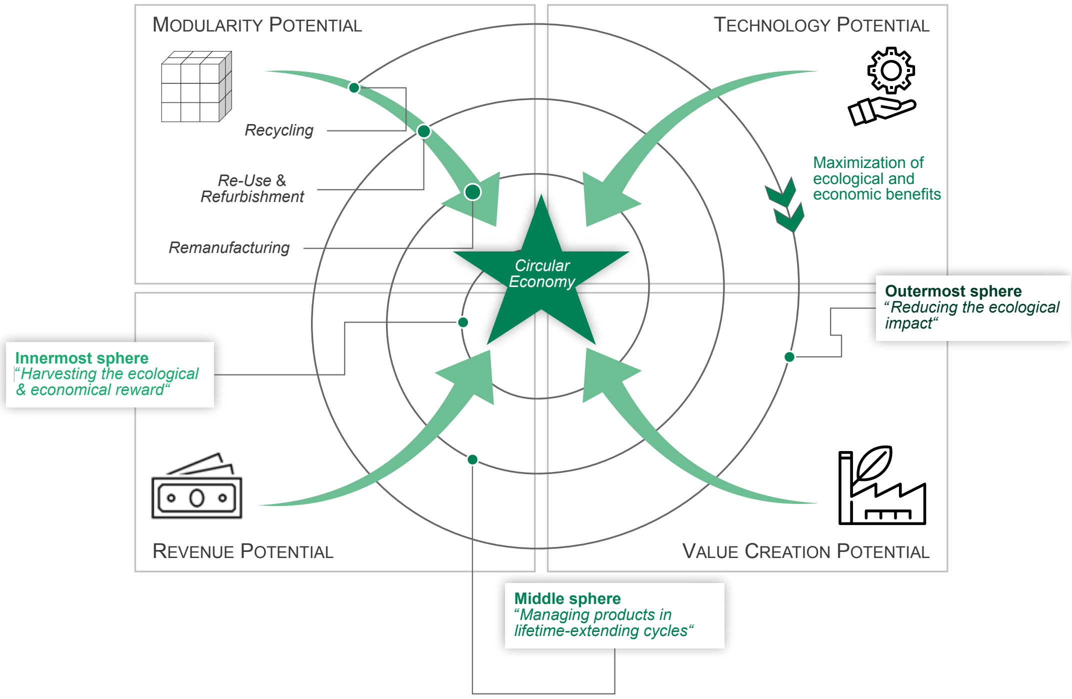

Figure 1.4: Synchronizing modularity, technology, value creation and revenue potential on the path towards a circular economy

This is realized by an active extension of utilization cycles and the continuous increase in product value through upgrades during the utilization phase, thus creating the possibility of recurring monetization.

The overall potential that companies can unlock is reflected in the spheres which align the activities within the different dimensions. The ecological and economic potential that can be realized increases significantly on the path to the inside of each dimension. Thereby, the targeted circularity activities set the pace and orchestrate the activities within the four dimensions. On the outermost sphere, these circularity activities focus on lower energy consumption in manufacturing and use, reduced use of environmentally harmful raw materials, and recycling. If companies extend their circularity activities and implement re-use and refurbishment approaches, they are able to extend the lifespan of products by managing products or their parts in cycles. In addition to optimized value creation, value preservation over an extended period of time is realized.

A change in thinking and a radical shift in value creation toward circularity lead to maximization of ecological and economic benefits in the innermost sphere. The lever is the active extension of life cycles through remanufacturing and the upgrading of products respectively their performance during the utilization phase. This even leads to a value enhancement within an extended life cycle.

Therefore, the challenge for companies is, on the one hand, to synchronize the different potential dimensions, which at first glance appear to stand apart from one another. In addition, it is important to constantly have the wider path towards the circular economy in mind, in order to prevent their own business from being disrupted in the future. Consequently, companies have to explore the required activities for the inner spheres while, at the same time, they still implement the approaches of the outer spheres.

New product modularization and technology roadmapping as key enablers forcircular products

At this point, the question arises concerning the measures that can be taken to prepare a company and its products for the transformation towards circular economy. To be able to follow the trajectory to the green north star within the inner sphere in Figure 1.4, it is necessary to prepare the product architectures of future products appropriately for the requirements of a circular economy. The product architecture needs to be purposefully designed to allow individual product components to be replaced, refurbished or upgraded. In this context, it is important to provide flexibility in relevant areas and to implement that flexibility through suitable interfaces. Accordingly, the key to the paradigm shift described above lies in a new product modularization for the realization of a circular economy, and in extended technology planning to anticipate the required flexibility and upgrades. Therefore, the goal of modularization is no longer the realization of economies of scale but the enabling of the value-enhancing extension of product lifetimes through module upgrades and replacements. This means that technology planning should no longer focus exclusively on new products, but, in particular, also on upgrades for existing products. As a consequence, holistic circularity roadmaps are emerging instead of roadmaps for individual products.

To realize circular products, product modularization and technology planning must be increasingly integrated and synchronized. Figure 1.5 shows a four-step approach for developing new modular product architectures for circular products and the corresponding technology planning.

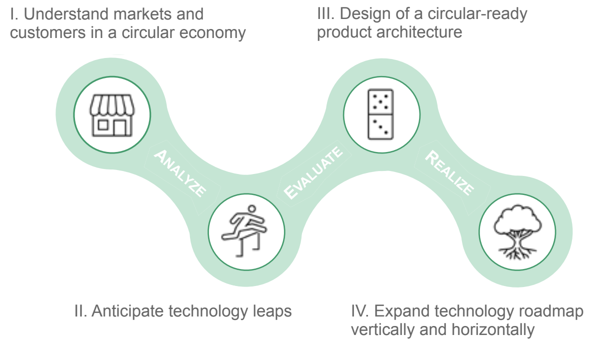

Figure 1.5: Four steps for a new modularization and technology roadmapping in the circular economy

First, an understanding of markets and customers in the circular economy is necessary in order to offer ecologically and economically sustainable solutions, today and tomorrow. In addition, regular upgrades require early anticipation of relevant technological leaps. Taking these two perspectives into account, the future core of circular products are modules, which can be introduced into cycles of circular value creation. Additionally, the technology view must be expanded vertically (to include technologies of circular value creation) and horizontally (to include remanufacturing and module upgrades).

Conclusion

Together with the WZL | RWTH Aachen University and the Fraunhofer IPT, the expert group consisting of industry specialists was able to develop an understanding of necessary changes in product development for the circular economy. In addition, an initial concept was developed that shows companies a possible approach for developing modular product architectures for circular products in this context.

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Impulse Session 01

Session 02

Resource efficient manufacturing

The sustainability of manufacturing represents a new target for manufacturing companies. Current challenges lie, in particular, in the holistic evaluation of quality, costs, and sustainability, as well as in the development of promising circular economy processes.

What do successful circular economy processes in manufacturing look like and which R-scenarios (Reuse, Remanufacture, ...) show a high potential for implementation? This session will discuss scenarios for the future of manufacturing with regard to the circular economy, present current successful approaches from practice, and give examples of promising products.

Manufacturing for a circular economy

T. Bergs, J. Brimmers

The sustainable usage of resources on our planet is the greatest objective for current and upcoming generations. The Sustainable Development Goals, SDGs, of the United Nations as well as the recently announced Green Deal of the European Union state that as a clear target of their agendas. The industry sector plays a major role in achieving this target. Thus, future value chains need to be reconsidered, putting circularity into the focus of action. Manufacturing chains need to be newly designed to achieve minimum consumption of energy and material resources and enhance the fast market entry of new sustainable products, both goals representing major challenges for the production sector.

Challenges for implementing of circular economy strategies in manufacturing

The life cycle of a product consists of five phases: product idea, product design and development, product manufacturing and assembly, product usage, and end-of-life. Each product has specific requirements and functions that need to be ensured along its desired life time while at the same time, keeping the running costs on a competitive level. In the future, the aspect of ecological sustainability of the product life cycle will be a strong constraint. Therefore, a holistic approach for quantifying the economic and ecologic impact of both product manufacturing and usage is required for a true determination of the level of sustainability. Information acquired throughout the life cycle must be available for manufacturing companies. Beside simply reducing the usage of resources (energy, material, etc.), the aim for a circular economy is to prolong the end of life (EOL) or even the end of usage (EOU) by various means, mainly regarded as the so-called "10 R-scenarios". Derived from those R-scenarios, manufacturing companies may consider four different principle approaches, see Figure 2.1. The first approach seeks new business models in order to preserve or even increase the value of the product. The second approach aims for a transparent and sustainable design of manufacturing chains. The third approach targets optimal product properties for maximum product usage efficiency. The last approach represents the life cycle analysis for the holistic sustainability quantification of ecological indicators. This approach is the backbone for a circular economy and enables quantifying of all different R-scenarios.
All approaches have one constraint in common: the availability of relevant, workpiece-specific information along its entire life cycle. Here the concept of the digital twin (DT) comes into play, gathering all relevant information specifically linked to the one physical object, the component or the product.

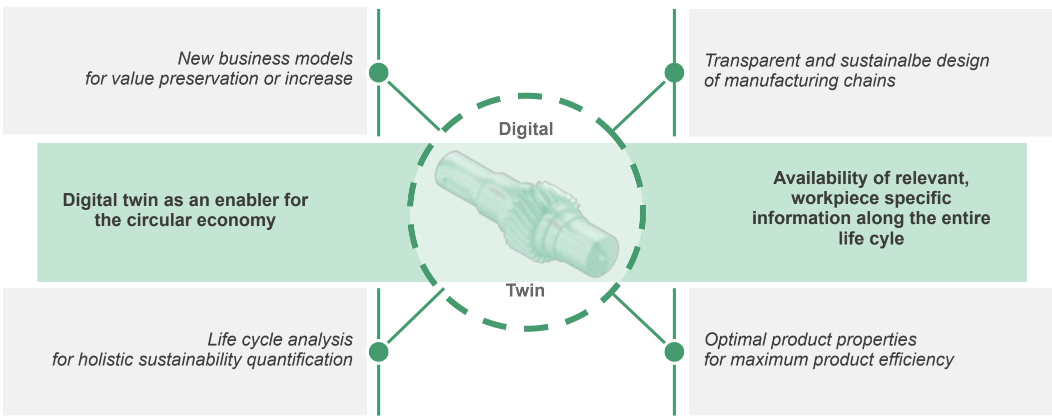

Figure 2.1: The digital twin as an enabler for the circular economy in manufacturing companies

Although the digitization and the digital twin are already under development and widely investigated, one can rarely see a general usage of the concept in the industry, particularly with respect to the aspect of sustainability. Current challenges result from missing standards regarding data formats within heterogeneous machine tool infrastructure and production systems as well as digital architectures. Furthermore, data ecosystems or platforms for free data exchange in a circular economy are still under development. Catena-X, or other initiatives like Manufacturing-X, are promising first steps.

Finally, a rather visionary approach for a circular economy will be presented with regard to preserving existing resources of components, which have already reached end of life and would usually be scrapped (see Figure 2.2). Based on a comprehensive implementation of digital twin concepts, carrying all relevant condition information, new trading platforms will be able to convey these secondary market components in new value chains, saving tremendous amounts of energy and material. However, innovative and adaptive process chain design for handling these individual components based on digital twins will be the main future challenge to be scientifically investigated.

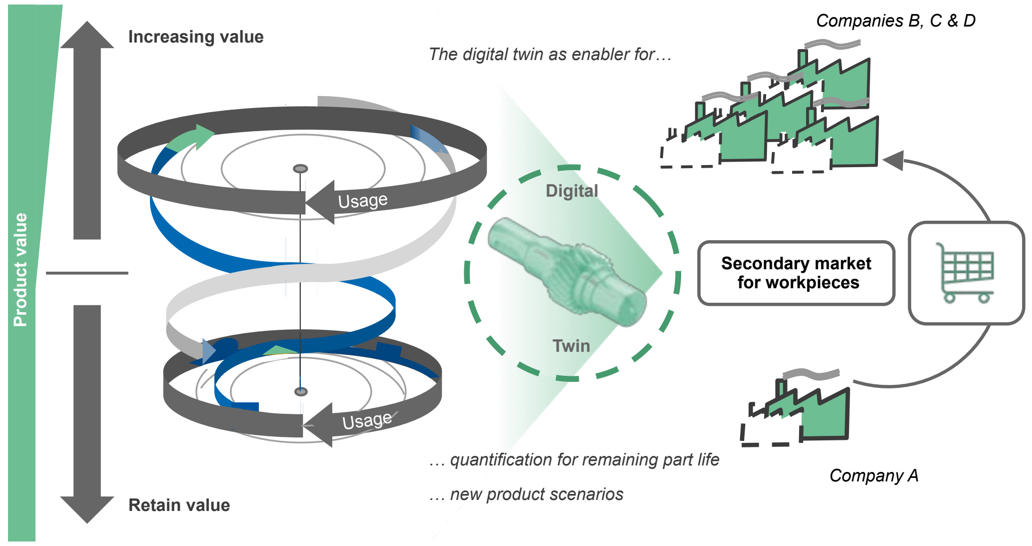

Figure 2.2: Increasing the circularity in manufacturing – using a secondary market for workpieces

Perspectives and use cases for a circular economy

As discussed in previous chapters, implementing circular economy strategies from the perspective of a manufacturing company is rather challenging. As a kind of best practices combined with new scientific approaches, this report presents, on the one hand, different use cases for sustainable manufacturing strategies. On the other hand, it also discusses challenges and opportunities for the production of innovative, sustainable products, such as flying fuel cells or electric drive components, which need to be economically scaled-up in a rather short-term perspective.

Conclusion

This report discusses challenges for manufacturing companies in implementing their strategies for a circular economy. In various use cases, first solutions are demonstrated.

However, there are still challenges to be solved through innovation and a rethinking future manufacturing processes, and – most importantly making use of the digital twin concept for the orchestration of sustainable, circular value chains.

Download full conference paper
Keynote Session 02

Energy and resource efficiency in manufacturing

T. Bergs, S. Barth, A. Koch, A. Beckers, A. Dehmer, G. Grünert, S. Prinz, J. Röttger, L. Stauder, T. Augspurger, S. Bastürk, F. Benner, M. Duscha, D. Friedrich, G. Fuchs, A. Heckl, H. Johann, L. Johannsen, M. Orth, R. Perez, T. Röthlingshöfer, J. Seele, U. Schleinkofer, M. Terhorst, J. Wiese, C. Zeppenfeld

In order to improve ecological sustainability, manufacturing companies are currently focusing on energy and material efficiency in their own production. Companies that have taken the initiative in this area can already leverage potential for energy savings in the short term, and manage valuable materials increasingly in material cycles. However, the broad and successful implementation of such concepts sustainability concepts. Reasons for this are that relevant levers for increasing sustainability and for realizing savings potentials are company-specific and strongly product-dependent. However, a distinction can be made between the extent to which environmental impacts occur during the manufacturing or in the use phase of the product. This can be illustrated by the three example products shown in Figure 2.3.

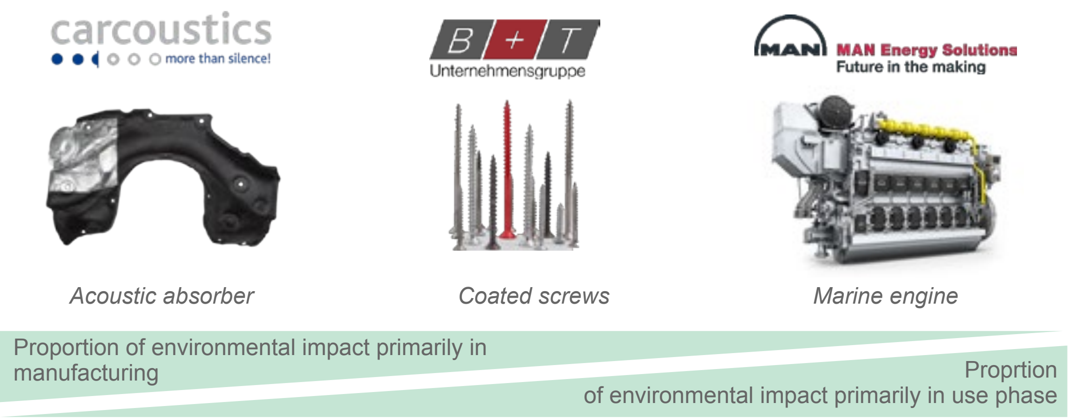

Figure 2.3: Product-specific environmental impacts illustrated by example products of the participating companies

requires the commitment of all involved stakeholders along the respective value chains, as well as an intensive information exchange among those involved. Therefore, this article presents current best practices for increasing energy and material efficiency in manufacturing, practices already being implemented at and with OEMs, component and machine manufacturers, equipment suppliers, and manufacturers of sensor and monitoring systems. With a view to tomorrow's potentials as well as future challenges, promising possibilities and examples for the realization of the urgently needed circular economy are highlighted, taking into account different R-scenarios based on the digital twin of product and manufacturing.

Special challenges due to high product and machine diversity in manufacturing

Due to the high product and machine diversity in manufacturing companies, there is currently no patent remedy for the implementation of ecological

In the case of the featured acoustic absorber, the environmental impact occurs mostly in the production phase (ecological sustainability primarily characterized by resource and energy consumption in production). In the opposite case of the exemplary marine engine, the environmental impact occurs especially in the use phase (ecological sustainability primarily characterized by CO_2 emissions from fuel combustion). However, the potential for increasing the product service life and efficiency in the use phase is also decisively realized with actions during production. The positive effect of the coated screw depends primarily on its use and the environmental conditions to which the screwed end product is exposed. For the detailed recording and evaluation of the energy and material flows for the manufacturing of the products as well as for the calculation of the emissions generated in the use phase, far-reaching data and methods must be used. This continues to present many manufacturing companies with great challenges.

Manufacturing as an enabler for a systematic increase in life-cycle-based environmental product sustainability

In order to meet these challenges and to contribute to increasing ecological sustainability in and with manufacturing, best practice examples were discussed together with experts from industry and research. First of all, examples of data-based transparency actions in manufacturing at the B+T group, and in the cooling lubricant circuit as well as production network at the Steyr plant of BMW AG are presented. The examples impressively show how energy efficiency in manufacturing can be increased in the short term. In close discussion with the machine manufacturers Makino, EMAG, GF as well as the spindle manufacturer GMN and the companies Grindaix-Quaker Houghton and Recondoil, the potentials of future plant generations, monitoring systems and operating material preparation for increasing sustainability in manufacturing are elaborated. The saving of ecologically critical primary raw materials also contributes to ecological sustainability, as shown by the example of the systematic recycling of hard metal components by Ceratizit. Current research results from the WZL | RWTH Aachen University and from MAN ES show how process knowledge, process innovations, and product adaptations for the optimization of tribological surfaces and the associated extension of the service life of technical products make a long-term contribution to sustainability. Schaeffler shows how products for the production of green hydrogen make a decisive contribution to ecological sustainability in the future through technological innovation and increased material efficiency both in production and in the use phase as well as enabling an increasing circular economy of the manufactured technical products. The realization of a sustainable circular economy is also a focus of the companies Carcoustics and IGUS, here specifically through monomaterial-based development for the production of automotive and machine components. The widely elaborated spectrum of both short-term realisable and long-term achievable contributions of manufacturing to ecological sustainability shows how manufacturing can contribute to the systematic increase of product lifecycle-based ecological sustainability. A central challenge in the long term will be the quantitative evaluation and product-dependent optimized design of suitable R-scenarios. Here, the concept of the digital twin offers a promising basis for fundamental support of the realization of circular economy potentials.

Stop starting, start finishing - success is the sum of the individual steps

By focussing on energy and material efficiency in manufacturing, producers are already able to realize short-term potential for energy savings and to keep valuable materials in their material cycles. The wide-ranging spectrum of contributions to ecological sustainability that can be realized in the short term and achieved in the long term in manufacturing, developed in close discussion with experts from research and industry, shows how numerous solution approaches in manufacturing lead to a continuous increase in product lifecycle-based ecological sustainability. In the long term, efforts to realise a circular economy will be supported by the concept of the digital twin, enabling the systematic evaluation of product-specific R-scenarios.

Download full conference paper
Expert Session 02

Scalable production of energy systems

C. Brecher, H. Janssen, D. Zontar, M. Kersting, K. Baer, T. Bastuck, S. Witt

The production of sustainable energy storage systems such as traction batteries, hydrogen fuel cells, and storage systems are becoming increasingly important for the immanent transformation of industrial value creation in Europe. Until now, the mass production of these storage systems has mostly taken place in Asia. The supply chains have also developed accordingly. On the way to green technologies, many economies are striving for a higher market share in the production of these energy storage systems. In addition, political instruments are influencing developments.

Challenges and opportunities for innovation of the production process

There are currently numerous efforts to establish the production of energy storage systems such as lithium-ion batteries and fuel cells in Europe. European industry has the potential to significantly improve the state of the art in production technology and the courage to use new technologies. Accordingly, established processes must be scrutinized, and optimization potential must be sought along the complete value chain. If no improvement were to be applied to existing machinery concepts, no innovation and therefore no real market advantage compared to the established state of the art production lines would be generated. Taking battery production as an example, this means that, in addition to the development of new product technologies, such as solid-state batteries, the supply chain, in particular mechanical and plant engineering, must also develop innovative and potentially disruptive solutions along the supply chain. In the following, this challenge is illustrated by three examples.

Direct coating of fuel cell components

While fuel cells, compared to batteries, are only on the verge of mass production, production routes are also orienting according to laboratory processes used to develop the product fuel cell. Scalable production as shown in Figure 2.4 should therefore be a target. One example of such hard-to-upscale processes is coating the catalyst onto a decal and transferring it onto the membrane via hot-pressing. The membrane is sensitive to moisture and temper-ature gradients, which is why this indirect method was developed. In low volume production, hot-pressing is typically carried out for more than one minute and at pressure levels of 10 bar. Commercially available scaled up processes employ hot-pressing by one or multiple calendar rolls, in which web speeds are very low. New developments are aiming at direct coating the catalyst onto the membrane which may be performed almost independent of the web speed, lowering the lines CAPEX and OPEX by leaving out one process step. Developing direct coating is nothing trivial. In fact, data-based product development as well as data-based machine controlling pave a way to mastering this ecologically and economically friendly alternative process step.

Energy savings in drying technology

In battery production, up to 47 % of the electrical energy in electrode production is used for drying. One way to reduce energy consumption is to optimize existing convection dryers in terms of user-friendliness, quality, web speed and air flow. With those measures, convection dryers may reduce CAPEX by 3 or 4 million € and OPEX by about 1 million €. Despite these CAPEX and OPEX advantages, conventional dryer designs are still being used. This is due to lack of knowledge about how even small changes in one process (e.g., drying) can influence the final product as well as unknown impacts on the reliability of the process. The only way to fill this knowledge gap is via data. To enable improvements on conventional processes by empirical decision, one therefore needs to gather and use data. More disruptive process developments, such as near infrared and laser drying, could lower the footprint of dryers by up to 90%. However, the introduction of modern technologies in large-scale plants often comes with a risk uncertainty for European producers. The risk assessment of the introduction of new technologies on a large scale can be supported by data to ease possible concerns regarding product quality along consecutive production steps.

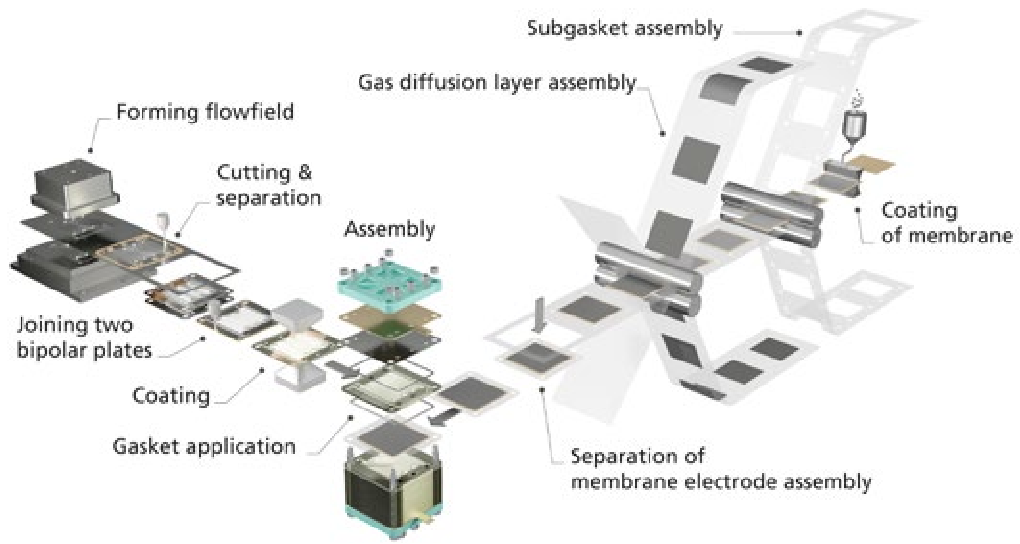

Figure 2.4: Exemplary process chain of fuel cell production

Assembly technology in battery production

Continuous electrode manufacturing for batteries provides coils which must be processed into a discrete cell and afterwards into modules or packs. These aggregations of cells need intermittent layers – for applications like mechanical and thermal safety – which are typically glued onto the cells. Housing, to prevent possible damage of the cells, also employs several kinds of glues or sticky tapes for closure. Many technological issues in the assembly of these modules and packs have already been solved in other sectors, or at least there is a lot of previous experience with similar problems. The key enabler for successful machine building in this area is, therefore, networking as well as knowledge management. German and European special machine builders are predestined to further apply their available knowledge to battery assembly and expand their application horizon by participating in industry networks. Examples of already available knowledge include the application of insulator and flame-retardant films as well as compression pads in industries like automotive body construction, lightweight construction, and large electrical appliances for household purposes. Apart from simply solving technological barriers, technology transfer may also have a positive impact on sustainable product design. Using the example of the battery pack, an acrylic foam for pack sealing and its application was developed by Tesa, Vulkan Technic and Liebherr Gear Automation. By using this technology, the battery pack can be opened non-destructively for repairs to the pack and therefore offers several possibilities for recycling as well as EoL testing.

Data-based improvement and disruptive technology development.

To achieve cross-value chain solutions, data-driven methods offer new possibilities. For example, continuous electrode production and discrete cell assembly can be virtually linked and optimized. This data-driven approach also enables energy- and resource-efficient production. The current production of lithium-ion batteries illustrates that sustainable solutions can reduce both CAPEX and OPEX, and thus form the basis for internationally competitive production in Europe.
The plant technology used to date can be a starting point for European production – if lessons are learned from its previous problems. Existing production chains must be rethought holistically and digitized to maintain a technological edge.

Conclusion

High CAPEX, quality requirements, and lack of data result in innovation challenges, triggered by unclear effects of changes in individual processes on the energy storage system. To strengthen medium-sized companies in the fast-moving market of energy storage systems, innovation must be validated based on data, and competitive advantages must also be developed regarding OPEX through efficient material flows. The continuous production of energy storage systems must therefore be considered along the entire value chain. Decisive improvements deviate from the old and require courage to do so. Data-driven decisions may help to find these disruptive changes in manufacturing. Recycling of material and energy flows is another important area where European machine builders can prove their strengths.

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Impulse Session 02

Panel Discussion 01

Data value to empower sustainability

The panel discussion highlights the importance of data and its value for sustainable manufacturing. The discussion will focus on the interconnection and collaboaration of companies along the entire life cycle.

Green production promotes the resilience of our value chains and calls for a cross-company and cross-domain approach. This requires the fresh ideas of non-profit research institutions to invent new methods and technologies and develop them in a way that enables the balancing act between protecting corporate interests and leveraging data across company boundaries.

Prof. Dr.-Ing. Robert H. Schmitt

Director of the Chair of Production Metrology and Quality Management, WZL | RWTH Aachen University and Director, Fraunhofer IPT

Host

Achieving Net Zero by 2040 is a key pillar of the Ericsson strategy. With our customers we break the energy curve when moving to the 5th generation of cellular technology and implementing use cases that contribute to sustainability.

Joe Willke

Head of Center of Excellence 5G Industry 4.0, Ericsson GmbH

Co-Host

Data value to

We can only operate successfully if we extend existing system boundaries and establish cross-company collaboration models while safeguarding in-house expertise.

Dr.-Ing. Jan Kantelberg

R&D Manager Lead Architecture, Vaillant Group

For the upcoming industrial transformation, e.g., the establishment of a European production of energy storage devices such as lithium-ion batteries, it is necessary to include the innovation potential of the entire supply chain, especially small and medium-sized enterprises. Digital methods can help to develop new, energy- and resource-saving solutions across companies.

Dr.-Ing. Stephan Witt

COO, Jagenberg Group

We need more data rivers, and not data lakes.

Dr. Arno Zinke

Senior Vice President Software Engineering, Hexagon AB

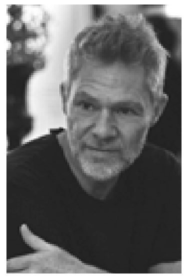
Co-Host

empower sustainability

Plenary Talk 03

Beyond sustainability – manufacturing a new mindset

Stefan Liske
Managing Director, PCH Innovations



Year of birth:
1966

Current position:
since 2021 Blank.AI
Founder + Partner
since 2006 PCH Innovations
Founder + Partner

Previous positions:
2003-2006 VW Group, Director Global Product Strategy + Innovation Projects
2000-2003 Arthur D. Little, Partner
1988-2000 BMW Group, Manager Special Vehicle + Design Division

Studies:
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until 1993 Dipl.-Ing. Mechanical Engineering, TU Munich
until 1990 MBA, Thunderbird School of Global Management

Sustainable transformation of means of production requires a shift in both culture and technology, at every level of the organization. It is not just about machines and processes; it is about people. Without a shift in culture and consciousness, we will only make marginal improvements, while disconnection between and within us increases. To address this, we propose an innovation framework that promotes harmony between humans and machines. This framework consists of three parts: Mindset, Organization, and Technology.
Innovation Mindset explores practices that address our minds and hearts, creating deeper awareness of caring, interconnected, and ultimately healing states. Keeping the balance between original and artificial intelligence.
Organization connects the shift in mindset to emerging production ecosystems that prioritize flow in networks over transactions in markets. It also highlights the need to embrace local, near, and far manufacturing capacity, open and adaptable fabrication systems, educational platforms, and spaces to build production communities. It even proposes a redesign of factories as manufacturing biomes.
Finally, the last pillar of the framework focuses on Technology applications that support this new human-machine harmony. It covers four main automation areas: design-to-make software pipelines, additive manufacturing, circular robotics, and generative AI. The keynote by PCH Innovations will provide a wealth of insights, ideas, and cases, drawn from our work as a creative engineering studio for exploratory technology in Berlin.

Sustainable transformation of means of production requires a shift in both culture and technology

Plenary Talk 04

Transformation of the steel industry – how to save 2.5% of German CO_2 emissions

Dr. Marie Jaroni,
Head of Decarbonization, thyssenkrupp Steel Europe AG

Year of birth:
1984

Current position:
since 2021 Head of Decarbonization of thyssenkrupp Steel Europe AG
since 2021 Member of the Supervisory Board of Eisen- und Hüttenwerke AG

Previous positions:
2017-2021 thyssenkrupp Steel Europe AG
2011-2017 McKinsey & Company

Studies:
2016 Promotion an der RWTH Aachen
until 2011 Studied metallurgy and materials engineering at RWTH Aachen University

tkH2Steel®: With hydrogen toward carbon-neutral steel
Steel production at thyssenkrupp is planned to be carbon-neutral by 2045. With our climate strategy, we are stepping up our previous activities to reduce emissions, accepting our social responsibility and showing our commitment to the 2015 Paris Climate Agreement. As an initial target for 2030, thyssenkrupp Steel is aiming to reduce emissions from its own production and processes and from the purchase of energy by more than 30 percent versus the base year 2018.

thyssenkrupp Steel is pursuing a technology-open approach and focusing on two parallel routes: The decisive step is the avoidance of CO_2 through the use of hydrogen ("Carbon Direct Avoidance", CDA). This is complemented by the use of CO_2 produced in steelmaking ("Carbon Capture and Usage", CCU).

thyssenkrupp Steel is continuously developing both ways. The company is always looking for even more efficient solutions or ways to accelerate the transformation, for example through new technological findings. In the hydrogen path, thyssenkrupp Steel also always keeps an eye on the availability of hydrogen, as the hydrogen economy is still in its infancy. To force the rapid development of a supply infrastructure for green hydrogen, thyssenkrup Steel is a partner in various national and international projects and collaborations.

Steel production at thyssenkrupp is planned to be carbon-neutral by 2045. With our climate strategy, we are stepping up our previous activities to reduce emissions, accepting our social responsibility and showing our commitment to the 2015 Paris Climate Agreement.

The first technology path contains the successive farewell to the blast furnace
In contrast to the blast furnace, DR plants do not produce hot metal, but solid sponge iron ("Direct Reduced Iron", DRI). By 2026, we will have built the first plant with a capacity of 2.5 million metric tons. This alone will save 3.5 million metric tons of CO_2, about 20 percent of our overall emissions. By 2030, we aim to produce 5 million metric tons of CO_2-reduced steel, and to cut CO_2 emissions by more than 30 percent. Steel production at thyssenkrupp Steel is planned to be completely carbon-neutral by 2045.
DRI must be melted down into a hot metal-like product so that it can be further processed into high-quality steel. Together with equipment builders, thyssenkrupp Steel has therefore developed a completely new unit in order to optimize the hot metal system. It is an electrical power-operated melter, which is combined with the DR plant. Direct reduction plants with a melter – just like a blast furnace – continuously produce a liquid product comparable to conventionally produced hot metal.
As a result, the new plants can be seamlessly integrated into the existing metallurgical plant. The great advantage is that the existing and proven processes in the Duisburg-based BOF meltshops can be maintained. The liquid product is processed into the proven steel grades there. Thus, the Duisburg steelworks is continuing to boil steel like in the past – but with hydrogen and green power instead of coal.

The second technological method thyssenkrupp Steel is pursuing in its goal to become carbon-neutral by 2045 is the Carbon2Chem® project.
As part of a project funded by the German government, thyssenkrupp Steel has been treating process gases from steel production and processing them into basic products for the chemical industry since 2018. In this way, synthesis gas, which until now has been obtained from fossil resources such as oil or natural gas, can be saved. On a test site close to the iron and steel plant, the company recycles process gases generated during steel production and processes them further. With the new process, thyssenkrupp Steel has produced ammonia and methanol from steel mill gases – the first time this has happened anywhere in the world. The basic chemicals are further processed in the chemical value chain into fertilizers, plastics or fuels, for example.
Using both of these methods – Carbon2Chem® and injecting hydrogen as a reducing agent – in parallel will allow thyssenkrupp to considerably reduce the emissions of its existing blast furnace route in future.

5G – Manufacturing a sustainable future by breaking the energy curve

Joe Wilke
VP, Head of Center of Excellence 5G Industry 4.0, Ericsson GmbH

Year of birth:
1967

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Every sector of society must work together to reach the global climate and energy challenge. Net Zero is the North Star of climate action and will be key for the industry. In the telecommunications industry, for instance, the deployment of new network generations usually means higher energy consumption. If 5G were deployed similarly to 3G and 4G, energy consumption would increase a lot.

Thus, breaking the energy curve of mobile networks is of utmost importance and will have the benefit of reducing energy use, cost, and environmental impact. Based on extensive research and development, this can be achieved through: 1) operating site infrastructure intelligently with artificial intelligence; 2) building 5G with precision and 3) implementing energy-saving software in radio equipment. Furthermore, the lifecycle of network hardware needs to follow a circular approach, where components are designed from sustainable material and facilitate re-use and recycling.

Sustainable, climate-friendly production is also the aim for most other industries, with a target to reduce carbon footprints and environmental impact. Next to the importance of contributing to sustainable development goals, industries can also reap economic profits from investing into green solutions. For manufacturers, this can be achieved through monitoring of production via sensors and derivation of optimization potential in processes which can lead to lower energy consumption and to reduction of scrap and rework.

Every sector of society must work together to reach the global climate and energy challenge. Net Zero is the North Star of climate action and will be key for industry.

Continuous monitoring provides real-time visibility of the status of critical, high-value assets and processes, and enables prompt reaction to potentially hazardous situations. It also allows machine maintenance to be performed proactively instead of reactively. Robotics operations are optimized – and battery life prolonged – by live mapping their locations and routes, thus avoiding collisions and unnecessary slow-downs.

This type of real-time monitoring requires a connectivity infrastructure that guarantees both flexibility and continuity in production, but also reliable transfer of large amounts of data – key characteristics of 5G. 5G is a platform that enables the build-up of cyber-physical systems with a closed feedback loop – beginning with the collection of live production data through different types of sensors in the physical production area, which are then analyzed in the virtual data layer. This is supported by artificial intelligence and ultimately leads to the automatic derivation of actions for the assets in the physical layer. In this session, we will explore how 5G enables automated and connected factories to reduce their environmental impact, while also benefitting economically from reduced resource usage.

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Transforming industry through the industrial metaverse – a catalyst for sustainability

Dr. Annika Hauptvogel
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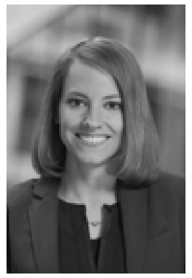

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Connecting people, data and things
The world faces growing environmental challenges, generated among other things by CO_2 emissions. Industry is responsible für 20% of global CO_2 emissions and more than 30% of global energy consumption. Therefore, the industry today is faced with the challenge of reducing both. The „Industrial Metaverse“ will play a major role to tackle these.

The industrial metaverse is the concept of a virtual world to mirror and simulate real machines and factories. It will be a world which is always on, allow for the interaction of an infinite number of people and assets, and offer the full immersion into a physics-based, photo-realistic, and real-time simulation. In this digital environment people can break the barriers of distance and work together across countries and continents, enabling a whole new level of collaboration. Problems can be found, analyzed, and fixed quickly – or even discovered before they arise. And businesses and economies will be able to become more sustainable, driving the decarbonization and dematerialization of product design, their processes, and production.
The industrial metaverse is still a vision, but it will be realized by technologies that exist even today. Digital twins are key building blocks for the industrial metaverse. The combination of several technologies like artificial intelligence, 5G/6G, blockchain, edge and cloud computing as well as augmented and virtual reality will combine the real and the digital worlds even more.

The industrial metaverse will enable a sustainable industry by saving energy, improving efficiency, and reducing waste across all phases of the product lifecycle, which will be shown by different use cases from design & engineering and production to operation & service. All these use cases are interconnected with each other, continuously exchanging data between physical and digital worlds.

During the design phase, the industrial metaverse will allow more collaboration between stakeholders, also involving non-technical stakeholders in the process. That drives the democratization of simulations, allowing experts to communicate more effectively with non-experts. It will be therefore possible to explore designs and manufacturing options more interactively, involving more viewpoints, and to create better resilient products. The whole process will be more efficient and – by trying out different scenarios in a virtual environment before building them in reality – material is saved, and waste is reduced.

The Industrial Metaverse is the concept of a virtual world to mirror and simulate real machines and factories. It will be a world which is always on, allow for the interaction of an infinite number of people and assets, and offer the full immersion into a physics-based, photo-realistic, and real-time simulation.

A major use case in the production phase will be the virtual commissioning of factories: virtually installing and testing of new devices and software without disturbing the ongoing production line. The industrial metaverse will allow to visualize the new equipment in the factory in augmented reality (AR) technologies and simulation of interaction with existing manufacturing assets. Industry professionals will collaborate in real-time, troubleshoot issues before they occur in the physical world, and develop new, innovative solutions which can prevent dangerous situations and enhance worker safety. It will forever change the way we collaborate – within organizations, ecosystems and between firms and their clients and customers and become a key enabler of Industry 4.0. It will enable more testing in the virtual world with fewer resources from the real world. In this way, resilient factories can be modeled and optimized in a virtual environment, reducing the need for physical testing and experimentation. These factories will rely on artificial intelligence and machine learning algorithms to optimize production processes, reduce downtime, and minimize waste.

For operations, the industrial metaverse allows not only the virtual training of the workforce on unusual scenarios, including access to virtual experts at large scale, but also it helps to visualize data and augment information (e.g., virtual sensors) associated with the physical asset though AR technology, using either glasses or a tablet.

The industrial metaverse will disrupt industries and enable sustainability. By leveraging this technology, we can create more sustainable and efficient industrial systems, reduce waste, and promote circular economy principles. Overall, it is a catalyst for building a more resilient, circular, and sustainable future.

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Session 03

Production-as-a-service

The goal of sustainable production is to meet market demand with minimal use of resources and to avoid overproduction.

For production lines, this means that fewer machines must meet demand with maximum utilization of their theoretically possible technical potential, low scrap, and long service life. Furthermore, manufacturing lines and their components must find a sustainable way out of or back into the circular economy at the end of their service life. History-based analysis of production data, using model knowledge, offers enormous potential to make all this possible. With the help of digital shadows, processes can be optimized to minimize their environmental footprint and create green production.

Sustainability in production lines

C. Brecher, M. Fey, M. Loba, O. Malinowski, J. Schäfer

Profound global change processes have increased the demand for sustainable action in recent years. The production industry is confronted with the accompanying sustainability transformation along the FESG factors (Financial, Environmental, Social, Governmental) as well. Within a sustainable market economy, the manufacturing sector will have to face major challenges and develop a new basic understanding of sustainable corporate management.

Goals of a sustainable market economy

It will be necessary for companies to meet the socially reasonable demand for goods and services, e.g. mobility or manufacturing capacity, with a minimum use of resources, and not to strive for maximum possible product sales, as in the past. Furthermore, a long-term goal of the sustainable economy is to reduce the number of products in circulation. By optimizing the utilization of the theoretical potential of the products currently in use, it is possible to meet the current demand even with a reduced number of products. In a production line, the formulated goals for increasing sustainability can be addressed in concrete terms when the following three approaches are pursued: more efficient use, extension of the use phase, and circular economy of means of production.

Measures to increase sustainability in production lines

Drawing up a life cycle assessment of a production line highlights the fact that energy consumption in the use phase is a main driver of resource consumption. Therefore, a more efficient use of production resources is of particular importance to reduce resource consumption. In order to be able to derive concrete optimization measures, in this case for a machine tool as a part of a production line, the power consumption in the use phase and its distribution to main and auxiliary units must be examined. The energy consumption of the auxiliary units, such as cooling and hydraulics units, plays a central role in the energy efficiency of a machine tool. In order to reduce the process-independent base load of these units, the use of energy-optimized systems is required. The next step is to design these systems adaptively. Model-predictive cooling, for example, makes it possible to shorten long warm-up phases of a machine tool and thus to produce immediately within tolerances and reduce energy consumption at the same time. Energy consumption per part can be additionally reduced by minimizing process times through productivity-enhancing measures. Sharing of process knowledge offers enormous potential for increasing the global productivity level of machine tools. For this purpose, expert knowledge regarding optimal operating parameters, for example from process planners or machine operators, must be digitized and objectified and, finally, be made available in transferable form through characteristic values. The comprehensive availability of expert knowledge is then the basis for an increase of productivity and quality.

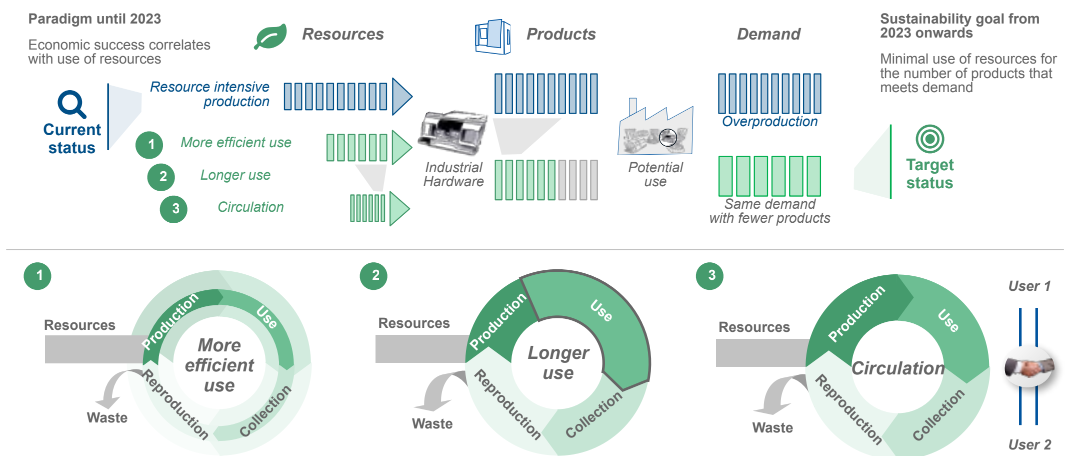

Figure 3.1: Status quo and scenarios to increase the contribution to sustainability

Similarly, this procedure can be applied to extend the lifetime of machine tools and relevant components, such as main spindles. Along the lifetime, load states are recorded parallel to the process. The transferability of the parameters enables the use of machine learning approaches to predict the condition and lifetime as a function of process parameters.
The generated expert knowledge, e.g. in form of information on optimum process conditions for a main spindle, must subsequently be digitized in turn. In this context, the circular economy is also optimized, since component states are known more precisely, less damage or failure occurs. The components can thus find their way into a further usage cycle.
The extraction and digitization of expert knowledge supports companies in the permanent preservation of in-house know-how. The transfer of expert knowledge to new, inexperienced employees is facilitated and the shortage of skilled workers resulting from demographic change is counteracted. In addition, there are opportunities for cross-departmental utilization, for example by using the knowledge of the machine operator in the context of CAM programming. In order to create global competition between companies to share sustainability-enhancing know-how on a broad scale, monetary incentives must be created through new frameworks in the form of new business models.

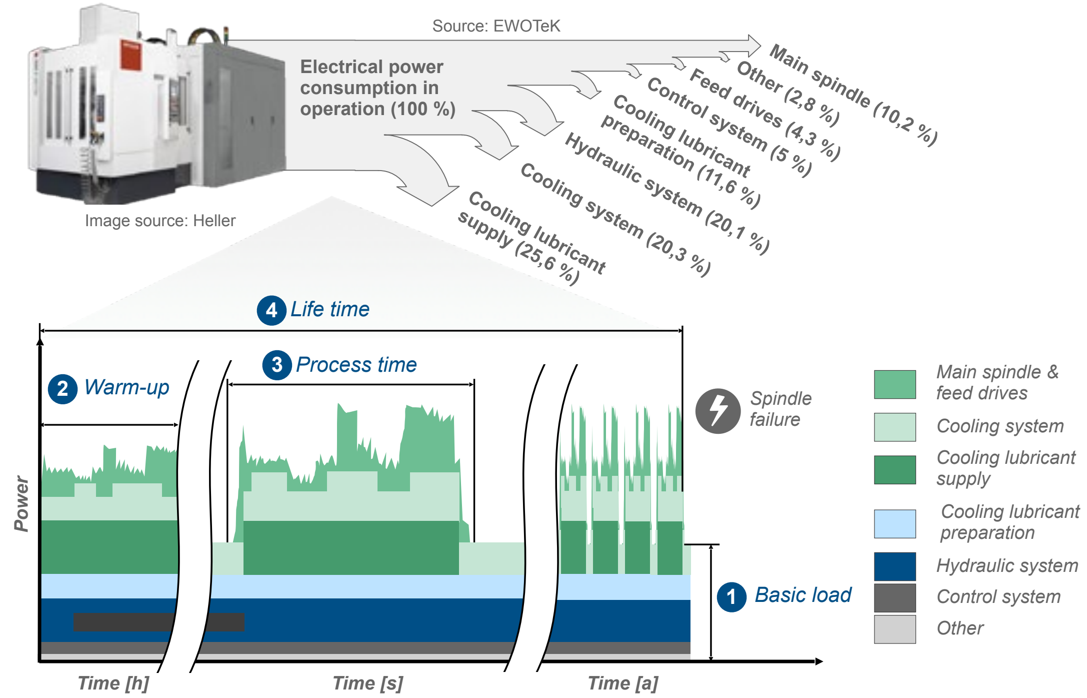

Figure 3.2: Power consumption of a machine tool and targets for optimizing sustainability

Summary

For a successful design of the sustainability transformation, one key lies in minimizing the overall use of resources. Against this background, it will not only be necessary to establish resource-conserving manufacturing of products, but also to reduce their number. This reduction must go hand in hand with the full utilization of the theoretical technical potential, otherwise the required demand cannot be met with a reduced number of products.
The formulated goals can be addressed in production lines when a more efficient use, in particular of auxiliary units, an extension of the use phase, and circular economy of production resources are pursued. AWK'23 presents concrete use cases based on the example of machine tools, which contribute to sustainable, and at the same time future-proof production through various measures within the three approaches.

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Keynote Session 03

Sustainable production-as-a-service

C. Brecher, O. Petrovic, P. Blanke, Y. Dassen, M. Trinh, S. Wurm, C. Alt, F. Breitenbach, T. Buchner, A. Engels, M. Kaldenhoff, S. Rekers, R. Schares, T. Taubert

Industrial production contributes significantly to global CO_2 emissions, which is why a shift towards sustainability is necessary in order to achieve climate targets and limit the global temperature increase to 1.5°C. Increasing efficiency, conserving resources, and avoiding overproduction are economic goals that are now also increasingly coming into focus in the context of sustainability.
The use of digital technologies can address these goals and offers the opportunity to enable the application of previously underutilized potential regarding sustainable and circular production.
Digitization is an overarching solution module that allows the collection and evaluation of data, e.g., on the energy consumption of individual processes or machines, and thus allows the identification of critical processes. Optimized production processes can be developed on this basis. However, the full potential can only be unlocked if a holistic data collection is carried out across the complete life cycle of a product. Data from the use phase, for example, can be fed back into engineering to ensure that the design is tailored to the requirements. Conversely, product information enriched by production and usage data can be used in downstream remanufacturing or recycling, for example in automated disassembly, thus enabling the return of components and raw materials to further life cycles.
Building on this, virtualization offers the potential to significantly extend the life cycle of production systems through the digital abstraction of physical components. Required functionalities of control systems, computing capacity, or evaluation modules can be flexibly switched on or off and are thus only used when needed. In addition, maintenance and updates can be carried out more easily, thus ensuring prolonged software functionality. In combination with an enriched digital twin of a machine, virtualization can also be used to realistically map control programs, and the corresponding system behavior, in a simulation. This can be used to reduce the number of iterations during ramp-up and to optimize the operating point.

Virtual environments such as the metaverse, in which the physical and digital worlds merge, are another promising digital technology. By using mixed reality technologies, the metaverse enables multisensory, dynamic interaction with 3D virtual environments, digital objects, and people in real time. In an industrial context, the metaverse can be used to simplify planning processes for products, plants, and entire factories, and to enable stakeholders to validate their developments before they are physically realized. Photorealistic renderings can also be used to generate synthetic data for training AI algorithms for use in vision systems, and physical and event-based simulations can be used to optimize operating parameters or virtually commission plants.
Furthermore, the application of artificial intelligence (AI) in engineering and production offers companies numerous possibilities for efficiency increases along the product life cycle. There is great potential in the optimization of the sustainability and lifespan of products. AI systems can help to develop products in such a way that their usage phase is extended and fewer resources are consumed in their production. In manufacturing, AI systems can help reduce energy consumption and minimize the production of scrap. In this way, companies can not only increase their competitiveness, but also contribute to conserving resources and reducing their ecological footprint.

What prevents sustainable production?

So, what is preventing small and medium-sized enterprises (SMEs) in particular from using these seemingly tangible digital solutions? The occasional high investment requirements, or the lack of transparency regarding the return on investment, and the lack of the necessary expertise regarding the implementation and maintenance of digital technologies inhibit many SMEs from implementing them. At the same time, sometimes fluctuating customer demand as well as unstable supply chains and the associated production downtimes require a certain flexibility and agility, which are opposed to long-term investments.

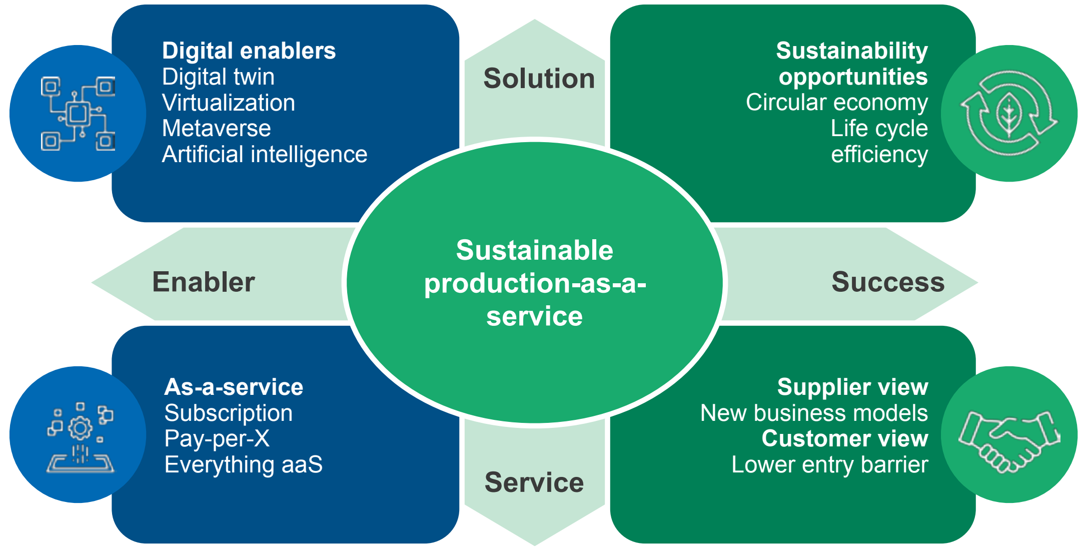

Figure 3.3: Sustainable production-as-a-service

As-a-service as an enabler for sustainable production

This circumstance can be countered with the encapsulated offering of digital solutions “as-a-service” (aaS): On the economic side, the associated payment models offer companies entry points with significantly reduced financial risk, while the demand-driven use of resources promoted by aaS supports sustainability. The customer gets the opportunity to try out a wide range of digital technologies, physical assets and associated services to find an optimal solution. By returning the product after its life or use cycle, the supplier is empowered to reprocess the product or individual components in the spirit of the circular economy and feed them into the next use cycle. Alternative distribution systems, such as machine sharing, also enable higher utilization of products or production systems. While aaS-based solutions enable the customer to bridge short-term interruptions in business operations, they open up opportunities for the supplier to tap into new customer groups.
In this article, the potentials regarding sustainability increases of digital enablers as well as the boundary conditions of the implementation are presented in order to subsequently illustrate the use in aaS models with practical application examples.

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Expert Session 03

Quantification of sustainability impact

T. Bergs, P. Niemietz, J. Mayer, J. Moon, D. Gelbich, J. Gerhard, T. Kaufmann, A. Peters, F. Seiferth

Quantification as a need for decision making
The global shift to a sustainable economy comes with a shift from a solely productivity- and efficiency-driven logic to a more sustainability-focused approach. However, the introduction of new technologies to the operations of a company not only impacts the total sustainability balance of a company's own operations, but potentially also impacts the sustainability balance of their partners. When investment decisions for the introduction of new technologies are required to take their sustainability impact into account, the possibility of a quantification thereof is imperative.
Through a comprehensive examination of a use case in the sheet metal supply chain in automotive, this contribution aims to shed light on the difficulties in assessing the sustainability impact of technologies by focusing on a use case in sheet metal forming, where the introduction of a technology has the potential to yield significant economic and ecological ramifications. The sheet metal processing industry in Germany is facing disruptive developments, I) the transition to a green economy; II) demographic change; and III) the diversification of future powertrains in the automotive industry. In short, this is problematic, because the parametrization of stamping processes for incoming material, for example, is still largely a matter of experience and therefore implicit knowledge rather than explicit knowledge of the underlying cause-effect relationships. In an environment where changes are common in I) incoming materials (grades) due to innovations in steel production, II) the supply of highly skilled labor coupled with an increased need for interdisciplinary expertise, and III) component requirements, this can drastically affect the reliability for business model critical tasks of evaluation based on heuristic experience.

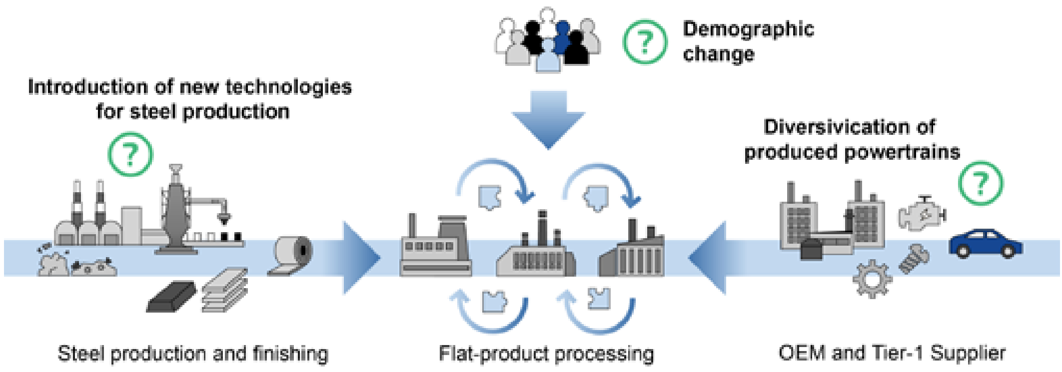

Figure 3.4: Current situation in the supply chain

Continuous material data as a means to collaborate
Specifically, the focus is set on the implications of the potential of introducing a technology for time- and spatially resolved characterization of the mechanical properties of flat steel products in the context of these challenges. A complete characterization and transparency of steel material enables a knowledge-based parametrization of forming processes based on data, a data centric collaboration between material suppliers and processing companies, as well as the optimization of material used along the entire chain up to potentially the finished product. However, currently, three major deficits exist that oppose the potential of this technology:

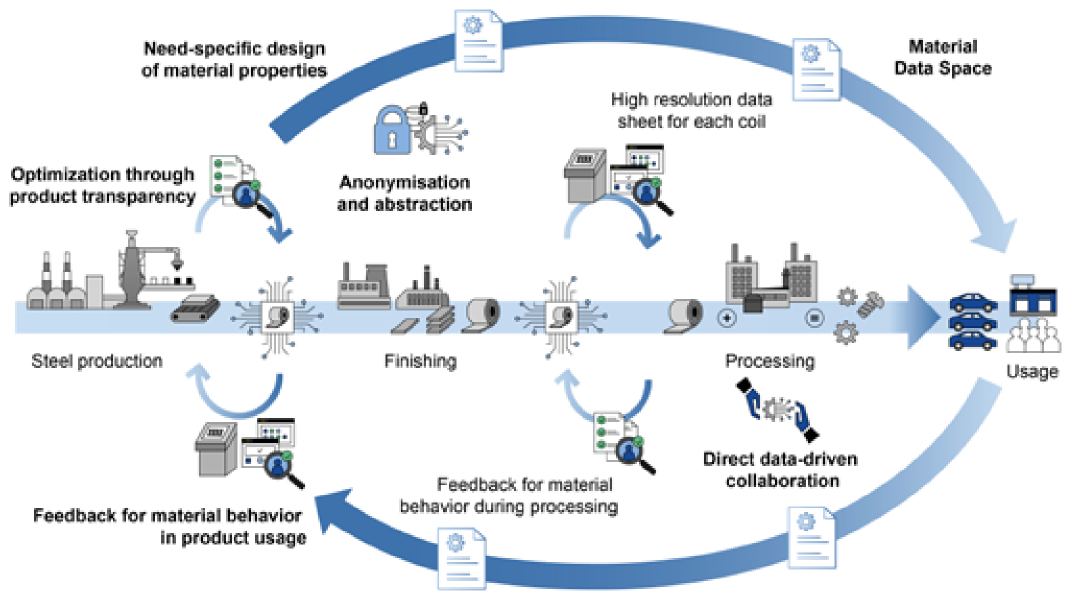

Figure 3.5: Optimizing supply chains through material data sharing

Lack of methodology: Non-destructive measurement systems for mechanical properties of flat products have existed for quite some time, but a methodology for utilization of the information contained in the complex signals acquired using such systems is missing. Without a methodology to condense the information, as well as to relate it to mechanical properties critical for the setup of complex manufacturing processes, the potential is inaccessible.
Lack of knowledge: When it is not possible to describe a methodology for characterizing the flat-product in the required detail, in the case of material-related issues, manufacturers rely on implicit knowledge gathered through experience to customize the applied process parametrization. With information available, chances are that explicit knowledge that can easily be expressed and transferred can be acquired and maintained sustainably.
Lack of digital integration: If sharing of material data is limited within the supply chain, there may not be enough collaboration to enable need-driven material selection. This lack of collaboration could hinder the creation of a feedback loop that would empower the steel producer to manufacture steel that aligns with the specific requirements of the application.

Outlook
The vision presented in Figure 3.5 highlights the potential of an understanding and use of data for the sheet metal processing supply chain. The use of non-destructive measurement systems for mechanical properties of steel enables the detailed characterization of flat products in detail. Based on this, the parameterization of the manufacturing processes to the specific individual profile of quality for each coil can be implemented, while simultaneously data sharing between the stakeholders in the supply chain is supported by initiatives such as Catena-X. This, together with the results of an industrial use case presented in the manuscript, indicate the potential of utilizing non-destructive measurements for transparency and process optimization and parametrization. However, even with the knowledge of the potential practical impact, the decision to invest in this is complicated by trust issues for SMEs in trust along the supply chain, availability of resources to develop digital innovations in interdisciplinary scenarios, and a highly cost-sensitive Industry like automotive. In this context, it is essential to quantify the sustainability impact of any new technology. However, such quantification is often not readily available, leaving decision-makers to rely on their intuition and feelings when making sustainability-driven investments. This highlights the need for better methods to measure and communicate the sustainability impact of new technologies, which would enable decision-makers to make more informed choices.

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Impulse Session 03

Session 04

Circular production economy

Circular value creation enables economic growth to be decoupled from resource consumption by maximizing the reuse and recycling of resources used in the production cycle. Up to 95% of the resources required compared to a new product (e.g. materials, personnel or energy) can be saved through circular value creation.

To ensure the highest possible resource conservation, manufacturing companies must increasingly consider not only newly produced primary products but also returned products as the starting point for their value creation. Maximum value retention of products, components and materials can be achieved by dedicated utilization of the potential service life by means of economic reuse, recycling or reprocessing. The central challenge is to identify the most suitable scenario in terms of sustainable production. For this purpose, digital shadows are required which provide clearly mappable basic information from development, primary production, multiple use, and reproduction cycles in real time. New product modularization, industrialized re-production processes and circular business models are further key enablers for the sustainable design of circular value creation.

Framework for circular production economy

G. Schuh, S. Schmitz, G. Lukas, M. Welsing, L. Niwar, R. Calchera

Introduction
The circular economy makes it possible to decouple economic growth from resource consumption through maximum reuse and recycling of the resources used in the production cycle. Up to 95% of the resources required in comparison to a new product (e.g. materials, personnel or energy) can be saved through circular economy. To ensure the highest possible resource conservation, manufacturing companies must increase consideration of recycled products - in addition to new products - as the starting point for their value creation. Maximum value preservation and value enhancement of products, components and materials is attained through dedicated utilization of the potential service life by means of economic re-use, recycling or reprocessing. Circular economy not only preserves value but also increases it. Complex series products such as cars, household appliances or machines can be systematically upgraded for a second, third or fourth life without customers having to forego additional services and attractiveness. Only 10-30% of the components of a complex serial product would have to be replaced in order to upgrade it to almost the same value as the current new product. The value-adding circular economy differs from the intuitive understanding of the circular economy in that it is not mainly raw materials and energy to be recovered from used
products, but rather used products and machines are industrially upgraded in a targeted manner and used for significantly longer.

Counterintuitive approaches to economically profitable sustainable production
Previous approaches have already significantly mitigated the negative environmental impacts of production. The digital shadow, which has been researched in the Aachen Cluster of Excellence Internet of Production, creates the conditions for now raising the by far greatest sustainability potential of industrial production. In order to succeed, the digital shadow of our products and their production processes must be developed and expanded. This can be achieved by improving the specificity and classification of product components and expanding the usage of data throughout the entire life cycle. Product files and their extracts must be easily accessible, effectively controlled, securely stored and efficiently transmitted in the internet of sustainable production, enabling access to countless industry and domain data lakes. The selection and aggregation into real-time capable digital shadows create the prerequisites for a wide variety of evaluation, optimization and decision-making algorithms for sustainable production.
For sustainable production to be economically profitable, new counterintuitive approaches are needed. So far, goals such as energy savings, efficiency improvements and scrap avoidance have been associated with sustainable production. These goals are important, but do not sufficiently reduce the environmental impact of production. Such a reduction is only possible within the framework of the circular economy. For this, the classic understanding of circular economy with reference to waste management and recycling must be expanded to include life-extending measures. Life-extending measures on the product require up to 50% less resources used in industrial production (raw materials, energy, means of production), save corresponding emissions from the production processes, and thus offer a higher benefit both economically and ecologically.

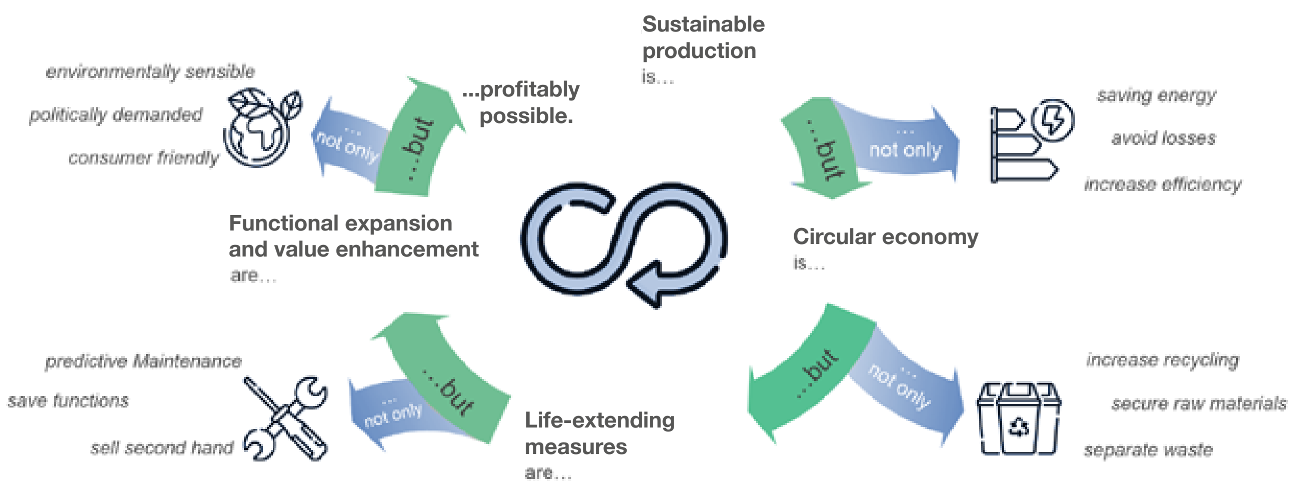

Figure 4.1: The counterintuitive profitability of sustainable production

Functional extension and value enhancement
Established measures to extend product life are usually aimed at maintaining functionality. For example, a product can be used longer through anticipatory maintenance and timely repair, or it can be resold second-hand to a second user. On this second market, however, used products do not fetch the same price as new products. One important reason for this is that new products with new functions offer more value to customers. In order for the circular economy to prevail in this area, it is therefore necessary to extend the functions and increase the value of used products. By replacing some components in time with new or refurbished components based on digital process files, not only can the functional capabilities of the products be maintained for longer, but new, improved functions can also be incorporated. Accordingly, the prod-uct is given a second or third life in an upgrade re-assembly factory by introducing updates and upgrades into the product. This extension of functions not only makes ecological sense but is also an important enabler for profitability due to the associated increase in value. For example, the lower material, production material and energy expenditures reduce costs without an associated reduction in sales volume, as the value is retained.

In this combination, the counterintuitive approaches presented in Figure 4.1 enable production that is sustainable and profitable.

Conclusion
The central challenge is to identify the most suitable scenario in terms of sustainable production. This requires digital shadows, which provide clearly mappable basic information from development, primary production, multiple use, and subsequent re-production cycles in real time. New product modularization, industrialized re-production processes in an upgrade re-assembly factory, and circular business models are further central enablers for the sustainable design of circular value creation. Through the utilization of a value-adding circular economy with the help of the internet of sustainable production, the ESG criteria can be achieved many times better than with the classic approaches of the circular economy. At the same time, the economic efficiency of industrial value creation can be significantly increased. The framework for circular production economy represents a guiding framework for the long-term sustainable production of products and components in the sense of a value-adding circular economy.

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Keynote Session 04

Green re-assembly upgrade factory

G. Schuh, W. Mauß, T. Potente, S. Schmitz, T. Adlon, J. Maetschke, H. Neumann, J. Salzwedel, S. Kozielski, M. Luckert, C. Reuter, M. Schmidhuber, J. Witthöft

The existing linear economic system, with its "take-make-dispose" principle, is often unsustainable and strains the earth's finite resources. For a meaningful paradigm shift towards a more sustainable upgrade circular economy, it is necessary to implement more comprehensive measures than isolated approaches aimed at reducing resource consumption. Production technology can realize an enormous sustainability potential when complex mass-produced products such as cars, household appliances, machinery, and plants are systematically upgraded for a second, third, or fourth life without customers having to forego increased performance and attractiveness of newly emerging products. To achieve this, it is necessary to allow for functional and value enhancements, i.e. upgrades, in the re-production process.
The "Green Re-Assembly Upgrade Factory" locates such upgrading function and value enhancement in a building that is equally function- and value-enhancing, with the longest possible life cycle and most resource-efficient operation.

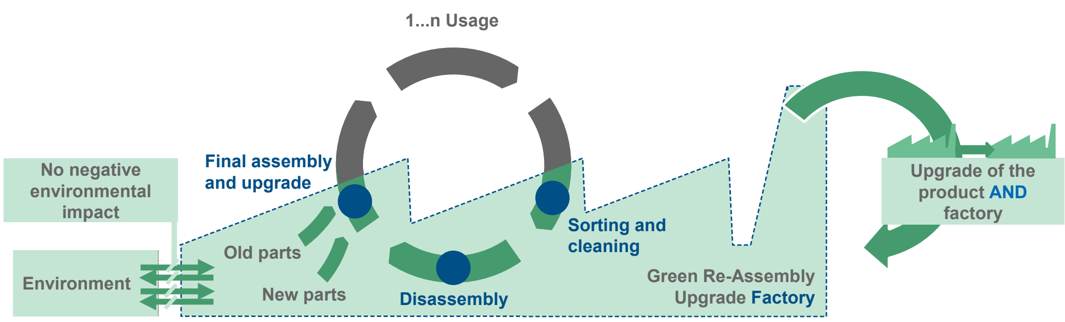


Figure 4.2: Re-production and upgrading in the green re-assembly upgrade factory

Product uncertainties and lack of sustainability transparency in re-production
At first sight, product processing appears to be economical only for products with a high material value and initial production and development costs, such as aircraft turbines or cruise ships. To enable functional- and value-upgrading re-assembly of products of lower value, a significantly higher degree of industrialization is necessary. This generates a higher utilization of resources and enables economies of scale similar to new production. It can be achieved by separating planning and execution of the necessary activities, as is common in industrialized production. But it is complicated by uncertainties regarding the condition and quantity of the returning products. Detailed information on the working time required and the spare parts needed in reprocessing only exists after inspection of the return. Fine planning of production can therefore only happen afterwards. The resulting informational asymmetries inevitably lead to higher inventory levels, process costs, and longer lead times and must be reduced through digital continuity by establishing data structures that span lifecycle phases – also known as the digital product record.
Although regulatory and societal pressure is driving manufacturers to adopt more sustainable practices, there is often uncertainty about where the greatest potentials in production are located and what measures are necessary to unleash them. Addressing this requires greater transparency about resource consumption in terms of quantity and location, as well as the long-term ability to repeatedly adapt buildings to new scopes. Additionally, new or modified metrics can help shift investment decisions toward more sustainable solutions. For example, including embodied "grey energy" of building materials, environmental impact, and the external societal emissions costs in existing KPI systems can encourage longer-term and more sustainable building solutions.

Life-cycle-wide data consistency and innovative processes
Across stakeholders, the digital product record connects data from the development (bill of materials, interfaces, etc.), production (component properties, process parameters, etc.), and various usage phases (operational lifespan, load profiles, etc.). Achieving this requires clear identification of relevant assembly groups and modules, coupled with easy data access.
The challenge for re-assembly upgrade processes is often to automate and industrialize as in the production of new products. An example is the complex removal of "non-detachable" material-locking screws or rivets. New time- and resource-saving processes, such as adaptive automation, must be developed and tested. This is vital to the industrialiation and optimization of re-assembly upgrade processes.
The unique challenges and complexities involved in the re-assembly upgrade process require a production building that is specifically tailored to its needs. Greater buffer and logistics areas are needed to accommodate process uncertainties and the deliv-ery of old and new parts. Flexibility and long-term adaptability are necessary to re-assemble multiple evolving products in the same building. Planning for a resource-efficient building life cycle of an upgradeable green re-assembly upgrade factory must consider durable building materials, continuous monitoring of building performance data, implementation of adaptable factory standards, and the use of building materials after the factory life cycle. In this regard, Building Information Modeling (BIM) can support all phases of the factory's life cycle by integrating relevant building data into an interdisciplinary model that describes both the building and its operation. This enables continuous monitoring and the realization and evaluation of measures for a more efficient and sustainable building operation.

Implementing a sustainable and profitable green re-assembly upgrade factory
To continuously realize product innovations and increase customer benefits, a specifically value-enhancing form of circular economy is required. Re-Assembly upgrade processes can save up to 50 % of all resources used in industrial production of new products and increase value creation per employee, for example in vehicle production, by about 30-60 %. This results in both sustainable and contemporarily profitable production by increasing margins.
However, its industrialization still faces challenges in terms of plannability and process implementation. Additionally, there is a lack of building concepts that enable such industrialized production to be resource-efficient in the long term. To overcome these challenges, it is necessary to adopt creative and innovative dismantling process solutions, ensure consistent data availability in production and buildings, and focus on factory planning that extends the building life cycle and enhances its functions.
Successful-practice examples from industry experts provide clear evidence of how a green re-assembly upgrade factory already enables value enhancement with minimal resource consumption. In addition, these case studies serve as valuable examples of how upgrade circular economy principles can be industrialized and inspire other manufacturing companies to consider similar approaches.

Download full conference paper
Expert Session 04

New quality paradigm for sustainable production

R. H. Schmitt, F. Sohnius, M. Padrón, R. Günther, J. Keens, D. Buschmann, R. Trappmann, A. Hauptvogel, P. Jatzkowski, F. Lesmeister, Y. T. Mertens, F. Quito, J. Rauchenberger, S. Stinner

Manufacturing companies are increasingly confronted with challenges regarding energy supply, monitoring global supply chains, and responsible use of limited resources. The resulting uncertainties are exacerbated by disruptions in the supply chain triggered by resource scarcity, political crises, and the already perceptible consequences of climate change. Furthermore, companies need to consider sustainability-oriented demands regarding environmental, social and governance (ESG) criteria from external stakeholders in addition to financial concerns. These challenges call for an improved way of managing manufacturing companies and steering their activities.

Paradigm shift for manufacturing companies

An essential prerequisite for the long-term success of companies is not only the flexibility and adaptability of their organization to changing conditions but also the adaptation and positioning of products according to changing customer needs. At the same time, companies need to operate to increase profits in the long term while permanently securing liquidity and coping with growing sustainability demands.
Due to the factors mentioned above, stakeholder management is becoming increasingly complex with regard to efficiently coping with ESG requirements. Consequently, management decision-making requires mechanisms to identify and evaluate key stakeholders and consider the associated requirements as part of target-setting and strategy development processes. The realignment triggered by legal and external requirements calls for a corresponding transformation of corporate identity at all levels, and sustainability principles need to permeate the entire operational level of manufacturing companies.
Over time, quality management has proven itself capable of transforming stakeholder requirements into quality requirements and subsequently translating them into management and operational activities within a company. Due to its interdisciplinary and cross-functional nature, quality management offers the best prerequisites for supporting a sustainability-oriented transformation. Despite all this, the current quality management mechanisms need to be further developed to meet the changing market conditions.

Quality management as part of the sustainability transformation

The Aachen Quality Management Model (ACQMM) offers a framework for the design of quality-oriented activities and can be used to analyze the levers for internal company changes. It is based on three perspectives of a company: the market perspective, the management perspective, and the operational perspective. To understand the market perspective, the various interest groups of a company can be analyzed using a materiality matrix, which represents both the relevance of sustainability for the stakeholders and the impact on the company's business activities. Sustainability as well as original quality requirements can be divided into must, should and can requirements, based on the existence and growth implications of fulfilling the needs for a company. In addition, a temporal development from optional to mandatory requirements is derived.
The evaluation of the requirements from the market perspective is translated into targets and decisions by the company management. As a result, the company's quality policy and system quality requirements are shaped accordingly, while the operational implementation of quality objectives influences the design of process quality. This concerns, in particular, the definition and the understanding of quality criteria in the functions quality planning, quality assurance, quality control, and quality improvement. The classic methods and tools from quality management can be adapted and expanded with an increased ESG focus. Here, interactions arise between the requirements of the product development process regarding environmental sustainability and the design of quality requirements and activities. R-strategies such as "Reuse", "Refurbishment", and "Remanufacturing" can be mentioned here as an example. To successfully implement the measures outlined, suitable structures for the generation, management, and use of relevant data are required. The importance of data is demonstrated using the example of the exchange and reporting of Product Carbon Footprint (PCF) data based on the Sigreen solution from Siemens AG. In this context, the purposeful design of data systems and data fidelity are evaluated as further ESG-related quality criteria in a company's system and process quality. It is further assumed that these quality dimensions are prerequisites and success factors for successfully implementing cross-company sustainability initiatives.

Accordingly, a sustainability-oriented definition of the requirements for the systems, quality functions and methods is necessary. For this purpose, analyses embedded in existing sustainability-oriented standards and legal requirements can support an effective and efficient interpretation of stakeholder requirements. In an increasingly digitalized economy, data is becoming the basis and a key factor for enabling internal and external sustainability initiatives. The ability to derive purposeful action from the perception of information reinforces a shift from quality management to quality intelligence.

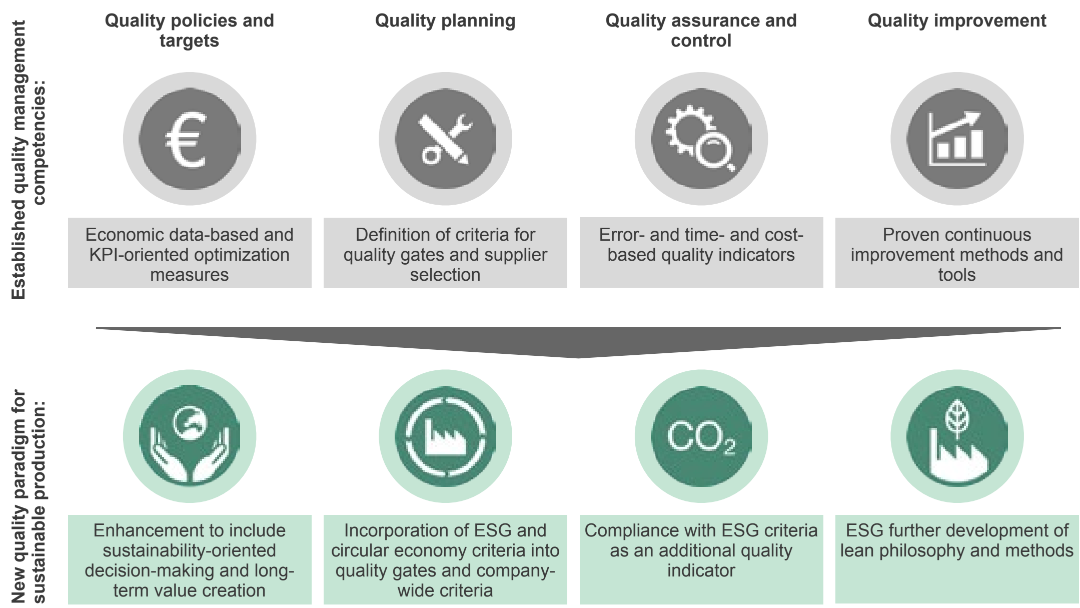


Figure 4.3: Paradigm shift for quality in sustainable production.

The shift of quality management to quality intelligence

The systematic and process-oriented implementation of sustainability-oriented targets does not require a fundamental redesign of existing mechanisms and methods but rather a redefinition and extension of the current understanding of quality and quality assessment. Both the design of sustainability-oriented management systems and the operational implementation of initiatives can be supported by existing systems, methods and tools of quality management.

In the long term, a rethinking of sustainability and quality will be required both at the level of employees as enablers and at the level of consumers as buyers. In addition, innovative concepts are needed to enable sustainability initiatives within the company for cost-efficient production. Here, research collaboration and the promotion of ecosystems for testing and validating new concepts are necessary. A realignment of the understanding of quality can represent an opportunity to develop and introduce new sustainability-oriented business models for manufacturing companies.

Download full conference paper
Impulse Session 04

User stories in circular production

The panel discussion will debate the contribution that user stories as digital product files can offer towards profitable circular production. The discussion centers on the question of whether systemically conceived user stories can be implemented by SMEs at all – or whether this will remain an exclusive tool for global players.

We have to stop taking too narrow a view of sustainability – we will only realize the real "double-digit loot" when we manage to achieve an alignment of ecological and economic objectives in the value creation system by means of circular production!

Prof. Dr.-Ing. Dipl. Wirt.-Ing. Günther Schuh

Director of the Chair of Production Engineering,
WZL | RWTH Aachen University and Director, Fraunhofer IPT

Host

Digitization is the most important lever for successfully implementing circularity – from design and production to sustainable operation and recycling.

Dr. Annika Hauptvogel

Head of Technology and Innovation Management,
Siemens AG

Co-Host

We already have all the tools for greener production today. To make our contribution, we need to think and act in a consistently sustainable way. It comes down to all of us.

Dr.-Ing. Philipp Jatzkowski

Head of Quality and Metrology Consulting,
Testo Industrial Services GmbH

We need transparency and knowledge transfer in the supply chain to jointly develop trust across company boundaries. The result is sustainability in the most efficient use of resources, which is also economically successful. For this, the interaction of technical expertise and academia is essential.

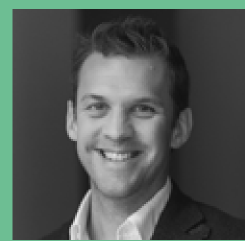
Jens Gerhard

Head of Technology & Process Development,
Feintool System Parts Jena GmbH

Circular production will require even greater digital networking across corporate boundaries. In Europe, we therefore urgently need to work on our digital sovereignty to reduce dependency in the area of critical digital infrastructure. Otherwise, we face the risk that production facilities designed "as a service" will soon be able to be shut down at the push of a button.

Dr.-Ing. Tilman Buchner

Partner & Director - Global Leader Innovation Center
for Operations, The Boston Consulting Group



Plenary Talk 05

Investing in the technology champions of tomorrow

Dr. Elisabeth Schrey
Managing Director, DeepTech & Climate Fonds

Year of birth:
1989

Current position:
since 2023 Managing Director of Deeptech & Climate Funds, a public investment fund of up to Eur 1bn for technology-enabled companies in the early growth stage

Previous positions:
2020-2023 Principal at btov Partners' Industrial Technology Fund, a private fund with Eur 100m for European startups in the industrial technologies
2017-2020 Investment manager at TechVision Fund in Aachen, a private fund with Eur 55m for early-stage technology enabled startups in Aachen, Cologne and Duisburg

Studies:
2017 PhD in innovation management, WZL | RWTH Aachen University
Until 2013 Bsc. and Msc. in Industrial engineering at RWTH Aachen University

Many young entrepreneurs dedicate themselves to the challenges of our society and economy. In particular, companies with disruptive technologies or new resource-saving business models have longer commercialization cycles and greater capital requirements.

Investments in such companies enable a rapid transformation into a resource-saving and climate-neutral economy. This transformation is fraught with uncertainty and risk, but it is also the greatest opportunity for our economy.

With growth capital and long-term commitment, we want to contribute to developing independent and successful technology champions in Germany and Europe.

With growth capital and long-term commitment, we want to contribute to developing independent and successful technology champions in Germany and Europe.

Imprint

Empower Green Production
31. AWK – Conference Abstracts

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About this book

"Empower Green Production” is the guiding theme of the 31st AWK, which will point the way to a value-adding circular economy in four parallel lecture series with a total of twelve technical and keynote lectures as well as eight plenary lectures from science and practice from May 11 to 12, 2023.

This conference abstracts use numerous concrete examples from current industrial and research projects to describe which technologies and strategies will promote this transformation, how companies can select their individual tools for the change from the wealth of methods available, and which challenges applied production research can specifically support. The four central thematic blocks of the AWK include contributions on high-performance and resilient data infrastructures, on modeling and analyses with the aim of more resource-efficient manufacturing, on scenarios and business models for sustainable value creation, and on technologies and processes for a value-adding circular economy.

This book summarizes the contents of the lectures, makes it avaccessible and intends to inspire the scientific community and the interested specialist audience in the form of an open access publication. Its individual contributions were compiled and elaborated by the staff of the Laboratory for Machine Tools and Production Engineering WZL | RWTH Aachen University and the Fraunhofer Institute for Production Technology IPT together with renowned experts and speakers from industry, economy, science and politics.

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