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UNLOCKING SUSTAINABLE PRODUCTION THROUGH DIGITALIZATION AND AUTOMATION

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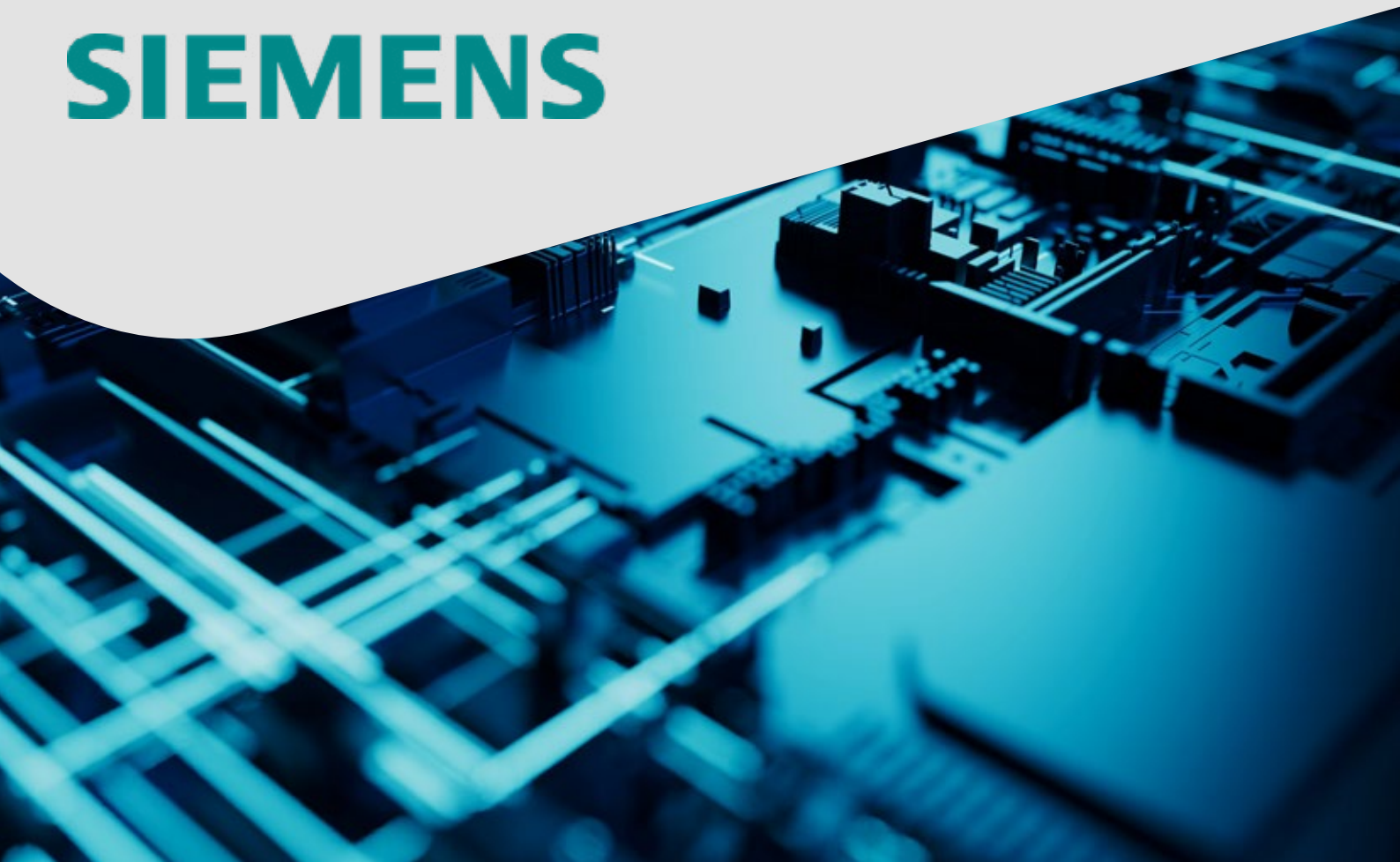
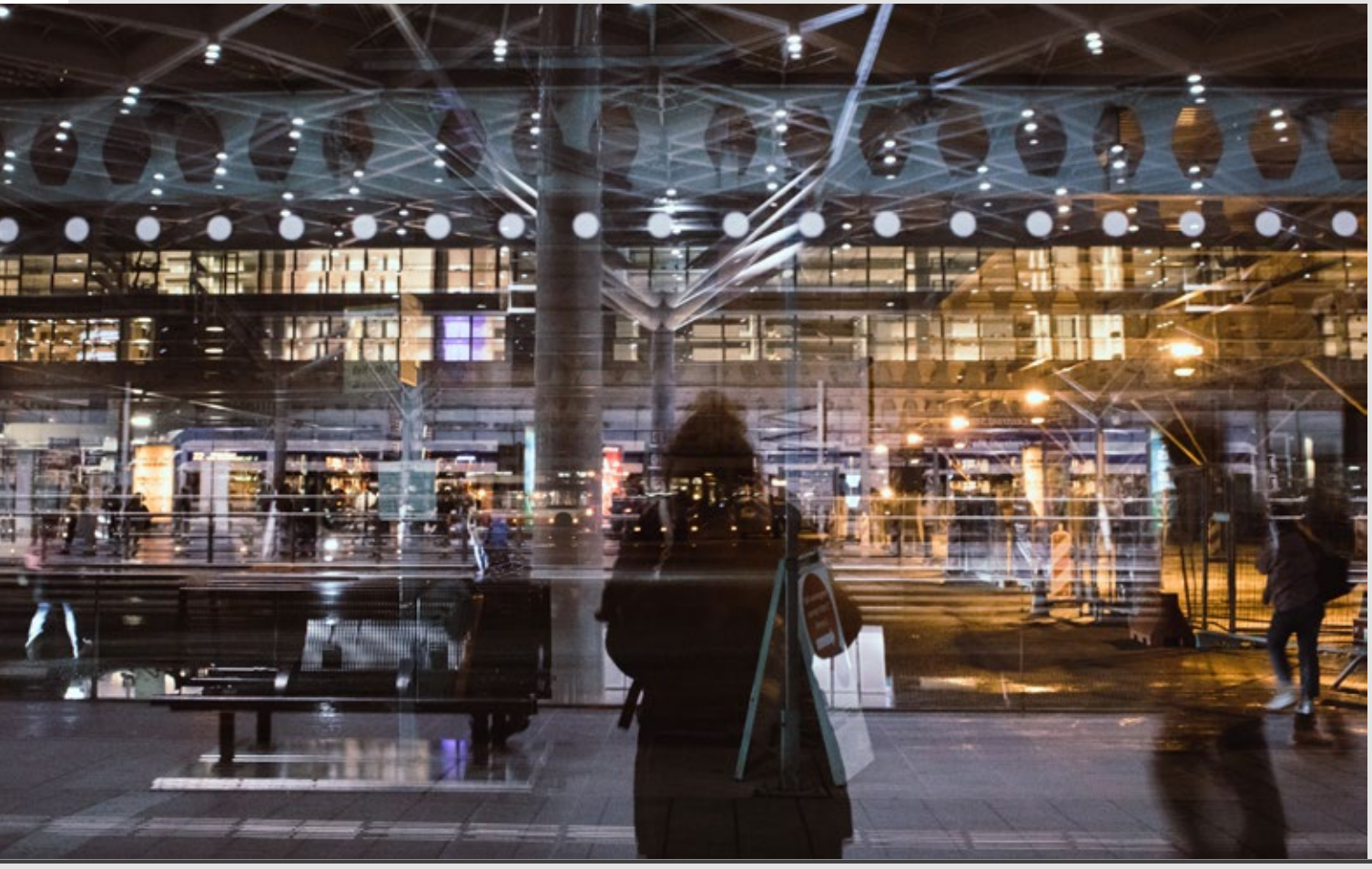


INTRODUCTION

The modern world relies on production. Goods must be manufactured so they can be bought and sold. In today's highly competitive global economy, this manufacturing has become highly focused in a few territories where production can be achieved most cost effectively based on access to fiscal incentives plus low-cost labor and materials.

As of 2019, the world's top five manufacturing nations were responsible for more than 61% of global production, with one country—China—accounting for almost 29%.[i] The highly concentrated nature of manufacturing takes a toll on the natural environment and local communities, which were never designed to support such intensive levels of activity and may not always offer the most sustainable conditions for production.

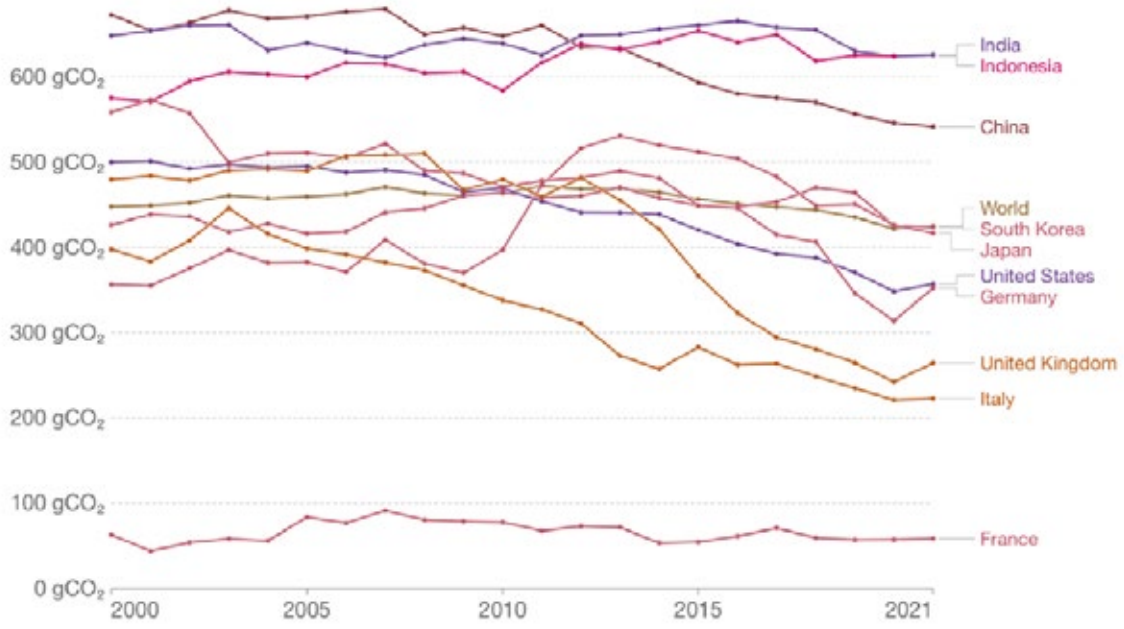
As the world struggles to reduce carbon emissions and quell a range of other major environmental impacts, it is becoming increasingly clear that manufacturing must become more sustainable. This paper, produced in association with industrial automation and digitalization leader Siemens, looks at how this sustainability could be achieved with the help of digital tools.



THE NEED FOR MORE SUSTAINABLE PRODUCTION

CARBON INTENSITY OF ELECTRICITY, 2000 TO 2021, MEASURED IN GRAMS OF CO_2 PER KILOWATT-HOUR OF ELECTRICITY, FOR THE WORLD'S TOP 10 MANUFACTURERS.

Source: OurWorldInData.[ii]



Global production consumes 54% of the world's energy sources and produces therefore a big stake in world's carbon emissions,[iii] even after decades of effort and investment into lean and efficient manufacturing processes. Based on modelling by the Intergovernmental Panel on Climate Change, these emissions must be reduced to net zero by 2050 if the world is to avoid the worst impacts of climate change.

Emissions are just one dimension where improved sustainability of manufacturing is required. Natural ecosystems are also struggling with resource depletion and pollution, both of which are exacerbated by unsustainable manufacturing processes. Since a wholesale transfer of manufacturing capacity to optimally sustainable locations seems unlikely and may not even be possible because of scale, today's production processes must embrace sustainability through other means.

One of these is circularity, whereby the waste of products from manufacturing are used as source materials elsewhere. Digital tools will play a vital role in improving circular and other sustainable processes.

INTRODUCING COLLECTIVE INTELLIGENCE

Today's production techniques are already highly efficient, having gone through decades of innovation and optimization. Given the importance of continuing improvements in efficiency, manufacturing thought leaders such as Siemens are increasingly advocating a move from plant-level, silo-based views to collective intelligence. This involves linking production and energy data, and analyzing it across industrial operations so asset owners can make data driven decisions.[iv]

Collective intelligence, enabled by digitalization and automation technologies, allow manufactures to make smarter decision. In the context of production, it is vital to look at operations as a system that can be optimized, and then to place this within the context of your wider supply and distribution value chains. KPIs must then be optimized and holistic, considering energy use, waste and water use, balanced against traditional drivers of cost and performance.

Three prerequisites are key to the development of collective intelligence:

- A system-of-systems approach to products and their environmental impact, considering production, use and next life to drive intelligence from across the entire product lifecycle and then using digital tools to continuously learn and drive innovation.
- Connected industrial ecosystems that allow carbon intensity and resource utilization to be tracked up and down value chains, from suppliers and distributors to energy producers and recyclers, capturing opportunities to partner, co-create and grow sustainably.
- Holistic sustainability indicators that leverage data from product lifecycles and industrial ecosystems to model a path towards better environmental outcomes, balancing considerations such as product carbon footprint, performance and profitability.

THE KEYS TO SUSTAINABILITY

Manufacturers are already moving to use renewable energy supplies and adopt more circular business models, such as using metal scraps for additive manufacturing.[v] Digitalization and automation allow manufacturing to achieve new levels of circularity and sustainability across four dimensions:

- **Energy use,** considering not only plant efficiency but also wider interactions between assets and the grid, for example to capture and reuse waste heat or maximize a factory's ability to self-consume renewable electricity generation, to shift production to times when renewables are available, and/or to curtail demand in response to power pricing.
- **Planning and optimization of production lines** and manufacturing facilities. Even heavily optimized plants may be able to achieve startling new levels of efficiency using technology tools such as digital twins. These allow for almost unlimited scenario modeling at low economic and carbon intensity cost, and therefore enables management of the full Product Carbon footprint.
- **Local and flexible production and innovation**, based on emerging concepts such as modular production, additive manufacturing, automated, guided vehicles (AGVs) for dynamic and scalable processing, and the use of artificial intelligence (AI) to improve resource utilization . This also allows for detection of anomalies in energy usage and production, ensuring that less or no energy is 'wasted' and thus less carbon it emitted.
- **Service engineering,** including developments in field and maintenance services, spare parts provision, repairs, retrofits, modernization and energy efficiency consulting. More widely, digital tools can help companies move to predictive maintenance models that reduce wastage and prevent downtimes.

Digital tools can yield improvements in any of these dimensions. Importantly, many modern digital platforms can address issues across all dimensions, so investments in digitalization can have important multiplier effects in terms of sustainability.

IMPROVING ENERGY EFFICIENCY

Manufacturing companies have a significant incentive to improve energy efficiency as a critical 'low-hanging fruit' of their decarbonization efforts. Whilst energy costs are traditionally a large operational expense for manufacturers, improved efficiency represents one of the least resistant pathways towards improving the sustainability of operations.

This has been accelerated by recent energy price-hikes. In Spain, for example, electro-intensive manufacturers are rushing to sign 12-year renewable energy power purchase agreements to cover up to 40% of their demand after seeing electricity prices—which account for around 60% of production costs—rise fivefold in the last two years.[iv] Digital technologies can help to reduce this cost, and its associated environmental impact, in several ways.

Collective intelligence, enabled by digitalization and automation, can enable optimized decision making on energy efficiency. By looking at the complete energy system across your manufacturing operations, including energy from your supply chain, energy-saving automation and digital tools can:

- Enable intelligent drive systems: through optimizing the overall system of efficient drives, using holistic digital strategy, companies can cut energy consumption by up to 60%[vii] through features such as eco operation modes, kinetic energy buffering and reactive power compensation.
- Deliver enterprise-wide energy management solutions. From field-level energy data recording to company-wide energy analysis, these solutions allow you to identify major energy consumers and take suitable measures to improve sustainability. Energy and production data can then be integrated to analyze and optimize not only energy consumption but also energy production of machine, plants, and processes.
- Provide software that monitors production-related power consumption on a companywide basis and helps with automated loads management, allowing loads, buffers and generators to be switched on or off automatically to optimize consumption and access reduced tariffs while keeping the production running and quality high.
- Enable smart energy solutions that deliver intelligence across the entire power supply chain, incorporating data from buildings, production, electric vehicle fleets and so on, to balance supply and demand and facilitate the adoption of a flexible generation mix, including renewables.

BETTER PLANNING AND OPTIMIZATION

The optimal state for most production lines and facilities is for them to be running as continuously as possible, to maximize output and rapidly amortize the capital cost of assets. This can make it hard to interfere with operations to test innovations that could further improve efficiency, such as trying out new components or processes. However, the picture is changing, in-part thanks to two specific tools.

The first is the digital twin, a virtual representation of a real product, process or plant that is used to understand and predict the physical counterpart's performance characteristics. Digital twins make it possible to carry out what-if scenarios without impacting physical production. The second tool is the industrial Internet of Things (IoT), a suite of network-connected sensors that allows companies to gather detailed real-time data on assets and environments. Multivariable regress analysis further provides a virtual representation of the process or machine, enabling greater understanding of its characteristics and contextualizing the energy data and production data and therein providing greater collective intelligence to enable smarter decisions towards sustainability.

Industrial IoT equipment can be used to feed real-life data into a digital twin, providing a highly detailed and realistic virtual model of physical production processes. This can be used to try out a wide range of manufacturing simulations, helping with planning, validation, commissioning and inventory optimization and allowing companies to study new ways of maximizing resource reuse and minimizing waste and emissions.

INNOVATIONS IN FLEXIBLE PRODUCTION

Flexibility and efficiency often go hand in hand, since the ability to adapt to new market conditions allows for the continued use of existing assets, reducing wastage. More flexible processes, such as those inherent in additive manufacturing, can also allow production to take place locally to consumption, reducing the losses involved in distribution. One important innovation in this respect is modular production, or the ability for a facility to be easily retooled or reconfigured so that any product can be manufactured at any time in any plant.

A prerequisite for this modular approach is standardized, cross-vendor interfaces which guarantee the efficient configuration, communication and integration of plant modules. Such interfaces define the information technology aspect of process modules or plant sections in such a way that they can easily be integrated into a comprehensive automation system.[viii]

Another digitally enabled flexible production approach is additive manufacturing, where products are made directly from a computer-aided design (CAD) or digital three-dimensional model. This allows products to be made directly on demand with minimum wastage and higher efficiency. Additive manufacturing has so far mostly been employed for small-scale production but companies such as Siemens now offer digital toolsets that allow it to be deployed at industrial scales.[ix]

More widely, manufacturing flexibility is being aided with the advent of digital tools such as AI, which can help optimize resource utilization, and automated guided vehicles, which can support dynamic, scalable and energy-efficient production. Improved flexibility could be crucial in helping manufacturers achieve further major shifts in production that may be required to reach global sustainability targets.

> ***"MANUFACTURERS NEED THE ABILITY TO PRODUCE IN EFFICIENT, FLEXIBLE, AND SUSTAINABLE WAYS. THIS MEANS RETHINKING PRODUCTION TO INTEGRATE SUSTAINABILITY AS ONE OF THE OUTCOMES." SAYS ERYN THOMAS DEVOLA, HEAD OF SUSTAINABILITY AT SIEMENS DIGITAL INDUSTRIES. "DIGITALIZATION AND AUTOMATION TECHNOLOGIES ARE KEY ENABLERS THAT DRIVE DATA TRANSPARENCY TOWARDS SMARTER DECISIONS ACROSS THE ENTIRE VALUE CHAIN."***

ENHANCING MAINTENANCE

A final area where digital tools can help improve manufacturing sustainability is in maintenance. Traditional maintenance involves fixing things when they go wrong, which is highly wasteful in terms of time and resources. With digital twins and industrial IoT equipment, it is possible to simulate accelerated usage rates for industrial equipment and predict where failures might happen—before they occur.

This allows maintenance to become predictive rather than reactive, with remedial work focused on extending the lifetime of assets while in operation rather than repairing faults. Lifetime extension may be achieved by replacing fault-prone components during periods of downtime or scheduled maintenance, or by adjusting modes of operation to minimize the chances of failure.

Optimum strategies can be investigated using a digital twin before applying it in the real world. Such techniques can be extended from manufacturing facilities to products, so industrial and consumer goods could last for much longer while in use. This opens the door to new commercial models where products become long-term platforms for service delivery rather than disposable assets, greatly reducing resource utilization in the process.

SUSTAINABLE PRODUCTION IN ACTION

While most of the digital tools available for improving manufacturing sustainability are still in the early stages of adoption, Siemens has brought them all together in a single digital-native factory in Nanjing, China. Siemens Numerical Control (SNC) produces high-quality computer numerical control systems, drives and motors, and became a digital enterprise by consolidating three production sites into one sustainable factory, undertaking the exercise during the COVID-19 pandemic.

Going digital-native has allowed SNC to double its production capacity, increase efficiency by 20%, enhance flexibility by 30%, shorten time to market by 20%, boost space utilization by 40% and make material flows 50% more efficient.[x] Plant-wide emissions have been reduced through technologies such as ground-source heat pumps and photovoltaic arrays, plus the phasing out of old, energy and emissions-intensive machines in favor of newer models.

"Improving plant-wide productivity helps reduce the level of emissions per product", says You Cai Yang, plant manager and sustainability officer at SNC. "All actions are linked," he says. "With these multiple solutions, we can improve our energy consumption in the factory."

That said, it's not only new factories that benefit from energy efficiency through data transparency. Siemens Electronic Works Amberg in southern Germany was appointed Sustainability Lighthouse by the World Economic Forum, acknowledging the factory's proactive approach to sustainable manufacturing with energy and resource-efficient operations. By applying holistic energy management to monitor the factory's energy consumption, Amberg was able to increase output by 70%, while reducing energy consumption per volume by 47% and emissions per volume by 69%.

OUTLOOK AND CONCLUSIONS

Cutting edge innovations, such as digital twins and modular production, will ultimately help energy, industrial and supply chain companies achieve more sustainable levels of production. "We have an ambition to use technology—automation and software—to drive excellence," says Yi Rong Zhou, general manager of SNC. "Siemens is very much focused on the environment, and we want to bring our technology and work together with our partners to improve the competitiveness of the complete value chain."

This underscores that fact that while completely sustainable production may still depend on the development of innovations in areas such as energy storage or clean fuels, a lot can be achieved with the application of digital and automation technologies today. In order to continue to transform sustainable production through collective intelligence with minimal interruption to daily operation, companies must accelerate the application of advanced technology tools from the start of the process.

Even before concrete begins to pour, digitalization and automation enable the simulation of performance of new products and buildings, allowing companies to precisely test and calibrate dimensions, material flows, media supplies and so on. This enables the full lifecycle to be optimized to deliver greater efficiency, cost saving and, ultimately, a reduced carbon and climate impact throughout the full production process.

Moreover, examples such as that in Amberg demonstrate that it is not only new productions that are planned from scratch which have the potential to become more sustainable. Rather, by applying digitalization and automation technologies, existing assets can tangibly improve output, whilst reducing energy consumption and emissions at the same time.

The experience of those, such as Siemens, already pioneering this approach illustrates how digital tools can transform the sustainability of production, and deliver heightened levels of circularity, energy and resource efficiency. Collective intelligence, which requires companies to incorporate data in collaboration with value chain partners, to make efficiency climate-conscious decisions through the full lifecycle of their products, is a fundamental enabler for this. With such tools now widely available to other manufacturers, the question is not if, but when global production will embrace digitalization for more sustainable operations.

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