

# Sustainable Manufacturing

## Driving a sustainable future by the digitalization of industry and international cooperation

**Digital Transformation in manufacturing has great potential** to reduce carbon footprints of manufacturers, establish sustainable manufacturing processes and provide visibility to the environmental impact of industrial supply chains. Sustainable Manufacturing is a strategic priority of both CESMII and the Plattform Industrie 4.0. **Sustainability plays a crucial role in staying competitive in a global economy**, both to ensure efficient use of (material) resources and to satisfy increased customer demand for sustainably produced products.

Connected and distributed production needs **international efforts** driven by the exchange of know-how and experience and ensuring that local solutions are applicable across borders. Reaching the climate goals of the COP 21 Paris Agreement and the United Nation's Sustainable Development Goals (SDGs) will require innovation, new technologies and a skilled workforce. These are topics closely linked to the digital transformation of manufacturing.

A common vision of CESMII and Plattform Industrie 4.0 experts is that **innovation and education are complementary**, especially to increase energy and resource efficiencies, create circular economies, provide opportunities for meaningful work, and introduce new business models. With **upskilling programs**, digital manufacturing can become environmentally sustainable, protect and create new jobs, and support sustainable economic growth in both Germany and the United States.

## Introduction

Experts of CESMII (US) and Plattform Industrie 4.0 (Germany) have been collaborating since June 2020. Workgroups on technology standardization and workforce skills & training represent areas of mutual interest for collaboration. Affiliated companies of both organizations work in supply-chain ecosystems that span across the Atlantic. They share manufacturing information infrastructure that requires interoperability and a common set of skills and competencies. Working together can help the small and medium sized enterprises in these international supply-chains, especially as they recover from the hardships of the COVID-19 pandemic and strive to create new jobs and industries for the future. Both Plattform Industrie 4.0 and CESMII experts recognize the commitments of their governments to environmental sustainability and define it as a central strategic aspect for the digital transformation of manufacturing.

Future competitive production is closely linked to environmental sustainability and an upskilling of the manufacturing workforce. Reaching the goal of the Paris Agreement to limit global warming to 1.5 degrees or the SDGs will require innovation, new technologies and a skilled workforce. The joint vision of CESMII and the Plattform Industrie 4.0 experts is that innovation and education are complementary and essential to achieving sustainability through smart manufacturing.

## The Impact of Manufacturing on Climate Change

The need to get to net-zero CO<sub>2</sub> emissions globally is understood and accepted by the United States and Germany. The manufacturing industry must play a significant role in this sustainability endeavor. Relative to the carbon emissions-intensive transportation and electric power generation sectors, manufacturing is considered the 'hardest to decarbonize' as carbon serves as both fuel and feedstock. In addition, the diversity of products, production processes, and resources in manufacturing require different technology strategies for significant decarbonization.

Manufacturing utilizes global supply-chains, connecting production across nations, firms, and sectors. While a subset of energy-intensive manufacturing that accounts for the majority of carbon emissions (chemicals, cement, iron/steel), these carbon intensive sectors provide the basic materials used in most other sectors.

The mechanical equipment sector is responsible for very few direct CO<sub>2</sub> emissions, but influences a large part of global emissions with its products.<sup>1</sup> Thus, manufacturers are reducing their own emissions in their own manufacturing facilities and the emissions of the products they produce. They also need to understand the life-cycle sustainability and emissions by their suppliers as they have wider impact on the sustainability of manufacturing value chains. More recently, they are looking to quantify the emissions of their facilities and entire supply chain, for example through wider use of international industrial standards like ISO50001. However, more investment and technology development are needed to get to this zero-emissions vision.

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<sup>1</sup> BCG, VDMA (2020) *For Machinery Makers, Green Tech Creates Green Business*; Oliver Wyman (2020) *Ride the Green Wave*

Manufacturing utilizes global supply-chains, connecting production across nations, firms, and sectors. Effective decarbonization of manufacturing will require sharing of information between firms that transcend national borders.

Reducing emissions and producing goods while using sustainable energy and sustainable material resources is a competitive advantage for an increasingly climate-aware customer base. Tomorrow, it may turn into a requirement based on standards, and thus, become the new normal. While specific mechanism for implementing emission standards may vary between nations, there will be a shared need to verifiably quantify emissions. Sustainability should not merely be considered as operational expense, but an opportunity to be successful in new markets and create new jobs in the process. Efficiency related sustainability can be net positive, as it reduces energy and material costs. To achieve this, new cost-competitive technologies and new operational and manufacturing processes need to be introduced.

## Potential Solutions

Both CESMII and the Plattform Industrie 4.0 experts see great potential in the following, focused solutions. Of course, achieving climate neutrality will require many more measures.

- **Industry best practices and international standards:** Developing new technologies must go hand in hand with establishing international standards for complex and diverse fields like sustainable manufacturing. The ecosystem of innovation and the implementation of Industry 4.0 solutions thus creates a fertile cross-pollination environment in which sustainability programs will result in modern Industry 4.0 solutions and deployed Industry 4.0 solutions can be optimized for sustainability. These solutions must be based on global reference architectures and data infrastructures such as Gaia-X that foster interoperability. Thus, they can be used by individual companies to enable vendor-neutral interoperability of their competitive solutions. International collaboration on leveraged standards and solution architectures thus enables seamless and cost-effective integration of supply-chains for a nation's firms.
- **Common Data Models:** Data modelling is often overlooked when new solution architectures are developed. However, interoperability, security, and standardization of the data model as well as vendor-neutral data sharing platforms to share manufacturing digital twins are important technologies that need to be standardized widespread to achieve scale and reduce costs of Industry 4.0 solutions. The harmonization of the Asset Administration Shell (Plattform Industrie 4.0) and Smart Manufacturing Profiles (CESMII), for example, enables the exchange of information between partners in value-added networks and along assets' life cycles.
- **Energy Productivity for Manufacturing:** Manufacturing processes need to be powered by clean energy, ideally produced locally to avoid transmission loss and provide resilience, while ensuring widespread stability and reliability of the power grid for all consumers. Once energy is in a manufacturing system, it needs to be consumed with high efficiency. Smart energy systems and applications make a major contribution to resource efficiency and strategic energy management. This productive use of energy

can be effective at individual manufacturing processes, within an entire facility, and across an entire manufacturing organization.

- Sharing data along supply-chain: Selection and reporting must pivot from cost, quality and time-driven criteria to increasingly include sustainability-focused factors. Additionally, the carbon footprint of a product needs to be traceable from the source and indicated to the customer. In product design, recyclability and reuse need to be considered from the start and mechanisms put in place to encourage the customer to initiate recycling at the end of a product's lifecycle. Creating data and finding easy ways to share this data, e.g. via digital twins or electronic material passes, will support decision processes and increase transparency, by both companies and customers.
- Resource optimization in systems: at a factory, at a company and across a supply chain. Resources include energy, material, water, capital equipment, time, land, the atmosphere and workforce. Being sustainable in manufacturing increasingly requires intelligence and information with respect to resources. This information enabled sustainable future can be enabled through smart manufacturing and Industry 4.0 operating at a global scale.
- New circular economies can be established for the manufacturing industry, beyond simply buying carbon credits. Carbon credits need to be transactionally verified for sustainability impact in manufacturing. Some good examples have recently been introduced in the automotive manufacturing industry, where the recyclability of batteries used in electrified vehicles plays an increasingly important role when new models are designed and produced. Recyclability is enhanced by new modular battery designs, digital parts tagging and tracking, and reduction of rare earths.
- In many industries new technologies and production processes are being developed, optimized, and inserted into the manufacturing supply chain. As these new technologies and production processes mature and scale (for example additive manufacturing, electro-fuel production of synthetic chemicals using CO<sub>2</sub> sinks as a feedstock, large-scale hydrogen by electrolysis, Industrial Carbon Capture, or Direct Air Carbon Capture process technologies), there is a huge opportunity to improve sustainability. Smart manufacturing is an essential tool in the adoption and scaling of new technologies and production processes, thereby reducing carbon emissions.
- Business Models for sustainable manufacturing: New outcome-based and sustainable business models need to be tested and established for many manufactured products. Standards for sharing best-practices and verifying information related to manufacturing processes will enable these new business models. Additionally, platform economy and networked value creation play an important role closely linked to the digitalization of manufacturing. Initially manufacturing companies are turning their expertise from transforming their own production sites to climate-neutrality and in some cases can turn this into consultancy subsidiaries. Others may implement pay per use models for new technologies or enable joint learning and collaboration through online platforms and consortia.

## Upskilling Enables Sustainable Manufacturing

Driving innovation in sustainable manufacturing requires people who explore, master, and apply new technologies and further develop resource efficiency systems. Providing the right competencies and skills is essential to continue the path of innovation and to drive adoption. Discussions between CESMII and Plattform Industrie 4.0 experts have shown that both groups share a common vision that innovation and education are complementary and necessary on a path to sustainability. Understanding differences in German and US education systems provides useful insights and has the potential to improve educational and workforce training outcomes in both nations.

Furthermore, CESMII and Plattform Industrie 4.0 experts agree that adoption of new technologies is a particular challenge for small and medium enterprises who need to carefully integrate upskilling into their ongoing operations without disrupting their business.

As manufacturing is globally connected, international trade partners like the US and Germany, will both benefit a shared set of skills and competencies.

## Potential Solutions

CESMII and the Plattform Industrie 4.0 experts see great potential in the following, focused solutions. Of course, achieving climate neutrality will require many more measures.

- More work is needed to define and drive the adoption of manufacturing know-how, e.g., sharing of best practices and student learning outcomes in university and school curricula (at both 4-year and 2-year level) to provide the smart manufacturing talent needed by businesses in the US and Germany.
- More engagement is needed for the cost-effective dissemination and training for small and medium sized manufacturing enterprises. With data-driven manufacturing as an emerging theme, there is a shared interest in approaches to knowledge dissemination through open and accessible information.
- Awareness is needed of technology that can be used for sustainable manufacturing and must be included in trainings and qualification programs. Tools for the upskilling of any organization's existing workforce and for preparing new employees, is crucial to shaping this transformation successfully and many new job opportunities will be created as a result.

## Outlook

This paper constitutes a beginning of discussions. CESMII and Plattform Industrie 4.0 experts will increase the exchange of know-how and pursue a mutually interoperable reference architecture that fosters sustainable production. Furthermore, hands-on experiences about how to set up sustainable global supply chains and value networks can be shared, especially focusing and building on the ecosystem shared by the US and Germany. In parallel, regional and global obstacles preventing sustainable production will be identified and potential solutions will be defined. Additionally, mutual learnings can be transferred and efforts coordinated to international discourse on sustainability, where adequate, to increase impact.

### Text, Editing, Design & Picture Credits

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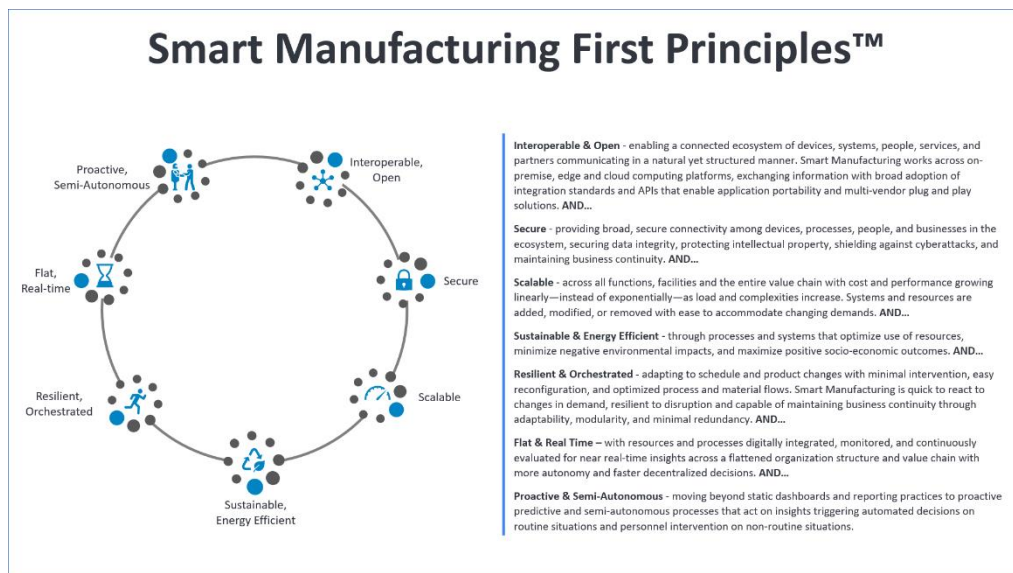
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## Appendix

In this document, the terms Smart Manufacturing and Industry 4.0 are used interchangeably. The members of both CESMII and Plattform Industrie 4.0 have published specific documentation of description relative to sustainability, the vast majority of which are aligned:

### Sustainability from CESMII's First Principles



Smart Manufacturing drives sustainable manufacturing of products through processes and systems that optimize use of resources, minimize negative environmental impacts, and maximize positive socio-economic impacts. It optimizes the use of energy as a direct ingredient, instead of treating it as overhead, and contributes to a circular product lifecycle by facilitating information for reuse, remanufacturing, and recycling scenarios. → read more on the First Principles [here](#)

## Sustainability from Plattform Industrie 4.0's 2030 Vision



Economic, environmental, and social sustainability is a fundamental pillar of the values of our society. This works in two directions: Firstly, sustainability is embedded in Industrie 4.0, and secondly, Industrie 4.0 permits substantial progress on sustainability. For example, the prosperity and quality of life of each individual largely depends on a forward-looking and competitive industrial sector. The ecosystem of innovation and the implementation of Industrie 4.0 thus create a fertile environment in which sustainability can result from Industrie 4.0 and Industrie 4.0 itself can be sustainable – and thus make a key contribution towards maintaining the standard of living of our society. → read more about the 2030 vision [here](#)

Based on the 2030 vision the platform's Industry 4.0 & Sustainability Task Force has discussed how Industrie 4.0 can contribute to a climate-friendly and resource-efficient future. **Three development paths towards a digital, networked and sustainable manufacturing industry** emerged from the analysis which are published in an [impulse paper](#).

- Path 1: Reduce consumption, increase impact: towards resource-efficient and carbon neutral, digitalised manufacturing.
- Path 2: From mass production to transparent service offerings: how a changed value proposition influences digital business models.
- Path 3: Sharing and networking sustainable digital business means cooperating and operating in circular economic systems.