

Creating Sustainable Production Systems Through Advanced Industrial Innovation

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Introduction

In recent years, sustainability has shifted from being an aspect of manufacturing strategies that was of secondary importance to being central to those strategies. Increased energy costs, tougher environmental laws, greater demands by consumers and investors, and real-world effects of resource shortages and global warming have turned sustainable manufacturing from a nice-to-have endeavor into a necessity for companies. On the other hand, the development of cutting-edge industrial solutions, such as process optimization through artificial intelligence and circular manufacturing, enables manufacturers to achieve both improved efficiency and decreased environmental impact.

This paper looks at sustainability and innovation in industry in relation to the tools that enable manufacturing companies to develop production processes that are environmentally sound and profitable in figure 1.

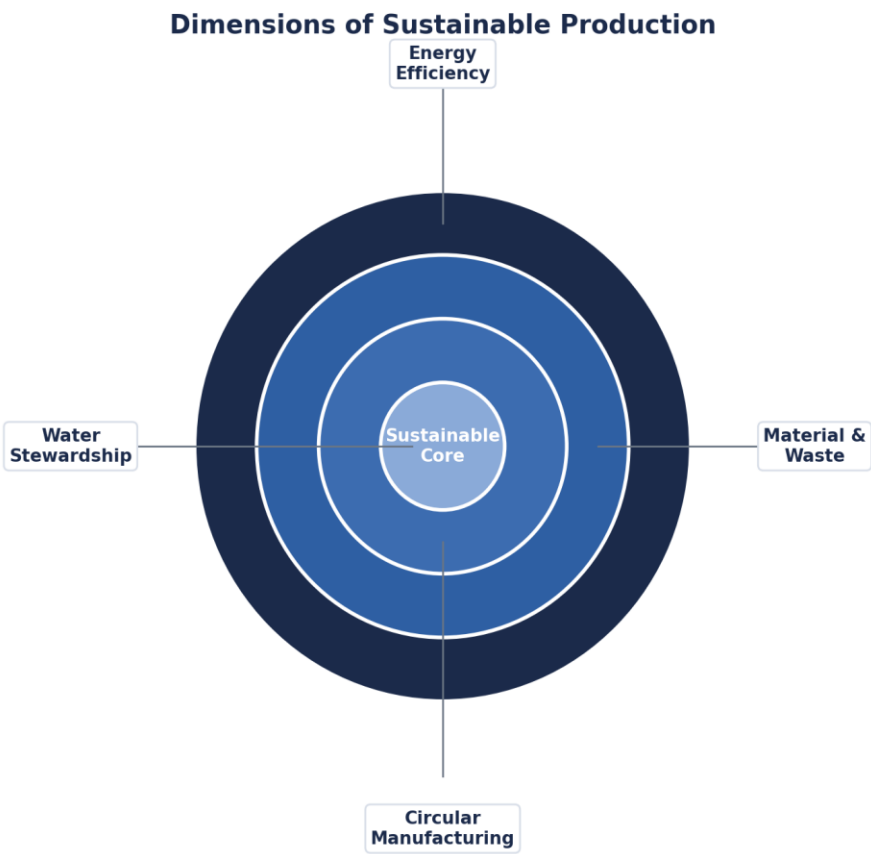


Figure 1: Process overview

The Competitive Edge of Sustainable Production Processes

Sustainability in the context of manufacturing has been viewed in the past as a factor that limits profitability. Today, however, several factors push manufacturing organizations to pursue sustainable production processes.

Governmental pressure. Environmental regulations have become increasingly strict in many countries and include measures such as carbon pricing, emissions reporting, and extended producer responsibility programs, which make producers accountable for the complete lifecycle of the products they manufacture.

Resource and energy costs. Fluctuating energy prices and resource scarcity have made it necessary for organizations to focus on the efficient use of resources in order to reduce costs even in the absence of any environmental concerns.

Customer and investor demand. Customers, especially those who work in the sectors that make their own sustainability pledges, want suppliers to prove environmentally friendly. The increasing importance of environmental, social, and governance (ESG) performance in investment decision making means that investors expect the same from businesses.

Key Components of Sustainable Production

Energy Efficiency

The reduction of the energy intensity in production processes continues to be one of the most direct and powerful tools at the disposal of manufacturers. Such actions include investing in efficient equipment, adjusting process parameters in order to reduce energy loss, recovering and reusing energy, and increasingly the generation of renewable energy sources on-site.

Material Efficiency and Waste Reduction

Sophisticated process controls and quality management systems can reduce material losses through defect elimination, optimal use of material resources, and improved process control. Lean production techniques, which were always dedicated to the reduction of any kind of waste from the very beginning, perfectly coincide with the goals of sustainable production.

Circular Manufacturing

Circular manufacturing systems try to prolong the period of using of materials and products as much as possible while minimizing the extraction of virgin material resources and waste creation. It means that the production should be based on design-for-disassembly and recycling, taking back of the product and its remanufacture, and integration of recovered resources in production processes.

Water Stewardship

Effective water stewardship practices, such as water conservation, water treatment and reuse, and minimizing the release of contaminants, have increasingly become critical components of sustainable production, especially in regions where water is scarce.

Sustainable Production Within the Supply Chain

Since a considerable amount of a company's total environmental impacts often occur upstream in the supply chain, the concept of sustainable production has increasingly gone beyond the boundaries of a factory to involve activities along the entire chain.

Sustainability through Advanced Industrial Innovation

Process Optimization Using Artificial Intelligence

Using artificial intelligence and machine learning, it is possible to recognize possibilities for efficiency that would not be found without the use of technology. Through the constant analysis of process data, such solutions are able to make recommendations for adjustments that reduce energy consumption, waste of materials, and optimize the whole process.

Sustainability Through Digital Twins

Through digital twins, companies are able to test how certain changes, improvements, or even new products will affect the environment, thus making sure that any changes made will have a positive impact on the environment.

Monitoring with the Help of Sensors

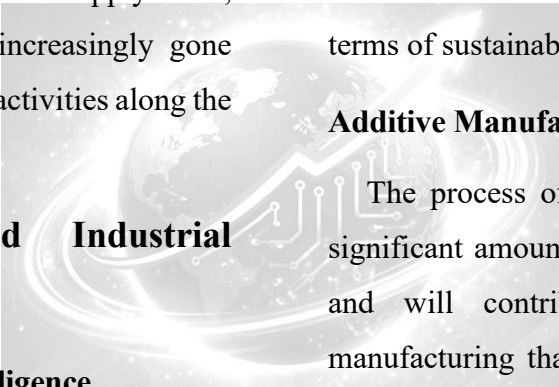
The complete monitoring of energy consumption, emissions, water consumption, and waste generation through advanced industrial sensors ensures the visibility of manufacturers in terms of sustainability goals.

Additive Manufacturing

The process of industrial 3D printing will help to save a significant amount of material, especially for complex shapes, and will contribute to the efficiency and on-demand manufacturing that will eliminate the environmental footprint related to the storage of the inventory and its transportation.

Advanced Materials

Materials engineering helps to design lighter, more robust, and recyclable materials, as well as bio-based alternatives to the traditional petroleum-based materials that will further minimize the environmental footprint of the produced goods.



Sustainability Strategies in Production Management

Setting Measurable Goals and Targets

Every sustainable strategy should be based on the setting of the measurable goals and targets for various parameters such as energy intensity, generation of waste, water use, and greenhouse gas emissions.

Life Cycle Assessment

A complete life cycle assessment involves assessing the environmental impact of a product throughout the life cycle of the product, including from resource extraction to product manufacturing, use, and disposal. This gives manufacturers an objective basis for determining areas with the greatest impact to target, rather than looking only at production-stage impacts.

Collaboration Among Functions

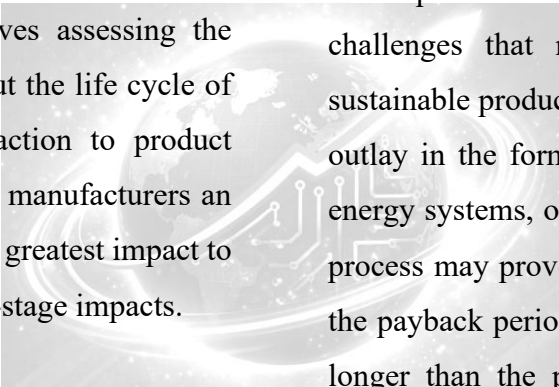
Sustainability production efforts usually involve close cooperation between operations, engineering, procurement, and sustainability functions, since sustainable gains require consideration of the entire production process, from design to sourcing to production.

Employee Involvement

Employees often have first-hand experience with inefficiencies in the process or sources of waste that are not evident from data. Engaging employees in the sustainability process, through idea generation and training, helps identify improvement opportunities and builds commitment to sustainability goals.

Challenges with Developing Sustainable Production Systems

Despite the strong business rationale, there are certainly some challenges that manufacturers encounter when developing sustainable production systems. The need for significant capital outlay in the form of energy-efficient machines or renewable energy systems, or the implementation of a circular production process may prove to be challenging for some companies, and the payback period for some sustainability initiatives may take longer than the payback period for other capital initiatives. Retrofits of existing factories and machinery, which have not been specifically built to enable sustainable practices, can also be difficult and expensive in figure 2.



Sustainable Production Improvement Cycle



Figure 2: Key framework at a glance

Conclusion

Sustainability in production is no longer an issue at the fringes; rather, it becomes more and more pivotal to the competitive advantage, regulatory compliance, and credibility of manufacturers. Emerging advances in industry, such as artificial intelligence, digital twins, sensing technology, additive manufacturing, and material science, are equipping manufacturers with effective means not only to minimize the

environmental impact but also to improve production efficiency and resiliency. Those manufacturers who embrace sustainability as the heart of production management, using the appropriate performance metrics, collaboration across functions, and employee involvement, will have the best chance to create production systems of sustainable value.