

Sustainable Manufacturing: A Primer

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ABSTRACT

Sustainable manufacturing is manufacturing products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. The goal of sustainable manufacturing is to minimize waste, maximize resource efficiency, and reduce the environmental impact of manufacturing. It is imperative that manufacturing processes should consider sustainability at every level, so that there will be comprehensive adherence to sustainability principles. Properly implemented, sustainable manufacturing can lead to several advantages. This paper provides a primer on sustainable manufacturing.

KEYWORDS: *manufacturing, sustainable manufacturing, sustainable development, green manufacturing, lean manufacturing*

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INTRODUCTION

Manufacturing is the main pillar of the modern society. Traditionally, manufacturing processes are generally designed for high performance and low cost with little attention paid to environmental issues. Although manufacturing systems create material wealth, they consume a great amount of resources and generate a lot of waste. The waste generated during the manufacturing processes is responsible for the degradation of the environment. Thus, such traditional manufacturing processes have retained the negative image of being inefficient, polluting, and harmful.

Today, humans are consuming natural resources through manufacturing activities at an alarming rate, which is not sustainable. For example, between 1950 and 2005, worldwide metals production grew six fold, oil consumption eight fold, and natural gas consumption 14-fold. The current assumption of unlimited resources and unlimited world's capacity for regeneration is no longer acceptable. Thus, minimizing the resource consumption and reducing

the environmental impact of manufacturing systems has become very important [1].

WHAT IS SUSTAINABLE MANUFACTURING?

Sustainable manufacturing (SM) (or green manufacturing) for our purpose can be defined as a method for manufacturing that minimizes waste and reduces the environmental impact. These goals are to be obtained mainly by adopting practices that will influence the product design, process design, and operational principles. Therefore, sustainable manufacturing may be regarded as an approach that integrates product and process that will consider sustainability at all levels of the life cycle of manufactured products. It promotes eliminating production and processing wastes through eco-efficient practices and encourages adopting new environmental technologies. The six major elements significantly affecting the sustainability of manufacturing processes are shown in Figure 1 [2].

Sustainable manufacturing involves developing sustainable products with total life-cycle

considerations. It is the creation of manufactured products using non-polluting, natural resources conserving, and economically sound and safe processes. Such manufacturing practices are safe for all stakeholders and are economically sound societally beneficial. When we talk about sustainability, we often mention the three Ps: people, planet, profit, as shown in Figure 2 [3]. The pillars of sustainability are a powerful tool for defining the sustainability problem. These consist of at least the economic, social, and environmental pillars, shown in Figure 3 [4].

Sustainable manufacturing requires that all manufacturers should aim for the following four activities that would help the environment across its entire supply chain [1]: (1) Energy use reduction, (2) Water use reduction, (3) Emissions reduction, (4) Waste generation reduction. Sustainable manufacturing should integrate the sustainable activities at all levels of manufacturing – product, process, and system. This may involve the following 9R: reduce, reuse, recycle, recover, redesign, remanufacturing, repurpose, refurbish, and refuse.

The manufacturing industry seeks indicators to measure sustainability of manufactured products and manufacturing processes. The main tool commonly used to implement SM is the Life Cycle Assessment (LCA). It is a method used in assessing environmental impacts associated with all the stages of a product's life, from cradle to grave. It is an approach to examine fully the environmental impact of different activities performed by humans including the production of goods and services by corporations. LCA is mainly concerned with identifying the environmental impact of a given product or process at each stage of their life.

SUSTAINABLE APPROACHES

The issue of sustainability is becoming more and more central to the industry. Manufacturers engaged in sustainability activities include those of all sizes, ages and sectors. The reasons companies are pursuing sustainability include [5]:

- Increase operational efficiency by reducing costs and waste
- Respond to or reach new customers and increase competitive advantage
- Protect and strengthen brand and reputation and build public trust
- Build long-term business viability and success
- Respond to regulatory constraints and opportunities

Ways that companies progress further on the path to sustainability include [5]:

- Address sustainability in a coordinated, integrated and formal manner, rather than in an ad hoc, unconnected, and informal manner
- Focus on increased competitiveness and revenues rather than primarily focusing on cost-cutting, risk reduction, and improved efficiency
- Use innovation, scenario planning, and strategic analysis to go beyond compliance
- Integrate sustainability across business functions
- Focus more on the long term
- Work collaboratively with external stakeholders

SUSTAINABLE MANUFACTURING EXAMPLES

Some examples of sustainable manufacturing include [6-8]:

- The automotive industry has undergone substantial changes in terms of increased performance, reduced fuel consumption, environmental impact, and improved safety of the products, employees, and community.
- The production of personalized products using sustainable manufacturing systems and supply chains allows localized manufacturing and therefore a shortening of supply chains becoming more energy and resource efficient.
- Starting January 1, 2006, 85%, on a mass basis, of vehicles produced in or after 1980 must be reused and recovered (recycling 80%). Reuse and recovery of 75% on a mass basis (recycling 70%) for vehicles produced before 1980 is also targeted in this directive. Starting January 1, 2015, vehicles must be constructed of 95% recyclable materials (with 85% recoverable through reuse or mechanical recycling and 10% through energy recovery or thermal recycling) (GHK, 2006).
- The pressing needs of energy, water, and other resource conservation worldwide is a major engineering challenge. The most recent data on water use in the US reported manufacturers consumed approximately 21 billion gallons per day from both municipal and self-supplied sources. As drivers such as population growth and climate change increase pressure on fresh water resources, both at the local and global level, manufacturers are seeking ways to incorporate more efficient and sustainable water use into their operations. This sustainable water use is driven from both an environmental perspective and from a business perspective.

- Sustainable manufacturing is causing companies to implement new design and analysis procedures, energy reduction methods, material reduction efforts, and improved materials handling practices. Reducing consumption of energy, water and other resources in a factory is challenging and often starts with the basics of switching off lights and replacing the luminaires with LEDs. Fabric waste is turned into tiles and furniture.
- Three sustainability tips for what you can do to think local are provided as follows. Volunteering is a way everyone can get involved and give back to the local community as well as promote social sustainability. Giving back is a great way to keep resources local while supporting fellow community members and local organizations. Communicate with your neighbors and community members about sustainability and social issues. Identify the challenges and opportunities that you could address to make positive changes in your community.

BENEFITS

An increasing number of manufacturers are realizing substantial benefits from sustainable business practices. Designing products to be environmentally benign can contribute to their successful introduction and maintenance. Sustainable manufacturing enhances the safety of the products, employees, and community. Other benefits of sustainable manufacturing include improved morale, improved brand value, lowered regulatory concerns, increased market opportunities, improved product performance, and decreased liabilities. SM considers the cost of compliance to the environmental guidance.

New technology, new business practices, and new lifestyle models will be the cornerstones of the new sustainable world. Sustainable manufacturing has become the most important aspect to be considered by all production engineers, because it is an obligation to the world we live in. The three major principles they should keep in mind are reducing the resource utilization, using environment-friendly materials, and reducing all forms of waste and reuse and recycle material. Sustainability is and will be a crucial issue for the present and future generations.

CHALLENGES

The major challenges faced by the manufacturing industry in its pursuit of sustainability goals are as follows [9].

1. The manufacturing industry is facing the challenge of measuring sustainability performance in a product's life cycle. Developing metrics for sustainable manufacturing is critical to enable manufacturing companies to quantitatively

measure the sustainability performance in specific manufacturing processes.

2. Industry is unable to measure economic, social, and environmental impacts and costs of their products accurately during the entire life cycle and across their supply chain.
3. Full life cycle analysis or assessment (LCA) of products requires new methods to analyze, integrate, and aggregate information across hierarchical levels, organizational entities, and supply chain participants. Existing methods of aggregation do not take into account sustainability issues.
4. Industry lacks neutral and trusted standards and programs to demonstrate, deploy, and accredit new sustainable manufacturing practices, guidelines and methods.
5. There are too many metrics; they need consolidation and harmonization.
6. Regulations need to be supported by industry standards. These regulations/standards should be harmonized.
7. Current manufacturing modeling and assessment criteria require intensive revisions and upgrades to keep up with these new challenges.

CONCLUSION

Manufacturers are under growing pressure from stakeholders and stricter regulations to minimize the environmental impact of their activities. Today, there is a growing awareness of sustainability. The implementation of sustainable systems is an essential requirement in modern manufacturing. Sustainability has become an increasingly important requirement for economic activities. It has been applied to many fields such as manufacturing, design, engineering, and environmental stewardship.

A growing number of manufacturers are treating "sustainability" as an important objective in their strategy and operations in order to increase growth and global competitiveness. Sustainable manufacturing, with promising environmental and social benefits, is the future direction for manufacturing. More information about sustainable manufacturing can be found in the books in [10-30] and the related journals:

- Sustainability
- International Journal of Sustainable Manufacturing
- International Journal of Sustainable Engineering
- International Journal of Precision Engineering and Manufacturing-Green Technology

➤ CIRP Journal of Manufacturing Science and Technology

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Figure 1 Six major elements affecting the sustainability of manufacturing processes [2]



Figure 2 The three Ps of sustainability: people, planet, profit [3].

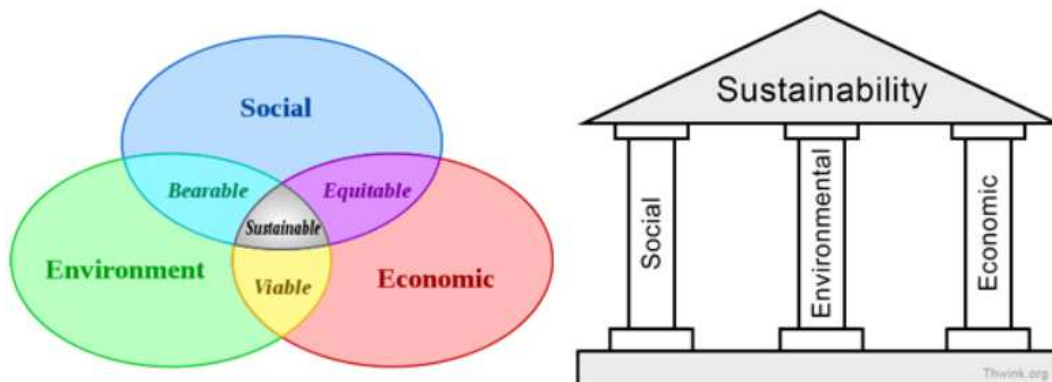


Figure 3 The three pillars of sustainability [4]