

# An Introduction to Green Manufacturing

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**Abstract**—All-natural, alternative, eco-friendly, sustainable, and green are all terms that companies use to encourage consumers to buy their products. In recent years going green and becoming sustainable has become a popular trend; as the human population grows, so does the need for raw materials, which transform into everyday items. The constantly evolving need for materials has brought to light social issues that individuals are now realizing can be resolved through thoughtful manufacturing also known as green manufacturing. The term "green" refers to the process of reducing the environmental impact of a manufacturing process or system [4]. More specifically, it is defined as being "concerned with or supporting environmentalism and tending to preserve environmental quality by being recyclable, biodegradable, or nonpolluting" [2]. This definition alone is broad, but when applied to manufacturing the general idea of green manufacturing is a process or system that has a minimal or nonexistent impact on the environment. By supporting green manufacturing, people and corporations are reducing their impact on the environment, addressing social issues, improving the quality of life for individuals and communities, improving business reputations, and are saving more money over the life of the product.

**Keywords**—Best Management Practice (BMP), Green Manufacturing, Sustainable Goods, Sustainable Manufacturing, Waste Reduction

## 1. What is Green Manufacturing ?

Green manufacturing is a method of manufacturing that minimizes waste and pollution [1]. To accomplish this type of manufacturing, many people become involved in the product design and process. Product design is defined as the product architecture and design, production, and testing of the system to ensure quality [1]. Another definition commonly used in conjunction with green manufacturing is sustainable manufacturing which according to the U.S. Department of Commerce is "the creation of manufacturing products that use materials and processes that

minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound" [3]. Within sustainable manufacturing is sustainable development which is defined by the World Commission on Environment and Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [5]. The concept of sustainability emerged from a series of meetings and reports in the 1970s and 1980s and was largely motivated by environmental incidents and disasters as well as fears about chemical contamination and resource depletion

Obvious practices to achieve sustainable or green manufacturing are to reduce the amount of energy and water used, reduce emissions from manufacturing processes, reduce waste, and recycle. When designing a product for green manufacturing sustainability must be at the forefront of the design for manufacturing or DFM [8]. For example, a design engineer creates a product that is easy to recycle at the end of its life, and in turn, makes it easier for the consumer to recycle the product which builds brand awareness and customer loyalty because the customer feels that they are a part of the solution.

Many design engineers and businesses in an effort to remain sustainability-conscious have adopted the four R's - reduce, reuse, recycle, and remanufacture. By embracing the concept of the four R's, people can reduce their carbon emissions, preserve natural resources, and reduce overall waste [9]. The most effective way to reduce waste is to not create it in the first place, however the effects can be minimized by reducing carbon emissions by purchasing products or services from factories that use renewable energy or buying energy effect products. Furthermore, natural resources can be preserved by choosing products and services that use recycled or remanufactured materials, including waste. Ultimately, the waste reduction can be minimized by purchasing products that can be reused or recycled.

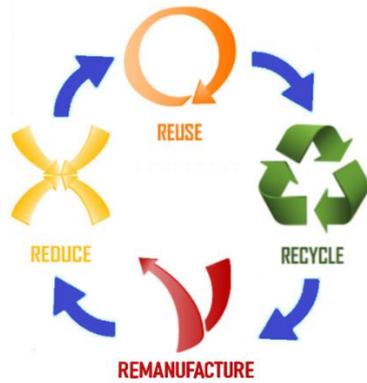


Figure 1. The graphic above shows the the 4R's of Green Manufacturing [10].

## 2.2. Economic Incentives

As previously mentioned, government policies and the ethicality of the modern consumer have placed regulatory pressure for businesses to conform to green manufacturing. As a direct result, investments have come around to this way of thinking and younger investors are more socially conscious. The bottom line is the potent combination of public pressure and support for sustainable manufacturing is driving the industry to support this model, and the industry is being rewarded by a generation of new investors that value ESG or Environmental, Social and Corporate Governance issues as being the primary drivers in where their dollars are invested. This new model of sustainable investing typically performs as well as traditional investments, sometimes even better and the investors feel as if they are making a difference.

## 2. Influencers of Green Manufacturing

Several catalysts motivate the manufacturing industry towards greener manufacturing processes and the three largest influencers can be summarized into these categories: regulatory pressure from the government and consumers, economic incentives, and competitive advantages [4].

### 2.1. Regulatory Pressure

Pressure from government regulations, penalties, and tax benefits is one major driver toward motivating green innovation due to the effect of ever more stringent environmental regulations. These regulations have the effect of encouraging green innovation and have made significant positive effects on the intelligent upgrading of manufacturing enterprises. Furthermore, regulation and tax policy have played a role in partially mediating between penalizing existing industrial shortcomings and encouraging the innovation that comes with the intelligent upgrading of manufacturing enterprises and practices. Additionally, another source of pressure is from society, consumers, customers, and other competitors. The societal pressure of modern times is a major cause toward policies that support green manufacturing besides, consumers and investors alike are making choices daily that they believe will help make the world be a better place. What products are purchased and how they are produced has become integral to how this generation views consumption and production. Public pressure helps to drive the industry into making sustainable choices in manufacturing processes and penalizes those companies that are not willing to make the necessary changes as they see fit.

### 2.3. Competitive Advantages

Green manufacturing also allows businesses a competitive advantage over those who do not conform to sustainable development practices. Moreover, sustainability attracts more buyers and investors than their counterparts because people want to do business with companies that not only excel at what they do but also do good for things that matter to them such as the environment. By establishing oneself with sustainable manufacturing, the company brand and people's perception of the company are heightened which can play a vital role in the success of a company.

## 3. Applications of Green Manufacturing

Manufacturing is both material and energy-intensive. It quickly uses resources such as oil, water, and energy which adds an environmental strain to the already stressed environment. Environmental impacts of manufacturing result mainly from the materials, water, minerals, and energy consumed in the manufacturing systems. Manufacturing is dominant in its environmental impacts in such categories as toxic chemicals, waste generation, energy consumption, and carbon emissions [6]. An effective way of achieving zero waste is through the waste assessment process and system approach [7]. This approach utilizes BMP or Best Management Practice, which is a method deemed the most "effective, practical means of preventing or reducing pollution from non-point sources" according to the United States Environmental Protection Agency (EPA) [7].

The EPA created a concept to use data to "develop a comprehensive system with changes that will drive environmental and economic performance versus routine incremental improvements" simply known as waste reduction [7]. Waste reduction is a broad term that can be broken down into smaller, more

manageable steps. The first step is to establish a solid waste minimization team that will identify the need to minimize solid waste and gain support from management. Once this step is achieved, the team defines goals, timelines, and budgets. The next step is to review existing records on waste, including the type, amounts, and any patterns in waste generation. This data is extremely useful to help the team gain insight on where to focus their efforts. Data should include material invoices, maintenance, waste hauling and disposal, contracts, production schedules, and the like. The purpose of this research is to determine the amount of waste produced annually. From here, a production analysis is performed to help understand any alternative solutions the company may be able to implement. This analysis includes a process flow chart that eliminates any extra steps. Data analysis can later be performed to provide an outcome of the annualized waste generation baseline for the facility. It can be further broken down by material, production, and waste. The team is then able to determine, evaluate, and select alternatives that reduce waste. Once the alternative has been selected, these ideas are placed into action and the team works towards greener manufacturing. The team keeps track of methods that are successful and continues to build on those successes. They continuously identify new ideas for waste production and find new ways to improve the old practices [7].

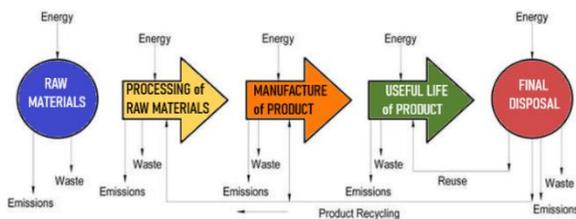


Figure 2. The graphic above shows the process of manufacturing a product [9].

#### 4. The Future of Green Manufacturing

The idea of sustainability is still rather new and thus will continue to make technological advancements. The factories of the future are rapidly adapting to changing their methodologies, which aim for a higher degree of sustainability. Perhaps the future of sustainability will be able to target types of wastes such as overproduction from early production, creating and ordering too much material, and having excessive inventories. The technology that is used will be able to monitor defects that include reworking, repairing, and being more cautious with excessive scrap, more efficiently than in the past. The transportation of products will be more conscious with its handling of materials, avoiding delays, and unnecessary movement

which applies to green manufacturing. Nevertheless, everyday workflow practices and ergonomics are being utilized and improved upon. Lastly, unnecessary production steps that add zero value to the product, also known as overprocessing, will be eliminated [4].

The introduction of automation is also essential for the progress of sustainable manufacturing. Automation will be able to “measure various process parameters and automatically control the relevant ones, automation systems will help manufacturing companies to successfully achieve the goals of sustainable manufacturing, which include achieving a high level of resource efficiency, reducing energy consumption, and minimizing land, water, and atmospheric emissions and pollutants.” [8].

#### Conclusion

Green manufacturing is a method of manufacturing that minimizes waste and pollution. This type of manufacturing has become increasingly popular as people shift toward an environmentally conservative outlook. People are becoming more conscious about their environmental footprint and are looking for ways to become more accountable for their actions. In doing so, there has been a rise in green manufacturing and sustainability. People are purchasing items that are ethically sourced and can be reused or remanufactured.

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