

# Green and Environment Conscious Manufacturing and Management Techniques

Luke Askew and Anoop Desai

Georgia Southern University  
Statesboro, Georgia, USA

Corresponding author's Email: [adesai@georgiasouthern.edu](mailto:adesai@georgiasouthern.edu)

**Author Note:** Mr. Luke Askew is a graduate student in the department of Mechanical Engineering at Georgia Southern University. Dr. Anoop Desai is an Associate professor in the aforementioned department.

**Abstract:** Contemporary industry is beginning to realize the negative impact that they have on the environment in terms of greenhouse gas emissions, destruction of natural habitats, hazardous waste emissions, etc. This new found consciousness has prompted a second look on part of the manufactures at how modern manufacturing practices can be modified so as to be more environmentally friendly. Environmental impact of manufacturing can be minimized in various ways. In this context, management is often called upon to provide active leadership in managing their facilities so as to minimize their environmental impact. Some examples of such activities include green supply chains and design for disassembly. Such activities help to create a closed loop product lifecycle that is required to reduce the amount of raw material used and the amount of waste created by production. Similarly using design for manufacturability principles aid in the minimization of raw material used and waste generated as well. Also, facilities are starting to move away from reactive approaches to environmental issues. They are now using proactive approaches and value seeking approaches where the environmental issues are dealt with before they are created. This paper presents an overview of environment conscious manufacturing practices that seek to minimize the negative environmental impact of manufacturing. Being a literature review, this paper primarily deals with state of the art in current practice pertaining to green manufacturing.

**Keywords:** Green manufacturing, Recycling, Environment consciousness.

## 1. Introduction

In today's industrial climate, green manufacturing and environmental conscious manufacturing and design are becoming a very important part of how efficient environmentally conscious facilities are being run. Green manufacturing is becoming a major issue in industry today because the world population continues to grow at a rapid pace. This is happening just as natural resources are being consumed at a non stable rate. If this trend of unsustainable consumption continues at the current rate, it would result in a scarcity of raw materials and resources that might prove insufficient to support future generations. In the past, natural resources have been exploited assuming an overabundance of supply. This approach cannot work indefinitely and managers who continue using reactive approaches to handling environmental issues need to realize this fact. Such approaches constitute what is often referred to as 'after the fact environmental management'. The principal reason for this practice is to be in compliance with state and federal regulations.

There are many problems that can arise from reactive practices to environmental management. Most of the repercussions are very harmful to the environment. One of the main problems that arise from this is that there is no thought put into the design of a product for their subsequent recycling and reuse. This is especially important to bear in mind in view of the fact that almost 70% of product lifecycle costs are ascertained at the design stage itself (Richardson, 1997; Stark, 2005; Luttrupp, 2006). A facility should strive to create a closed loop life cycle of a product where the product is produced then used by the customers and recycled. After it is recycled it should be reused so that the constituent material is used to make other products. This can be facilitated to some extent by developing a product 'take-back' program wherein companies routinely collect end of life products from customers. The products that are collected from consumers are recycled and the consumers are offered an incentive for turning in their used products. If facilities would work to achieve this objective, it would reduce the amount of raw materials being utilized for production. Similarly, it would also reduce the amount of waste produced. From the macro perspective, manufacturers continue to use traditional supply chains wherein raw materials are received by a supplier and made into a product and sent out to the customer. Manufacturing and engineering should be oriented in such a way as to put more emphasis on green extended supply chains to reduce the amount of waste generated as well as raw material used.

It hasn't been until recently that this issue has become major concern for manufacturers worldwide. In light of dwindling natural resources, it is imperative that manufacturers and product designers make environment conscious manufacturing their primary concern. This can be facilitated by designing a product in such a manner as to minimize the environmental impact over the course of its lifetime. Adoption of Design for manufacturability principles can go a long way in achieving this objective. Civic institutions can promote recycling and reuse more vociferously and thus educate the population about its benefits. There are two approaches that need to be implemented if there will ever be a move towards green manufacturing. These approaches are defined as the proactive approach and the value seeking approach.

Kopicki et al. (1993) introduced three approaches to environmental management namely the reactive, proactive and value-seeking approach. In the reactive approach, companies commit minimal resources to environmental management. In this approach, companies start to procure some products with some recycled content, label products that are recyclable and use filters that serve to lower the environmental impact of production. It should be borne in mind that filters are an "end of pipeline" initiative. They are primarily used to comply with environmental legislation that do not take away any of the causes of the environmental impact (Luttrupp, 2006). In the proactive approach, companies try to anticipate new environmental laws by committing a modest resource allocation to initiate the recycling of products as well as designing green products. Thus the company assumes responsibility over product re-use and recycling as an integral part of environmental management. The most far reaching approach seeks to add value. In this approach, environmental activities are integrated into a business strategy and the firm is operated so as to reduce its impact on the environment. This activity comprises a strategic initiative on part of the company. Strong environmental commitment is established by the CEO if the company and the capital commitment is shared among partners in the supply chain. Thus, proactive approaches are approaches that try to reduce the amount of pollution being produced (Kopicki et al., 1993; Stark, 2005). This approach is being implemented today by using lean manufacturing and just in time manufacturing techniques. The end goal should be value seeking. This is when management implements environmental activities into their facility to reduce environmental impact and also benefit the manufacturer. The main hypothesis is that if a manufacturer implements the environmental management practice of green product design, they will become more environmentally friendly and also save money in the process.

A comprehensive review of literature is presented in the following pages to illustrate the importance of green manufacturing. Several techniques currently being used to further this practice are also presented. It is a highly important contemporary issue; a fact that is corroborated by the spate of research that has been recently performed in this area and which will be presented in the following pages. This paper serves as a preface to a comprehensive methodology to enable environment conscious manufacturing.

## 2. Green Manufacturing

Green manufacturing can be very beneficial to manufacturing facilities because it can lower raw material cost. It can lower material cost because if the facility is recycling material that it has also purchased then it is not wasting money on new material. Second, green manufacturing can also help a facility with production efficiency. Third, green manufacturing can decrease environmental and occupational safety expenses. It can achieve this because if the facility is using less hazardous materials for production then less money will be spent on transporting and disposing of the hazardous waste (Rusinko, 2007). Also, less money will be spent on training and personal protective equipment for the facilities employee's handling of the hazardous waste. Lastly, green manufacturing can improve a facilities image in the public's eyes because if they are using less hazardous material and are producing less waste, the public will be more accepting of the facility (Richardson, 1997).

One of the draw backs of this is that some products are made out of problematic material which makes them very expensive to recycle. Such materials are expensive to recycle because remanufactures want to separate the product back into the original components. Also the process of collecting, transporting, sorting of end of life products and waste is highly expensive (Richards, 1997). Some of the aforementioned materials can be removed from products by smart design, but it is impossible to remove all problematic materials. This is when industry needs to make the decision of trying to reuse the material or dispose of the material. Another immense problem in the United States is that the waste exchange systems that we have are very small scale, and for green manufacturing to work, these exchange systems need to be on a large scale to keep up with demand. Trying to reorganize a firm to accommodate reuse material can also be a big problem. Altering the concept of what constitutes a product as well as the addition of new metrics to evaluate environmental sustainability to the process of product design may not necessarily be in complete agreement with the fundamentals on which a company has been founded.

There are also regulation issues in the United States because there are so many classifications for hazardous and non hazardous waste. For instance, corrosive resistant coating is applied to auto bodies by passing the auto body through a zinc phosphate bath. It is only a matter of time before the bottom of the bath become saturated with a slurry that is rich in Zinc. In one instance, it was common practice to remove the slurry periodically when the tanks were cleaned. The slurry was then sent to a zinc smelter. The smelter, in turn, processed it. The resulting zinc was put back into the industry supply stream. Over time

and over the course of regulatory actions, the slurry was classified as hazardous waste. Upon knowledge of this action and the potential repercussions that would follow, the smelter refused to accept the material any more. At this time this anecdote was told, the slurry was being sent to a landfill (Richardson, 1997; Srivastava, 2007). This can be a very big drawback to re-using material because if a material is classified as a hazardous waste, facilities are not going to want to handle the material because of the liability involved in handling hazardous waste. There are ways around these problems. They are usually solved by obtaining exceptions on a case by case basis.

### 3. Sustainable Manufacturing

Sustainable development and manufacturing is defined as a holistic approach that seeks to harmonize ecological, economical and socio-political needs with respect to the superior objective of enhancing living standards of human beings (Seliger et al, 2008). Sustainable manufacturing consists of designing manufacturing to meet our needs now and still allow for the next generation to meet their own needs. The main challenge of sustainable manufacturing is engineering products and process to be competitive in the market and still be environmentally friendly (Jovane et al, 2009). One of the principal avenues to achieve sustainable manufacturing is through the use of innovative technologies in manufacturing that seek to reduce waste (Jayal et al, 2010). In the past, sustainable manufacturing sought to use less energy and to make products efficiently. In the future, it will most likely deal with designing products to reduce the amount of waste produced and increasing the amount of recyclable materials being used in the supply chain (Seliger et al., 2008).

Product planning is an important element of green manufacturing (Baldwin et al, 2005). Products that are designed to last for a certain amount of time and then recycled and reused are a lot more environmentally friendly than its counterpart that is disposed into a landfill after being used once (Jovane et al, 2008; Herron, 2006). Designing products to be competitive in global markets is starting to become increasingly difficult (Ijomah et al, 2007). Organizations that excel at such endeavors are increasingly using technology to increase product functionality and environment friendliness. One of the main ways to design products with a certain lifecycle is top-down iterative methodology. This methodology consists of the following four steps (Kimura and Kato, 2002):

- Modes of product usage and life cycle scenarios associated with such modes are proposed. These are based on the capability of manufacturers as well as specific requirements of customers.
- The proposed product lifecycle can be designed and evaluated by simulating the product flow and services included in the life cycle,
- Products can be designed using a modular structure and individual components can be adapted to the proposed life cycle and particular modes in which they would be used,
- Product usage support can be evaluated in a more detailed manner by maintenance during product operation.

### 4. Application of Supply Chain Management Principles to Green Manufacturing

Environmental life cycle assessment comprises one of the principal clean technology processes. It is a formal approach that involves defining and evaluating the total environmental load that is associated with providing a service. The environmental load evaluation is performed by following the flow of material and energy from the 'cradle' to the 'grave'. (Kirkwood and Longley, 1995) The basic concept behind life cycle assessment is to look at everything that goes into a particular part or service and determine where the most waste is created (Darnall et al, 2006). Once the areas with the most waste are identified, it can be decided if the area can be totally eliminated or the surrounding processes or services can be changed so as to minimize waste (Vachon, 2006).

Sustainable products and services development (SPSD) is defined as the process of making products and/or services in a more sustainable manner from conception to end of life. Thus, it involves a lifecycle approach to design (Maxwell and van der Vorst, 2003) The goal of SPSPD is to produce products and/or to provide services, which are sustainable and functionally sound, meet customer requirements and are cost effective as well (Maxwell and van der Vorst, 2003; Seuring et al, 2008). Sustainable products and service development are important in green manufacturing because they offer the same quality part with the same economic value and they are also very good on the environment (Walker et al, 2008). They offer benefits to the environment because they don't use as much energy and natural resources to make (Barreto et al, 2010). Additionally, most of the waste that is created is recycled and reused to make new parts and services. One of the main concepts of sustainable products and services development is depicted in figure 1. Figure 1 explains the concept of product of service life cycle. This figure depicts the flow of the product from the concept stage to the end of life. The material loop is closed by means of the product being returned back into the supply chain in the form of raw material after the process of recycling.

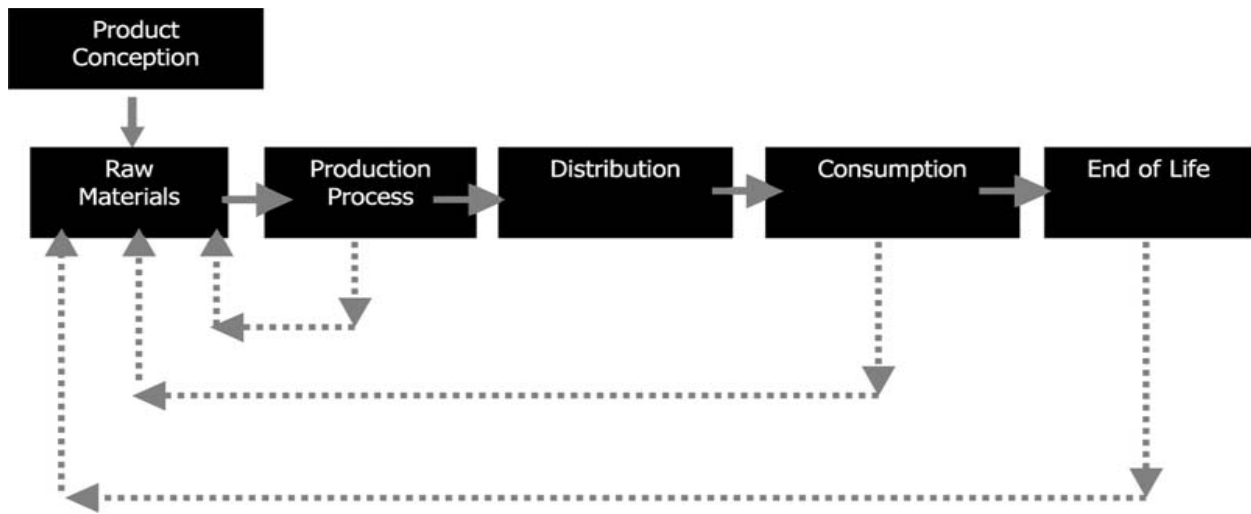


Figure 1: Stages of The Product Life Cycle (Maxwell, van der Vorst, 2003):

SPSD doesn't just look at the individual facility producing the product or service, it goes beyond and looks at the underlying supply chains. Green supply chain management is defined as 'integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life'. (Srivastava, 2007) A manufacturing organization receiving non-recyclable materials from a supplier adds to the total waste produced. Green supply chain management starts with designing products that use recyclable materials to reduce the amount of waste that the facility produces. Green supply chain management doesn't just involve the suppliers of the raw materials. The companies themselves are suppliers to the end consumers (Vachon, 2008). This underlines the need to design products that can be recycled and reused. Waste starts with the supplier and usually products are not produced just by one facility. The constituent materials are sourced from several facilities to make the final product assembly. Incorporation of sustainable and green manufacturing philosophy on part of suppliers often results in enhanced system wide efficiency.

Table 1 presents the steps that need to be taken in order to move from just recycling products back into the system to 'greening' the supply chain. This evolution constitutes a move away from reactive approaches (That seek to merely comply with regulations) to a more expansive attempt that seeks to add value, proactively with the objective of enhancing competitiveness (Hoek, 1999; Vachon, 2008). The perspective is thus modified from viewing the concept of 'greening' as a burden to considering the process as a potential source of competitiveness. This can be based on the following factors:

- A marketing edge is created by using the concept of 'greening' as an outstanding selling point with customers who are environmentally conscious.
- Innovation is leveraged by using strategies such as Design for disassembly. In such cases, the design could be based on smart product connectors that are easier to (dis-)assemble, thus resulting in lower assembly lead-times.
- Cost-savings are realized through resource savings. This is accomplished by using less fuel. Fuel consumption can be reduced by minimizing trucking miles, thus resulting in not only lowering emissions but also savings in terms of fuel expenses and drivers' working hours.

Supply chains are important in developing a lean production system. A firm using green suppliers will be leaner and greener due to the presents of less hazardous waste as well as the use of materials that can be recycled. This results in substantial monetary savings. There could be some problems with the implementation since it could cause a facility to spend more money to transfer over to different suppliers (Vachon, 2008). However, it has been proven that a well-developed green supply chain will lead to a reduction in overall cost. The characteristics of a well-developed lean supply arrangement constitute high levels of information sharing, rapid improvements in performance in suppliers and low transaction costs (Lamming, 1993; Dyer, 1997). For many years facilities have just implemented enough environmental management practices to comply with government regulations but one of the key concepts of supply relationship tries to move away from this. The supply relationship allows customer firms to obtain a better grasp of the environmental impacts of their supply activities. This may lead to mutual improvements in environmental management practice and realizing environmental solutions that are also cost effective (Simpson, Power, 2005). In other words it allows for facilities to understand the environmental impact of their suppliers so they can devise better ways of producing cleaner products. One of the ways to improve customer supplier relationship is for the customer to become more involved in the supplier facilities what goes and be cognizant of the processes and materials

involved in making their product. In this context, lean manufacturing is a very important part of green manufacturing. The lean production philosophy is comprised of four separate elements, namely just-in-time, preventive maintenance of equipment, quality management and human resource management (Womack et al., 1990; Shah and Ward, 2003). One of the best ways to improve lean manufacturing is by implementing lean suppliers into the supply chain. Lean suppliers exhibit strengths as well as drawbacks. Transitioning to a lean supplier often results in high transaction costs, erosion of goodwill from the preexisting supplier as well as with other suppliers who are witness to this event. It is often difficult to obtain new lean suppliers due to the nature of their strong relationship with other customers (Simpson and Power, 2005). It has been observed that competitive forces in many markets are often lacking in their ability to generate a ready pool of qualified lean suppliers (MacDuffie and Helper, 1997; Lamming, 1993). The best way to get around these problems is to improve current suppliers' lean manufacturing practices.

## 5. Industrial Ecology

A related thought on sustainable manufacturing is the idea of ecologically sustainable development. Ecologically sustainable development is the idea of allowing the current generation to meet their needs while still allowing the next generations to meet theirs.

In the next twenty years, the world population is expected to double putting a big strain on the earth's resources if current practices related to resource utilization are not changed. (Turner et al., 1991; Schafer, A and Victor, D; 2000). Government regulations have started the move to ecologically sustainable development (ESD) but this is only happening in developed countries (Gibbs et al, 2005). According to global ESD, more affluent entities should adopt lifestyles that are within the ecological means of the environment (Hertwich, 2005). Simultaneously, it requires that the total population of the world be limited, and involves managing global resources as the earth is transformed by anthropogenic actions (Turner et al., 1991). It seeks to attain an alternative form of economic growth that is ecologically sustainable. It tries to achieve this by using energy conservation, resource regeneration, environmental preservation, and minimization of wastes (Costanza, 1992).

There are four basic strategies to ecologically sustainable development: The first strategy involves management of the impact of populations on ecosystems, the second strategy consists of ensuring worldwide food security, the third strategy involves managing ecosystem resources in order to maintain their long-term viability, and the fourth strategy consists of creating ecologically sustainable economies. (Shrivastava, 1995) It is also very important for corporations and facilities to contribute to ecological stability (Gibbs, 2007). The four mechanisms through which companies can contribute to ecological sustainability are enlisted as follows (Shrivastava, 1995):

- Total quality environmental management [TQEM],
- Ecologically sustainable competitive strategies,
- Technology-for-nature swaps [transfers],
- Corporate population impact control).

Ecologically sustainable competitive strategies are another important concept. The market for environmentally friendly products has risen greatly in the past few years and this is causing companies to invest more money in these strategies so they can gain an advantage over other facilities that are not investing in such strategies. Another problem with reaching environmental stability is that developed countries consume a lot more resources than do developing countries. The main reason for this is that developing countries don't want to spend the money to invest in new technologies to reduce the amount of waste that they create. Lastly to achieve ecological sustainability, population growth needs to stabilize.

Since human population is on the rise it has created more environmental stress mainly due to the pollution and waste that humans have created in the process. In the future, sustainability is going to have a major influence on everything that we do from how we use our land to our manufacturing process. To deal with this issue we are going to have to become more advanced in clean technologies when dealing with industrial processes and the waste that they produce.

There are two means of approaching industrial ecology. The first is material specific. It consists of selecting a material or group of materials and analyzing the manner in which it flows through the industrial ecosystem. The second type of industrial ecological analysis is product specific. It selects a particular product and analyzes the manner in which its different component materials flows may be either modified or redirected so as to optimize product-environment interaction. (Jelinski, 1992; Gibbs, 2007) Most facilities are moving away from this and it is very important that we do so because the natural resources that we have left cannot support the way that we are using them now. Industry needs to begin using less resources and creating little waste by using the ecological method of producing the product, sending it to the customer and then recycling and reusing the material over again.

Industrial ecology can also be linked to the business side of a company. One of the main ways to link ecology with business is to consider the environment as a customer as well. This makes the designers of the product have to design the

product to accommodate the environment also and not just the customers that will be using the product. There is also a technique that takes into account the environmental concerns of the customers that the facility is trying to sell their products to and how it will increase the business value of their product if they accommodate these customers' concerns. Lastly, there is a technique called the Kano technique that is used to develop an environmental strategy that links business strategy, cost reduction, etc. There are several one dimensional attributes that need to be addressed when using this technique. These attributes are explained below and presented in table 1.

First an environmental product attribute is perceived as being one-dimensional by a customer if he or she is satisfied when the environmental attribute is designed into the product. Conversely, they can feel dissatisfied when the attribute is absent. Secondly, a customer could view an environmental product attribute as must-be if he or she is dissatisfied when the attribute is absent from the product but feels indifferent or has no feeling when the attribute is designed into the product. Thirdly, an environmental product attribute is considered attractive to a customer if he or she experiences a feeling of satisfaction when the attribute is present but has no feeling when the attribute is absent. Fourth, an indifferent environmental product attribute creates no feeling for a customer when it is present and no feeling when it is absent. Fifth an environmental product attribute is considered reverse if a customer experiences a feeling of satisfaction when the attribute is absent or a dissatisfied feeling when the attribute is present (Kano, 1996).

Table 1: Definition of Kano categories for a single product attribute and related customer perceptions (Finister et al, 2002)

Type of Attribute	When the attribute is present in the product	When the attribute is absent from the product
One- Dimensional	Satisfied	Dissatisfied
Must-be	No feeling	Dissatisfied
Attractive	Satisfied, delighted	No feeling
Indifferent	No feeling	No feeling
Reverse	Dissatisfied	satisfied

## 6. Environmental Management

Environmental management is defined as implementing aggressive environmental programs and policies to reduce a facilities environmental footprint. Environmental management has been said to be harmful to a company's performance by costing them more money. In the face of growing government regulations related to environmental conservation, firms that proactively adopt green technologies will already be ahead of the competition. Another way that environmental management can help a facility is that it can prevent spills or releases of waste into the environment that would cause the facility to be fined if such an accident had happened. Many surveys have demonstrated that consumers would rather use environmentally friendly products if presented with the choice. Environmental management allows for facilities to make environmentally friendly products which would enable them to appeal to the customers and eventually get into other markets that they would otherwise not have been able to.

Companies around the United States and the world are starting to become more environmentally friendly. According to a survey done by Florida and Davison (2001), 24% of the respondents have an environmental management system, and 28% have adopted and pollution prevention program. Out of these almost 18% are classified as high-adopters. This implies that they have adopted both an environmental management system and a pollution prevention program. On the other hand, other companies either did not have a program or did not respond to the survey. The companies that did have these programs were usually a great deal larger than the ones that didn't. These companies usually averaged around 250 people with many more people on their environmental staff. There are three main reasons for adoption of these programs:

- First is in response to government regulations,
- Second is to improve environmental performance,
- To be more competitive and efficient (Florida and Davison, 2001).

Most companies are motivated by a commitment to environmental improvement. They are driven mainly by corporate goals and objectives. This is evident from table 2. From the Data collected in the survey done by Florida and Davison there is a total motivation factor of 56.1% for commitment to environmental improvement and a 55.1% motivation factor for corporate goals and objectives. Federal and state regulations are not far behind. They are around 53 and 54 percent respectively. Similarly, there are many benefits that can be accrued from advanced environmental management practice. They range from efficient use of raw materials, reduction in fines to quality improvements.

Table 2: Factors Motivating EMS and P2 Adoption (Florida and Davison, 2001)

Factors	Total(N=214)	High-adopters(N=62)	Non-Adopters(N=99)
Commitment to environmental improvement	56.1%	91.9%	22.2%
Corporate Goals/ objectives	55.1%	88.7%	20.2%
State regulatory climate	54.2%	85.5%	23.3%
Federal Regulatory climate	53.7%	83.9%	24.2%
Economic benefits/ business performance	52.3%	87.1%	19.2%
Improved community relations	51.9%	85.5%	21.2%
Other	1.9%	3.2%	0.0%

Companies that have developed EMS program were also a great deal more innovative than factories that haven't developed an EMS program. These companies were more likely to be ISO 9000 certified, have total quality management programs, just in time, etc. Figure 2 shows the percent difference of advanced practices developed between high adopting factories and non-adopting facilities. In a survey done by Florida and Davison the data shows that employee involvement and internal audits are the most commonly used practices. In high adopting factories these practices amount to about 90 percent while they much lower in the non-adopting factories.

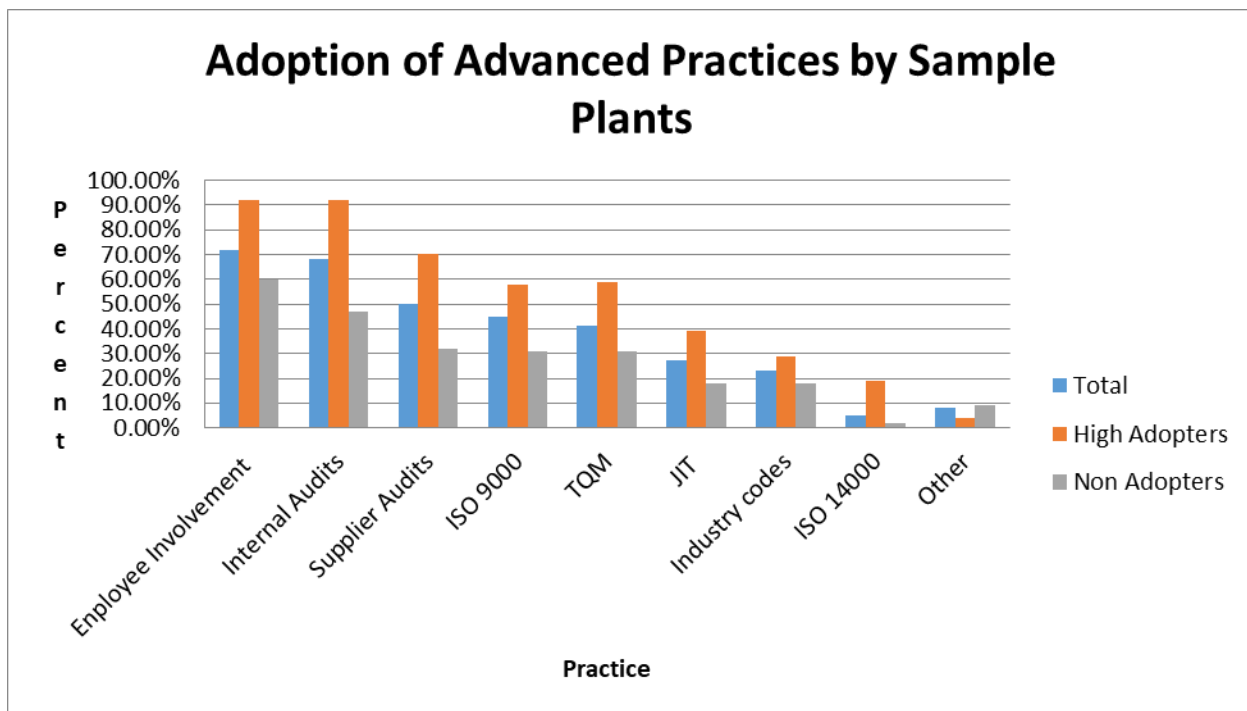


Figure 2: Adoption of Advanced Practices by Sample Plants (Florida & Davison, 2001)

Florida and Davison (2001) also completed a survey that evaluated the environmental performance between adopters and non-adopters of an environmental management system. From figure 3 it is easy to see that EMS adopters had a much higher environmental performance than the non-adopters. In every category the adopters of EMS outperformed the non-adopters by about 20 to 30 percent

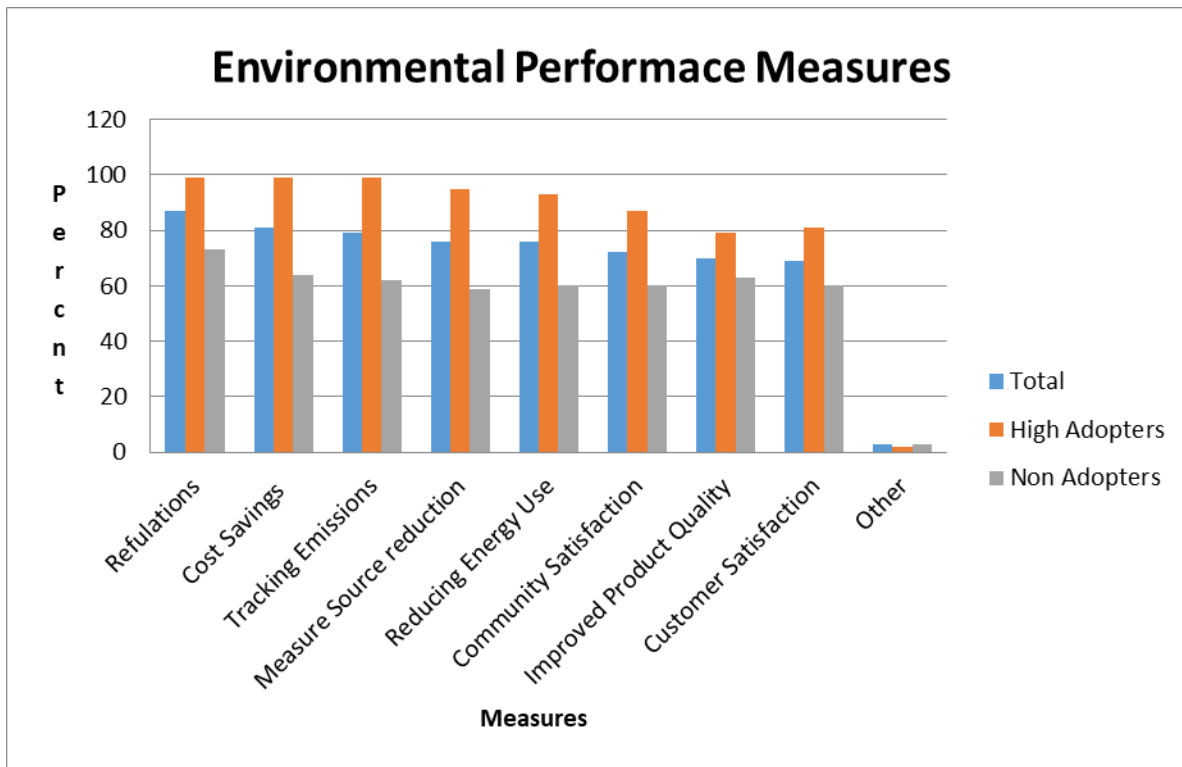


Figure 3: Environmental Performance Measures (Florida & Davison, 2001)

## 7. Environmental New Product Development

Environmental New Product Development (ENPD) is important when trying to design green products. ENPD is defined as product development which incorporates the integration of environmental issues in order to create products that are one of the least environmentally harmful products that have been recently produced by a firm (Pujari et al., 2003). This includes redesigning a product that already exists and making it more environmentally friendly (Luttropp, 2006). One of the main problems with designing environmental new products is that they have to be competitive with products that already exist so that consumers will start to buy the green products. Another method for environmentally friendly products is product design for environmentability (Luttropp, 2006). The advantages of this approach include simpler product structures with reduced part count, lower product cost, reduced rates of defects, higher degree of reliability, lower costs and shorter development cycles (Dewhurst, 1993). Dewhurst also hypothesized that such design requirements would result in less expensive service procedures, more efficient final disassembly, delayed product disposal and, above all, more profitable part and material recovery procedures. A good example of this is how car manufacturers are now designing plastic panels for their cars that are easily removed with a few fasteners. They are also labeled with the resins that they are made of. This allows for the panel to be easily removed and recycled. Luttropp (2006) also designed a tool for EcoDesign education that he called The Ten Golden Rules:

- First, the use of toxic substances is not allowed and utilize closed loops should be utilized for necessary but toxic ones.
- Second, energy and resource consumption should be minimized in the production phase and transport. This can be achieved through improved housekeeping.
- Third, structural features and high quality materials can be used to minimize product weight if such choices do not interfere with the necessary degree of flexibility, impact strength of other functional priorities.
- Fourth energy and resource consumption in the usage phase should be minimized. This is especially true for products with the most significant aspects in the usage phase.
- Fifth, repair and upgrading practices should be promoted. This is especially true of system-dependent products.



- Sixth, long life should be promoted. This is especially true for products that have significant environmental aspects outside of the usage phase.
- Seventh, it is important to invest in better materials, surface treatment or structural arrangements. This is necessary to protect products from direct, corrosion and wear, thereby ensuring reduced maintenance and longer product life.
- Eighth, prearrange upgrading repair and recycling through access ability, labeling, modules, breakpoints and manuals.
- Ninth, upgrading, repair and recycling should be promoted by using few, simple, recycled, not blended materials and avoiding alloys as much as possible.
- Tenth, the number of joining elements should be minimized as much as possible. This includes avoiding using use screws, adhesives, welding, snap fits, geometric locking, etc. according the life cycle scenario.

Small and medium enterprises are important in green manufacturing because they make up a large portion of the manufacturing market. There are several problems that keep many of these facilities from going green. One of the main reasons is that the facility has to invest in technologies in different areas than in traditional technologies and this can become very expensive. Also there could be a bigger demand for green products in different parts of the country and this could also hinder a facilities decision when considering going green (Luttrupp, 2006). There are four environmental strategies defined by Steger (1993) that are usually adopted by manufacturers:

- An indifferent strategy. This strategy is usually adopted by firms which perceive little potential for market opportunities and low environmental related risk associated with their operations.
- A defensive strategy. This strategy implies investment in 'end of pipe' technologies to ex-post correct the environmental impacts of products and processes.
- An offensive strategy. In this strategy, a company may develop or modify some of its current products in order to gain a competitive advantage;
- An innovative strategy. This strategy consists of introducing major and systematic changes in the company's products, processes, and management system.

## 8. Conclusion

There are many methods available to choose from to implement green manufacturing into a company. In the past, green manufacturing was not important, but as the population continues to increase, lean and green manufacturing approaches are beginning to be used. Today's industries are implementing proactive and value seeking approaches to green manufacturing. Sustainable product and service development is another key through which green manufacturing can be achieved. It involves the entire life cycle assessment, supply chain development, and product design. There are many methods that involve management, employees, and suppliers to create green manufacturing processes. If the company is large or small, there is always something that can be done to achieve green sustainable manufacturing. This paper sought to present a comprehensive review of literature pertaining to green manufacturing, related terminologies as well as obstacles to implementation. The authors are working on a proactive methodology to incorporate green practices into product design, which they hope to present in a subsequent paper.

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