Volume 4 Issue 2 (2016) 482-488 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

Implementation of green Manufacturing: A Review

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Article Info
Article history:
Received 29 January 2016
Received in revised form
18 May 2016
Accepted 5 June 2016
Available online 15 June 2016

Keywords Cement industry, environmental hazardious material, green manufacturing.

Abstract: The concept of green manufacturing is to reduce the waste and environmental hazardous materials from the manufacturing process. This also involves the recycling of the waste and involving biological raw materials. This discussion deals the various aspects that promote, facilitate and evaluate the green manufacturing process. To depict the green manufacturing effect, we consider a cement industry data over a period of 48 months, where different aspects will be modified with green manufacturing inputs and thus obtained data when analysed showed that green manufacturing inputs have improved the manufacturing process.

1. Introduction

Green manufacturing is described as "manufacturing processes that do not hurt the environment during any of the product's journey phases," and includes green product design, use of environmentally friendly raw materials, eco-friendly packaging, distribution, and reuse once the product's life cycle has ended. It reduces pollution and delays the loss of natural resources, it covers a number of manufacturing issues, including reduce, reuse, recycle, recover, redesign and remanufacturing conservation, waste management, environmental protection, regulatory compliance, pollution control, and other allied requirements. In the modern context the green manufacturing has gained momentum, as a result of various individual inputs. The term green manufacturing can be explained in various ways, such as producing environmental friendly products, using the natural raw materials and also cutting down the major pollutant aspects in the manufacturing process.

Many manufacturing businesses need a lot of energy, whether it's coal or electricity. Throughout addition, in the production process, they employ a lot of chemicals and harmful materials. As a result, a significant amount of pollution will be released during the manufacturing process. Without good management, it may cause significant environmental harm. As public awareness of environmental preservation grows, more and more businesses are taking steps to safeguard the environment. The government also plays an essential role in establishing environmental policies and punishments. Green manufacturing has received a lot of attention in recent years.

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Environmentally aware manufacturing, commonly known as green manufacturing, is a contemporary industrial paradigm. It takes into account the effects of the environment as well as resource efficiency. The goal of green manufacturing is to have as little impact on the environment as possible while maximising resource use.

1.1 Concept of green Manufacturing

The term "green manufacturing" was coined to characterise the modern manufacturing process, which incorporates numerous green tactics and techniques to become more environmentally friendly. This include creating items and systems that consume less material and energy, swapping out input materials, etc., converting undesired outputs to inputs, and minimising unwanted outputs. As a result, while the term "green" is used to describe a manufacturing method that is aware of its production/product impact on the environment and resources and incorporates such impact into its overall efficiency planning and management, when it is applied to manufacturing, it is used to characterise a manufacturing approach that is aware of its production/product impact on the environment and resources and incorporates such impact into its overall efficiency planning and control.

2.Forces Driving Green Manufacturing

There are some factors that force the manufactures to implement green manufacturing into their system

2.1 Increasing emissions and the resulting climate change

Greenhouse gas (GHG) emissions have risen dramatically in recent years, and this trend is expected to continue. Temperatures have climbed by 0.74 degrees Celsius worldwide in the last century, the fastest rate of warming ever recorded on the planet. Emissions will treble by 2050 if current trends continue, compared to 2000 levels.

By the end of the century, this might entail a temperature rise of 4–6ºC above pre-industrial levels. The global environment, hydrological system, sea level, crop output, and associated activities are all projected to be severely impacted by this unprecedented event.

2.2 Natural resources are rapidly depleting

With ever-growing population and industrialization, demand for natural resources such as wood, coal, oil, food, and water is constantly increasing, while supply is rapidly diminishing. This has resulted in recurrent demand–supply imbalances and rapidly volatile prices, which have impacted both company profitability and consumer spending. There is a pressing need to

(a) properly manage the use of these resources and

(b) find and develop less limited alternatives, such as wind and sun.

2.3 Pollution and trash creation are increasing.

Waste output and pollution have increased dramatically as a result of increased industrialisation and urbanisation. Industrial waste with a chemical composition can be hazardous to one's health, and its untreated disposal pollutes both land and water. Industrial effluents are wreaking havoc on local ecosystems when they are discharged into rivers and other bodies of water. E–waste is becoming a major cause of pollution as the demand for and usage of electronic items grows.

A growing number of businesses are incorporating green efforts into their daily operations. Five causes are driving these initiatives:

Costs of energy and inputs are rising. Green products are becoming increasingly popular among consumers. Regulatory constraints are increasing as policymakers enact new and more stringent environmental and waste management rules.

Technological advancements that create new and appealing business prospects The necessity to improve competitive difference, especially for first movers or those who can break the compromise between short–term greater costs and a plethora of advantages (example: brand premium, new customer segments)

2.4 Efficiency

Producing the similar product using fewer resources and/or energy is an effective money-making method. To put it another way, being efficient through preventing waste is both environmentally and financially efficient. As a result, management should recognize that the expense of green manufacturing efforts will be offset by the money saved in a more efficient system, which will benefit the industry. There are several wastes that may be removed in the production process as well as the finished product.

Green efforts benefit companies in terms of brand improvement, political traction, and regulatory compliance, as well as increased capacity to attract and retain personnel, improved customer retention, and possible cost savings. However, because the economics of green manufacturing are not fully understood, these benefits need a long-term commitment and trade-offs with short-term goals.

2.5 Industries that are adopting green manufacturing

Green manufacturing entails three steps:

(1) using green energy,

(2) developing and marketing green goods,

(3) incorporating green processes into corporate operations.

According to a latest global study, as many as 92 percent of the organisations polled are involved in green efforts. Green manufacturing techniques help organisations not just in terms of long–term cost savings, but also in terms of brand improvement with customers, improved regulatory traction, increased capacity to attract talent, and increased investor interest.

The manufacturing sector if divided into categories of their production capacity then we get large, medium and small-scale industries. When we talk about implementation of green manufacturing in the large-scale industries, there had been considerable effort made by these companies to reduce their carbon footprint. This process is being done by implementing various green manufacturing processes like manufacturing less non-degradable products, maintaining low wastages and the use of environmentally friendly raw products. The implementation of these aspects will lead to change in product classification or product contents produced by the company, but the large industries owing to their brand image can adopt the change in minimum time and maintain their brand image un-altered. The same case is not with the small and medium manufacturing companies.

The small and medium scale industries have not yet achieved their strong brand image among their customers when compared to large scale industries. The companies have their own cycle of production and selling which is running the company successfully. The sudden change in this cycle may lead to drastic in the production and sales numbers. The green manufacturing also means use of more quantities of environmentally friendly Raw materials, this means changes of raw material supplier to the company. Similar way, every new aspect in the manufacturing cycle will lead to change in some correlating aspect in the manufacturing leading to replacement of existing suppliers to the industry. This way shifting to green manufacturing does not have same effect large industries and small industries. But there are other factors also which do not compel the small industries to shift towards the green manufacturing, these factors are such as lesser carbon foot print in comparison to the large-scale industries, low brand image or lesser brand loyalty among customers makes these companies to stick towards growing brand image rather than shifting to environmentally friendly manufacturing.

The next aspect which impacts or influence the green manufacturing is the demand of the customers, any company operates on the basis of demand and supply factors. The companies had to shift towards green manufacturing if the demand for the environmentally friendly products increase among the consumers. The consumers on the other hand in the present scenario are not very much concerned about the impact created by the waste created by them. When considered examples of the plastic wrappers around the products have no actual use to the end consumer and this is a major non- degradable product. This way there are many such un-noticed waste from the consumer's side, the recycling or management of which the people are not concerned. When people become aware of the waste created by them and demand for more environmentally friendly products will force the companies to shift towards green manufacturing.

3. Cement Industry

Due to significant economic growth, India's cement output reached 337.32 million tonnes in 2011, with an installed capacity of 537 million tonnes, accounting for around 7.1 percent of world production. Global cement output was 4.1 billion tonnes in 2010, according to the United States Geological Survey (USGS). Huge amounts of green-house gases (GHG) are released throughout the clink erization process, particularly from limestone calcination (60 percent CO2) and fuel combustion (40 percent CO2). The dry technique is used in nearly all Indian cement plants. The cement industry is primarily concerned with minimising energy use, clinker factor, and CO2 emissions. To combat this, the Indian cement industry produces blended cements as Portland Pozzlona cement (PPC), Portland Slag Cement (PSC), and Composite cement, among others. Fly ash and slag usage increased to 31% and 57 percent in 2010. Reduced GHG emissions, conservation of natural resources, and use of industrial wastes are all advantages of blended cements. Fly ash, slag, and Portland cement are combined to make composite cement.

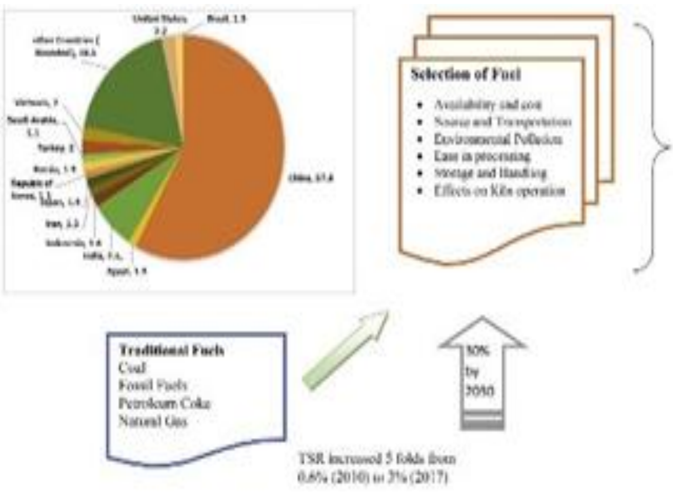

Fig.1: Cement Production in the world

Concrete is a fundamental construction material that will continue to be in high demand for many years to come. Ordinary Portland Cement (OPC) is difficult to envision. Although many varieties of concrete have been produced for diverse uses, they all share the same characteristics: familiarity, adaptability, strength, durability, broad availability, fire resistance, weather resistance, and a cheap cost. Carbon dioxide (CO2) is a by-product of the chemical conversion of limestone (CaCO3) to lime used in the manufacturing of clinker, a component of cement (CaO). CO2 is released during cement manufacturing from the burning of fossil fuels and is compensated for elsewhere.

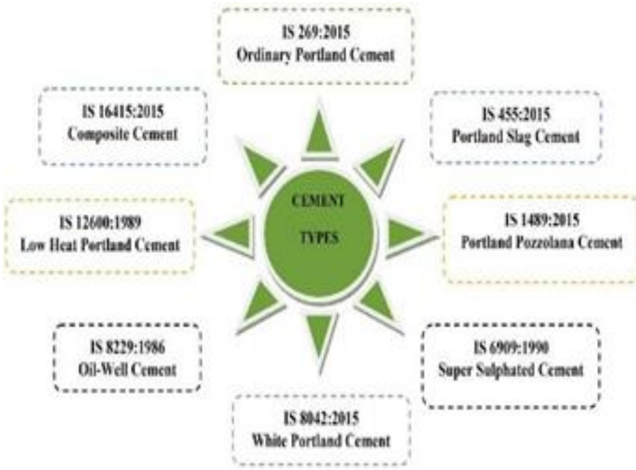

Fig.2: Cement Types

Following the power plant sectors, the cement industry is one of the largest emitters of greenhouse emissions. Cement production accounts for around 8 to 10% of worldwide anthropogenic CO_2 emissions, and it is likely to continue to rise in the future, releasing additional CO_2 into the atmosphere. According to a research, by 2050, the cement industry should cut cement clinker by 60% and adopt particular efforts to capture and store CO_2.

3.1 Carbon Emission

During the manufacturing of clinker, a component of cement, carbon dioxide is emitted as calcium carbonate ($CaCO_3$) is heated in a rotating kiln to cause a series of complicated chemical reactions. CO_2 is emitted as a by- product during calcination, which happens at temperatures of 600-900°C at the upper, cooler end of the kiln, or a proclaimer, and results in the conversion of carbonates to oxides. The following is a simplified stoichiometric relationship:

$$CaCO3 + heat = CaO + CO_2$$

At greater temperatures towards the bottom of the kiln, lime (CaO) interacts with silica, aluminium, and iron- containing components to produce minerals in the clinker, a cement intermediate product. The clinker is then removed from the kiln to cool, pulverised into a fine powder, and mixed with a little quantity of gypsum (about 5%) to form Portland cement, the most common type of cement. The second most common form of cement is masonry cement. Because masonry cement requires more lime than Portland cement, it generates more CO_2.

During the calcination of cement kiln dust in the kiln, CO_2 is also emitted. Cement kiln dust is a by-product of the kiln process, and some of it is returned to the kiln to be mixed in with the clinker. The rest is thrown away, either in a landfill or for other purposes. The CO2 emissions from lost cement kiln dust are not considered when calculating clinker emissions.

3.2 Techniques for CO2 reduction in cement industries

Some of the techniques to producing more sustainable cement have been recognised as carbon capture and storage (CCS), material substitution, alternative fuels, and energy efficient technology.

3.2.1 Carbon capture and storage (CCS)

CCS methods, such as absorption, membrane-based processes, mineral carbonation, and the utilisation of oxyfuel, have all been investigated as viable options for reducing CO2 emissions in the atmosphere. Modified cement products, such as CO2 concrete, as well as various other innovative technologies, such as Solidia technology, Carbicrete, and Carbon cure, are being investigated in order to reduce CO2 emissions from cement manufacturing and make cement a more sustainable building material.

3.2.2 Supplementary cementing materials (SCMs)

Material replacement is another often utilised strategy. To partially replace Ordinary Portland Cement, SCMs such as fly ash, slag, GGBFS (Ground-granulated blast- furnace slag), limestone powder, silica fume, RHA (Rice Husk Ash), calcined clay, metakaolin, and pumice have been utilised. By pozzolanic or cementitious reactions, these compounds aid in increasing the performance of concrete. All of these SCMs, however, have their own set of constraints. Fly ash is one of the most widely used SCMs for improving concrete durability, particularly the alkali-silica reaction; nonetheless, fly ash availability has been a cause of concern in the past. Limestone dust is another extensively used SCM, particularly in European nations; nevertheless, the lower strength of later age limestone restricts substitution levels over 15%. Furthermore, natural pozzolans such as RHA, Pumice, and calcined clay are not evenly distributed throughout the globe, raising worries regarding long-term supply.

3.2.3 Nanotechnology

Nanotechnology has recently been brought into the sector to compensate for the constraints of replacing SCMs in cement. Nanotechnology is the usage of materials with a diameter of less than 100 nanometers (10 times smaller than a cement particle), such as nano SiO2, nano TiO2, nano CaCO3, nano Fe2O3, nano Zr2O3, nano Al2O3, and nano graphene (CNTs and CNFs). Nanomaterials alter the structure of hydrated paste at the nanoscale, resulting in remarkable improvements in compressive and flexural strength, performance, and durability.

Most nanomaterials, on the other hand, come at a high cost, potentially raising building costs, and may not be a feasible solution for the construction industry. Furthermore, the efficiency of nanomaterials is primarily dependent on adequate nanoparticle dispersion, and dispersion procedures like as sonication are expensive for construction companies to use. As a result, the economic and technological constraints of employing nanomaterials have been a barrier to commercialization for the cement industry.

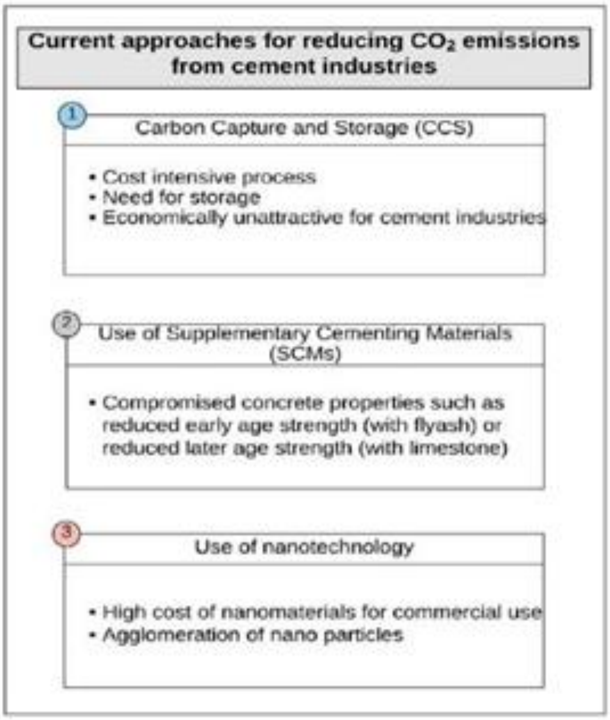

Fig.3: Reduction Techniques

3.3 Integrated approach for producing new generation cement

Nanotechnology would almost probably be implicated at a commercial scale if the cement industry were to absorb CO2 and use it to manufacture nano CaCO3 within the plant. The creation of nano CaCO3 in the cement plant, as well as the intergrinding of these nano materials with cement clinkers (and limestones as SCM), will contribute in the development of next-generation cement. The comprehensive strategy for creating ecologically friendly and long-lasting cement is depicted in this figure. In this process, CO2 will be removed from flue gas coming from the clinker producing unit (calciner and kiln). Purified CO2 will be transported to the production room, where precipitated nano CaCO3 will be made using a bottom up chemical synthesis method. In contrast to the top-down technique, which requires an energy-intensive process for fine grinding limestone, the released CO2 will be used in the bottom-up strategy, which will save future CO2 emissions. The bottom- up process produces precipitated nano CaCO3 by flowing pure CO_2 through an agitated aqueous calcium solution, resulting in a more efficient and homogeneous precipitated nano material. Calcium supplies for this operation

Volume 4 Issue 2 (2016) 482-488 ISSN 2347 - 3258
International Journal of Advance Research and Innovation

might include steel slag, cement, and kiln dusts, as well as calcium chloride from the Solvay process. To manufacture blended Portland cement with nano CaCO3, the precipitated nano CaCO3 (in the required proportion) is combined with cement clinkers and pulverised with nano CaCO3 and raw limestone. The remaining nano CaCO3 will be marketed to other businesses, generating revenue for cement plants.

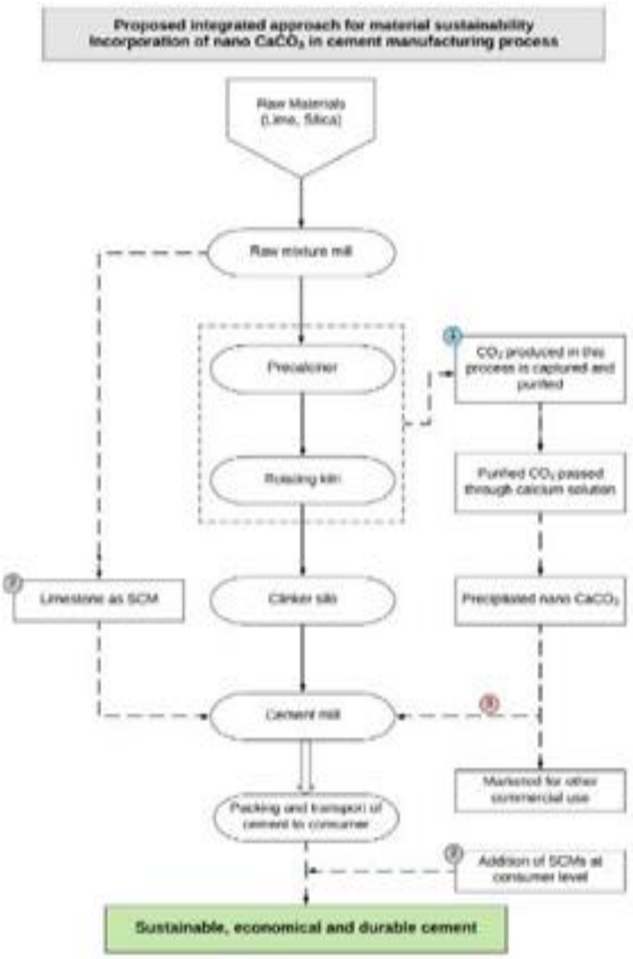

Fig.4: Integrated Approach for Material Sustainability

4. Analyzing the data of the cement plant

The various aspects of the cement processing are modified with the green manufacturing applications and their data is collected over 12 months for a period of 4 years. This data shows the cost of burning clinker and their allied consumption on the rest of the factors like recycled waste, power consumption, dust generated. This data is processed through regression analysis for further discussion.

4.1 Year 2008

Table 1: Model Summary

Mode l	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	a	109	_225	268552	109	327	3	8	.80 6

a. Predictors: (Constant), Dust emission, Recycled waste,Electricity in kilowatt

Table 2: Green Manufacturing in 2008

Year	Month	Operational performance measure	Green manufacturing practices		
2008		Y1 (Cost of Burning Clinker)	X1 (Recycled waste)	X2 (Electricity in kilowatt)	X3 (Dust emission)
	Jan	8629687241	1166.6	9686854.8	481.65
	Feb	7527062436	546.25	8995317.45	560.5
	Mar	7315544917	618.45	10045127.4	353.4
	April	10644159560	517.75	6869286.9	353.4
	May	9322477798	635.55	9209022.9	590.9
	June	10730461414	689.7	10478336.4	346.75
	July	7441209643	608	8685361.65	270.75
	Aug	11811441362	709.65	8901387.6	270.75
	Sept	10863911261	609.9	9384859.05	1202.7
	Oct	10155593181	501.6	9139830.63	656.45
	Nov	15941410060	404.7	8572726.89	220.4
	Dec	8461672284	533.9	8928470.25	218.5

Table 3: Anova matrix

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.065E+18	3	2.355E+18	.327	.806[b]
	Residual	5.770E+19	8	7.212E+18		
	Total	6.476E+19	11			

a. Dependent Variable: Cost of Burning Clinker

b. Predictors: (Constant), Dust emission, Recycled waste, Electricity in kilowatt

Table 4: Collinearity Diagnostics

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	Recycled waste	Electricity in kilowatt	Dust emission
1	1	3.755	1.000	.00	.00	.00	.01
	2	.195	4.384	.00	.04	.00	.94
	3	.046	9.069	.05	.87	.02	.03
	4	.004	30.609	.95	.08	.98	.01

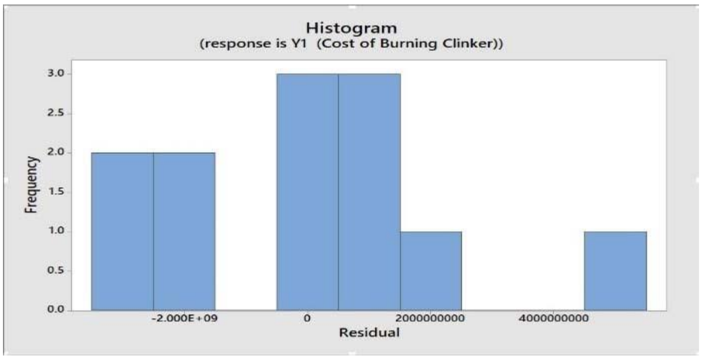

Fig.5: Residual Histogram for Y1 (Cost of Burning Clinker)

In this year we get an R2 value of 0.109, which depicts that the parameters which we have taken are contributing only to a 10.9% of the whole process.

The generalised equation we get will be

Y= -3280943.882X1 -334.203X2 -217455.393X3 +15098745638

Where X1= Recycled waste, X2= Electricity in kilowatt, X3= Dust emission, Y= Cost of Burning Clinker

5. Conclusion

In this discussion we have taken a example study of the cement manufacturing industry to analyse, which on interpreting with the values relating to green manufacturing aspects such as recycled waste and dust emissions showed us that the total effect of such factors on the cost of production processes like clincker burning is only 23% where rest 77% is dependent on other factors. But still we can see on bright side 23% of production process is transformed towards green manufacturing successfully with only three parameters change.

The discussion concludes that small, medium, and big manufacturing industries are two critical contributors to any economy's industrial growth and development. In the context of a rising country like India, which is rapidly emerging as a global manufacturing powerhouse, the importance of both sectors grows several times. Both sectors are interdependent and impact one another. Pressures from national and international organisations to move to green manufacturing from conventional manufacturing are increasing the necessity for both sectors to do so. If done effectively, green manufacturing reduces waste and pollution while also providing financial benefits and a better image. Due to government pressure to minimise waste and pollution, big industrial enterprises have been forced to convert to green manufacturing. This trend toward green production in major corporations is putting pressure on smaller businesses, especially small and medium-sized businesses. However, rather than imposing penalties on manufacturing enterprises, the government may educate the public about the importance of green manufacturing and the idea of carbon footprint. As a result, when customers express an interest in purchasing more environmentally friendly items, demand rises, and manufacturers must change to green manufacturing to match consumer expectations.

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