

Green Manufacturing (GM) is the way forward for the sustainable growth

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Abstract:

Green manufacturing (GM) is a term used to describe manufacturing practices that are environmentally friendly throughout any part of the manufacturing process. Green Manufacturing (GM) is rapidly emerging as a sustainable manufacturing solution with the potential to solve most of the problems facing the world today. It focuses on the use of processes that do not cause environmental pollution or harm to consumers, employees, or other members of the community. GM emphasizes the optimum use of consumables, the rationalization of materials and the reuse of components to make products more efficient to manufacture. There is a very large volume of GM literature covering many aspects. This paper is an attempt to review about research process, study, review , survey process & the results reveal that there is a need for the manufacturing Companies/ Units/ Plants small, medium, big or all should adopt the Green Manufacturing Practices/initiatives which will enable them to play a significant role in reducing the environmental impact while increasing the value of their products in terms of higher yield, Low cost of Production, higher productivity, Better Quality, higher profitability, satisfied employees, stakeholders, customers, community & society and significantly contributing to the targeted GDP of the Nation for sustainable growth

Keywords — Sustainability; Renewable Energy; Challenges; Assessment; Opportunities, Green Manufacturing, Critical Success Factors, Factor Analysis

I. INTRODUCTION

Manufacturing is the main driver for welfare and prosperity of human being. However, manufacturing also strongly contributes directly and indirectly to the depletion of natural resources, environmental burdens, affecting the health of animals, humans, living beings and eco-systems, as well as to social conflicts. These negative effects expand along with the worldwide demand for industrial products, which will further increase since the global population is still growing and less developed countries strive for the standard of living which richer countries have already achieved. Despite being aware of the prevalent limitations of natural resources and

absorption capacities of our planet against various harmful emissions, the demand for resources and the related pollution to the environment has continued to rise drastically.

The topic of Green Manufacturing emerged in the early 1990s and had been driven by human concerns about the protection of environment. Green Manufacturing is the creation of manufactured products that use processes that are non-polluting, conserve energy and natural resources, are economically sound, and safe for employees, communities, consumers, and thus for the living being on our planet earth. Green manufacturing is fast emerging as the sustainable manufacturing

solution that has the potential to solve most problems that the world faces today. Green Manufacturing covers the entire product life cycle from conceptual design to disposal in a benign, harmless manner causing no or minimal adverse impact on environment by optimum use of resources and reduction of waste and pollution. 4Rs (reduce, reuse, recycle, remanufacture) is slowly being accepted and adopted as the model of sustainable growth throughout the world.

Environmental, economic and social changes of any significant proportions cannot take place without a major shift in the manufacturing sector. In today's manufacturing processes, economic efficiency is realized through high volumes with the use of specialized machine tools. Change in society, such as in the form of mobility and digitization, requires a complete overhaul in terms of thinking in the manufacturing industry. Moreover, the manufacturing industry contributes over

19 % to the world's greenhouse gas emissions. As a consequence of these issues, a demand for sustainable solutions in the production industry is increasing.



FIGURE-1

The manufacturing industry influences economic, ecological and social development worldwide. Industrial energy consumption has been increasing in most developed and undeveloped countries over the last decades. Nearly a third of the worldwide energy consumption as well as CO₂-emissions are related to the production industry. Furthermore, an increasingly mobile and digital society is calling for

new customized technical solutions to a diverse array of products both anytime and anywhere.

The health of the workforce (human) is vital for social as well as economic sustainability. In terms of economic sustainability, direct costs due to unfavourable working conditions reduce a country's Gross Domestic Product (GDP), which is considered to be one of the main economic sustainability indicators defined by the United Nations—Department of Economic and Social Affairs.

It needs sustainable design and product development which starts by limiting potential harmful effects of the product along its whole lifecycle for various stakeholders (Work force, consumers and society at large). Classical examples in this context are gaseous emissions contributing to anthropogenic climate change, toxic liquid and solid waste or unnecessary cost for the company, customers or the society. Despite the prevention of negative effects sustainable products also provide opportunities to fulfil human needs and provide value in all areas of human living.

Sustainable (**Figure-1**) Product Development characterises the science and art of foreseeing the whole product lifecycle by handling multiple decision criteria at the same time to find a compromise between all involved stakeholders including the company, society, environment, and future generations. Hence, research on sustainable product development focuses on a diverse set of research questions of which some are listed below in an exemplary manner:

- i. What constitutes a sustainable product?
- ii. How can sustainability be integrated into the design/design management process?
- iii. Which forms of decision support are necessary to enable stakeholders for sustainable product development?

Further, while discussing economic component as above it is relevant to refer to a circular economy which is an economic system of closed loops in which raw materials, components and products lose

their value as little as possible, renewable energy sources are used and systems thinking of conservation of overall non-renewable material is at the core. This concept further strengthens the Green Manufacturing concept.

In view of the above this research, study and review is focused on the four integral elements of manufacturing – **Human** (for their safety and sustainable growth), **Input** (required for operations), **Operations & Products** (Output) Green Manufacturing as the core concept for sustainable growth (**Figure-2**).

II. OBJECTIVES

- i. To study, review and carry out research on Green Manufacturing (GM) Concept.
- ii. To study the “Four integral components” of (GM).
- iii. Conservation of Non-renewable material and energy.

III. REVIEW OF LITERATURE

Green Manufacturing (GM) has been explained by various authors. During our study and review on the topic (GM) we have observed that there are many frame works that have been used interchangeably by the researches, for example

- i. Cleaner production,
- ii. Sustainable production,
- iii. Sustainable manufacturing
- iv. Dornfeld defined GM as a process or system to promote sustainability and to reduce the environmental impact by minimizing resources and reducing pollution by recycling or developing green products
- v. Deif explained that GM reflects a new manufacturing paradigm that integrate various green strategies, drivers and techniques to become more eco- efficient, including reducing material and energy, substituting input materials and recycling.
- vi. Shrivastava and Shrivastava noted that GM is a method for manufacturing that minimizes waste and pollution, inhibits the rate of use of

natural resources and reducing input material, reusing components, to help to build products more efficiently.

- vii. Chuang and Yang analyse some literature and concluded that GM is a manufacturing method, the process of transforming materials or parts into finished goods and fulfill customer expectations that minimizes waste and pollution.

Southworth (2008) stresses on reducing harmful waste. Melnyk (2002) emphasis on managing the flow of environmental waste with the goal of minimising environmental impact while also trying to maximise resource efficiency. Hicks and Dietmar (2007) stresses on design improvement, utilization of clean energy and raw materials, the implementation of advanced processes, technologies and equipment. According to Pojasek (2008), GM has different meanings to different people, usually based on their discipline and training. Becoming Green should be considered to be a journey, not a destination or static state. From the above discussion, it is concluded that GM is a process which minimises environmental impact by minimising waste, pollution and toxics during production. It optimises use of raw material and energy by implementing necessary tools such as Lean & Operational Excellence. Thus, optimum use of resources, enhancing the productivity and maximising the profit should be the goal.

As per ISO 14001:2015 achieving a balance between the Environment, Society and the Economy is considered essential to meet the needs of the present without compromising the ability of future generations to meet their needs. Sustainable development as a goal is achieved by balancing the three pillars of sustainability (**Figure-1**).

Societal expectations for sustainable development, transparency and accountability have evolved with increasingly stringent legislation, growing pressures on the environment from pollution, inefficient use of resources, improper waste management, climate change, degradation of ecosystem and loss of biodiversity. This has led the organizations to adopt a systematic approach based on **Plan- DO-Check-**

Act to Environmental Management by implementing Environmental Management Systems (ISO 14001:2015) with is the aim of contributing to the environmental pillar of sustainability.

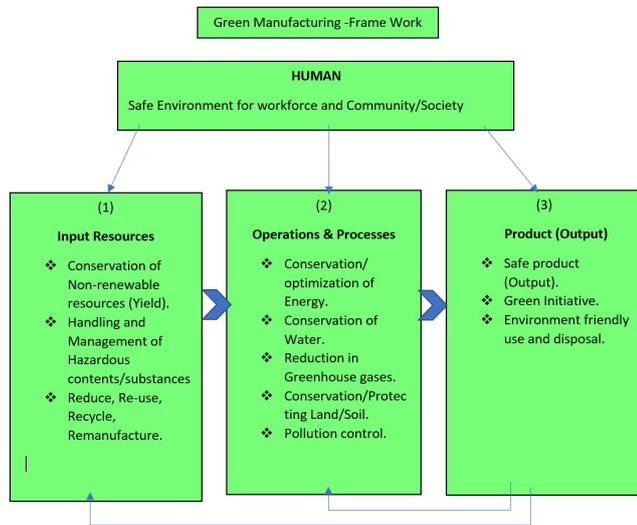


Figure-2

The Factory/ workplace has a significant impact on **human** working there as also on its surrounding community/ society. It needs overall participation of workmen and management to regularly identify hazards and timely eliminate the same.

Factories use **input material/ resources**, process/operate them to deliver the desired products/ goods (output) for the customers/consumers.

Non-renewable resources are derived from the Earth. Importantly, they have a finite supply that can take billions of years to replenish. Among the most common examples of natural resources are crude oil, coal, uranium, and mineral sources such as gold, Iron ore etc. The non-renewable materials may end up as part of the product itself and some may also be waste. This makes it necessary for accounting of non-renewable materials at the input stage. Consumption of non-renewable material could be reduced by reducing quantities sent to scrap, substituting with renewable materials (such as bioplastics) or redesigning the product to use less of the materials and **enhancing the Yield (Figure-3) through innovations/ new initiatives**. Extending the lifetime

of products is one approach to reducing the need for non-renewable materials.

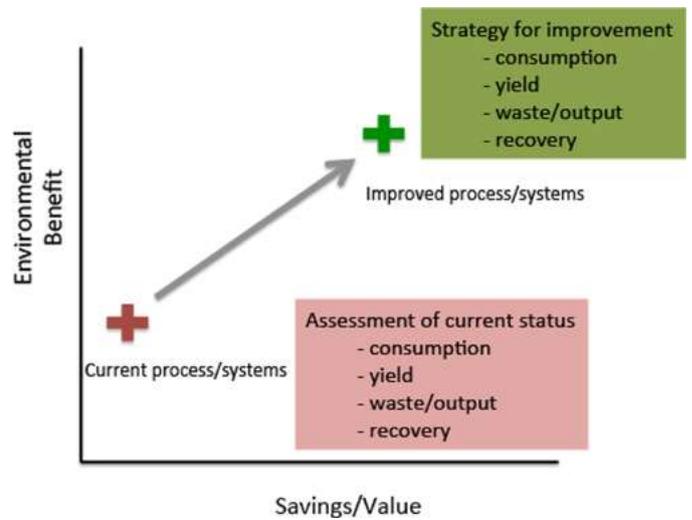


Figure-3

Let us take the example for production of Crude Steel – In order to produce 1000 Kgs (1 MT) of it the main inputs are roughly 1370 Kgs. of Iron Ore, 780 Kgs. of Coal, 270 Kgs. of lime stone and 125 Kgs. of Steel Scrap thus the total input material required would be 2545 Kgs (2.545 MT) and 1.34 GJ electricity is consumed. Thus, if through technological innovations / initiatives if we enhance the yield during its consumption in such a way that 1 MT of crude steel is saved i.e. consumption is reduced by 1 MT then we shall save 2.545 MT of Non-renewable material and conserve 1.34 GJ of electrical energy.

Many materials contain **restricted/ hazardous substances/ contents** that can cause harm to human or the environment if released. Release of the such substances could be avoided during product design stage or end-of-life stage. In case where it is not possible to avoid such substances programmes such as take-back or recycling could be established to manage such products/material.

Need for **Reduce, Reuse, Recycle, remanufacture** of materials is driven by product design. The demand for new materials can be lowered by incorporating a higher proportion of recyclable/reusable materials i.e. this concept should be taken care from the beginning – product design.

Conservation/ optimization of Energy during **Operations / various processes** is receiving increased/ focused attention due to rapidly growing demand of power, higher energy prices and awareness of environmental concerns. Focus is on **Renewable Energy, (Figure-4)** often referred to as **clean energy**, comes from natural sources or processes that are **constantly replenished** and thus **sustainable**. Renewable Energy Sources are **Solar, Wind, Hydroelectric, Geothermal, Ocean, Hydrogen, Biomass**

Changes in share of power generation in India in the stated policies scenario 2010-2040

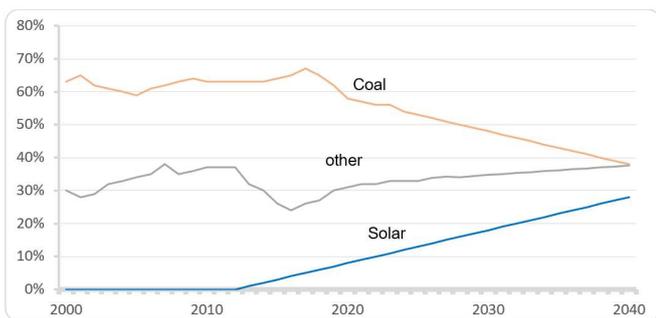


Figure-4

Conducting **Energy audits** to explore new avenues towards conservation & optimization of energy, Projects for improving **process efficiency**, purchase and installation/commissioning of **energy efficient equipment**, use of innovative methods/advance technology to **reduce specific energy consumption** are the core activities for the sustainable growth.

Water shortages and quality issues with it are the frequent problems. Depletion of rivers and lakes and the lowering of ground water tables could be caused if water withdrawn for industrial processes is not returned to the same water body in its original quantity and quality. **Water Balance** exercise should be carried out by the establishments periodically with valid consumption data tracking data. Effluent treated water should have nonhazardous content and used for gardening purpose. Adoption of Rain water harvesting.

Greenhouse gases are a group of substances that contribute to global warming. Exploring avenues to use clean fuels to reduce emissions from processes such as using PNG (piped natural gas) instead of diesel or furnace oil in furnaces/ovens.

The soil is an integral part of the natural environment. Improper disposal of industrial waste, drainage contaminates the **soil/ land**. Industries must handle the hazardous waste/substances in compliance with the norms set by respective pollution control board to protect the land and further provide green cover to land through plantation.

Industries bring prosperity but at the same time they increase **pollution** and degrade environment by creating four types of pollution to Air, Water, Land (Soil) and noise. Industries must comply with the statutory and regulatory requirements.

Good design and manufacturing processes are essential to ensure industry in meeting the technical, statutory, regulatory, safety and legal requirements of their **products**. Green innovations play a key role for manufacturing industries in moving towards sustainable production. Assessment of environmental impact should be carried out for its all stages of the **product life cycle (Figure-5)**, steps should be taken towards developing energy efficient products and solutions. Investment should be made into research to develop green products, products that are environment friendly, biodegradable, completely recyclable or decomposable.

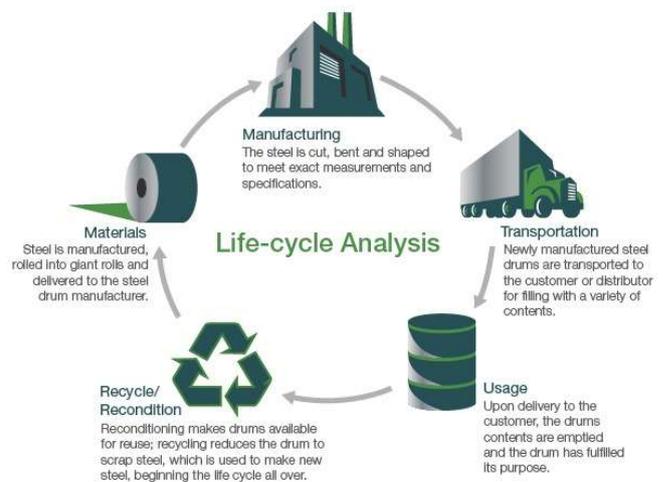


Figure-5: Life Cycle Analysis of MS/Metal Drums/ Containers

IV. SCOPE AND RELEVANCE OF STUDY

The **scope of Green Manufacturing** spans from product development to management of the entire product life cycle involving such environmental practices as eco-design, clean production, Reduce,

Reuse, Recycle, remanufacture, enhancing the yield, optimizing the consumption, energy with a focus on minimizing the expenses associated with **manufacturing**, distribution, use, and disposal of products.

In this global world environment, resources and population are major problems. Environment is crucial one with and change in climate at any point leads to the imbalance of the earth. The ISO has proposed the new quality management system for products and even for Environment management system. The main era is to minimize the environmental damage due to industries. There is a need of new manufacturing process i.e. Green Manufacturing which is required for sustainable development. The cost of energy and resources are constantly increasing due to rising demand and limited supply. We see that a lot of energy is used day by day and lots of waste being generated, the waste is hazardous and can lead the human being to a termination point. Toxic hazards are really crucial for human being. We have to continuously enhance the generation and use of renewable energy sources particularly Solar and our dependence on coal-based energy has to minimize at faster rate. Yield of non-renewable material has to be continuously increased through use of innovations. There has to be focus on Innovations and Research & development initiatives for green manufacturing processes. Hazardous waste has to be appropriately handled/ managed to ensure that our overall environment remain protected. The topic of Green Manufacturing is very vast and researchers are continuously working on it. Industries are becoming more aware. Successful Implementation of ISO 14001: 2015 Environmental Management System, compliance with statutory and regulatory & legal requirements further make companies to focus on green manufacturing practices. It enables them to reduce their overall cost of production and enhance profitability. Thus, Green manufacturing is a relevant topic for the current situation for the sustainable growth.

V. RESEARCH DESIGN AND METHODOLOGY

We thought about the following questions while **Designing the Research** for Green Manufacturing Topic, as above:

- (i) What is the study about? (ii) Why is the study being made? (iii) Where will the study be carried out? (iv) What type of data is required? (v) Where can the required data be found? (vi) What periods of time will the study include? (vii) What will be the sample design? (viii) What techniques of data collection will be used? (ix) How will the data be analysed? (x) In what style will the report be prepared?

Accordingly, we decided to visit a manufacturing Unit where Green Manufacturing initiatives have been taken and meet its Head and his team and have detailed discussions in form of Questionnaire (**Qualitative Research Methodology**) and collecting the real / actual data (**Quantitative Results**) on benefits of its implementation, their future plan and **correlate** the same with our study, review and concept on Green Manufacturing.

In line with the same we met the **Plant Head (Mr. S.P.Singh) and his team** (In charge Production, In charge Mechanical & Electrical Maintenance, In charge HSE, Sales Desk, Commercial, Human Resource & Administration, Shop floor supervisors, Manager, and identified Work Force) of **M/s Balmer Lawrie & Co. Ltd., Industrial Packaging, Asaoti, Plant , Faridabad. They have received an award on Green Manufacturing Challenges.**

First set of Questionnaire as given below used to interview/survey with Senior Executives, Officers & Staff:

- (i). What Green Manufacturing stands for your organization (ii). What are the major raw materials (input) Plant is using to manufacture the final product (iii). What actions have been taken to enhance the yield (iv). By reducing the consumption of 1 Unit of the major raw material how much associated non-renewable material (tentative data) would be saved (v). Current data on Yield and future plans. (vii). Restricted substances in Input material, if any and how they are handled/managed (viii). How implantation of ISO 9001:2015, ISO 14001:2015 & ISO 45001:2018 enables the Plant to contribute toward Green & sustainable Manufacturing. (ix). What are the tools being used to implement GM. (x)

What is level of participation of workers (xi). What are the energy sources Plant is using (xii). How much (KWp) renewable energy source (Solar) installed and what is its share in the total demand/ requirement of Power for the plant (xiii). What fuel being used in Oven/ furnaces HSD or PNG. (xiv). What is the source of water and consumption pattern (xv). Capacity of Effluent Treatment Plant and its efficiency to deliver treated water for gardening purpose (xvi). Any Rain Harvesting Unit/ System (xvii). What hazardous waste being generated and their disposal methodology/processors/ Authorized agency (xviii). Whether Energy Audit has been carried out and necessary corrective measures taken in line with the observation report (xix). What are the main consents to operate the plant from Haryana Pollution Control Board?

Answers received to the above questionnaire are very encouraging and motivating and highly oriented towards green manufacturing concept/process.

1. There are about 110 employees working in plant inclusive of workmen, staff and officers. They focus on **Human** Safety first, as safe human being can only contribute for the sustainable growth. CR/MS/GP Steel is the main raw material /**input** for manufacturing of their products (**output**). They focus on increasing the **yield** through **Lean Manufacturing, operational excellence tools**, controlling rejections at various stages of manufacturing, use of superior Quality of Steel and continuous technological upgradation where **worker participation** plays vital role. By enhancing the yield without affecting the Strength and Quality of their final Product with focus on achieving their customer's needs every **1 MT** of Steel saved by them enables our mother Earth planet to save **2.54 MT of associated Natural Resources/ Non-renewable resources** and **about 1.34 GJ of energy** and thus they significantly contribute towards Green Manufacturing and Sustainability.
2. Further they continuously invest through annual capital expenditure on upgrading their infrastructure/ Machines for better

efficiency/productivity. Their New Electrical Resistance Welding Machine consumes about **75 amperes** of current whereas their old traditional welding machine was consuming **about 300 amperes current**. It is an initiative towards conservation and optimization of energy.

3. They have **230 KWp solar unit** which gives on an average annual output of – **225000 units which is about 20%** of their total power requirements for their plant.
4. They have Effluent Treatment Plant with about 95% efficiency, output (treated water) of which is being used for gardening purpose. There is a rain harvesting system which is only opened during rainy day well connected with their clean drainage system.
5. They have system in place for reduce, re use, re cycle and re manufacture. We have personally observed that their team has been using the metallic packaging of their Steel coils for making ducting system for their various exhaust system, trays for storage of Paint, thinner etc. for spillage control.
6. Last Energy Audit carried out during January 2018.
7. LED Lights have been installed throughout the plant and office and being operated in an optimized manner.
8. Earlier they had been using HSD (High Speed Diesel) for their Ovens/ furnaces currently **Piped Natural Gas** being installed from Adani Total Gas Ltd.
9. They also have Solvent Extraction System which recovers 85% of the used thinner from input sludge.
10. They release their product for sale/dispatch once the same are cleared from their Quality Assurance after all testing including destructive testing is performed along with the Final test Report. They have complete awareness about their product life cycle analysis (**Figure-5**) and the same being communicated to their final customers.

Second set of Questionnaire as given below used to interview/survey with the core shop floor employees (identified member from each

category of Unskilled, Semi-skilled, Skilled, Higher Skilled and Supervisors) based on their valuable answer on the scale of 1 to 5:

(i). Their satisfaction level with the safety measures being taken/implemented (ii). Are they getting good quality of input material? (iii). Level of their satisfaction with the available infrastructure/ Machines to process the input (iv). How they rate for training on 4R, Conservation and optimization of Energy (v) How effective their Solar Unit (vi). How they rate for the Plantation of saplings drive of the company (vii). How they rate for the outcome of their Daily Management Tool (DMT) talk/meeting.

Answers to above found @ 4 Point for all, except 5 for their daily DMT meeting.

Their most of the **customers** are export oriented and periodically verify the success rate for the implementation of the Sustainability Programme at the Plant. They send Questionnaire and conduct periodic audits / rate the plant for the sustainability. Customer Satisfaction Survey Report shows the satisfied customers. Their market share and the profitability are continually growing year-over-year (YOY).

Above results validates the success of sustainability (Figure-1) programme of the Plant/Company.

VI. CONCLUSION

Our above research process, study, review , survey process & the results reveal that there is a need for the manufacturing Companies/ Units/ Plants small, big or MSME (Micro Small Medium and Medium Enterprise) all should adopt the Green Manufacturing Practices/initiatives which will enable them to play a significant role in reducing the environmental impact while increasing the value of their products in terms of higher yield, Low cost of Production, higher productivity, Better Quality, higher profitability, satisfied employees, stakeholders, customers, community & society and significantly contributing to the targeted GDP of the Nation for sustainable growth.

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- [8] Attended Webinar organized by GAIL on 30.04.2021 to celebrate 75 years of India's Independence. The theme of the webinar / seminar was "Role of Energy Conservation & Alternate Energy Sources towards India's Growth Strategy".
- [9] Attended Webinar: INDIA GREEN MANUFACTURING CHALLENGE (IGMC) conducted by International Research Institute for Manufacturing (IRIM).
- [10] Visit and interview/survey at Balmer Lawrie & Co. Ltd. Industrial Packaging Asaoti, Faridabad for their Green Manufacturing Practices.

