

Carbon Footprint Reduction in Manufacturing and Services

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Abstract- The industrial segment may become a major basis of energy-consuming data as it rapidly transitions to a digital paradigm. The growth of readily available cloud services makes it easy for storing such information and transmission also storage costs have drastically diminished. The carbon footprint landscapes of these enormous data collection, transmission, storage, and management processes did not receive enough attention in a sustainability perspective. One reason for this exclusion might be the belief that huge cloud data centres would eventually become carbon neutral due to renewable energy sources for both generation and storage. The present climate change scenario necessitates swift action to guarantee sustainable growth, and lowering carbon emissions may be a crucial component of that strategy. This paper's objective is to classify and arrange important strategies according to various production levels. Using an efficient version of manufacturing levels, a literature evaluation was conducted to gather all technologies and approaches that aim to reduce the carbon footprint in industry. These were then categorized by manufacturing level, going beyond the factory level, and considering Industry 5.0 characteristics. Every technology and strategy were evaluated in terms of cost and sustainability from an environmental and financial standpoint. The study demonstrates that enterprises ought to examine these technologies' social and economic implications in addition to their environmental ones.

Keywords: Carbon footprint, industry 5.0, energy efficiency

1. INTRODUCTION

Research shows that industries and their activities contribute the most to carbon emissions. The increased demand for new products is linked to the manufacturing and consumption of goods and services emphasising sustainable growth and efforts to minimize carbon emissions. Many manufacturing companies are aware of the reality of carbon emissions, though numerous firms continue to explore strategies to reduce these emissions, particularly during transportation and delivery [1]. The industrial sector uses more than half of all the energy in the world right now, and its energy use has almost doubled in the last 60 years. It is also expected that industrial energy use will go up by 40% from 175 quadrillion Btu in 2006 to 246 quadrillion Btu in 2030. In 2006, the United States spent almost \$100 billion on energy. The industrial sector used 34% of all energy in the country. According to the U.S. Energy Information Administration, fossil fuels provide more than 85% of the country's primary energy. Because of this, the industrial sector is responsible for 27% of the nation's greenhouse gas emissions, making it the second largest contributor after transportation [2].

ICT, or information and communication technology, has changed the way people work, study, play, and live. However, it is also bad for the environment in many ways. Computer literacy is now a must-have skill for almost every profession in the public and commercial sectors, which has led to a lot of job openings around the world. Businesses utilise computers a lot to conduct a lot of different clerical, accounting, and service documentation duties because they can swiftly and cheaply store, retrieve, and change large amounts of data. But computers have environmental problems at every stage of their lives, from making them to using them to getting rid of them. Many writers and specialists have talked about their research on ICT and how it affects the environment. There is still debate on how well green computing works for IT that is good for the environment and lasts a long time. "Green computing" is the term for using computer resources in a way that is good for the environment while still keeping the computer's overall performance high.

2. AN OVERVIEW

According to the latest National Climate Assessment of the U.S. Global Change Research Program (USGCRP), climate change has occurred over the last 50 years through the burning of fossil fuels and the deforestation of trees, and that human beings are primarily the cause [3,4]. Greenhouse gas emissions have always been the responsibility of people since the industrial revolution of 1800 [5,6]. Various sections of an organization control the ensuring that the new products, system design, core processes, supply chain management, promotion, and advertising are carried

out in an environmentally friendly manner. In the previous effort to control the environment, therefore, operations managers were peripherally engaged. This is no longer the case. It is best practice to ensure that there is a combination of environmental management and continuous manufacturing processes. Considering the above incident, consumer pressure, the support of the business organization, the coverage of the firm, and size, the financial wellbeing of a manufacturing organization has been revealed to significantly influence the extent to which the carbon efficiency strategy is implemented [7]. Bottcher and Muller recently coined the low-carbon operations management practices to assist the businesses in achieving a competitive advantage on a long-term basis. The term can be used to describe the way the carbon questions, questions, and decisions involving low carbon are incorporated in the planning, delivery, and management of operating processes. The approaches proposed by Bottcher and Muller could be classified into three categories, i.e. low-carbon logistics, low-carbon commodities, and low-carbon processes [8].

3. CATEGORIES OF EMISSIONS

World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) came up with the Greenhouse Gas Protocol as a way to measure carbon emissions. It has set up scopes that cover numerous areas for a business [9, 10]. These groups are:

Category 1 Emissions: These emissions that come from the organization's direct operations and may be measured.

Category 2 Emissions: We measured emissions from indirect actions, including buying electricity.

Category 3 Emissions: An organized activity is indirectly linked to alternative emissions. Including emissions from different parts of the supply chain. Examples of category 3 actions are getting and making materials that were bought, moving fuels that were bought, and using goods and services.

Several authors have looked at how pollutants spread around the supply networks of manufacturing enterprises [11, 12-14, 15-18]. Most of these articles were on how to manage and regulate category three emissions, which are quite similar to supply chain management. This is because it lets you find the area with the most emissions and the best techniques that can be used to reduce them. Foot printing, or carbon auditing, is seen as the first stage in a strategy plan to include cutting down on carbon emissions in supply chain management [19, 20].

3.1 Parameters of Competitive Advantage

According to the "carbon disclosure project (CDP)," almost half of an organization's emissions are caused by its supply chain [21]. Eight factors make up the metrics used to assess an organization's or manufacturing company's corporate competitive advantage in this instance [22,23] lower costs relative to competitors, higher-quality goods and services, a more inventive R&D department, improved managerial skills, a more lucrative business profile, faster growth, competitive edge in business innovations, and a more positive corporate image [22]. According to Stabell and Fjeldstad [24] a company's competitive advantage can be ascertained by analysing the various activities it engages in during the value generation process rather than by reviewing the entire business. Because supply chains are where the greatest value is created this explains why scholars have highlighted that rivalry has moved being a firm basis to a supply chain foundation [25-28, 14, 29, 30]. According to Li et al [26] the ability of a company to establish a market role ahead of its rivals is the basis for measuring competitive advantage. In this instance, it indicates that a manufacturing company needs to acquire unique talents to get an advantage over rivals.

3.2 Investments and Gains of Competitive Advantage

The strategic inputs that organisations employ to gain a strategic superiority and the results that are frequently reflected in the competitive advantage attained are depicted in Figure 1. These can be used in production environments with carbon constraints, where businesses must monitor their carbon footprints while satisfying customer demands. To gain a competitive edge or "strategic fit," Hofmann suggested combining the supply chain and the competitive strategy [31].



Fig 1: Competitive Advantages

3.3 Challenges in Achieving Carbon Efficiency in Supply Chains

Even with the reasons listed above, there are still a number of problems that need to be solved before carbon reduction measures can work. Figure 2 shows that these problems include inaccurate data, no common way to do carbon audits, and no coordination amongst everyone in the supply chain. Also, the main problem for a firm that works with small and medium-sized local suppliers is that it does not have enough money or resources. Jabbour et al. and Renwick et al. show that human resources practices are vital for good environmental management. [32, 33, 34].

3.4 Factors Promoting Carbon Efficiency in Supply Chain

Most manufacturing enterprises that adopt carbon-efficient methods do not do so just to help the environment.

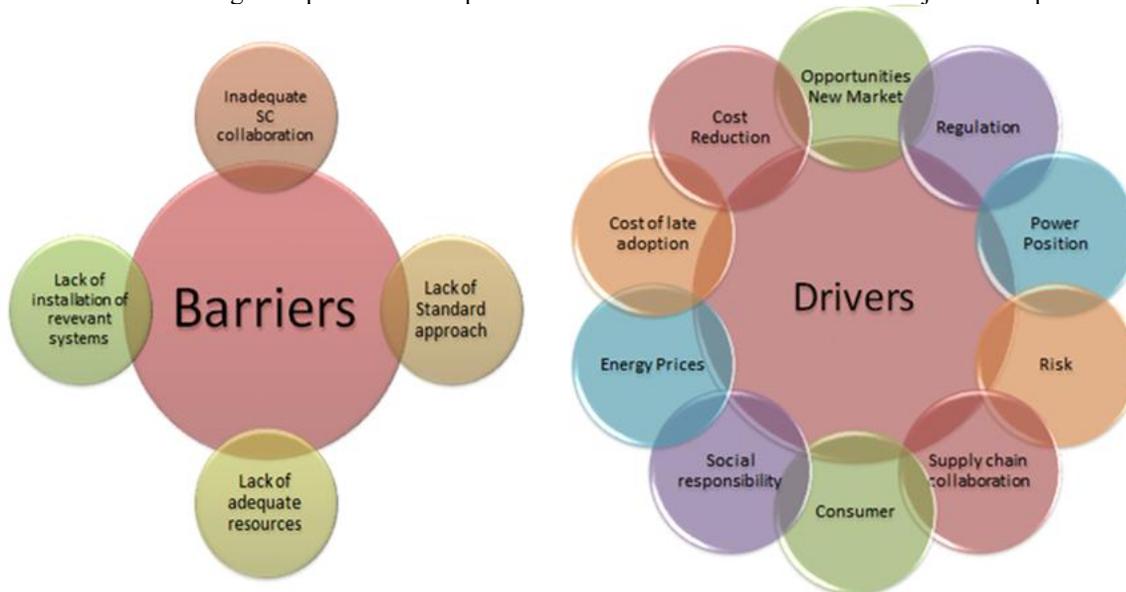


Fig2: Barriers and Drivers

The main reason most people follow the rules is that they know the risks and other things that come with not

following them [35, 36, 37]. As seen in Figure 2b, several scholars have identified various elements that enhance a carbon-efficient supply chain. These include risk, working together in the supply chain, [38] making consumers more aware, growing energy prices due to climate change, the influence of the dominant manufacturing business, and cutting expenses [39]. The study lists physical danger, supply chain risk [19, 36, 40], compliance risk, competition risk, lawsuit risk, reputation risk, and brand value risk as some of the risk drivers [13, 36, 41, 42]. Companies are taking a more active role in dealing with emissions that they cannot directly control after understanding how important it is for everyone in the supply chain to work together [43]. So, working together at the supply chain (SC) level will make it easier to manage risks and add environmentally friendly practices to the way things are made.

3.5 Sustainable Practise to Lower Carbon Footprint Through the Manufacturing Supply Chain

Organisations are employing different ways to cut down on energy use and carbon emissions at different points in the supply chain. Good practices that have helped manufacturing companies reduce their carbon footprints include carbon-efficient supply and procurement, manufacturing, warehousing, logistics, and transportation, as well as carbon efficiency at the customer end. These practices have led to some kind of benefit and a measurable and significant compensation for the carbon footprint of the supply chain [20, 30, 44, 45]. Most businesses today are also joining up for schemes like the UK's Voluntary Scheme, the EUETS, and the CRC. Green supply chain management, trading carbon emissions, and redesigning the supply chain are some good ways to cut down on carbon emissions. However, some people think that emissions trading could hurt businesses that use a lot of energy or do business in other countries, since they might face more competition in countries with different emissions trading systems, like the US, because it costs a lot to comply [46]. Instead of possibilities based on carbon pricing, emissions trading has taken over the risk in package manufacturing. These include a longer period between production runs, higher operational costs that could cause money problems, and so on [13, 47].

3.6 Carbon Efficient Manufacturing and Supply Chain

A supply chain that reduces greenhouse gas (GHG) emissions at every level, from sourcing raw materials to shipping completed items to customers and overseeing end-of-life procedures (such as recycling), is said to be carbon-efficient. Reducing the carbon footprint while preserving or enhancing operational performance is the aim.

3.6.1 Advantages of Carbon Efficient Manufacturing and Supply Chain

According to the interview conducted on some of the large manufacturing businesses and enterprises, the benefits of a carbon efficient manufacturing and supply chain in manufacturing are as follows:

- Carbon efficiency in supply chains maximises on cost savings whether a corporation is strategically oriented or not.
- Supply chain carbon efficiency can also make delivery responsive depending on the approach to be incorporated.
- Carbon efficiency can be used to boost innovation, which depends on its implementation.
- Carbon efficiency can also increase the quality of a product depending on the implementation. The other suggestion of quality improvement is supported because quality is described as the elimination of carbon emissions as waste.
- Carbon efficiency can increase the customer service as a support to different customer service ideas depending on the implementation.

3.6.2 Carbon Emission Reduction Strategies in Manufacturing Enterprises

In order to maximise advantages and improve competitive advantage, the research suggests the following operational measures to reduce carbon emissions over the course of manufactured items:

- At every stage of product development, innovation
- Green supply and procurement practices that work

- Adherence to environmental laws
- Eco-friendly packing and delivery methods
- Techniques for raising consumer awareness and educating them
- Acceptable carbon compliance across the whole production process
- Common metrics and indicators for compliance
- IoT-driven internationalisation of carbon emission reporting
- Similar manufacturing organisations working together to reduce their carbon footprint
- Making a conscious effort to remove suppliers who are not in compliance throughout the supply chain
- Carbon emission compliance should be a part of personnel appraisals since humans have been recognised as a crucial stakeholder in reducing carbon footprints.

4. CONCLUSION

Modern world-wide production networks are being designed and managed with sustainability and environmental impact as their primary motivators. Reducing carbon footprints depends on the strategic choices made to create an energy-efficient supply chain. The paper examined the factors that encourage and hinder a manufacturing company's supplier chain from reducing carbon emissions in a competitive manner. While outlining the competitive strategy, the best practices were emphasised.

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