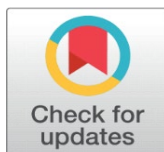
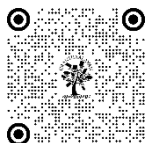


# ENVIRONMENTAL IMPACT OF STEEL PRODUCTION AND ITS CHALLENGES IN ACHIEVING SUSTAINABILITY

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## ABSTRACT

Steel industry is one of the important industries which contributes towards infrastructure, transportation and manufacturing. It is one of the biggest emitters of carbon dioxide (CO<sub>2</sub>), making sustainability in steel production is the global priority. This paper explores the environmental impact of the steel production and challenges in achieving sustainability. The respondents are managers working in manufacturing organisation and specifically in the steel manufacturing companies.

This paper explores the views of the managers working in steel manufacturing Industries. The result shows that the factors affecting environment are CO<sub>2</sub> emissions, water usage, resource depletion and waste generation. The challenges faced in the steel manufacturing industry to achieve sustainability are technological dependency on coal, high energy demand, economic competitive and recycling & material efficiency.

**Keywords:** Sustainability, Steel Production, Challenges, Lean, Green

## 1. INTRODUCTION

The steel industry is essential to the modern global economy, which accounts to 1.8 billion tons of the steel produced annually. Steel is integral to construction, automotive industries, and consumer goods, making it indispensable. However, this widespread utility comes at a significant environmental cost. The sector contributes approximately 7-9% of global CO<sub>2</sub> emissions, driven primarily by its dependence on coal for iron ore reduction.

The global force toward sustainability has placed industries under pressure to reduce their carbon footprints, and the steel industry is no exception. Sustainable steel production aims to minimize environmental impacts while maintaining economic viability.

## 2. LITERATURE REVIEW

### 2.(a) Environmental Impact of Steel Production

Steel production is an energy-intensive process, with significant emissions generated at various stages, from mining iron ore to smelting and refining. The key environmental impacts include:

**2.a (1).CO<sub>2</sub> Emissions:** The steelmaking process is predominantly dependent on carbon-intensive energy sources like coal, which is used in blast furnaces. This process releases vast quantities of CO<sub>2</sub>, contributing significantly to global warming.

With respect to CO<sub>2</sub> emissions, the Steel industry is responsible for a major portion of the complete Co<sub>2</sub> emissions at a global level and has an estimate of 17 to 27 percentage of the entire emissions in the globe (Jaimes & Maroufi, 2020). CO<sub>2</sub> emissions come from the blast furnaces and electric Arc furnaces, for example in Indonesia the electric Arc furnaces contribute to 39 percentage of the entire emissions of Co<sub>2</sub> in steel production (Sari & Kurniawan, 2023). Due to the carbon intensive characteristic of steel making process there is emission of approximately two tons of CO<sub>2</sub> for every ton of steel produced. (Singh & Rout, 2018).

**2.a (2). Water Usage:** Steel manufacturing requires large volumes of water, mainly for cooling. Effluents from steel plants can also contribute to water pollution. There is a significant amount of water usage in steel production and it is very rarely highlighted in the literature compared to CO<sub>2</sub> emissions. In the process of steel production, the cooling as well as cleaning process requires a substantial amount of water. There is a lot of environmental impact in using water. Water pollution can be a result of the discharge of pollutants from the Steel Making process. Recycling of water and usage of closed loop systems are sustainable practices which will help in reducing water consumption within the Steel Making process (Ji et al., 2020).

**2.a (3). Resource Depletion:** The extraction of iron ore and other raw materials leads to habitat destruction, soil degradation, and biodiversity loss. Nonrenewable resources are one of the major sources in steel industry particularly the coal and iron Ores which are always rising growing concerns about the depletion of resources (Jaimes & Maroufi, 2020). Environment footprint of steel production can be reduced by using the scrap steel and it is always helpful in mitigating the resource depletion to increase the demand for ecofriendly materials (Liu et al., 2020). There is an immense need for different energy sources and alternative materials in steel production as the major input of resource consumption is coal for the galvanized steel sheets (Ji et al., 2020). Resources can be conserved and the environment burden can be reduced by increasing the rate of recycling scrap steel (Ji et al., 2020).

**2. a (4). Waste Generation:** By-products of steel production, such as slag and furnace emissions, contribute to land degradation and air pollution. Slag, sludge, gaseous emissions and wastewater and dust (Backes et al., 2021) that are significant waste generated in steel production process have to be managed properly to minimize the environmental impact (Ji et al., 2020). The environment burden and waste generation can be reduced by using the by products as well as recycling the zinc wastes (Ji et al., 2020).

### 2.(b) Challenges faced to achieve Sustainability in Steel manufacturing Industry

Sustainability in steel production faces several challenges, and the important challenges identified in this study are as follows:

**2.b (1) Technological Dependency on Coal:** Steel production remains heavily reliant on coal across the basic oxygen furnace channel. While alternative technologies exist, transitioning on a global scale requires significant investment. Maximum Percentage of the energy used in steel making is due to the Co<sub>2</sub> emissions and the Reliance on coke and coal (Jaimes & Maroufi, 2020). There is a requirement of investment as well as technical efficiency to move into new energy sources. (Filho et al., 2024). Replacing the fossil fuels with renewable energy sources as well as making enhancing the energy efficiency will reduce the greenhouse gas emissions as stated by the green Steel Technology (Majumder & Phani, 2023).

**2.b (2) High Energy Demand:** Steelmaking consumes approximately 20 gigajoules of energy per ton of crude steel. Shifting to renewable energy sources requires considerable infrastructure changes. Massive amounts of water, gas and electricity is consumed for steel production and it is one of the most energy intensive industrial processes (shokrizadeh & shokrizadeh, 2023). Sustainability goals can only be met when energy saving technology and renewable energy systems are adopted (Majumder & Phani, 2023).

**2.b (3) Economic Competitiveness:** Implementing sustainable technologies and practices often incurs significant costs, creating economic challenges in a competitive global market. Regulatory and certain market competition and volatile input prices are some of the economic challenges that the steel industry has to face on a day-to-day level (Vögele et al., 2020). The introduction of green Steel is very supportive of the transition of the industry to become less carbon intensive and on the other hand will cause International and Domestic market competitiveness issues (Muslemani et al., 2021). The competitiveness and economic viability will be ensured when policy is are made to support green steel production (Muslemani et al., 2021).

**2.b (4) Recycling and Material Efficiency:** Although steel is highly recyclable, achieving material efficiency is difficult due to varying scrap quality and availability. Hydrogen plasma waste smelting shows promise in addressing the problems of material efficiency and contamination (Filho et al., 2024). Steel making slags are used in Marine forest to ensure that there is recycling and reduction in wastages (Matsuura et al., 2022). Even though the Steel Industries are moving towards sustainability there are a lot of challenges that remain.

**2.b (5) Regulatory and Policy Gaps:** There are gaps in regulations regarding emissions and waste management across different regions, leading to uneven sustainability efforts globally. Policies and sustainability indicators that are standardised will help in integrating the environmental consideration within the value chain of the industry as well as it will help in promoting transparency and accountability (Tolettini & Maria, 2023) (Casazza & Barone, 2023).

#### Research Questions:

- What are the factors that influence the Environmental impact of Steel Production
- What are the Challenges faced to achieve Sustainability in Steel manufacturing Industry

### 3. METHODOLOGY

Exploratory and descriptive research methodologies are used in the study. Convenience sampling has been adopted. 200 respondents were considered to fit the analysis. A structured questionnaire for data collecting the data was administered to the managers working in various steel manufacturing Industry. The responses were recorded by the managers working in manufacturing, Quality control, Research & development, Materials management departments. All respondents had more than 10 years of working experience in Steel manufacturing Industry.

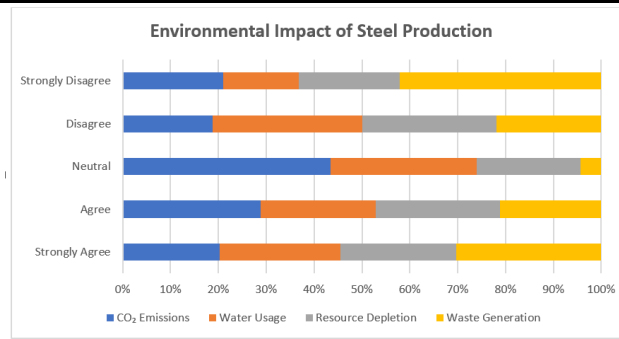
#### Data analysis:

The manager's opinion is captured by using Likert scale as shown in Table 1.

**Table 1:** Environmental Impact of Steel Production

Environmental Impact of Steel Production					
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
<b>CO<sub>2</sub> Emissions</b>	40	60	10	6	4
<b>Water Usage</b>	50	50	7	10	3
<b>Resource Depletion</b>	48	54	5	9	4
<b>Waste Generation</b>	60	44	1	7	8

The data collected for Environmental Impact of Steel Production is as shown in the chart No.1



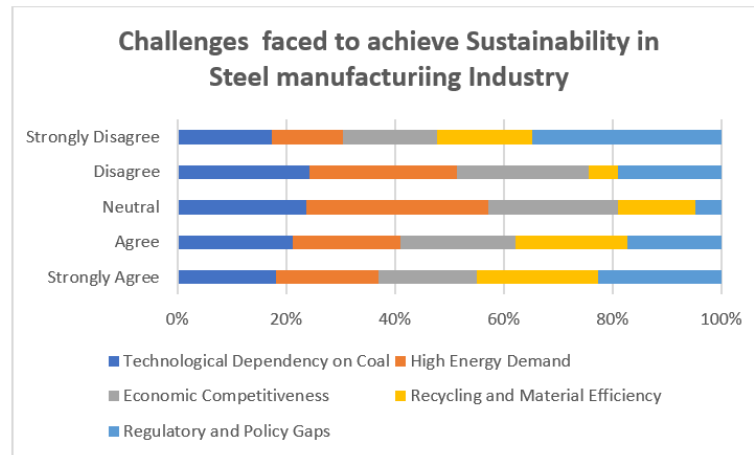
**Chart No.1:** Environmental Impact of Steel Production

There are a lot of challenges faced by the Steel industries and there are many more opportunities of improvement through the usage of Technology as well as Changing of the policies to adopt new principles of production. Recycling and efficiently using the resources place a very pivotal role in reducing the impact of steel production on environment. In conclusion there is a major requirement for sustainable steel production practices.

The manager's opinion is captured by using Likert scale as shown in Table 2.

**Table 2:** Challenges in Achieving Sustainability in Steel

Challenges Achieving Sustainability in Steel					
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
<b>Technological Dependency on Coal</b>	48	54	5	9	4
<b>High Energy Demand</b>	50	50	7	10	3
<b>Economic Competitiveness</b>	48	54	5	9	4
<b>Recycling and Material Efficiency</b>	59	52	3	2	4
<b>Regulatory and Policy Gaps</b>	60	44	1	7	8



**Chart No.2:** Challenges Achieving Sustainability in Steel Manufacturing

## 4. RESULTS AND DISCUSSION

- 1) Majority of the respondents are of the opinion that the factors such as CO<sub>2</sub> Emissions, Water usage, resource depletion and waste generation are the major factors which effect the Environmental Impact of Steel Production
- 2) Technological dependency on coal, high energy demand, economic competitiveness, recycling and material efficiency, regulatory and policy gaps are the major Challenges faced in achieving Sustainability in Steel

manufacturing sector according to the managers, which is evident according to the data collected and represented as shown in Table 2.

#### **4.1. IMPLICATIONS FOR THEORY**

- Management and stakeholders can focus on right CO<sub>2</sub> emission, water usage, resource depletion and waste generation in the steel manufacturing industry and provide measures on reducing the same.
- Need to focus on Transitioning to the alternative technology, renewable energy sources to become more reliable in the competitive world.

#### **4.2. IMPLICATIONS FOR PRACTICE: IN ORDER TO FOCUS ON THE ENVIRONMENTAL FACTORS DISCUSSED ABOVE**

- Lean philosophy can be adopted by practicing waste elimination (MUDA), continuous improvement (Kaizen), Value stream mapping, standardization and work empowerment.
- Green manufacturing practices such as energy efficiency, material efficiency, ecofriendly material and pollution control measures can be implemented.

### **5. THE FUTURE OF SUSTAINABLE STEEL: OPPORTUNITIES AND PROSPECTS**

The future of sustainability in steel lies in the successful integration of lean and green practices with emerging technologies and policies. Lean management enables the steel industry to optimize processes, reduce waste, and improve efficiency, while green innovations help to reduce emissions and promote environmentally friendly practices. By implementing lean and green concepts, the steel industry can achieve a economic growth and maintain environmental sustainability, aligning itself with global climate goals while maintaining competitiveness.

Energy efficiency improvements, renewable energy integration, and circular economy principles will drive further sustainability gains. Policy support through carbon pricing and regulatory frameworks will be key in accelerating the adoption of these technologies.

### **6. CONCLUSION**

Factors identified in this study affecting Environmental impact of steel production are CO<sub>2</sub>, water usage, resource depletion and waste generation. The challenges are faced to achieve sustainability in steel manufacturing industries are technological dependency on coal, high energy demand, economic competitiveness, recycling and material efficiency, & regulatory and policy gaps. These factors and challenges are identified by the practicing managers working in Steel manufacturing Industries. Sustainability in the steel industry is both a necessity and an opportunity for survival today in the global market. The integration of lean and green manufacturing practices enhances operational efficiency and environmental performance.

### **CONFLICT OF INTERESTS**

None.

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