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Energy Intensity of Iron and Steel Manufacturing in India

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Abstract- This study examined trends and changes in energy intensity in India's iron and steel manufacturing sector from 2016–17 to 2022–23, with the objective of assessing progress in energy efficiency relative to economic output. Using an analytical research design, the research relied on secondary data from official government sources, including energy consumption statistics and gross value added (GVA) figures. The methodology standardised energy data to a common unit and calculated energy intensity as the ratio of total energy consumption to real GVA, then analysed year-on-year variations. Findings showed that energy intensity did not follow a steady trend during the study period: while it generally declined in some years, indicating improved efficiency, it increased sharply in others, especially in 2022–23. These fluctuations were influenced by factors such as industrial slowdowns, economic recovery periods, and changes in production practices. The study suggests that further improvements in energy efficiency can be achieved by adopting advanced technologies, increasing renewable energy use, strengthening energy management and monitoring, and enhancing government policy initiatives. The results highlight the ongoing need to prioritise energy-efficient practices to ensure sustainable growth in India's iron and steel sector.

Keywords- Energy efficiency, Energy intensity, India, Iron and steel, Manufacturing

I. Introduction

The production of iron and steel is one of the most significant and energy-consuming parts of the manufacturing industry, serving a vital function in areas such as infrastructure, construction, transportation, capital goods and the broader process of economic development. In India, the sector has grown greatly as a result of increasing domestic demand and greater investment, and it has also become more and more important as the country moves towards sustainable industrial development. The Bureau of Energy Efficiency (BEE) lists iron and steel among the most energy-intensive industrial sectors; in the financial year 2022–23 it accounted for approximately 15.29% of the country's industrial energy use. The high level of energy consumption in steelmaking is mainly due to processes including ironmaking, steelmaking, coke production and rolling, especially in the case of conventional methods of production. According to the BEE, there are large differences in energy requirements depending on the production technology, with the primary method requiring about 6 to 8 Gcal per tonne of crude steel. By contrast, secondary production methods generally need much less energy. Therefore, improving energy efficiency is necessary not only to lower production costs but also to boost the competitiveness and environmental sustainability of iron and steel manufacturing in India.

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Energy intensity refers to the amount of energy needed to produce a unit of economic output and is therefore useful for evaluating changes in energy efficiency over time. In India, the Bureau of Energy Efficiency has identified the iron and steel industry as an energy-intensive sector under the Perform, Achieve and Trade (PAT) scheme, which aims to reduce specific energy consumption by improving efficiency among certain industrial consumers. The Ministry of Steel also states that energy use in integrated steel plants in India is generally about 6 to 6.5 Gcal per tonne of crude steel, showing strong potential for further efficiency improvements. At the same time, India's shift toward low-carbon and green steel means both energy and emission intensity must be reduced. The International Energy Agency (IEA) points out that if steel production in India increases without appropriate mitigation measures, emissions could rise rapidly. In view of this, the current study looks at the energy intensity of iron and steel manufacturing in India, with a special focus on the relationship between energy consumption and economic output. The study examines trends in energy intensity and offers insights into the energy-efficiency challenges and opportunities encountered by India's iron and steel manufacturing sector.

II. Review of Literature

The literature shows that the iron and steel industry is one of the most energy-intensive manufacturing sectors, which is why energy efficiency has become a key area of research. Reddy and Ray (2011) examined physical energy intensity in India's manufacturing industries between 1991 and 2005 and found that improvements in energy efficiency greatly reduced energy consumption in the iron and steel sector. Morrow and others (2014) also estimated the potential to reduce both energy use and emissions in India's iron and steel industry, noting significant opportunities for cost-effective energy savings through better technologies and efficiency measures.

Various studies have since concentrated on measuring energy efficiency at both the firm and regional levels. Ohlan (2019) employed Data Envelopment Analysis (DEA) to examine Indian iron and steel firms from 2004 to 2012 and discovered that energy efficiency increased while energy intensity decreased; yet there was still a great deal of room for reducing energy consumption, especially in the case of smaller firms. Haider and Mishra (2020) used a meta-frontier DEA method and found that there were significant variations in energy efficiency between the different regions of India, indicating a large amount of room for improvement through technological progress and improved energy management. In their study of 82 Indian iron and steel firms from 2003 to 2017, Haider and Mishra (2021) applied Bayesian Stochastic Frontier Analysis and found considerable heterogeneity in energy efficiency, as well as the fact that R&D expenditure, patenting activity, and disembodied technology flows had a positive effect on energy efficiency.

Recent research has looked ever more closely at the effectiveness of government energy-efficiency policies, especially with regard to the Perform, Achieve and Trade (PAT) scheme. Chauhan and Thangavel (2025) discovered that the PAT scheme led to a reduction in energy intensity of around 1.7% in India's iron and steel sector from 2004 to 2019. Yet the scheme's effectiveness differed according to the energy-intensity levels and the ownership structures of the firms. A recent study carried out at the plant level on 43 Indian iron and steel industries also found only a small improvement in pure

technical efficiency between 2009 and 2019 and pointed out a large amount of potential for further reductions in energy intensity.

Objectives

- The aim is to look at the trend and the amount of energy used in the iron and steel manufacturing sector in India during the period under study.
- The energy intensity of iron and steel manufacturing in India should be estimated and analysed by relating energy consumption to real Gross Value Added (GVA).

III. Research Gap

While a number of studies have looked at energy efficiency and energy consumption in India's iron and steel industry, the majority of the existing literature has been concerned with firm-level technical efficiency, technological aspects, regional variations, and the effects of energy-efficiency initiatives such as the Perform, Achieve and Trade (PAT) scheme. Yet relatively little attention has been paid to the general trend and the changes in energy intensity in the iron and steel manufacturing in India over a long period. It is also important to find out whether a proportional reduction in energy use has gone hand in hand with increases in industrial output. Hence, the present study seeks to address this gap by examining the trends and patterns of energy intensity in Indian iron and steel manufacturing, offering insights into the sector's progress in achieving greater energy efficiency and sustainable manufacturing.

Reason for the study

The production of iron and steel is one of the most energy-intensive activities in India and is of great significance for the nation's industrial and economic development. Since the demand for steel is on the rise, there is also a greater need to use energy resources in an efficient manner while at the same time reducing the environmental effects associated with production. It therefore follows that looking at the energy intensity of iron and steel production can show whether or not the sector is becoming more energy efficient over time. The purpose of this study is to offer valuable insights into the promotion of energy-efficient and sustainable manufacturing practices in India.

Scope of the study

The study is concerned with the energy intensity of iron and steel production in India, paying special attention to the connection between energy use and the sector's economic output. It looks at how the Indian iron and steel manufacturing sector has performed during the period under review and investigates changes that have taken place in energy use and energy intensity over time. Since energy intensity is a key measure of energy efficiency it shows how much energy is needed to produce one unit of output. The study includes a number of major indicators, such as energy consumption, gross value added, output, and the energy intensity of iron and steel manufacturing. Its aim is to determine the trends and changes in energy intensity and to evaluate whether or not the industry has become more energy efficient during the study period. The study is limited to the Indian iron and steel manufacturing sector and does not extend to other manufacturing sectors. The findings are expected to offer valuable insights into energy efficiency, technological progress, and the potential for reducing energy consumption and energy-related environmental impacts in the iron and steel manufacturing sector in India.

IV. Methodology

The study employed an analytical research design in order to look at the trends and changes in the energy intensity of iron and steel manufacturing in India from 2016–17 to 2022–23. For this study, secondary data were obtained from official government sources, mainly the Ministry of Statistics and Programme Implementation (MoSPI) and the Ministry of Petroleum and Natural Gas (MoPNG). Energy consumption figures were taken from MoPNG's Indian Petroleum and Natural Gas Statistics and gross value added (GVA) data were acquired from the Annual Survey of Industry. The researchers first sorted the data by year and examined it for any missing entries, differences in units, revisions, and consistency throughout the study period. Since the various energy sources were given in different physical units, the appropriate quantities were converted into a single energy unit in order to allow for aggregation and comparison. The GVA data were converted into real GVA at constant prices so as to eliminate the effects of price changes and to ensure that the figures for the different years were comparable. Energy intensity was then calculated as the ratio of energy consumption to real GVA, according to the formula Energy Intensity = Total Energy Consumption / Real GVA. The annual percentage change in energy intensity was also determined in order to detect the year-by-year variations. A decrease in energy intensity showed that energy efficiency had improved, which meant that less energy was needed to produce a unit of real GVA. On the other hand, an increase indicated that more energy was being used in relation to economic output.

V. Analysis and Interpretation

Energy Intensity of Iron and Steel Manufacturing in India, 2016–17 to 2022–23

Year	Energy Intensity	Annual Change (%)
2016–17	0.160833	—
2017–18	0.143154	-10.99
2018–19	0.141916	-0.86
2019–20	0.178165	25.54
2020–21	0.101590	-42.98
2021–22	0.072189	-28.94
2022–23	0.132741	83.88

Source: Calculation by the author using the data from MoSPI (2024) and MoPNG (2024)

The figures show that energy intensity in India's iron and steel industry varied greatly between 2016–17 and 2022–23. It fell from 0.160833 in 2016–17 to 0.143154 in 2017–18 and then to 0.141916 in 2018–19, indicating improved energy efficiency because less energy was needed per unit of real GVA. However, it rose to 0.178165 in 2019–20, indicating that energy consumption increased more rapidly than real GVA over the year. This may reflect a slowdown in industrial activity and changes in production and capacity utilisation. Energy intensity then dropped sharply to 0.101590 in 2020–21 and

to 0.072189 in 2021–22. The sharp fall in 2020–21 should be treated with caution, since the COVID-19 pandemic had a major impact on industrial production and energy use; hence, the decrease does not necessarily mean only an improvement in technological efficiency. In 2022–23, energy intensity jumped up to 0.132741, showing that more energy was used relative to real GVA, possibly because of the recovery and expansion of industrial activity and the high energy demands of steel production. The iron and steel sector is one of India's most energy-intensive industrial sectors, so energy efficiency is especially important (Bureau of Energy Efficiency [BEE], 2024). Overall, although energy intensity in 2022–23 was lower than in 2016–17, fluctuations show that energy efficiency did not improve steadily over the period.

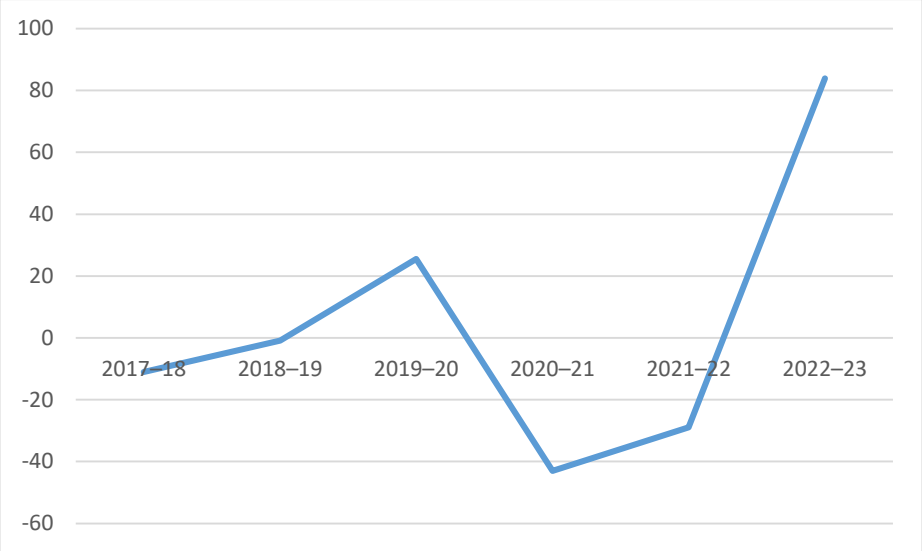

Figure 1: Trend in Energy Intensity of Iron and Steel Manufacturing in India, 2016–17 to 2022–23

The graph shows that the annual percentage change in energy intensity varied greatly between 2017–18 and 2022–23. It decreased in 2017–18, 2018–19, 2020–21 and 2021–22, indicating improved energy efficiency, whereas it increased in 2019–20 and rose sharply in 2022–23. The 83.88% increase in 2022–23 was the largest rise in energy intensity over the study period and suggests a large increase in energy use relative to real GVA. Therefore, the graph shows that energy efficiency in the iron and steel manufacturing sector did not follow a steady trend and was affected by changes in industrial activity and economic conditions.

Suggestions

- Use energy-efficient technologies in processes which are energy intensive, such as iron making, steel making, coke production and rolling, in order to reduce energy consumption.
- Encourage the use of renewable and cleaner types of energy in order to decrease reliance on coal and other fossil fuels.
- Improve waste-energy recovery systems by making use of the waste heat and by-product gases produced during steel production.

- Improve energy monitoring and management by regularly measuring energy consumption and energy intensity at each stage of production.
- Promote digitalisation and automation in order to achieve real-time monitoring of energy use, to detect energy losses, and to improve production efficiency.
- Strengthen the government's energy-efficiency programmes, especially the Perform, Achieve and Trade (PAT) scheme, by prompting industries to meet increasingly stricter energy-efficiency targets.
- Offer financial and technological assistance to smaller manufacturing units so that they can adopt modern and energy-efficient production technologies.
- We should increase our investment in research and development relating to low-energy and low-carbon technologies such as hydrogen-based ironmaking, direct reduced iron, and electric arc furnace technology.
- Encourage iron and steel manufacturing units to benchmark their energy intensity in order to spot out those that are inefficient and to promote the adoption of best practices.
- Make energy efficiency part of sustainable manufacturing policies so that as India's iron and steel manufacturing sector expands, its energy intensity decreases and its environmental impacts are reduced.

VI. Conclusion

The study concludes that energy intensity in India's iron and steel manufacturing fluctuated during the study period. While energy intensity increased during the initial years, it declined considerably during 2020–21 and 2021–22 before rising again in 2022–23. The findings highlight the need to continue adopting energy-efficient technologies, cleaner energy sources, and improved energy-management practices to reduce energy intensity and promote sustainable, energy-efficient iron and steel manufacturing in India.

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