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Enhancement of Energy Efficiency for Decarbonization in the Indian Manufacturing Sector: A Review

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Abstract- Primary energy consumption doubled since the 2000s, between 440 and 880 million TOE. It is projected to double within the next 20 years, reaching approximately 1,900 million TOE, and to reach 1,500 million TOE by 2030. It is anticipated to double over the next 20 years to around 1,900 million TOE, and by 2030, it will reach 1,500 million TOE. The manufacturing sector in India uses the most energy. Energy use in the global industrial sector accounts for one-third of total consumption, according to a review of energy analysis. So that effort has been made to improve the energy efficiency (EE) of the industry to enhance performance. Energy efficiency means using less energy to do an identical task while lowering energy costs and emissions. A key component of the all-encompassing plan to decarbonize industrial operations is energy efficiency. This research intends to investigate the most current systematic literature evaluations on energy efficiency in the industrial sector that were published between 2017 and 2023, taking into account this vast amount of information. The current study creates and establishes six distinct groups that reflect the state of the field's research after conducting qualitative and topical evaluation: Energy Conservation and Innovation, Energy Diagnostics, Energy Monitoring, and Energy Optimization. It consists of the automated and comprehensive formulation of measures for energy efficiency utilizing energy efficiency analysis, broad and flexible modeling of consumption of energy at various production stages to determine technological efficiency possibilities, and the comprehensive evaluation and sorting method taking into account the relationships among methods.

Keywords – Energy efficiency, Systematic literature review, Manufacturing sector etc.

I. INTRODUCTION

The rise in expenses for energy, coupled with sustainability demands from consumers and investors, necessitates that industrial actors prioritize the decarbonization of their business practices. Decarbonization refers to a way of reducing or eliminating CO2 emissions from the Earth's atmosphere. Decarbonisation can be accomplished in a number of ways, including switching to sources of renewable energy, increasing energy performance, and implementing carbon collection and storage technology. Since over 75% of GHGE in India is due to energy consumption, it is essential to decarbonize the energy structure [1]. Even though there has been an uptick in total figures, the power demand per capita is just 36% of the global average. The intensity of energy use has also diminished. India's total greenhouse gas emissions rose by over 50% compared to amounts in 2005. India has currently met its emission quantity of GDP decrease target for 2020-21, which was set at 24%. With 1.6 tons of CO2 per capita, India's CO2 emissions are significantly lower than the global average of 4.4 tons of CO2. Historically, India's cumulative CO2 emissions are significantly lower (1,750 onwards - EU 28%, US 25%, China 13%, India 3%) [2].

Decarbonization of industry and its significance in the Indian context - emission outline

Table 1

Sector	CO_2 Equivalent Emissions (Billion Tons)
Energy	2.13
Agriculture	0.41
IPPU	27
Waste	0.08
LULUCF	-0.31
Total without LULUCF	2.83
Total with LULUCF	2.53

According to estimates industrial emission levels amount to 1.20 billion tons, which involves emission levels from industrial electricity consumption in the energy subsection, manufacturing and industries emission from the energy subsection, Manufacturing Operations and Product Use. This contains refineries however restricts the production of solid combustibility. With this goal in mind, governments around the globe have initiated various programs aimed at cutting energy use in energy-intensive industrial sectors, referred to as Industrial Energy Efficiency programs (IEEPs) [3] Safarzadeh

et al., 2020. A theoretical model outlining the necessary steps and Key components for employing EE in manufacturing were created by May et al. [4]

In every place at which energy is consumed, a chance exists to enhance efficiency. Certain items, like HVAC system and Boilers, are significant energy consumers. Enhancing their energy efficiency (EE) can lead to substantial reductions in both the energy consumed and prices. [4] Energy efficiency protects the climate. The quantity of scientific articles concerning Energy Efficiency in the Manufacturing Industry (EEMI) had been increasing consistently, encompassing a variety of research. This study's foundation is a fact-finding investigation that sought to identify the primary drivers, constraints, and efficacy of incorporating energy efficiency in industry. To gain additional knowledge about manufacturing energy efficiency and identify any gaps between reality and theory.

List of abbreviations	
AI	Artificial intelligence
EE	Energy Efficiency
EEI	Energy efficiency improvement
EEM	Energy efficiency in manufacturing
EEMI	Energy efficiency in Manufacturing Industry
EPI	Energy Performance Indicator
GDP	Gross domestic product
GHG	Greenhouse Gas
GHGE	Greenhouse Gas Emissions
HVAC	Heating, Ventilation, and Air-Conditioning
IEEP	Industrial Energy Efficiency program
IPPU	Industrial Processes and Product Use
LULUCF	Land use, land-use change, and forestry
TOE	Ton of oil equivalent

Energy Statistics India:
The percentage of India's entire energy supply generated (in petajoules of energy) through various sources of commerce in the fiscal year 2022–2023. (Fig.1)

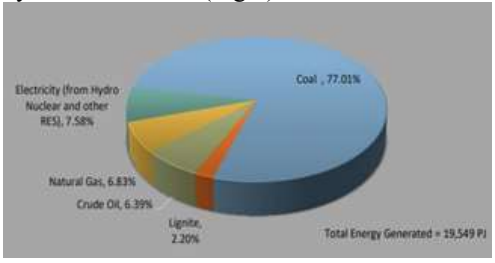

Fig. 1. Energy Statistics India

In addition to accelerating the development of clean and renewable energy sources, nations must promote more effective energy resource management. [5]
This study's goal is to provide a theoretical structure that integrates energy efficiency. This entails enhancing the efficiency of operations, materials, and energy while concentrating on a decrease. The initial concept of this manufacturing decarbonization tackle is improving energy efficiency (EEI) [6]. This phase is crucial due to its links to budgetary cost efficiency, assurance of energy, and reduced GHGE.

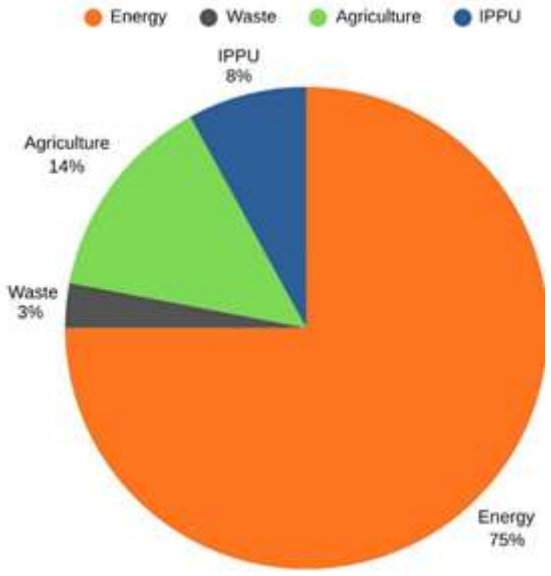

Fig. 2. Distribution of GHG Emissions (Billion Tons of CO2e) by sector 2016

An analysis of the body of current literature indicates several review investigations focused on energy efficiency in manufacturing production operations. Li et al. [7] examined the approaches and tactics for assessing EE in industries with a great deal of intensity, energy efficiency benchmarking, and centering on the energy performance parameters. The channels for India to reach zero GHGE will be difficult, as the amount of emissions reduction needed to attain net zero by 2050 and beyond will need to be substantially greater than historical movements. 30% of the reduction of manufacturing emissions relies on EE methods (Fig. 2)

II. METHODOLOGY

The term literature review is defined as " a systematic, transparent, and repeatable procedure for determining, evaluating, and integrating the current compilation of completed and documented research produced by researchers, scholars, and practitioners." Systematic reviews present advantages compared to traditional narrative reviews which lack a formal methodology.

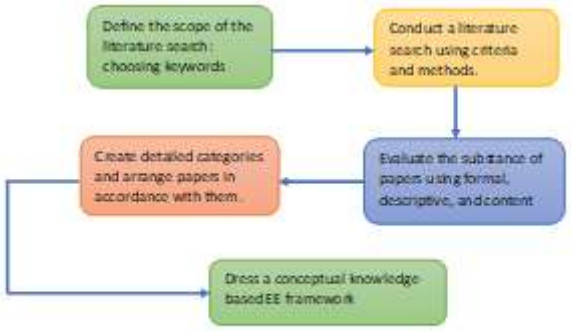

Fig. 3. Literature Search Strategy

The methodical literature reviews need to adhere to a scientific methodology to literature reviews in order to be objective, repeatable, and comprehensive, even if they are the product of research work that is very different from laboratory research. This section outlines the literature review's approach, and Fig. 3 displays the recommended architecture.

Construction for enhancing energy efficiency

Energy Consumption Measurement

Collecting information about how much energy is used from electricity bills, readings from meters, and other means. Figure out what needs to be fixed and establish objectives for energy conservation.

Benchmarking the Performance

After measurement of energy consumption benchmarking the industry performance. Comparing the existing energy consumption to a similar industry.

Finding Possible Ways to Save Energy

Using benchmarking evaluation, finding ways for the industry to save energy. This involves making changes to the industry systems such as lighting, HVAC, etc.

Creating a plan for action

Planning and carrying out action plans to increase energy efficiency, in addition to regularly assessing EE these include, the cornerstones of industry success.

Execution and Tracking of Modifications

Following the creation of an action plan, make adjustments gradually while monitoring your progress toward the energy-saving goals you have set. Mapping new energy levels against previous data allows you to track how successful adjustments are.

Continuous Improvement

Conducting routine energy consumption measurements, comparing industrial performance, and spotting new areas for energy savings. through continuous improvement, energy efficiency optimization, and cost reduction.

Energy Balance

A framework for comprehensive data on all energy items arriving, existing, and utilized within a particular nation over a reference time (such as a year) is called an energy balance. It makes it possible to define a product by expressing each value in standard energy units.

There are several reasons to create an energy balance based on the different commodities balances, including: providing the foundation for estimations of CO2 emissions and aggregated macroeconomic indices; Providing a method to guarantee fundamental data are accurate, consistent, and comparable [8].

Energy (in KToe) = Commodity Quantity * Converting Variable

1 Toe = 41868 MJ

Conversion factor = [Net Calorific Value] / Mega joules per ton of oil equivalent

where Net Calorific Value (NCV) is in kJ per kg and Gross calorific value (GCV) minus (% Moisture Content) equals Net Calorific Value (NCV).

The review process

A methodical method for studying literature is shown in Fig. 4. to research. In the examination process, evaluation criterion is defined, described, and evaluated in an iterative manner.

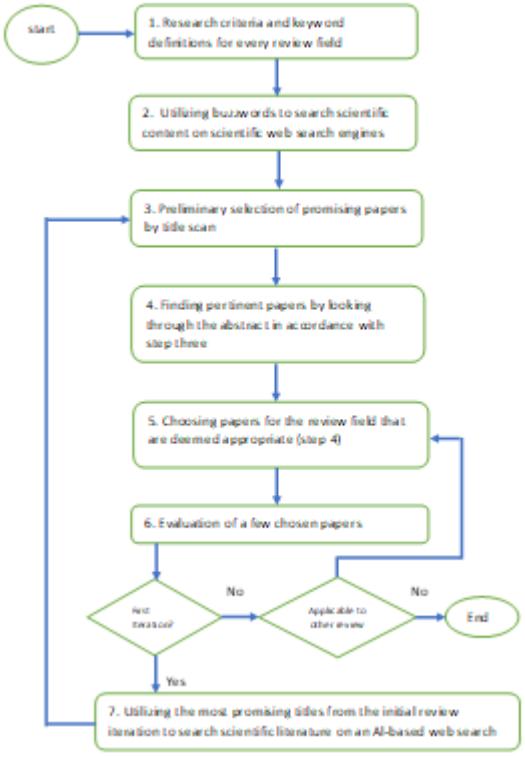

Fig. 4. A systematic approach to studying literature

Manufacturing industries is included in the study's focus. Both the fee-based and curated database Scopus and the widely utilized license-free internet search engine Google Scholar have been employed for a thorough literature review.

III. RESULTS

In order to identify EEM, structured methods are currently devised. Assessments often come from at the machine/process and manufacturing plant stage, and they usually depend on literature study.

Retrieval of energy statistics:

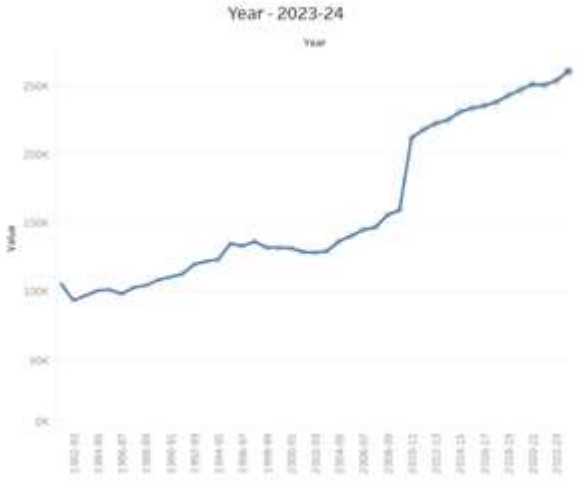

Fig. 5. Number of Factories by Year

India Production Companies: In 2022, there were 249,987.000 units of companies. Compared to the earlier figure of 250,454.000 units for 2021, this is a reduction (Fig. 5). India Production Sectors: Data on the number of factories is revised annually, with 41 inspections and an average of 132,814.000 units from March 1982 (Median) to 2022. The statistics showed a record bottom of 93,166.000 units in 1983 and a record high of 250,454.000 units in 2021.

EEMI are evaluated primarily on the basis of their technical relevance and lowering possibilities. In these situations, ecological criteria are typically used to determine the priority EEM.

Identifying energy-saving measures

Synthesized the findings from articles using the method of constant assessment technique. Six significant areas emerged from this:

- Energy Monitoring
- Energy Diagnostics
- EE Improvement
- EE Innovative Perspectives
- Energy and Technology
- EE Factors and Constraints

Equipment and procedures for diagnosing and examining energy utilization and utilization in the manufacturing sector are included in the category of energy diagnostics. Energy auditing, benchmarking instruments and methods, including consumption evaluation are its primary foundations. Energy audit offered a great foundation for comprehending inside energy movement, utilization, and wastage in order to manage an organization's usage of energy [9] (Sandberg; 2003, Rohdin and Thollander, 2006). "Energy and Technology" was typically observed in a multi-disciplinary area.

Energy Efficiency Benchmarking

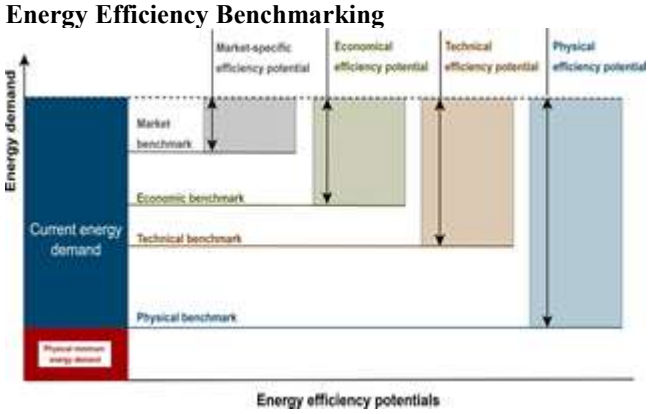

Fig. 6. The prospective of several energy efficiency benchmarks to lower the present demand for energy

Any strategies that don't fit into any of the above-mentioned ways are grouped under "alternative strategies." Various EEPs can be found based upon the benchmarking technique.

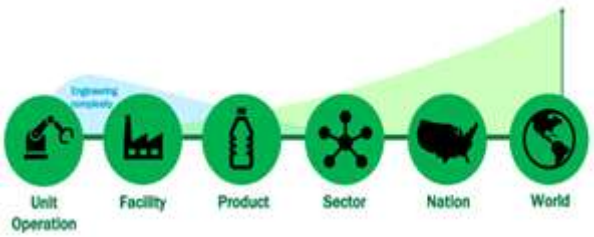

Fig. 7. The perspective of several energy efficiency benchmarks to lower the present demand for energy

Collective benchmarking is used in this evaluation to find EEPs of methods, goods, facilities, firms, or regions via an easy evaluation of the Energy Performance Indicator (EPI). Mahamud et al. [10] present a general approach for evaluating EE at the level of manufacturing within the context of energy benchmarking, which is meant to be relevant to a variety of industrial industries. The minimal energy demand is utilized as a reference value in both quantitative and numerical modeling

methodologies described by the authors to assess the EE of phenomena. [11]

IV. DISCUSSIONS

Limitations of the findings

Search engine algorithm: Because widely referenced articles are ranked first in the initial search results, newly released articles cannot be found by this search engine.

Buzzwords: The accuracy of the search outcomes is impacted by variations in the level of information of buzzwords across review areas, necessitating the use of highly targeted keywords. The constraints mentioned herein may cause some pertinent literature to go unnoticed, regardless of whether the literature examination was conducted utilizing a variety of search engines by means of AI.

V. CONCLUSION

In order to successfully decarbonize industrial manufacturing procedures, an integrated plan involving many paths is essential. Therefore, by examining key techniques and strategies comprehensively, this investigation enhances our understanding of thorough EEI. To do this, a framework that acknowledges EEP in addition to the development, evaluation, and ranking of EEMI is used to describe the steps and operations of the entire EEI.

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