REPORT

Towards Optimal Energy Use

Estimating Industrial Efficiency and Mapping Policy Needs in Bangladesh

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Contents

List of Figures

List of Tables

Acronyms and Abbreviations

Acronym	***Full Form***
SDGs	*Sustainable Development Goals*
SDG 7	*Sustainable Development Goal 7: Affordable and Clean Energy*
SDG 12	*Sustainable Development Goal 12: Responsible Consumption and Production*
GHG	*Greenhouse Gas*
IEA	*International Energy Agency*
IEEFA	*Institute for Energy Economics and Financial Analysis*
EECMP	*Energy Efficiency and Conservation Master Plan*
SREDA	*Sustainable and Renewable Energy Development Authority*
LNG	*Liquefied Natural Gas*
DEA	*Data Envelopment Analysis*
DMU	*Decision-Making Units*
HS Code	*Harmonized System Code*
SMI	*Survey of Manufacturing Industries*
BBS	*Bangladesh Bureau of Statistics*
SBM	*Slack-Based Model*
VRS	*Variable Returns to Scale*
CCR	*Charnes, Cooper, and Rhodes (DEA Model)*
BCC	*Banker, Charnes, and Cooper (DEA Model)*
GDP	*Gross Domestic Product*
GVA	*Gross Value Added*
CO2	*Carbon Dioxide*
BDT	*Bangladesh Taka*
DCs	*Designated Energy Consumers*
EMS	*Energy Management System*
EMP	*Energy Management Program*
BEER	*Building Energy and Environment Rating*
EECPFP	*Energy Efficiency & Conservation Promotion Financing Project*
IEPMP	*Integrated Energy and Power Master Plan*
BAT	*Best Available Technologies*
MWh	*Megawatt-hour*
toe	*Tonne of Oil Equivalent*
kgoe	*Kilogramme of Oil Equivalent*
kgoe/t	*Kilogramme of Oil Equivalent per Tonne*
$kgoe/m^2$	*Kilogramme of Oil Equivalent per Square Metre*
PPP	*Public-Private Partnership*
MPP	*Merchant Power Plant*

BERC	*Bangladesh Energy Regulatory Commission*
IDCOL	*Infrastructure Development Company Limited*
BIFFL	*Bangladesh Infrastructure Finance Fund Limited*
TES	*Total Energy Supply*
FY	*Financial Year*
SMEs	*Small and Medium-sized Enterprises*
LDC	*Least Developed Country*
DCCI	*Dhaka Chamber of Commerce & Industry*
SANEM	*South Asian Network on Economic Modeling*
WDI	*World Bank: World Development Indicators*
BUET	*Bangladesh University of Engineering and Technology*
MJ	*Megajoules*
MJ/GDP	*Megajoules per Gross Domestic Product*
PAT	*Perform, Achieve, and Trade*
SROs	*Statutory Regulatory Orders*

Executive Summary

As Bangladesh is rapidly industrializing, the energy system is under tremendous pressure to meet the increased industrial demand while at the same time addressing the climate change commitments under Sustainable Development Goals (SDGs) and the Paris Agreement. The industrial sector in Bangladesh is consuming over one-third of the total energy consumed in the country, and hence, while this sector poses the greatest challenge to energy sustainability in the country, it also presents the greatest opportunities for improving energy efficiency. The study applies Data Envelopment Analysis (DEA), a widely used tool for organization evaluation within both domestic and cross-country contexts, to measure industrial energy efficiency, evaluate energy efficiency support environment, and learn from stakeholders.

Methodology

The study aims to gauge industrial energy efficiency in Bangladesh through the application of Data Envelopment Analysis (DEA) in two different frameworks of analysis. First, the study has been conducted as a domestic benchmarking study where manufacturing industries within the country have been compared against each other using individual industries as Decision-Making Units (DMUs) and subsequently against the best practice within the country. The second framework of analysis has been conducted as an international comparison where industries of 13 countries around the world have been compared against each other, where countries have been used as DMUs. In both frameworks of analysis, the study employed well-established non-parametric methods of DEA to measure the technical efficiency of the DMUs under study by means of comparing input-output relations among them. In this study, four inputs, i.e., capital, labor, raw materials, and energy, have been used to generate a single output, i.e., gross value added by individual industries.

The study used a well-established approach of Data Envelope Analysis, i.e., Slack-Based Measure approach, to measure the overall technical efficiency of the DMUs under study and to quantify slack in all dimensions of inputs and outputs. The study contains two separate DEA-based analyses. The first analysis, titled Domestic Efficiency Benchmarking for Manufacturing Industries of Bangladesh aims to develop an efficiency benchmark for manufacturing industries of Bangladesh. Four major inputs of capital, labor, raw materials, and energy are considered to generate gross value added (GVA) as output. The second analysis, titled International Efficiency Benchmarking for Industrial Energy Use of Bangladesh, treats 13 countries, including Bangladesh, as DMUs. Three inputs of capital, labor, and energy are considered to generate industrial value added as well as to measure CO2 emissions as output. The study compares the industrial energy efficiency of Bangladesh with 12 advanced countries, including Japan, and 12 emerging countries, including China, India, Indonesia, and Turkey, a group of industrial powerhouses. The study aims to identify the sources of inefficiency in industrial energy use in Bangladesh and to provide policy suggestions to improve industrial energy efficiency in the country.

Key Findings

Domestic Performance: Intra-country Analysis: Efficiency by Industry- A brief overview of 36 manufacturing industries in Bangladesh, and the levels of energy efficiency of individual industries are presented in this analysis. Results indicate that only 14 industries are on the efficiency frontier with energy efficiency scores of 1.0. These industries are: Spinning & Weaving of Textiles; Plastics Products; General-purpose Machinery; Ship & Boat Building & Repairing; Food & Beverages; Tobacco Products; Rubber & Plastics Goods; Other Non-Metallic Mineral Products; Paper & Paper Products; Publishing; Printing & Reproduction of Recorded Media; Leather Tanning & Dressing; Other Textiles Manufacturing; and Leather Products. In contrast, the large majority of industries in the manufacturing sector in Bangladesh are operating below the efficiency frontier.

For the industries where the analysis revealed degrees of inefficiency, the relative efficiency scores ranged between 0.30 and 0.76, where the beverage manufacturing industry, for example, has a score of 0.76, indicating that there is scope for 24% energy savings. The dairy products industry has the second-highest score of 0.40, indicating that there is scope for 60% energy savings. The tanning and dressing of the leather industry has a score of 0.30, which indicates that there is scope for 70% energy savings. On the other hand, there are 20 industries that are located in the bottom twenty percent of all industries, where the scores ranged from 0.03 to 0.06. This would mean that theoretically these 20 industries have the potential to reduce their energy usage by more than 81% and still keep their levels of output the same.

Cross-Country Comparative Analysis

The cross-country analysis positions Bangladesh's industrial energy performance in a global context, revealing thought-provoking results. The performance of the countries is ranked based on their energy efficiency scores (a score between 0 and 1), and Bangladesh ranks 10th with a score of less than half, or 0.47 (or 53% of potential efficiency). The top 5 countries include the Philippines, China, Egypt, Sri Lanka, and Japan, all scoring 100% or 1.0 on the energy efficiency scores. Turkey follows at 0.72, Morocco at 0.61, and Thailand at 0.60.

This pattern reflects macro trends in global energy dynamics. Emerging economies in this region tend toward high energy intensity due to energy-intensive industrialization patterns and relatively older, less efficient capital stock. Advanced economies like Japan have prioritized high-technology manufacturing and stringent efficiency standards. The wide disparity between Bangladesh and frontier countries demonstrates substantial scope for industrial competitiveness improvement and energy cost reduction.

Barriers to Implementation

Although policies and tools for promoting industrial energy efficiency exist, there are several systematic barriers that impede their effective implementation on a structural, institutional, and operational level.

(a) Energy Supply Challenges: Load-shedding, unreliable voltage, lack of natural gas for power generation, and a host of energy distribution network-related problems, including faults, obsolete distribution networks, and uncontrolled industrial development, interfere with and create barriers to increasing energy efficiency in industry.

(b) Insufficient Energy Auditing: This problem is most pronounced in high-energy-using industries such as the steel and cement sectors. Here, energy audits are generally conducted for external buyers as part of a tender for supplies and/or services. Such audits do not fulfill the needs of managers intent on running efficient industries on an ongoing basis. Most importantly, the absence of systematic energy auditing means that there are no inefficiencies identified on a systematic basis.

(c) Inadequate Technical Capacity: The number of certified energy auditors remains insufficient for industrial demand, while most firms lack trained energy managers capable of interpreting audit findings. Shortage of credible laboratory facilities for testing equipment further compounds this gap, discouraging innovation and slowing technology adoption.

(d) High Investment Requirements: Although energy-efficient technologies can pay for themselves through the savings in energy costs, many industries are reluctant to invest in such technologies due to the high initial costs, particularly for Small and medium-sized enterprises. Commercial banks charge elevated interest rates and lack expertise in evaluating efficiency proposals, causing industries to hesitate in replacing obsolete technologies despite documented savings potential.

(e) Policy and Regulatory Weaknesses: On a national level, the goals of energy master plans are not being met with the appropriate and adequate tools to implement them. In addition, there are currently too many mandates that overlap in their implementation, and the capacities of the current regulatory bodies are not sufficient to monitor compliance and take the necessary action when required.

(f) Quality Issues for Imported Machinery: Cheap machinery, like air compressors and generators of very poor quality, is imported because they save money. Most buyers do not even check the specifications to confirm that the machine will deliver the required efficiency. They are not even aware that there are higher efficiency models of the same machinery available in the market. In the long run, such poor quality of imported machinery increases the cost of industry.

(g) Lack of Infrastructure: Old gas pipeline networks, high losses in the energy system, and a low degree of energy storage pose challenges to a reliable supply of energy. Most industries require a constant power supply. In case of power failures, they are compelled to increase their energy and production costs through reheating.

(h) Unplanned Industrial Locations: Most of the industries are located far away from each other. It becomes a great challenge for power suppliers to provide them with a continuous and reliable power supply. In addition to this, due to the far-off locations of industries, there is also a problem of high transmission losses. In order to install high-capacity sub-stations to provide power to such units, many restrictions are created.

(i) Less-prioritized issue in industry Culture: The industrial sector is currently operating to fulfill short-term objectives, such as increasing the quantity of production to benefit from the low price of energy currently in place. The lack of awareness about improving the efficiency of energy use by the industries in question is significant.

(j) Industry-Specific Challenges: The poor quality of the scrap that is used by the steel industry to increase the recycled content of their production is affecting their energy efficiency. The cement industry is another energy-intensive industry, and most of the electricity that is used by this industry comes from the grid without any plans for the use of renewable energy. This industry is also highly affected by load-shedding, as most of the factories are relying on their diesel generators to keep their production going. The textile industry is another industry that is affected by load-shedding, as most of the factories are relying on their diesel generators to keep their production going. Challenges in these industries can best be addressed through specific solutions that consider the unique characteristics of each sector and the specific operational constraints that they are facing.

(k) Coordination Gaps Among Stakeholders: There is a lack of information exchange among energy regulators, distribution companies, and industry associations. There is no central industrial energy database to monitor and follow up on energy issues in industry. Lack of coordination among stakeholders to translate policy into practice.

Conclusion and Path Forward

The industrial energy efficiency gap in Bangladesh is not only a technical issue, but also an economic issue of great significance. Industry in Bangladesh has energy intensity less than average, indicating a moderate energy-intensive industrial structure. However, the DEA analysis in this study has shown the reality that a large amount of inefficiency exists in converting inputs to outputs in the industry in the country. Thus, instead of consuming less energy, the country needs to generate more value with less energy. This requires a change in paradigm from a voluntary approach to energy efficiency to a holistic, enforced, and incentivized approach to energy efficiency. The government has to take three immediate steps to address the industrial energy inefficiency issue. First, the existing financial ecosystem for energy efficiency must be transformed into a credit guarantee scheme. This will facilitate bank finance for the industrial sector to carry out energy efficiency projects. Second, national-level training programs in energy management have to be introduced through the country's engineering universities for better exposure and availability. Third, the government should move towards a data-driven approach to the regulation of energy use by Designated Energy Consumers through digital, real-time monitoring of their energy consumption to allow for more targeted intervention.

Addressing the industrial energy efficiency gap has become an economic survival issue for Bangladesh. In line with international practices for compliance on outbound trade, the carbon footprint of Bangladeshi products will have to comply with higher international standards. Implementation of recommendations addressing sectoral inefficiencies could enable billions in savings, secure domestic energy supply, and delink economic growth from carbon emissions. To bring about a cultural shift from present practices of energy efficiency inattention in the industries to management orientation, required policy intervention and public-private partnerships are necessary. The resulting changes will enable the country to pursue efficient as well as cleaner, greener, and sustainable industrialization.

1. Introduction

Bangladesh, with its rapid economic growth, faces a formidable challenge of keeping the balance between its economic uprising and sustainable development. This challenge directly affects the progress of the country towards the United Nations' Sustainable Development Goals (SDGs), specifically SDG 7 (Affordable and Clean Energy) and SDG 12 (Responsible Consumption and Production). According to the Global Climate Risk Index 2021 published by Germanwatch, Bangladesh is ranked 7th among the countries affected most in 2000-2019 due to climate change (Department of Environment, 2024). The geographic location and topography are the primary reasons for this vulnerability. However, the journey as a developing country is causing the country to undergo expanded economic activities. The demand for energy has been rising, consequently. With the expanded economy, the country is now experiencing a surge in energy demand, which has increased the import dependency for fossil fuels over the last few years. This reliance is affecting the resilience of the economy in two ways: one, it is exposed to the global energy shocks; two, it is making the country more climate vulnerable than before. The government of Bangladesh, both in the previous regime and in the current regime, has been struggling to balance the energy demand with reliable but sustainable sources. Often, environmental compatibility was compromised due to immediate need, for example, during the COVID-19 pandemic, the global energy crisis in 2022, etc. These decisions kept Bangladesh far away from the international commitments, such as the Paris Agreement.

In this complex scenario, the industrial sector is the most crucial sector of the economy, which can create a significant impact, either positively or negatively, depending on the policy and implementation pathways. Industries are primary drivers of both economic growth and energy demand. Globally, the industrial sector consumes about 37% of total final energy consumption, and most of the energy comes from fossil fuels (IEA, 2023). In developing countries, industrial energy demand can reach as high as 50% of total consumption (Hasan et al., 2021). Bangladesh also has some similarities in this way. According to the National Energy Balance FY2021-22, industries consumed more than one-third of the country’s natural gas supply, where a significant amount of gas supply comes from costly liquefied natural gas (LNG) imports (SREDA, 2023). Hence, industrial energy efficiency has become the most practical strategy to balance economic growth with climate and energy security goals. Studies show that efficiency improvements not only reduce greenhouse gas (GHG) emissions but also lower production costs and ease pressure on energy imports, which makes it viable for reconciling growth with sustainability (World Bank, 2018; IEEFA, 2023).

These findings make energy efficiency a global and national priority. Realizing the significance, Bangladesh has made policies to improve industrial energy efficiency. The Energy Efficiency and Conservation Master Plan (EECMP) set a target to reduce national energy intensity by 20% by 2030 (IEEFA, 2023). In 2023, the government also required large industrial energy users to do regular energy audits, which makes them report their energy use and find more efficient options. This push, along with initiatives of certifying energy managers and auditors by SREDA, is meant to bring energy management practices into the industry. While the EECMP is taking a step in the right direction, its lack of sector-specific targets remains a significant weakness that could hamper progress.

International examples show useful lessons for Bangladesh to improve industrial energy efficiency. Countries like India, China, Germany, Vietnam, and Singapore have already made progress with strong efficiency programs. For example, India's Perform, Achieve, and Trade (PAT) scheme for big industries has reduced industrial energy use a lot in the last 20 years (Pal et al., 2024). In the same way, China reduced its energy intensity by half between 1990 and 2001, reaching erstwhile Premier Deng Xiaoping's goal of making GDP four times larger while only doubling energy use, even though fossil fuels still made up over 94% of the energy mix by 2000 (Guilhot, 2022). Using proven strategies like these could help Bangladesh move forward in improving industrial energy efficiency.

This study has presented a comprehensive picture of the energy efficiency landscape for the industrial sector in Bangladesh. Data Envelopment Analysis (DEA), based on two-stage empirical research, constitutes the basis of our study. The first analysis is internal, seeking to understand relative energy efficiencies of different manufacturing industries operating in Bangladesh using data from the 2019 Survey of Manufacturing Industries (SMI) to identify domestic benchmarks and potential areas for improvement. Through external benchmarking, the second analysis brings out the context and tries to benchmark with peer countries to provide an estimate of where Bangladesh stands when compared to its peer countries in terms of energy efficiency performance in all industries. In addition, the report draws from international references and good practice country case studies, providing an extensive review of Bangladesh's policies and regulatory arrangements. Combining these analyses, synthesis derives actionable recommendations and strategies to pave the way for a cleaner, greener industrialization for Bangladesh.

2. Objective

The prime objective of this study is to develop an assessment with empirical evidence of industrial energy efficiency in the manufacturing sector of Bangladesh and, accordingly, put forward policy suggestions for improvement of industrial energy efficiency in the country. Two specific objectives of this study are:

(a) To evaluate industrial energy efficiency of manufacturing industries of Bangladesh on a comparative basis through a study (i) intra-country comparison and (ii) cross-country comparison by using Data Envelopment Analysis (DEA) and to identify efficiently operating industries, potential for energy savings of inefficient industries, and overall efficiency of industrial energy usage in Bangladesh in comparison with similar countries of the world; and,

(b) To conduct an exhaustive review of existing policies, rules, and regulations and the institutional framework for promoting industrial energy efficiency in the country, and to identify possible barriers and implementation gaps, and to develop suggestions and recommendations based on existing knowledge

This research report aims to provide evidence to develop an Industrial Energy Efficiency Policy for the industrial sector with specific rules, regulations, and mechanisms for its implementation. It is expected that the study outcome will help the government, private sector, and other stakeholders to develop an integrated industrial sector energy efficiency policy along with developing specific rules, regulations, and mechanisms for its implementation.

3. Literature Review

The world needs energy to support social and economic progress that can contribute to a better living standard for all. However, since 2021, the global energy market has experienced significant volatility, including the rapid turnaround in the economy after the pandemic. The Russia-Ukraine war further exacerbated the energy market condition, which resulted in high global inflation and slowed down developing economies. The nations are currently trying to guide their energy markets toward sustainable growth in the face of high fuel prices and supply chain disruptions.

Industrial sectors account for a significant share of the energy market. In 2022, the share was almost 37%, or 166 EJ (Simon et al., 2023), globally, giving rise to the need to meet the climate imperatives and to curb the high energy price. Energy efficiency is being identified as an impactful strategy to reduce greenhouse gas emissions and enhance industrial competitiveness without curbing a nation's economic development. However, achieving energy efficiency is riddled with obstacles. Multiple studies identified some drivers and barriers influencing energy efficiency, often classified into technological, organizational, financial, institutional, and behavioral dimensions (Thollander et al., 2013; Hasan & Trianni, 2020). Simultaneously, energy conservation and energy audits act as drivers of energy efficiency. Overall, achieving energy efficiency requires behavioral changes and proper regulatory initiatives, which, unfortunately, remain nonexistent in many economies.

Germany has long been a frontrunner in industrial energy efficiency within its Energiewende framework. They reduced the share of power generated by coal from 52% in 2000 to 22% in 2024, while wind and solar grew from 15% to 43% (Ember, 2025). While the policy framework institutionalizes efficiency, sectoral studies highlight different drivers of efficiency. In textiles, higher energy costs and investment improve efficiency, whereas firm size and capacity utilization have limited effects (Martínez, 2010). The analysis of the steel sector reveals diffusion of technologies such as basic oxygen furnaces and continuous casting reduced energy intensity, though uneven adoption left an untapped savings potential of 4.5%; feasibility, capital constraints, and site conditions explain these gaps (Arens & Worrell, 2014; Arens et al., 2017). Germany's policy framework institutionalizes efficiency through mandatory audits under the Energy Services Act (2009) and incentives for SMEs to adopt energy management systems under the EU Efficiency Directive. Audits have revealed substantial savings potential, though barriers such as finance and low technical capacity persist (Fresner et al., 2017). Financial instruments such as KfW loans, grants, and ESCO performance provide further support. However, poor energy statistics remain a problem, though, limiting strong monitoring and evaluation in the long run (Saygin et al., 2012).

While Germany focused on renewable energy integration, China highlighted industrial restructuring through policy interventions. The 2005 Steel Industry Policy Guideline and the 2009 Steel Industry Restructuring and Revitalization Plan are such notable initiatives from the Chinese government. The plans targeted energy consumption per ton of steel, shut down inefficient enterprises, and encouraged investment in the field of research and development.

The regulatory enforcement and international capital flows brought down China's industrial emissions to around 3% (around 150 Mt CO2) in 2022, due to a decrease in emissions from its cement (10%) and steel (3%) sectors (Simon et al., 2023). The industry, accounting for 15.2% of national energy use, has also seen scale efficiency gains through mergers and acquisitions, though pure technical efficiency improvements remain limited (He, 2013).

China's decades of success are a testament to mandatory energy auditing, institutional regulation, and long-term planning. Consecutive Five-Year Plans established mandatory energy intensity reduction targets since most are state-represented "command-and-control" mandatory emissions reduction targets. Energy Conservation Law (1997, amended 2007) established mandatory product standards, labeling programs, and prohibitions on inefficient technologies. The Top-1000 was later revised to be the Top 10,000 Enterprises Program, and required the top industrial firms to conduct mandatory energy audits, install monitoring systems, and meet legally binding efficiency targets. Mandatory audits and industry-sector standards, especially in the steel, cement, and petrochemical sectors, were instrumental in curbing inefficiencies. New platforms such as Energy Service Companies (ESCOs) and energy performance contracting also enhanced access to energy-efficient technology. Studies show that apart from technological advancements, structural reforms in industries such as cement, with global technology transfer and emphasis on non-monetary bottlenecks such as information asymmetry, yielded longer-term efficiency gains (Hasanbeigi et al., 2012; Wen et al., 2014). Nevertheless, even though energy intensity plummeted by 75% between 1990 and 2020, structural inefficiencies remain because China's per unit GDP energy use is still 1.5 times the world average (Lin & Li, 2025).

In India's case, policy mechanisms such as the Perform, Achieve, and Trade (PAT) scheme and investments in advanced energy-efficient technologies demonstrated potential. Regulated energy audits under the PAT program entail regular energy audits for Designated Consumers (DCs) from energy-consuming sectors such as steel, cement, power, and textiles. Mandatory Energy Audits (MEA) at three-year intervals are complemented by Monitoring & Verification (M&V) audits in the target year of a PAT cycle. By 2022–23, the PAT units collectively saved 25.77 million tons of oil equivalent (MTOE), or some 8% of their total annual energy consumption, as an illustration of cost savings alongside reductions in greenhouse gas emissions (PIB Delhi, 2024). The results can be translated to the plant level in a study by Jadhav et al. (2017). A lighting audit and electric load management audit done through their study revealed opportunities to reduce lighting load by 40.47% through LED replacement, saving approximately 3.536 kW and achieving a payback period of 18 months. Load management audits also revealed peak-net and waste consumption elimination opportunities, demonstrating how audits make energy a controllable expense, encouraging day-to-day conservation practices among employees.

The industrial sector in Bangladesh plays an essential role in economic development as well as in energy demand, as energy-intensive industries support export earnings; at the same time, they are the source of growing consumption and emissions. Industrial sectors, notably cement, textiles or ready-made garments, steel, brick or kiln, pulp and paper, are among the largest energy users in Bangladesh, consuming over 3.316 Mtoe of electricity in the industrial sector (SREDA, 2024).

Arguably, the RMG sector is the backbone of Bangladesh's economy, earning 83% of total export revenues while consuming 15.4% of industrial energy. The share rises to nearly 30% when textiles are included (BGMEA, n.d.; SREDA, 2024). Energy efficiency measures in this sector could reduce over 30% of the baseline energy consumption amidst the barriers and opportunities revealed by the factory-level analysis. The internal barriers, including low staff awareness, insufficient funding, and the absence of dedicated energy management teams, limit progress.

Technical advancements have revealed enormous efficiency potential in this sector. Actions such as daylight harvesting, LED lighting, IE3-class motors, boiler and pumping system efficiency, on-site energy management, renewable adoption, energy audit, and circular economy practices would save 25% of certain energy consumption, reduce CO_2 emissions by 14,932 tons per year, and generate cost savings of about BDT 115.5 million annually (Khan et al., 2022; Tushar et al., 2024). Sustainability certifications further incentivize these practices. LEED, ISO 14001, OEKO-TEX, GOTS, and the Higg Index are a few of the globally accredited certifications. These strengthen firms' competitiveness by embedding efficiency and sustainability standards, which is supported by case studies such as VIYELLATEX. The firm shows how commitment to meet international standards and technical support facilitates efficiency and resource conservation (Khattak & Park, 2018). Despite having 192 factories with LEED certification, of which many hold multiple accreditations (Rahman et al., 2025), these qualifications by themselves cannot reverse factory-level inefficiencies unless complemented with systemic policy and financing initiatives.

The cement industry is small in energy share at 2.9% (SREDA, 2024), with substantial efficiency potential. Atmaca & Atmaca (2016) found in their study that around 110 kWh of electrical energy produces one ton of cement. So, while it is not the most significant industrial energy consumer, the cement industry presents potential for improved energy efficiency and emissions reduction. However, institutional obstacles as low ESCO involvement, no standard audit, and poor access to finance and technologies in building energy use, including HVAC and compressed air systems, delay the momentum (Siddique et al., 2022; Hossain et al., 2020). International experience proves that by introducing organized energy management, huge savings can be achieved, such as energy plans in the industry in Denmark that resulted in a reduction in energy consumption in 400 companies from up to 62 per cent. Similarly, for Bangladesh, Hossain et al. (2020) suggest that systematic energy management can gain 4–5% improvement in energy efficiency in the cement mills, if organizational capacity is strengthened.

The brick industry is an example of how issues of energy efficiency extend beyond technology to governance and society. Being one of the most common building materials in Bangladesh, coal-fired kilns used in the brick sector alone contribute to 17% of the national annual CO_2 emissions and 11% of $PM_{2.5}$ pollution (Eli et al., 2020). Despite decades of regulation efforts, including the Department of Environment (DoE)'s CASE Project and World Bank-funded projects, a staggering 98% of the traditional kilns remain inefficient (Brooks et al., 2024). While some interventions have reduced up to 70% of particulate emissions and 30% of coal use, due to lax enforcement, misaligned incentives, and limited kiln operators' influence, the interventions could not meet their goals yet (Khaliquzzaman et al., 2020). Abrupt reforms also pose the risk of job loss and brick price rises, suggesting that phased, participatory approaches are essential (Darain et al., 2015).

In contrast to China, India, and Germany, which boast a well-established tradition of industrial energy audits, Bangladesh is progressing towards establishing its regulatory and institutional framework. The government recently revised energy efficiency rules to mandate industrial audits under the Energy Efficiency and Conservation Master Plan (EECMP). SREDA administers implementation, auditor certification, and data collection. Industrial energy auditing in Bangladesh is still facing challenges, though. These are the scarce pool of trained auditors, poor industry awareness and training, insufficient financial incentives, technological resistance to uptake, and operational constraints in improving current platforms such as Building Management Systems. Challenges in data collection and the absence of more concerted regulatory agency-industry collaboration further pose a challenge. Low staff awareness was regarded as the most important impediment by 86% of the companies surveyed (Hossain et al., 2020). Compulsory auditing, however, can release significant energy efficiency gains and contribute to the country in achieving its goal to reduce energy intensity per GDP by 20% by the year 2030.

Overall, these industry samples reveal patterns in common. From RMG, cement, to bricks, firm-level barriers, namely low awareness, inadequate capital, and low institutional capacity, systematically limit efficiency gains. On another plane, opportunity exists in the form of technical improvements, green certification, energy audits, ESCO engagement, and policy reforms by aligning economic incentives with sustainability goals (Uddin et al., 2023; Rahman & Islam, 2023). Mukherjee et al. (2018) suggest broader adoption of access to finance, operational capacity building, and policy and industrial innovation alignment. The literature shows Bangladesh's growing awareness and selective adoption of energy-efficient practices. The gaps in institutional capacity and financing mechanisms, however, suggest the need for targeted interventions and sector-specific strategies.

Case Studies

India

India is considered a South Asian industrial energy efficiency champion due to its strong institutional framework and new policy tools. The Energy Conservation Act of 2001 was the foundation behind the establishment of the Bureau of Energy Efficiency (BEE) and provided the framework for the country's national energy policy. BEE increases efficiency in industries, transportation, and infrastructure. Later reforms, such as the Energy Conservation (Amendment) Act of 2022, mandated stricter rules. The amendment expanded regulations to more areas like vehicles and automobiles, as well as encouraging carbon credit trading (Malhotra et al., 2021).

The biggest energy efficiency program is the Perform, Achieve, and Trade (PAT) scheme, which started in 2012 under the National Mission on Enhanced Energy Efficiency (NMEEE). This program is market-based and gives efficiency targets to big industries such as cement, iron and steel, and textiles. If companies go beyond their targets, they get tradable Energy Saving Certificates (ESCerts) (Pal et al., 2024). If they fail, they must buy them. This makes companies conserve energy for profit. The first cycle (2012–2015) saved 8.67 million tonnes of oil equivalent (MTOE), which was more than national expectations (Hudedmani et al., 2019).

India has also included some national demand-side schemes. UJALA scheme is one of them, which distributed over 368 million LED lights, reducing peak consumption by 1.5 GW and saving 48 billion kWh annually. At the same time, programs such as the Energy Efficiency Financing Platform (EEFP) and the Partial Risk Sharing Facility (PRSF) promoted the flow of private funds into efficiency projects (Singh et al., 2018).

The manufacturing industry of India improved its energy efficiency by 39% in twenty years, and the industrial energy intensity decreased as well. In 1980, the sector spent Rs. 30.56 on energy per Rs. 100 of output, which fell to Rs. 23.84 by 2018 (Bagchi & Sahu, 2020). This combination of regulation, market tools, and finance has made India a model in the South Asia region for maintaining both strong industry and energy efficiency.

China

China has made big steps in energy efficiency by putting it inside its Five-Year Plans since the 1980s. From 1990 to 2020, China cut energy intensity by about 75%, but it is still higher than OECD levels (9: Energy Efficiency - Guide to Chinese Climate Policy, 2022).

The 11th Five-Year Plan (2006–2010) targeted to reduce energy intensity by 20%, and it was successful to achieve as well (Zhang et al., 2011). The 12th and 13th Plans also had high goals, though some were not fully achieved (*Conclusion - Guide to Chinese Climate Policy*, 2022). To make things stronger, China introduced the Top-1000 Enterprises Program in 2006, later expanded to the Top 10000 Enterprises Program. These required big energy users to do audits, set up energy management systems, and meet mandatory targets. These programs together covered almost two-thirds of national energy use (De Gouvello et al., 2021).

China's Energy Conservation Law (1997, amended 2007) and other policies made efficiency more formal (IEA, 2021). Achievements include implementing ultra-supercritical technology in coal plants, removing inefficient boilers, and making green building rules. By 2018, about 40% of new houses were green-certified (Shen & Faure, 2020).

In recent years, China has moved toward climate targets called "30·60" (peak emissions by 2030, neutrality by 2060) (*4: Climate Goals - Guide to Chinese Climate Policy*, 2022). The 2024–2025 Action Plan said it would save 50 million tonnes of coal equivalent each year, cut 130 million tonnes of CO_2, and raise non-fossil energy to 20% by 2025 (Enerdata, 2024). China shows how long-term planning, strict sector rules, and money incentives can change industrial efficiency at a very large scale.

Vietnam

Vietnam is moving fast in Southeast Asia in terms of efficiency. Its main effort is the Vietnam National Energy Efficiency Program (VNEEP), now in phase three (2019–2030). The program aims to cut 5–7% of energy use by 2025 and 8–10% by 2030 (ASEAN Centre For Energy, 2023).

The Law on Economical and Efficient Use of Energy (2010) states that large energy users must do audits and appoint energy managers. This has made energy management part of industries and connected it with Vietnam's sustainability goals. Another important point is training. The government of Vietnam built training programs for auditors and managers, giving them the skills to find and apply savings. This increased the number of experts who can support companies (Luong, 2015).

Finance is also another important aspect for achieving energy efficiency. Projects such as the Vietnam Energy Efficiency for Industrial Enterprises (VEEIE) and the Scaling Up Energy Efficiency Project (VSUEE) gave loans and incentives so industries can buy efficient technology (Chu & The World Bank in Vietnam, n.d.). Public awareness has also contributed to energy efficiency achievement. The country ran campaigns and surveys to change consumer and business habits, showing efficiency as both a cost-saving and environmental benefit.

These measures have been effective. For example, Decision 280/QD-Ttg plans to save 5–7% of total use and cut electricity demand by up to 15% in some sectors by 2030 (ASEAN Centre For Energy, 2023). Vietnam's case shows how laws, finance, training, and awareness together can push industrial efficiency.

Singapore

Singapore lacks dependable energy resources and largely depends on imports, but it is now seen as a leader in energy efficiency. The policies of the country combine regulation with cautious urban planning. The Energy Conservation Act (2012) makes big energy users, called registrable corporations, set up Energy Management Systems (EnMS), hire energy managers, and submit plans to improve efficiency (Government of Singapore, 2012).

Alongside this, the Green Building Masterplan (GBMP) aims to make 80% of buildings "green" by 2030. The "80-80-80" vision says that by 2030, 80% of new buildings will be Super Low Energy, and the best ones will be 80% more efficient than 2005 levels (Browne, 2023). The rules are strict. If firms do not follow the Minimum Energy Efficiency Standards (MEES), they face penalties. Incentives are also offered for those who comply early.

As a result, Singapore is one of the most efficient countries in Asia. Its regulatory style is praised and often seen as a model for other nations that have limited resources but want efficiency.

Germany

Germany is seen worldwide as a leader in efficiency policy. It made efficiency a central part of its Energiewende, or Energy Transition. Its Energy Efficiency Strategy 2050 says "efficiency first." The goal to cut primary energy use by 50% by 2050 compared to 2008, and 30% by 2030 (Federal Ministry for Economic Affairs and Energy, 2020).

The main efficiency policies of Germany include the National Action Plan on Energy Efficiency (NAPE 2.0), which requires 300 TWh of savings by 2030. Another is the Energy Efficiency Networks Initiative, where industries join together to share ideas and practices (Federal Ministry for Economic Affairs and Energy, 2020).

Buildings are a big part of energy use, 35% of the total. Policies such as the Building Energy Act (GEG, 2020, amended 2023) require new heating systems to use at least 65% renewable energy. The state development bank KfW helps with retrofits, and audits are required by law for industries (European Commission, 2020).

Germany also uses carbon pricing, digital tools, and green finance in its strategy. It sees efficiency not only as a way to cut emissions but also to improve energy security and keep industry competitive (Agora Energiewende, 2023; Clean Energy Wire, 2023; Deloitte Deutschland, 2023).

By 2022, Germany had already cut energy use by 28% compared to 1990 (AGEB, 2023) and lowered CO_2 emissions by 46%, while keeping its economy growing (AP News via Fast Company, 2024). The summary of different countries' energy efficiency policies and achievements is presented in Table 1.

Table 1: Overview of Energy Efficiency Policies and Achievements by Country

Country	Key Energy-Efficiency Policies & Programs	Institutional Framework	Achievements / Status
Bangladesh	Energy Efficiency & Conservation Master Plan (EECMP) up to 2030; Energy Efficiency & Conservation Rules (2014); Energy Management, EE Labelling, and EE Buildings Programs; Industrial Energy Efficiency Finance Program (BIEEFP)	SREDA (EE&C lead); Bangladesh Energy Regulatory Commission (BERC) for enforcement incl. certified co-generation assessments	Groundwork in place but implementation barriers persist (technology gaps, finance, weak MEPS/enforcement, data limitations, immature ESCO market). T&D loss reductions could save approx. 884 GWh/year if improved by 1%
India	Energy Conservation Act (2001; amended 2022 to widen coverage incl. vehicles/vessels & strengthen penalties); Perform, Achieve & Trade (PAT) cap-and-trade for industrial efficiency; UJALA national LED rollout; EEFP/PRSF for EE finance	Bureau of Energy Efficiency (BEE); Energy Efficiency Services Ltd (EESL)	PAT Cycle-I exceeded target (≈5.3% vs. 4.1%); UJALA + SLNP drove mass market LED uptake and peak-demand cuts (1.5 GW); manufacturing energy-efficiency improved 39% over two decades
China	Energy Conservation Law (1997, 2007 update); Top-1000 / Top-10,000 Enterprises mandatory programs; binding Five-Year Plan intensity targets; sectoral standards & green-building codes; 2024–25 State Council Action Plan to accelerate intensity cuts	State Council; NDRC; provincial targets with "dual control" on consumption & intensity	75% drop in energy intensity (1990–2020); massive ESCO/retrofit & standards push; ongoing 2024–25 actions to lift non-fossil share & tighten industrial benchmarks
Germany	Energy Efficiency Strategy 2050 ("efficiency first"); NAPE 2.0; Building Energy Act (GEG, 2020; amended 2023); competitive STEP up! tenders; carbon pricing for heat/transport	Federal Ministry for Economic Affairs & Climate Action (BMWK); KfW programmes; legally mandated audits (EDL-G)	Primary energy use down 28% vs 1990; CO_2 down 56% vs 1990 (with continued growth)

Country	Key Energy-Efficiency Policies & Programs	Institutional Framework	Achievements / Status
Vietnam	VNEEP 2019–2030 with national savings targets; Law on Economical & Efficient Use of Energy (2010); Decision 280/QĐ-TTg; concessional-finance programs VEEIE & VSUEE	Ministry of Industry & Trade (MOIT) and its EE department; mandated energy managers & audits for large users	Targets: 5–7% total energy-use reduction by 2025 and 8–10% by 2030; strengthened compliance via audits/management systems
Singapore	Energy Conservation Act (2012) with mandatory EnMS, qualified energy managers & MEES; Green Building Masterplan ("80-80-80 by 2030")	National Environment Agency (NEA); Building & Construction Authority (BCA)	Progress toward SGBMP: just under 60% of buildings (by GFA) "greened" as of mid-2024; continued push to SLE standards and mandatory energy improvement regime in pipeline.

Source: SANEM's Compilation

4. Industrial Energy Efficiency in Bangladesh: Performance Analysis

This study takes dual approach to understand the industrial energy efficiency performance of Bangladesh based on the Data Envelopment Analysis (DEA). It begins with an analysis of the Bangladesh domestic manufacturing sector and then offers a comparative study, which compares Bangladesh to similar peer countries. DEA is a non-parametric, data-oriented technique that compares the relative efficiency of a group of comparable entities (we call them Decision-Making Units or DMUs). The details of the DMUs involved are different for each exercise in this study. For the intra-country analysis, every DMU corresponds to an individual manufacturing industry in Bangladesh (as defined by its 3-digit HS code) and therefore enables a comparison of performance relative to other industries within the domestic industrial framework. In the cross-country application, each DMU represents the sectoral structure of a country. The need of the DEA model is due to the complexity of the production technology in either context, which is characterized by multiple inputs and outputs without previous knowledge of its form. In both analyses, a production frontier is derived from the data, which serves as reference of best practice by defining the maximum feasible output for any given set of inputs.

Data Envelopment Analysis (DEA) is widely used for complex production situations and therefore is a very well-founded choice for our intra-country as well as cross-country. By dealing with several inputs and outputs simultaneously, DEA has the advantage that it does not require an exact specification of a production function (Wang, Wei & Zhang, 2013). Each country can be evaluated for energy saving potential using the DEA approach (Camioto, Rebelatto, & Rocha, 2016). Moreover, the energy composition of countries, industrial structure and institutional arrangements operate differently. The SBM approach allows these differences to be included, presenting an overview of energy efficiency which is not only related to the use of energy, but also considers CO2 emissions and economic productivity.

With a wide array of manufacturing sectors in Bangladesh for the analysis, DEA facilitates direct comparisons to locate efficient domestic industries, and thereby domestic industries that need improvement. The same comparative capability renders it particularly suitable for cross-country analysis, where it provides a critical external reference by measuring various national economies in relation to a best-practice frontier that may inform national policies and targeted investments (Mardani et al., 2017).

4.1 Empirical Method

Traditional DEA models are radial which measure the energy efficiency as a whole, either increase of decrease of all inputs or outputs, for example, CCR or BCC models. These models cannot identify the unique source of inefficiency. Contrary to radial models, which lift all inputs or outputs together, SBM can identify which input is too much or which output too short (e.g. the energy is inefficient if the labor is alright). Tone (2001) first proposed a non-radial, Slack-based Model (SBM) to overcome this challenge. Tone's model deals with the "slacks" issues which means there could be excess inputs or shortage of outputs in production process causing inefficiencies. By "slacks", the gaps that are precise and given by measurement are represented, they are essentially (a) inputs that can be reduced without shifting the net production technology and (b) outputs that can be produced further without a shift in production technology. Hence, this model can capture all sources of inefficiencies that might be missed while using radial traditional DEA model, for example, there might be energy inefficiency in a country while the labor use is efficient.

Since in both exercises the compared DMUs represent quite different size and shape of development blocks it has been assumed that Variable Returns to Scale (VRS) has been considered as the most appropriate. This enables a more reasonable comparison, even between large, more mature manufacturing industries within Bangladesh versus other smaller, more nascent ones within the same country. In the same way, in the cross-country comparation, VRS ensures that each country is compared to a feasible combination of countries of comparable economic size. This allows us to compare DMUs that operate at different scales with one another in both contexts. The assessment is done not only for desirable outputs (extent of the economic output), but also for undesirable outputs (carbon-di-oxide emission), though for the intra-country analysis, it could not be considered due to data unavailability. By including CO2, the undesirable output, the efficiency frontier bends in a way that discourages emissions.

SBM Model

This study has followed the SBM-VRS based DEA analysis inspired by Yan et al. (2021). The methodology was applied in two separate exercises. The first exercise was an intra-country analysis of manufacturing in Bangladesh. The entity under investigation is a specific industrial sub-sector, or DMU. Merging firms with identical 3-digit Harmonized System (HS) code into product groups using firm-level data from Survey of Manufacturing Industries (SMI) 2019, Bangladesh Bureau of Statistics (BBS); Using this, each DMU i corresponds to one product-level industry in Bangladesh, hence, the current analysis provides a way to measure relative energy efficiency among all manufacturing sectors of Bangladesh. This exercise has considered one desirable output (gross value added) that is produced using four inputs (capital, labor, raw materials and energy), without an undesirable output due to data unavailability.

The second exercise was a cross-country analysis. This analysis reframes the DMU i from an industry to a country. It regards the 13 countries as each DMUs i.e. j = 1,...,13 and the aggregate production technology consist of 3 input: Capital (K), Labor (L) and Energy (E). These involve the production of a single desirable output, industrial value added, and a single undesirable output, CO2 emissions. The selection of the 12 countries other than Bangladesh(Japan, Egypt, Morocco, Sri Lanka, Turkiye, Philippines, Indonesia, Viet Nam, Thailand, China, Pakistan and India) was governed primarily by the availability of consistent and comparable panel data for all the essential variables (capital stock, labor, energy consumption and industrial value-added/industrial output) over the common time span for each country. Moreover, this group is a relevant and heterogeneous set of economies with varying levels of industrialization. It consists of an advanced industrialized country (Japan), numerous important emerging industrial powers (China, India, Indonesia, Turkiye), and additional developing nations in Asia and North Africa. This heterogeneity facilitates stronger analysis, as it enables a within-country comparison of energy efficiency frontiers across nations that differ in economic structure, technological advance, and policy environment, making the results more generalized and informative.

The optimization problem is as follows:

$$Min\ [\gamma - \epsilon(\theta^T s^- + \theta^T s^+)]$$

Here, Radial efficiency improvement= γ

Non-radial slack variables are s^-(for inputs) and s^+(for outputs)

γ denotes the common (radial) shift, slack terms denote any gross, non-common adjustment not corrected by the radial movement alone. But, for instance, if γ indicates a 5% cut to an input, the fact that it still has non-negative slack energy means that energy is still going to profit from some additional drop beyond that 5%.

The objective function indicates that the radial efficiency improvement will be achieved by minimizing γ and maximizing sum of all non-radial slack variables. To ensure that all inefficiencies have been considered, a small non-Archimedean number ϵ is used.

Subject to:

1. $\gamma x_{io} = \sum(\alpha_j {*} x_{ij}) + s_i^-$
2. $y_{ro} = \sum(\alpha_j * y_{rj}) - s_r^+$
3. $\gamma b_{ko} = \sum(\alpha_j {*} b_{kj}) + s_k^{b-}$
4. $\sum \alpha_j = 1$
5. $\alpha_j, s_i^-, s_r^+, s_k^{b-} \geq 0$

Here, x represents the regular inputs, for example, labor and capital, y is the desirable output or GDP, b is the undesirable outputs and α_j denotes the peer weights.The first constraint connects usual input, i.e, labor and capital of a country to the efficient frontier. γx_{io} is the radially adjusted target for inputs and s_i^- represents additional non-radial slack. The second constraint builds the frontier for desirable outputs whereas s_r^+ is the slack variable depicting the shortage of output or GDP. The third one defines the frontier for undesirable output (CO2 emission) while minimizing the inputs. The slack term in this constraint denotes excess emission. To impose the Variable Returns to Scale (VRS), a convexity constraint has been considered so that it can ensure that benchmarking countries would be against peers with similar scale. The last constraint is basically a non-negativity constraint, which confirms that all slack as well as weighting variables are zero or positive.

According to the core principle of efficiency,

Efficiency= (Target Input/ Actual Input)

The target input is the quantity of energy input that should be utilized by a DMU if it were operating on the efficiency frontier. This is basically a weighted average of the most efficient comparable countries.

From constraint 1, $\gamma x_{io} = \sum(\alpha_j * x_{ij}) + s_i^-$

If the above constraint is written only for energy input,

$$\gamma e_{io} = \sum(\alpha_j * e_{ij}) + s_{ei}^- \text{.......}(1)$$

Hence, γe_{io} is radially adjusted actual energy, $\sum(\alpha_j * e_{ij})$ is the target for efficient energy on the frontier and s_{ei}^- is energy input slack.

So Target energy= $\sum(\alpha_j * e_{ij})$= $(\gamma e_{io}$- $s_{ei}^-)$; [Derived from equation 1]

Therefore, if actual energy input is denoted by e_{io}, energy efficiency = $(\gamma e_{io}$- $s_{ei}^-)/\ e_{io}$

An energy efficiency of 1 means that the country/industry is already on the frontier for energy; a number such as 0.90 indicates energy use could be cut by 10% without sacrificing desirable output or increasing detrimental output. For example, where e_{io} = 100 then γ = 0.95 and s_{ei}^- = 5 then Target energy = 90 and efficiency = 0.90

4.2 Empirical Outcome

Data Sources

The data for the analysis came from two separate sources, one for each of the two analyses. To study the manufacturing sector within an economy in Bangladesh, industry-level data were sourced from the 2019 Survey of Manufacturing Industries (SMI) conducted by the Bangladesh Bureau of Statistics (BBS). All data for the cross-country comparison were extracted from the World Bank: World Development Indicators database, except fossil fuel consumption (% of equivalent primary energy), which was derived from Our World in Data. The final cross-country dataset consists of 410 country-year pairs spanning 13 countries, with the lowest number of years per country being 23 (Philippines) and maximum being 34 (Egypt, Indonesia, Morocco, Turkey, China and India).

4.2.1 Energy Efficiency in Bangladesh's Manufacturing Industries

The DEA empirical results initially identify a group of effectively efficient industries that represent the best practice frontier of the manufacturing sector for Bangladesh. The following table (Table 2) shows the benchmark DMUs in terms of energy efficiency, and all of them scored 1. Such a score indicates that there is no excess energy consumed by the sector, for example, 'Spinning, weaving and finishing of textiles' (HS Code 131) and 'Manufacture of plastics products' (HS Code 222). Such reference peers are the firms that have been selected as the benchmarks measuring the relative inefficiencies and potential energy savings of all other industries in an analysis.

Table 2: Firms on efficient frontier

HS_code_3digit	Product name	Energy efficiency
281	Manufacture of general-purpose machinery	1
222	Manufacture of plastics products	1
292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	1
102	Processing and preserving fish, crustaceans and mollusks	1
104	Manufacture of vegetable and animal oils and fats	1
301	Building of ships and boats	1
131	Spinning weaving and finishing of textiles	1
143	Manufacture of knitted and crocheted apparel	1
341	Recycling	1
321	Manufacture of jewelry, bijouterie and related articles	1
241	Manufacture of basic iron and steel	1
302	Manufacture of railway locomotive; and rolling stock	1
264	Manufacture of consumer electronics	1
120	Manufacture of tobacco products (cigarettes & others)	1

Source: SANEM Estimation

After the full efficient industries are identified, we examine performance of the inefficient sectors. These inefficient industries that operate near the best-practice frontier are reported in the table (Table 3) below for the top 15 industries. The leading industry of this group is "Manufacture of beverages" (HS 110), which is the most efficient one among all inefficient economic sectors, with an energy efficiency index value equal to 0.76. Even though it is the best performing industry among the relatively efficient group, there is still notable energy savings potential of nearly 24%.

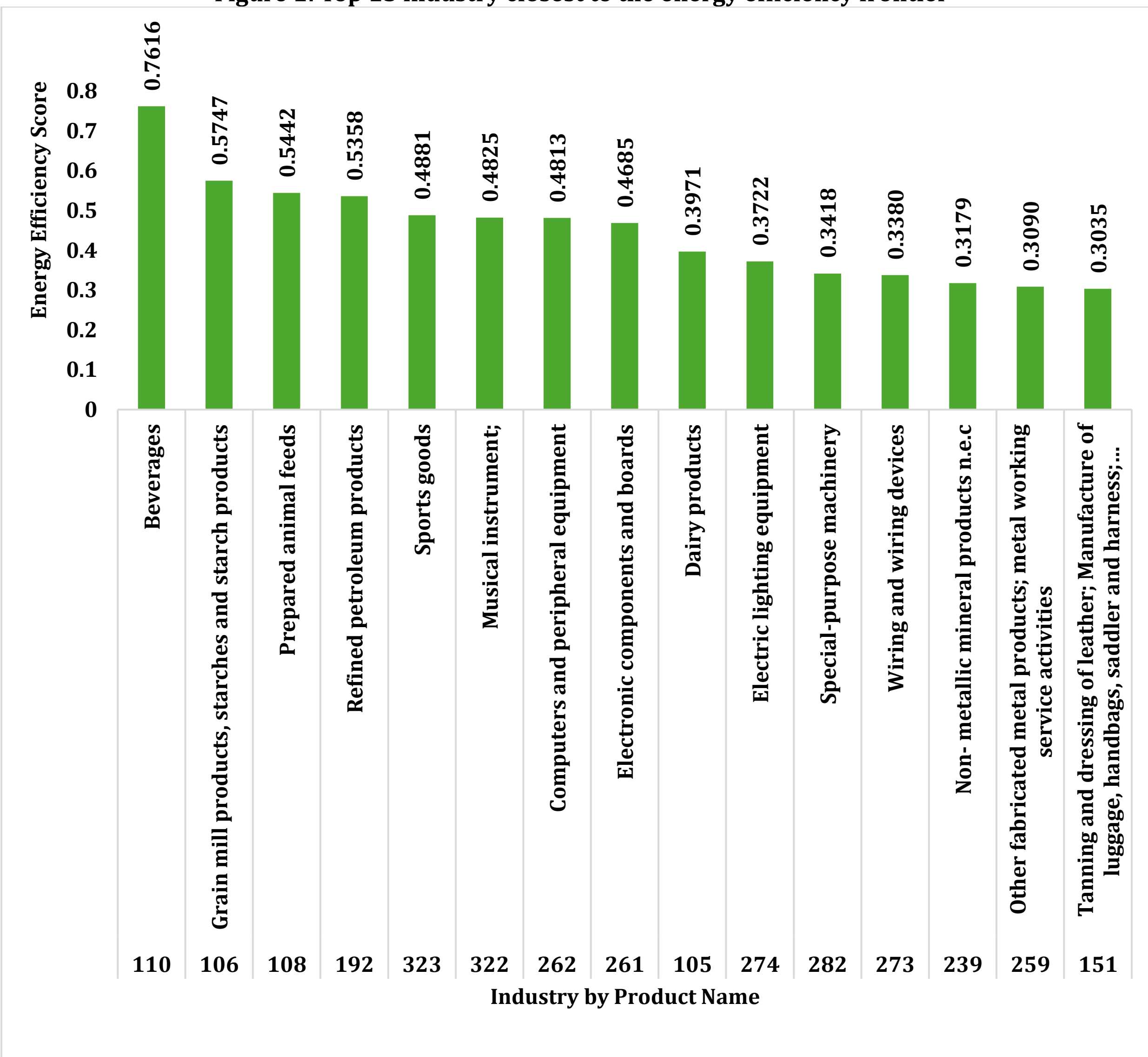
Table 3: Top 15 Inefficient Firms (Closest to Frontier)

HS_code_3digit	Product name	Energy efficiency	Energy savings percentage
110	Manufacture of beverages	0.7616313	23.83687
106	Manufacture of grain mill products, starches and starch products	0.5747225	42.52775
108	Manufacture of prepared animal feeds	0.5441771	45.58229
192	Manufacture of refined petroleum products	0.5358073	46.41927
323	Manufacture of sports goods	0.4880699	51.19301
322	Manufacture of musical instrument;	0.4824593	51.75407
262	Manufacture of computers and peripheral equipment	0.4813069	51.86931
261	Manufacture of electronic components and boards	0.4684747	53.15253
105	Manufacture of dairy products	0.3970621	60.29379
274	Manufacture of electric lighting equipment	0.3721909	62.78091
282	Manufacture of special-purpose machinery	0.3418245	65.81755
273	Manufacture of wiring and wiring devices	0.3379929	66.20071
239	Manufacture of non-metallic mineral products n.e.c	0.3179315	68.20686
259	Manufacture of other fabricated metal products; metal working service activities	0.308959	69.1041
151	Tanning and dressing of leather; Manufacture of luggage, handbags, saddler and harness; dressing and dyeing of fur	0.3035372	69.64628

Source: SANEM Estimation

Further down the list, demonstrations of inefficiency increase with sub-sectors like “manufacture of dairy products” (HS code 105) and “tanning and dressing of leather” (HS code 151) scoring significantly lower in terms of efficiency level which are 0.40 and 0.30, respectively, translating into a potential energy saved at over and close to 60% and almost 70% respectively. This suggests that even the relatively efficient industries in inefficient groups have a large potential to reduce energy consumption. Figure 1 shows that most of the closest to frontier firms have an efficiency score below 0.5, that is, they have more than 50% energy saving potential.

Figure 1: Top 15 industry closest to the energy efficiency frontier



Source: SANEM Estimation

While the industries nearest to the frontier tend to be significantly more efficient, the furthest 15 manufacturing industries, listed in Table 4, are in the least efficient group. These sectors are the key potential areas for energy saving. At the lower end of the performance ranking is "Manufacture of glass and glass products" (HS code 231), which has an impressively low energy efficiency value of 0.06 only. This represents an enormous room for improvement, with a resultant energy savings of more than 93%.

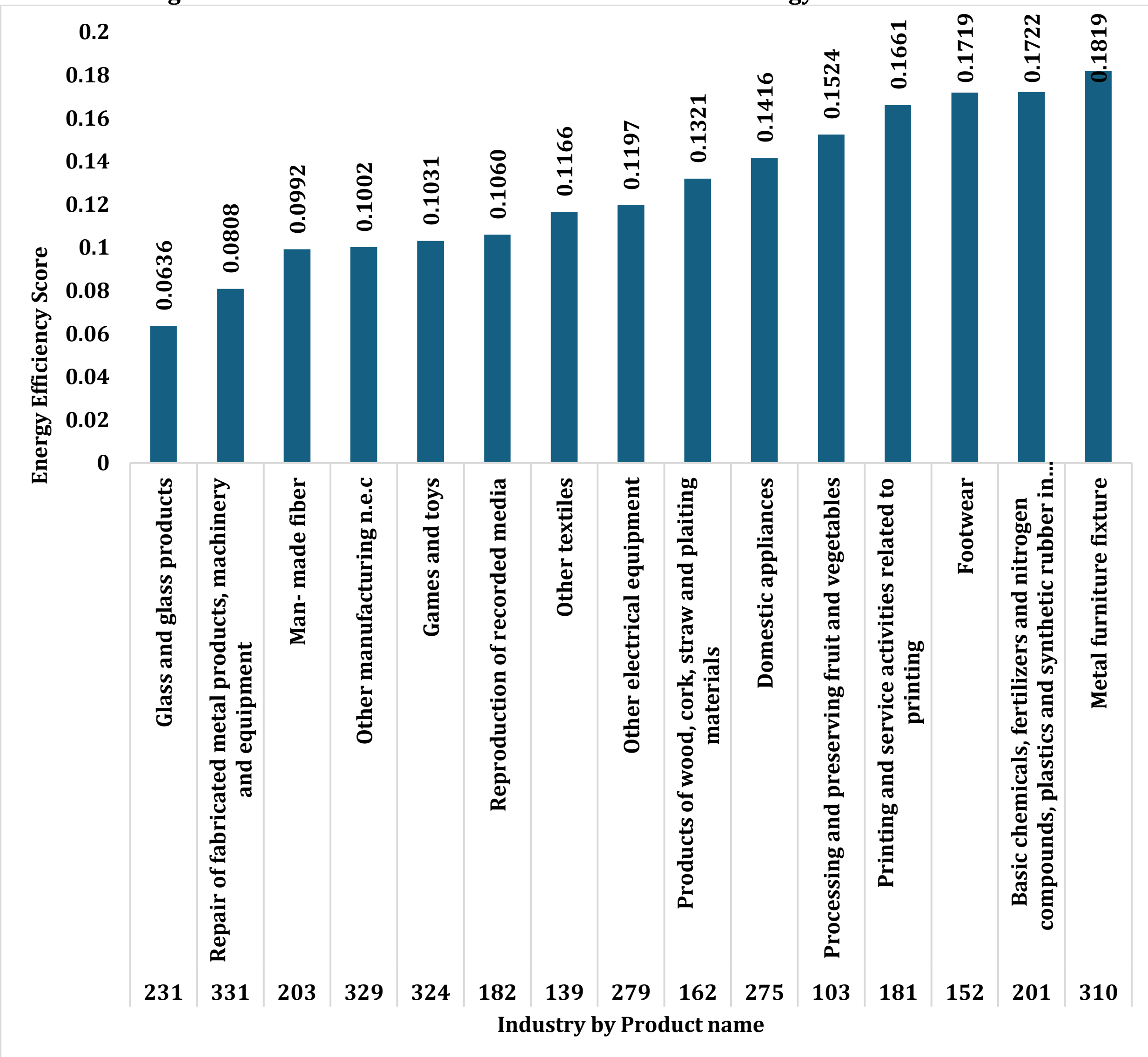
Table 4: Bottom 15 Inefficient Firms (Furthest from Frontier)

HS_code_3digit	Product name	Energy efficiency	Energy saving percentage
231	Manufacture of glass and glass products	0.0636258	93.63742
331	Repair of fabricated metal products, machinery and equipment	0.0808236	91.91764
203	Manufacture of man-made fiber	0.0991798	90.08202
329	other manufacturing n.e.c	0.1002036	89.97964
324	Manufacture of games and toys	0.1030527	89.69473
182	Reproduction of recorded media	0.1059834	89.40166
139	Manufacture of other textiles	0.1165602	88.34398
279	Manufacture of other electrical equipment	0.1196536	88.03465
162	Manufacture of products of wood, cork, straw and plaiting materials	0.1320526	86.79475
275	Manufacture of domestic appliances	0.1416427	85.83573
103	Processing and preserving fruit and vegetables	0.1524163	84.75837
181	Printing and service activities related to printing	0.1661352	83.38648
152	Manufacture of footwear	0.1719354	82.80646
201	Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms	0.1722322	82.77678
310	Manufacture of metal furniture fixture	0.1819499	81.80501

Source: SANEM Estimation

Indeed, in all related activities of the bottom 20%, industries were strongly energy wasteful, where each could save by more than 81% of current consumption (Figure 2). These results identify a definite priority region, i.e. areas to be addressed with targeted policies and technological advancement if significant energy conservation gains were sought from the national economy.

Figure 2: Bottom 15 Inefficient Firms Furthest from Energy Efficient Frontier



Source: SANEM Estimation

Energy efficiency results of major manufacturing industries in Bangladesh ranked by energy efficiency potential for improvement is presented in Table 5. The energy efficiency score indicates the energy used per unit of value-added relative to a best-practice frontier; a value of 1 indicates that an industry is perfectly efficient. The results are then summarized in two principal metrics, "potential energy savings," and "energy savings percentage." Potential energy savings is the total amount of excess energy consumed by an entire industrial sector expressed in original dimension (BDT in this case). This is the amount of energy waste that could be removed if the industry existed on the efficient frontier. On the other hand, the energy savings percentage is a relative metric which signifies what fraction of an industry is currently consuming inefficient energy. This more comprehensive relative measure suggests, for example, that the general "Manufacture of non-metallic mineral products" (HS 239) has the greatest potential with just under a total 120 billion units of energy absolute savings, but its savings percentage of 68.2% suggests that more than two-thirds of its current energy use is somehow inefficient. On the other hand, industries such as "Manufacture of other textiles" (HS 139) have a smaller absolute savings potential, but very high relative inefficiency, with their 88.3% savings percentage revealing that they are using their energy far less efficiently than their industry average. The least energy-efficient sector, " Manufacture of beverages" (HS 110), has the greatest potential for improvement, with 23.8% of energy consumption being economically feasible to achieve with existing technology.

Table 5: Firms with Largest Energy Savings Potential

HS_Code_3digit	Product name	Energy efficiency	Potential energy savings (BDT)	Energy savings percentage
239	Manufacture of non- metallic mineral products n.e.c	0.3179315	119896170496	68.20686
106	Manufacture of grain mill products, starches and starch products	0.5747225	29033433088	42.52775
139	Manufacture of other textiles	0.1165602	25313036288	88.34398
107	Manufacture of other food products	0.2646453	20341577728	73.53547
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	0.248475	9554157568	75.1525
210	Manufacture of pharmaceuticals, medicinal chemical and botanical products (Allopathic)	0.2809611	7277478400	71.90389
201	Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms	0.1722322	5861094912	82.77678
170	Manufacture of paper and paper products	0.1902609	4593863680	80.97391
259	Manufacture of other fabricated metal products;	0.308959	4285817600	69.1041

HS_Code_3digit	Product name	Energy efficiency	Potential energy savings (BDT)	Energy savings percentage
	metal working service activities			
152	Manufacture of footwear	0.1719354	3462749696	82.80646
310	Manufacture of metal furniture fixture	0.1819499	3404150784	81.80501
110	Manufacture of beverages	0.7616313	3007836160	23.83687
272	Manufacture of batteries and accumulators	0.2711883	2797622272	72.88116
263	Manufacture of communication equipment	0.2764461	2407885568	72.35539
261	Manufacture of electronic components and boards	0.4684747	2405453824	53.15253

Source: SANEM Estimation

4.2.2 Cross-Country Analysis of Industrial Energy Efficiency

This exercise examines the two sets of countries: a nucleus of most efficient nations among 13 countries (Table 6). With an efficiency score of 1.0, five countries: Philippines, China, Egypt, Sri Lanka, and Japan represent the best-practice frontier. There is vast scope of improvement for most of the nations, with Bangladesh being the 10th out of 13 nations evaluated. With an energy efficiency index of approximately 0.47 it is functioning at a little less than half its potential functionality, which corresponds to a huge energy savings potential of more than 53%. This indicates a huge scope for Bangladesh to improve the competitiveness of its industries and decrease the price of energy by learning from the technologies and practices of the frontier countries.

Table 6: Country-wise energy efficiency performance

Rank	Country	Energy efficiency	Energy savings percentage	co2_efficiency
1	Philippines	1.0000	0.00	1.0000
2	China	1.0000	0.00	1.0000
3	Egypt, Arab Rep.	1.0000	0.00	1.0000
4	Sri Lanka	1.0000	0.00	1.0000
5	Japan	1.0000	0.00	1.0000
6	Turkiye	0.7160	28.40	0.7107
7	Morocco	0.6105	38.95	0.6030
8	Thailand	0.6015	39.85	0.5974
9	Indonesia	0.5807	41.93	0.5762
10	Bangladesh	0.4653	53.47	0.4593
11	Pakistan	0.4466	55.34	0.4409
12	Viet Nam	0.4353	56.47	0.4276
13	India	0.3378	66.22	0.3302

Source: SANEM Estimation

This pattern of relatively low efficiency rankings for fast-growth South and Southeast Asian economies (India: 0.34; Viet Nam: 0.44; Bangladesh: 0.47) is consistent with macro trends in global energy. Emerging economies, especially in this region, tend to have high energy intensity due to the energy-intensive structure of industrialization among the developing economies, and the existence of relatively old and inefficient capital stock, according to the International Energy Agency (IEA). Frontier countries such as Japan, on the other hand, have cared about high-tech manufacturing and high efficiency standards for a long time. As a result, the model's result demonstrates that the potential for energy savings is great in Bangladesh.

For comparison with the relevant countries' energy intensity value in 2023, Table 7 is presented:

Table 7: Energy Intensity for Selected Countries (2023 Data)

Rank	Country	Energy Intensity (MJ per GDP PPP)	Year
1	Bangladesh	1549.12	2023
2	Sri Lanka	1590.98	2023
3	Philippines	2512.08	2023
4	Japan	2805.16	2023
5	Indonesia	3140.10	2023
6	Viet Nam	3223.84	2023
7	Pakistan	3223.84	2023
8	India	3642.52	2023
9	Thailand	3809.99	2023
10	China	5484.71	2023

Source: IEA,2023

If we contrast these DEA rankings with the most recent 2023 data on energy intensity (Table 7), it is clear that relative efficiency in the case of a country does not only come down to being low on energy intensity. For example, the DEA model shows Bangladesh to be worst in terms of efficiency ranking, but the year 2023 value ranks its energy intensity (1549.12 MJ/GDP) lowest in the group, indicating that a less energy-demanding industrial structure overall. On the contrary, China, which is on the efficient frontier of DEA, has the highest energy intensity (5484.71 MJ/GDP). The apparent contradiction reflects that the DEA methodology is robust; it does not merely measure the energy-GDP ratio. Instead, it measures the efficiency with which a country turns all its inputs (capital, labor, and energy) into outputs. China gets branded as "efficient" because, despite the energy-intensiveness of its industry, it is using its massive scale of inputs to produce as much as it possibly can. Hence, in the case of Bangladesh, it has not been able to efficiently transform its special mix of inputs into industrial value added compared to the best-performing countries.

5. Barriers to Energy Efficiency in the Industrial Sector

The major barriers for Bangladesh to gain industrial energy efficiency are structural, institutional, and operational. They are persistent and constantly limiting progress across the sector. Thorough discussions with industry representatives, technical experts, and personnel from relevant institutions revealed that weak energy supply conditions and unreliable infrastructure are the biggest barriers to achieving the much-needed energy efficiency.

Energy supply challenges

Frequent load-shedding, voltage instability, and natural gas shortages disrupt production flows and increase dependence on diesel-based captive power, which is inefficient and costly for production. Such issues also force factories not to invest in improved technologies. These problems are also worsened by grid faults, obsolete distribution networks, and unplanned industrial expansions, mainly around urban centres like Dhaka.

Insufficient Energy Auditing

For this discussion, one of the most unavoidable barriers will be the limited practice of energy auditing. High energy-intensive sectors such as steel and cement operate without systematic audits. In other sectors where audits happen, the production factories are forced to meet external buyer requirements rather than internal management needs. Experts from energy regulatory agencies and sector associations noted that only a small share of designated large consumers have completed formal audits. The absence of audit culture prevents identifying inefficiencies, benchmarking, and strong compliance with national energy policies.

Inadequate technical and human resource capacity

Despite the increase in recent times, the number of certified energy auditors remains insufficient for the scale of industrial demand. Most of the firms lack trained energy managers who can interpret audit findings or operate efficient systems. Industry leaders also pointed out a shortage of credible laboratory facilities for testing and certifying motors, boilers, and other equipment. This capacity gap discourages innovation, slows down technology adoption, and decreases trust in efficiency recommendations.

High investment requirements

Energy efficient upgrades such as technically advanced motors, boilers, variable frequency drives, and rooftop solar need significant capital, which most of the firms cannot access. This is particularly true for almost all SMEs. There are concessional financing schemes for such upgrades, but industry representatives repeatedly emphasised that commercial banks charge high interest rates, impose complex loan approval processes, and often lack the expertise to evaluate efficiency-related proposals. Thus, industries hesitate to replace outdated technologies even when the savings potential is well-informed.

Policy and regulatory weaknesses

The national energy master plans and other relevant policy documents outline broad objectives. On the other hand, stakeholders noted gaps in enforcing rules, sector-specific standards, and implementation mechanisms. Mandatory audit and reporting requirements are not consistently enforced, and regulatory bodies face undercapacity for compliance monitoring. Overlapping mandates between different agencies create confusion and delays. Stakeholders said that investor confidence is also reduced by changes in tariff structures and pricing policies without clear long-term signals.

Quality issues of imported machineries

Industry representatives reported widespread circulation of low-quality imported components such as motors, inverters, and solar accessories. As quantity control mechanisms remain weak, industries purchase cheaper products that fail to reach expected efficiency. For this reason, trust in energy-efficient technologies reduces, and lifecycle costs increase. The market for high-quality efficiency equipment will hardly grow without stronger standards and testing facilities.

Lack of infrastructure

Absence of required infrastructures significantly hampers efficiency upgrades. Old gas pipelines, high system losses, insufficient storage, and limited refinery capacity for fuels reduce reliable energy access. Energy supply institution experts pointed out that the gas supply deficit continues despite planned exploration programs and imports. Industries dependent on continuous heat and power, such as steel, cement, pharmaceuticals, or plastics, face production interruptions, waste of partially processed materials, and repeated reheating; all because of such deficits. They raise energy intensity and production cost and lower overall production efficiency.

Locations of industries

Representatives from power distribution agencies explained that factories have developed in scattered, unplanned locations, and this makes reliable supply difficult. Transmission loss is increased, installation of high-capacity substations is restricted, and opportunities for cogeneration or waste heat recovery are limited. Concentrated industrial zones with dedicated feeders, modern substations, and shared services are limited. All these shortcomings reduce the potential for achieving energy efficiency.

The deprioritization of energy efficiency in industrial culture

Stakeholders observed that industries often prioritise short-term production goals over efficiency improvements, particularly when energy prices are subsidised. For reducing energy consumption, awareness of operational practices remains low and simple behavioural changes are often overlooked. Industries generally procrastinate efficiency investments until they face certain crises, such as fuel price hikes or severe outages, so it is understood that they lack long-term planning.

Industry-specific challenges

Many specific sectors have their unique set of problems which prevents them from achieving energy efficiency. In the steel industry, poor scrap quality as raw material increases melting time and energy use. Load shedding during furnace operations significantly raises energy costs. The cement sector heavily depends on grid electricity for grinding stones, but they do not have any renewable energy usage plan or audit practice. In the garment and textiles industry, reliance on captive diesel-based power generators during loadshedding disrupts production and increases costs.

Coordination gap among the stakeholders

The final barrier mentioned in the discussions is the coordination gaps. Energy regulators, fuel and energy distribution companies, and industry associations often operate with limited information sharing and uncoordinated planning. Absence of a central database on industrial energy use restricts monitoring and weakens the ability to design effective interventions. If there is no strong collaboration between government, industry and research institutions, the country will struggle to transform policy commitments into practical measures.

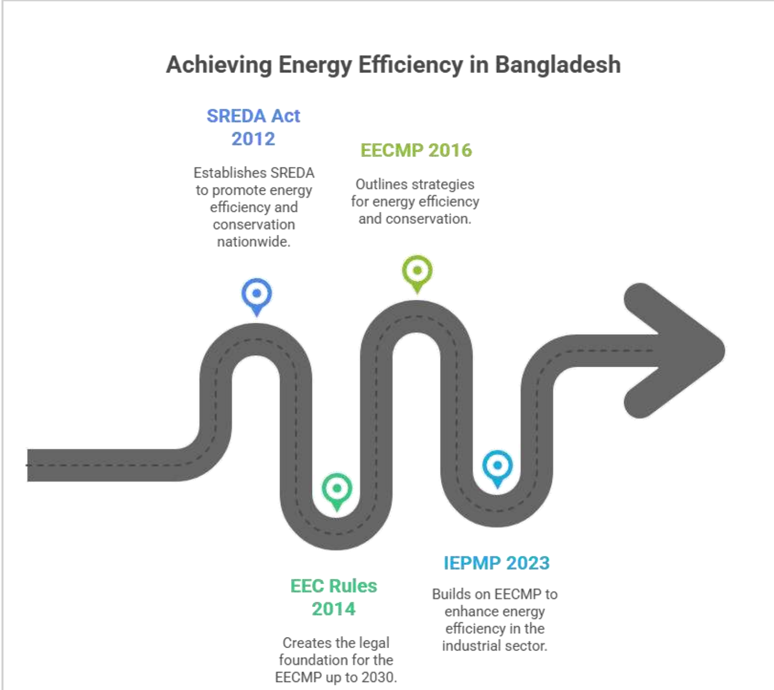
6. Policy and Regulatory Framework for Industrial Energy Efficiency

This section includes the policy and regulatory framework with the current government documents regarding energy efficiency, with a focus on the industrial sector. A comprehensive overview of current legal documents (policy, plan, SROs etc), key programs under the legal documents, and recently proposed policy documents is included in this section.

6.1 Foundational Legal Instruments and Programs

There are several government documents regarding energy efficiency (Figure 3). This includes the Sustainable and Renewable Energy Development Authority Act (2012), which established SREDA and its mandate to promote energy efficiency and conservation (EE&C) nationwide. Draft Energy Efficiency & Conservation Rules (2014) established the legal foundation for the development and implementation of the Energy Efficiency & Conservation Master Plan (EECMP) up to 2030 and related initiatives. Integrated Energy and Power Master Plan (IEPMP) 2023 is built upon the efforts outlined in the EECMP 2016, continuing to focus on improving energy efficiency within Bangladesh's industrial sector.

Figure 3: Government initiatives to improve energy efficiency



Source: SANEM's compilation of secondary data

6.1.1 Sustainable and Renewable Energy Development Authority Act, 2012 (Act No. 48 of 2012)

This act led to the establishment of the Sustainable and Renewable Energy Development Authority (SREDA) in May 2012. SREDA is the national organization responsible for promoting demand-side EE&C and promoting the renewable energy sector. SREDA Act 2012 acts as the legal basis for EE&C efforts and those in the industrial sector. SREDA is responsible for certified Energy Managers and Energy Auditors so that they can monitor energy access across sectors, policy formulation related to renewable energy with grant funds, loans, and private investment (Figure 4). The Act gives SREDA a broad mandate that encompasses technical, promotional, and regulatory responsibilities:

Energy Efficiency and Conservation

Encouraging energy efficiency, creating equipment labelling and standardization, accrediting Energy Managers and Auditors, and assisting with energy audits and associated research and development.

Development of renewable energy

Includes creating inventories of renewable resources, establishing adoption goals, assisting with demonstration projects, offering financial and technical support, and enlisting private investment.

Policy and Coordination

Helping the government create laws and policies, working with pertinent ministries and agencies, suggesting tariffs for renewable energy, and establishing global connections.

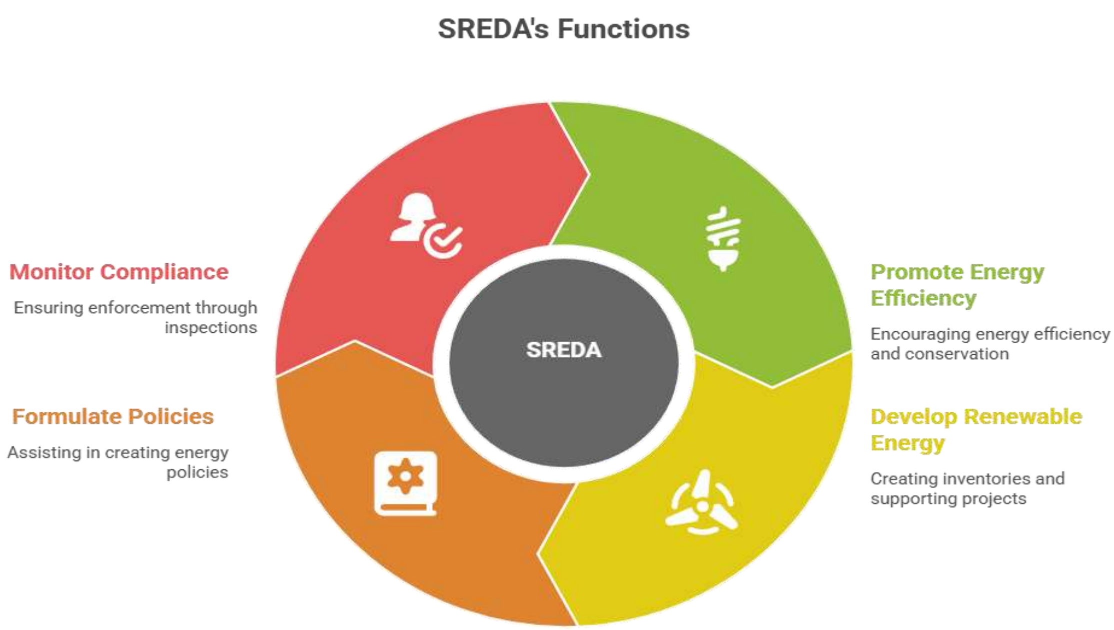
Monitoring and supervision

Include assigning customers to compliance, providing yearly financial and activity reports, and guaranteeing enforcement through inspections.

Energy Auditors and Energy Managers

Professionals need to pass tests, fulfil educational and experience requirements, and adhere to set energy efficiency guidelines. Conducting energy audits, submitting thorough reports on energy use and potential savings, and putting energy-saving measures into action are all the responsibilities of certified individuals. Certifications must be renewed by submitting updated reports and proving ongoing adherence to energy standards; they are valid for five years. Penalties or certification revocation may result from noncompliance. Certification, renewal, and report submission all come with fees, which vary according to the kind and extent of services provided.

Figure 4: Functions of SREDA



Source: SANEM's compilation

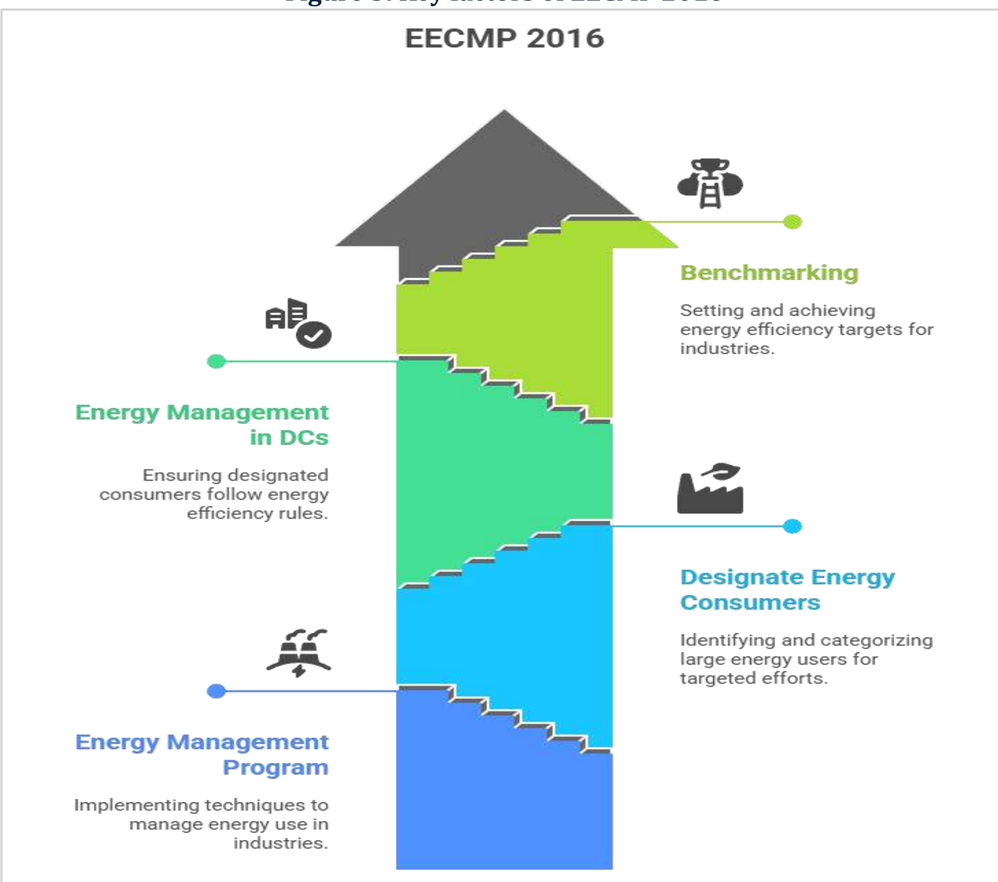
6.1.2 Energy Efficiency and Conservation Rules (2014)

The legal basis of EECMP 2016 is based on the Energy Efficiency and Conservation Rules (2014). The rules require the preparation of the EECMP 2016, and its implementation support is given by the government administrative authority. The related laws, programs, and guidelines, such as the Energy Management Program (EMP), Energy Efficiency Labeling, and the Building Energy and Environment Rating (BEER) Program, follow the structure set by the EECMP. An initial draft of the Rules appeared in 2012, and the government planned to begin enforcing them in the 2015–16 fiscal year.

6.1.3 Energy Efficiency & Conservation Master Plan (EECMP) up to 2030

For promoting energy efficiency and conservation (EE&C), Bangladesh's highest-level framework is the EECMP 2016. This plan includes a roadmap and action plan that describes institutional, operational, and legal structures to achieve EE&C goals by 2030 (Figure 5). This acts as the main reference point for all EE&C-related policies that guide the development of laws, programs, and standards. The plan sets a target of reducing primary energy consumption per GDP by 20% by 2030. 50% of national primary energy is consumed by the industrial sector. The impact of EE&C measures is huge where almost 10.5% of the energy consumption can be decreased.

Figure 5: Key factors of EECMP 2016



Source: EECMP 2016

Energy Management Program (EMP)

The EMP promotes energy management techniques by focusing on major industrial energy users. This entails identifying major energy users, accrediting energy managers and auditors, requiring energy audits, and disclosing energy usage. Another important component of the program is benchmarking industrial energy consumption. By identifying energy consumers, accrediting energy managers, and establishing benchmark goals, SREDA plays a crucial part in the energy management program. SREDA is also in charge of gathering and analysing data and offering technical assistance to approved energy users. Additionally, SREDA certifies energy auditors, guaranteeing that they possess the necessary education and credentials. In turn, designated energy consumers must set up an EMS and designate an energy manager to supervise energy management operations. For monitoring and future enhancements, they must report their EE&C efforts to SREDA and adhere to benchmarks. Authorized energy auditors are responsible for conducting mandatory energy audits for large energy-consuming industries, ensuring compliance with energy efficiency standards. Additionally, they conduct voluntary audits to assist small and medium-sized businesses in enhancing their energy management procedures.

Designation of Large Energy Consumers

By adhering to the guidelines established by SREDA, the Designated Energy Consumers (DCs) program seeks to improve energy efficiency in these significant energy-consuming industries. About 100 DCs are expected to take part first, with plans to increase that number. According to table 5, the criteria for classifying energy consumers are determined by their yearly energy consumption.

Table 8: Classification of Designated Energy Consumers

No.	Category	Criteria for DCs (Annual Energy Consumption, toe)	Number of Candidates for DCs
01	Chemical fertilizer factories	10,000	10
02	Paper and pulp industries	6,000	8
03	Textile industries: - Spinning, Weaving, and Dyeing	3,000	15
04	Garments industries	3,000	7
05	Cement factories and clinker grinding factories	10,000	14
06	Iron and steel (rerolling mills)	10,000	23
07	Chemical and pharmaceutical industries	6,000	9
08	Glass industries	6,000	5
09	Ceramic industries	6,000	9
10	Transportation terminals (including seaports, airports, stations)	3,000	2
11	Commercial and institutional buildings (including office buildings, hotels, shopping malls, hospitals, educational facilities)	3,000	10
99	Other industries and installations as published by government notifications	3,000	1
Total			**113**

Source: EECMP 2016

Energy Management in DCs and Other Energy Consumers

In order to carry out energy efficiency and conservation measures, DCs must implement "mandatory energy management" in their factories and/or buildings within the timeframe specified in the EE&C Rules. These consist of establishing EE&C goals, assembling an energy management group, hiring a full-time energy manager, and carrying out EE&C initiatives as specified in the EE&C promotion plan. In accordance with the energy audit regulation, DCs must also follow energy efficiency goals, perform energy audits, and fulfil certain requirements like benchmarks and minimum energy standards. Additionally, since ISO 50001 accreditation will be acknowledged as the establishment of EMS, DCs are in charge of training management and staff on EE&C activities. The energy manager performs internal energy audits and supervises the EMS's operation. Additionally, DCs must conduct recurring energy audits and report the findings to SREDA; large DCs must employ certified energy auditors. Additionally, DCs must submit yearly energy reports to SREDA, which will assess the trend of improvements in energy efficiency over a five-year period. Total energy consumption (by source), information about energy-intensive equipment, productivity and energy efficiency levels, and the name of the energy manager should all be included in these reports. Along with a medium-term EE&C plan that will be reviewed by SREDA, they must also include an annual EE&C plan with measures and targets.

Benchmarking

Setting target energy efficiency values for major energy-consuming subsectors, like steel production, cement, paper and pulp, and soda chemicals, is known as benchmarking. Usually, kgoe/ton of production or kgoe/m^2 of floor area are used to measure these benchmarks. These industries' energy intensity data can typically be compared to international standards because their manufacturing processes are similar to those in other nations. Through an annual energy report, DCs must provide SREDA with periodic reports on energy production and consumption data. The government will recognize and award factories that show notable improvements in energy efficiency (SREDA). Table 9 lists the industries that are eligible for benchmarking during the first phase of implementation, as well as their benchmark indices and target levels. Although the actual targets for Bangladesh's industries will be decided through discussions between SREDA and the manufacturers, these target levels are based on international reference data.

Table 9: Industries Eligible for Benchmarking, Benchmark Indices, and Targets

Sector	Benchmark Index	Target Level
Steel-making by high-frequency induction furnace	(Energy consumption in steel-making) / (crude steel production) + (Energy consumption in rolling) / (rolled steel production)	212 kgoe/t or less
Steel-making by a re-rolling mill	(Energy consumption in rolling) / (rolled steel production)	50 kgoe/t or less
Cement manufacturing with rotary kiln	(Energy consumption in raw material) / (clinker production) + (Energy consumption in burning) / (clinker production through burning) + (Energy consumption in finishing) / (cement production)	93 kgoe/t or less

Sector	Benchmark Index	Target Level
	+ (Energy consumption in delivery) / (cement and clinker volume delivered)	
Cement manufacturing by grinding process	(Energy consumption in finishing) / (cement production) + (Energy consumption in delivery) / (cement and clinker volume delivered)	16 kgoe/t or less
Printing paper manufacturing	(Energy consumption) / (production)	204 kgoe/t or less
Board paper manufacturing	(Energy consumption) / (paper production)	118 kgoe/t or less
Soda chemical	(Energy consumption in electrolysis) / (caustic soda weight in electrolysis bath) + (Steam consumption in condensation) / (liquid caustic soda weight)	82 kgoe/t or less

Source: Data provided by Prof. Ijaz, BUET
Target level will be changed with the increase of EE technologies

6.1.4 Energy Efficiency & Conservation Promotion Financing Project (EECPFP)

SREDA oversees the distribution of low-interest loans under the two-step loan system used by the EECPF Project to support policy financing. Industries that invest in energy-efficient machinery and equipment, which are marginally more costly than traditional alternatives but provide long-term energy savings, are the target of these loans. SREDA encourages industries to choose energy-efficient technologies by lowering financial barriers. According to the project, the energy-efficient equipment that was made possible by the loans could save 116,852 MWh of energy or 33,071 toe (tonne of oil equivalent) a year. It is anticipated that these 21 sub-projects will result in annual energy savings of BDT 950 million, with each MWh of electricity costing BDT 8,150.

6.1.5 Integrated Energy and Power Master Plan (IEPMP) 2023

The Energy Efficiency and Conservation Master Plan (EECMP) 2016 initiatives are expanded upon in the Integrated Energy and Power Master Plan (IEPMP) 2023, which continues to concentrate on improving energy efficiency in Bangladesh's industrial sector. Important changes include the requirement that large energy-consuming entities set up Energy Management Systems (EMS) and designate Certified Energy Managers and Auditors, as well as the increase in the number of Designated Energy Consumers (DCs) from 113 to 150. The plan also highlights a Benchmarking Program, which sets energy efficiency goals for subsectors such as paper, cement, and steel production and submits periodic energy reports to SREDA. With BDT 21 billion in loans given to 43 businesses by December 2022, energy audits continue to be an essential component, backed by both public and private funding. The plan also places a strong emphasis on human resource development, with a particular emphasis on Certified Energy Auditors and increased training opportunities. Finally, the IEPMP seeks to promote industry-wide adoption of energy-efficient practices by regularly updating and disseminating a list of Best Available Technologies (BAT).

Expansion of Designated Energy Consumers (DCs)

The number of DCs has increased from 113 (EECMP 2016) to 150 (IEPMP 2023), with large energy-consuming entities required to establish EMS. This program includes the appointment of Certified Energy Managers and Energy Auditors to promote energy efficiency across industries. A total of 18 individuals, including SREDA members, hold the title of Certified Energy Auditor.

Benchmarking Program

The IEPMP 2023 emphasizes setting energy efficiency targets for specific industrial subsectors, such as steelmaking, cement, and paper, based on energy consumption per unit of production. Periodic reporting of energy data will be submitted to SREDA for analysis and award recognition for industries showing significant improvements.

Energy Audit and Financial Support

Public and private financial institutions are lending money to businesses for energy-efficient technologies, and the plan calls for the ongoing promotion of energy audits. 43 businesses had obtained loans totaling BDT 21 billion as of December 2022, assisting sectors like glass, cement, and textiles in increasing their energy efficiency. By reducing the upfront costs associated with switching to energy-efficient technologies, these financial incentives aim to increase the viability of energy-saving investments by industries, especially small and medium-sized businesses.

6.2 Recent and Proposed Policy Developments

With an emphasis on efficiency, sustainability, and lowering dependency on natural gas, the Draft Policy for Enhancement of Private Participation in the Power Sector, 2025, seeks to expand private sector involvement in power generation. This policy introduces important measures to improve the performance and capacity of the power sector.

Encouragement of Renewable Energy

The policy promotes the use of hydroelectric, solar, and wind energy, among other renewable energy sources. Its goal is to lessen the carbon footprint, especially in sectors like clothing and textiles that are under growing pressure from global consumers to use green energy.

Merchant Power Plants (MPPs)

In order to sell electricity directly to major consumers at mutually agreed-upon tariffs, private investors are urged to set up MPPs. In order to diversify the energy mix and lessen reliance on natural gas, these plants can also provide public utilities with up to 20% of their capacity.

Public-Private Partnerships (PPPs)

The policy encourages the growth of PPPs for power generation, in which public utilities and private investors work together to construct and run power plants. The goal of this strategy is to increase generation efficiency and capacity.

Wheeling of Power

With the advent of wheeling, MPPs can now directly supply power to large commercial consumers and industries via public transmission and distribution lines. Customers can obtain more affordable electricity thanks to this provision, which is overseen by the Bangladesh Energy Regulatory Commission (BERC).

Increased Generation Capacity

The policy lays out plans to boost Bangladesh's power generation efficiency and capacity through both new construction and improvements to current infrastructure.

Financial and Regulatory Support

The policy offers private investors access to government financial institutions such as IDCOL and BIFFL, tax breaks, and green energy certificates, among other financial incentives and regulatory support. In order to guarantee alignment with Bangladesh's sustainability objectives, it also requires environmental impact assessments.

7. Concluding Remarks and Recommendations

Bangladesh is at a critical juncture for its industrial sector, with the need for continuous economic growth on one side and environmental sustainability on the other. This study has offered a systematic and evidence-based review of the current state of energy efficiency in the manufacturing sectors of the nation, as well as the current state of industrial energy efficiency of Bangladesh in comparison with other peer countries. Based on two-stage Data Envelopment Analysis (DEA) combined with comprehensive policy framework analysis and stakeholder consultations, this research demonstrates that although Bangladesh has developed energy efficiency policies, its energy efficiency implementation is still a fraction of what it could be. The results show that energy efficiency cannot be approached as just another technical fix but as a critical economic tool needed to enable the nation to step away from reliance on fossil fuels and toward a viable industrial future that is strong and resilient.

Intra-country analytic results demonstrate a stark divide in the manufacturing sector; only a handful of sectors, e.g., spinning and textiles, shipbuilding, and pharmaceutical processing, function on the efficiency frontier, while the bulk of the industrial base clearly operates far from it. It found that even the best of the inefficient group, like beverage manufacturing, could eliminate at least 24% of energy use. For some of the lowest-performing industries, like glass manufacturing and fabricated metal products, efficiency rates dip below 0.10, indicating that more than 90 percent of the energy being used today could be avoided or used in a more cost-effective way.

Secondly, the cross-country econometric analysis places the performance of Bangladesh in a global context, and what it uncovers is a dismal reality. The current efficiency of Bangladesh (0.47) is the 10th-ranked on the list of 13 peer economies, projecting that this sector is running less than 50 percent of its efficiency potential. The energy efficiency position of Bangladesh is intuitive when compared to the energy intensity data. Bangladesh has a low energy intensity per GDP, indicating an industrial structure that does not demand as high an energy input overall, but the DEA results show that it is inefficient in converting inputs such as labor, capital, and energy into value-added output. Essentially, while the nation may consume less energy overall than China (the highest among the comparable countries in this study), it creates much less economic output per amount of energy it actually does consume. This difference is critical for policy makers: it should not merely be about 'consume less energy', but 'generate more value' per unit of energy consumed.

Unfortunately, the road to eliminating this efficiency gap is littered with longstanding structural and institutional barriers. The qualitative analysis through interviews and discussions shows that the entrenched "industry culture of undervaluation of energy efficiency" is a systemic condition largely due to decades of subsidizing energy prices, which actively disincentivized conservation. On the one hand, this cultural inertia is accentuated by concrete operational challenges, for example, frequent voltage instability and gas shortages, leading to captive power solutions that are invariably inefficient despite their emissions-oriented nature. Another challenge that remains unaddressed is the shortage of certified energy managers and auditors. Without sufficient technical capacity, it is hard for firms to find and act on savings opportunities. Moreover, with large upfront costs required for modern technology and a banking sector that is poorly positioned to appraise efficiency projects, SMEs are stuck in a downward spiral of obsolescence.

The policy landscape review indicates that the legislative framework is in place, yet the implementation architecture is tenuous. This vision already exists in formal terms in the Sustainable and Renewable Energy Development Authority Act (2012) and the Energy Efficiency and Conservation Master Plan (EECMP) until 2030. The plans in EECMP continued through integrating mandatory energy audits for Designated Energy Consumers (DCs) and incentivizing through awards in the Integrated Energy and Power Master Plan (IEPMP) 2023. But the gulf between how policy is supposed to look and how policy plays out is long and deep enough. These mandates are already weakened by flaws, including a lack of sectoral targets, poor monitoring of audit compliance, and no national industrial energy database. The regulators are often constrained by structural and financial capacity, which often makes their mandates overlap and leaves stakeholders confused. In the absence of an efficient, implementable regulation, targets laid out by the government will persist as mere ambition.

Thus, a paradigm shift from optional or ad hoc efficiency solutions to a holistic, enforced, and incentivized regime is required. This study proposes to formulate a "Draft Industrial Energy Efficiency Policy" that aims to fill these gaps. The idea stresses to avoid one size fits all methods of the past. Instead, it requires different approaches: heavy-handed regulation and technological uptake for the big, polluting factories, and financial facilitation and capacity development for the cash-poor SMEs.

In order to work towards the intermediate goal of establishing a consensus on drafting the industrial energy efficiency policy, the government needs to take three immediate steps. Among all, changing of the financial ecosystem comes first. This is not only about subsidized cheap loans but about establishing credit guarantee schemes to enable commercial banks to confidently lend to efficiency projects. Second, there is a major gap in technical capacity to manage modern industrial systems, and this must be addressed through an active national program of training, perhaps in association with our engineering universities and technical institutes, to generate a cadre of energy professionals. Third, the regulatory architecture must move to a more data-driven model. By establishing a digital, real-time energy monitoring tool for the Designated Energy Consumers, it will remove the problem of information asymmetry, and SREDA can further target its interventions and solutions efficiently.

Finally, industrial energy efficiency is not just a regulatory compliance issue in Bangladesh for meeting international climate commitments such as the Paris Agreement; industrial energy efficiency is a matter of economic survival in Bangladesh. Therefore, as the nation looks to transition from an LDC, it will be held to a new level of international compliance over carbon footprints on outbound trade. As this study shows, Bangladesh could save billions, secure its domestic energy supply, and delink economic growth from carbon emissions if it implements the recommendations by finding solutions to existing inefficiencies in sectors. The transition from a culture of deprioritization to one of active energy management is challenging, but with the necessary policy changes and a public-private partnership, it is entirely achievable.

Reference

Agora Energiewende. (2023). *Carbon pricing's role in the German and European energy transition*. Agora Energiewende. Retrieved from https://www.agora-energiewende.org/about-us/the-german-energiewende/how-does-carbon-pricing-affect-the-german-and-european-energy-transition

AP News (Fast Company). (2024, January). *Germany's CO_2 emissions at their lowest in 7 decades, new data shows*. *Fast Company*. Retrieved from https://www.fastcompany.com/91006299/germanys-co2-emissions-lowest-7-decades-new-data-shows

Arens, M., & Worrell, E. (2014). Diffusion of energy efficient technologies in the German steel industry and their impact on energy consumption. Energy, 73, 968–977. https://doi.org/10.1016/j.energy.2014.06.112

Arens, M., Worrell, E. & Eichhammer, W. (2017). Drivers and barriers to the diffusion of energy-efficient technologies—a plant-level analysis of the German steel industry. Energy Efficiency 10, 441–457. https://doi.org/10.1007/s12053-016-9465-4

ASEAN Centre For Energy. (2023, October 6). *Energy Efficiency Target of Vietnam - ASEAN Centre for Energy*. ASEAN Centre for Energy. https://aseanenergy.org/policy/energy-efficiency-target-of-vietnam/

Atmaca, A., & Atmaca, N. (2016). Determination of correlation between specific energy consumption and vibration of a raw mill in cement industry. Anadolu University Journal of Science and Technology-A Applied Sciences and Engineering. http://dx.doi.org/10.18038/btda.11251

Bagchi, P., & Sahu, S. K. (2020). Energy Intensity, Productivity and Pollution Loads: Empirical Evidence from Manufacturing Sector of India. Studies in Microeconomics, 8(2), 194–211. https://doi.org/10.1177/2321022220930968

BGMEA. (n.d.). BGMEA | About Garment industry of Bangladesh. https://www.bgmea.com.bd/page/AboutGarmentsIndustry

Brooks, N., Biswas, D., Maithel, S., Kumar, S., Uddin, M. R., Ahmed, S., Mahzab, M., Miller, G., Rahman, M., & Luby, S. P. (2024). Building blocks of change: The energy, health, and climate co-benefits of more efficient brickmaking in Bangladesh. Energy Research & Social Science, 117, 103738. https://doi.org/10.1016/j.erss.2024.103738

Browne, R. A., Esq. (2023). Green building and energy efficiency of select countries in East and Southeast Asia: Malaysia, Vietnam, Singapore, and China. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4595088

Camioto, F. de C., Rebelatto, D. A. N., & Rocha, R. T. (2016). Energy efficiency analysis of G7 and BRICS countries: A study based on Data Envelopment Analysis. *Energy Procedia*, *100*, 430–435. https://doi.org/10.1016/j.egypro.2016.10.198

China unveils 2024-2025 plan for energy conservation and carbon reduction. (2024, May 31). Enerdata. https://www.enerdata.net/publications/daily-energy-news/china-unveils-2024-2025-plan-energy-conservation-and-carbon-reduction.html

Chu, T. B. & The World Bank in Vietnam. (n.d.). *VIETNAM ENERGY EFFICIENCY FOR INDUSTRIAL ENTERPRISES (VEEIE)*. https://vepg.vn/wp-content/uploads/2022/12/5_EN_WB_TWG4-Meeting_VEEIE_VSUEE.pdf

Clean Energy Wire. (2023). *Green and sustainable finance in Germany*. Retrieved from https://www.cleanenergywire.org/factsheets/green-and-sustainable-finance-germany

Climate Goals - Guide to Chinese climate policy. (2022, October 27). Guide to Chinese Climate Policy. https://chineseclimatepolicy.oxfordenergy.org/book-content/domestic-policies/climate-goals/

Conclusion - Guide to Chinese climate policy. (2022, October 24). Guide to Chinese Climate Policy. https://chineseclimatepolicy.oxfordenergy.org/book-content/conclusion/

Darain, K. M. U., Jumaat, M. Z., Islam, A. S., Obaydullah, M., Iqbal, A., Adham, M. I., & Rahman, M. M. (2015). Energy efficient brick kilns for sustainable environment. Desalination and Water Treatment, 57(1), 105–114. https://doi.org/10.1080/19443994.2015.1012335

De Gouvello, C., Taylor, R., & Song, Y. (2021). China. In *World Bank, Washington, DC eBooks*. https://doi.org/10.1596/36667

Deloitte Deutschland. (2023). *Financing the green energy transition*. Retrieved from https://www.deloitte.com/de/de/issues/sustainability-climate/financing-the-green-energy-transition.html

Eil, A., Li, J., Baral, P., & Saikawa, E. (2020). Dirty stacks, high stakes. In World Bank, Washington, DC eBooks. https://doi.org/10.1596/33727

Ember. (2025, April 11). Bangladesh | Ember. https://ember-energy.org/countries-and-regions/bangladesh/

Energy Efficiency - Guide to Chinese climate policy. (2022, October 27). Guide to Chinese Climate Policy. https://chineseclimatepolicy.oxfordenergy.org/book-content/domestic-policies/energy-efficiency/#reference-3

European Commission. (2020). *Directive (EU) 2018/2002 amending Directive 2012/27/EU on energy efficiency*. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018L2002

Fathi, B., Ashena, M., & Bahari, A. R. (2021). Energy, environmental, and economic efficiency in fossil fuel exporting countries: A modified data envelopment analysis approach. *Sustainable Production and Consumption, 26*, 588–596. https://doi.org/10.1016/j.spc.2020.12.030

Federal Ministry for Economic Affairs and Energy. (2020). *Germany's integrated national energy and climate plan (NECP)*. European Commission. https://energy.ec.europa.eu/system/files/2022-08/de_final_necp_main_en.pdf

Fresner, J., Morea, F., Krenn, C., Uson, J. A., & Tomasi, F. (2017). Energy efficiency in small and medium enterprises: Lessons learned from 280 energy audits across Europe. Journal of Cleaner Production, 142, 1650–1660. https://doi.org/10.1016/j.jclepro.2016.11.126

Government of Singapore. (2012). *Energy Conservation Act 2012*. Singapore Statutes Online. https://sso.agc.gov.sg/Act/ECA2012

Guilhot, L. (2022). An analysis of China's energy policy from 1981 to 2020: Transitioning towards to a diversified and low-carbon energy system. *Energy Policy, 162*, 112806. https://doi.org/10.1016/j.enpol.2022.112806

Hasan, A. S. M. M., & Trianni, A. (2020). A review of Energy Management Assessment Models for Industrial Energy Efficiency. Energies, 13(21), 5713. https://doi.org/10.3390/en13215713

Hasanbeigi, A., Morrow, W., Sathaye, J., Masanet, E., & Xu, T. (2012). A bottom-up model to estimate the energy efficiency improvement and CO2 emission reduction potentials in the Chinese iron and steel industry. Energy, 50, 315–325. https://doi.org/10.1016/j.energy.2012.10.062

He, F., Zhang, Q., Lei, J., Fu, W., & Xu, X. (2013). Energy efficiency and productivity change of China's iron and steel industry: Accounting for undesirable outputs. Energy Policy, 54, 204–213. https://doi.org/10.1016/j.enpol.2012.11.020

Hossain, S. R., Ahmed, I., Azad, F. S., & Hasan, A. S. M. M. (2020). Empirical Investigation of Energy Management Practices in Cement Industries of Bangladesh. Energy, 212, 118741. http://dx.doi.org/10.1016/j.energy.2020.118741

Hudedmani, M. G., Soppimath, V., Hubballi, S., & Kundur, Z. (2019). Perform Achieve and Trade (PAT) a revolutionary measure in energy efficiency and conservation - review. *International Journal of Advanced Science and Engineering*, *6*(1), 1206–1212. https://doi.org/10.29294/ijase.6.1.2019.1206-1212

Industrial energy efficiency offers a multitude of benefits to Bangladesh | IEEFA. (2023). https://ieefa.org/resources/industrial-energy-efficiency-offers-multitude-benefits-bangladesh

International Energy Agency. (2021). *National Energy Conservation Law of China (amendments in 2016)*. https://www.iea.org/policies/7910-national-energy-conservation-law-of-china-amendments-in-2016

Jadhav, V., Jadhav, R., Magar, P., Kharat, S., & Bagwan, S. U. (2017, May). Energy conservation through energy audit. In 2017 International Conference on Trends in Electronics and Informatics (ICEI) (pp. 481-485). IEEE.

Khaliquzzaman, M., Harinath, A. S., Ferdousi, S. A., & Khan, S. M. M. H. (2020). Thirty years' quest for emission reduction and energy efficiency improvement of brick kilns in Bangladesh. International Journal of Environmental Monitoring and Analysis, 8(1), 11. https://doi.org/10.11648/j.ijema.20200801.12

Khan, S. I., Islam, A., & Islam, M. (2022). Auditing and energy efficiency of a Ready-Made Garment factory in Bangladesh: a case study. Energy and Power Engineering, 14(08), 387–403. https://doi.org/10.4236/epe.2022.148020

Khattak, A., & Park, Y. (2018). Environmental upgrading of an apparel firm in Bangladesh: a case study of VIYELLATEX. Emerald Emerging Markets Case Studies, 8(3), 1–16. https://doi.org/10.1108/eemcs-06-2017-0129

Lin, B., & Li, Y. (2025). Managing China's energy efficiency. Journal of Global Information Management, 33(1), 1–28. https://doi.org/10.4018/jgim.372901

Luong, N. D. (2015). A critical review on Energy Efficiency and Conservation policies and programs in Vietnam. *Renewable and Sustainable Energy Reviews*, *52*, 623–634. https://doi.org/10.1016/j.rser.2015.07.161

Malhotra, A., Mathur, A., Diddi, S., & Sagar, A. D. (2021). Building institutional capacity for addressing climate and sustainable development goals: achieving energy efficiency in India. *Climate Policy*, *22*(5), 652–670. https://doi.org/10.1080/14693062.2021.1984195

Mardani, A., Zavadskas, E. K., Streimikiene, D., Jusoh, A., & Khoshnoudi, M. (2017). A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency. *Renewable and Sustainable Energy Reviews*, *70*, 1298–1322. https://doi.org/10.1016/j.rser.2016.12.030

Martínez, C. I. P. (2010). Energy use and energy efficiency development in the German and Colombian textile industries. Energy for Sustainable Development, 14(2), 94-103. https://doi.org/10.1016/j.esd.2010.02.001

Pal, K., Mukhopadhyay, J. P., & Bhagawan, P. (2024). Does cap-and-trade scheme impact energy efficiency and firm value? Empirical evidence from India. *Energy Economics*, *134*, 107581. https://doi.org/10.1016/j.eneco.2024.107581

Pal, K., Mukhopadhyay, J. P., & Bhagawan, P. (2024). Does cap-and-trade scheme impact energy efficiency and firm value? Empirical evidence from India. *Energy Economics*, *134*, 107581. https://doi.org/10.1016/j.eneco.2024.107581

PIB Delhi. (2024, July 29). PERFORM, ACHIEVE AND TRADE (PAT) SCHEME. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2038503

Rahman, M. M., & Islam, M. E. (2023). The impact of green accounting on environmental performance: mediating effects of energy efficiency. Environmental Science and Pollution Research, 30(26), 69431–69452. https://doi.org/10.1007/s11356-023-27356-9

Rahman, S., Kamal, M., & Sabastini, P. (2025). Drivers and challenges in Green Transition: A case of Bangladesh's textile industry. Circular Economy and Sustainability. https://doi.org/10.1007/s43615-025-00566-8

Saygin, D., Worrell, E., Tam, C., Trudeau, N., Gielen, D. J., Weiss, M., & Patel, M.K. (2012). Long-term energy efficiency analysis requires solid energy statistics: The case of the German basic chemical industry. Energy, 44, 1094-1106. https://doi.org/10.1016/j.energy.2012.01.062

Shen, Y., & Faure, M. (2020). Green building in China. *International Environmental Agreements Politics Law and Economics*, *21*(2), 183–199. https://doi.org/10.1007/s10784-020-09495-3

Siddique, M. N. I., Hasan, A. S. M. M., Kabir, M. A., Prottasha, F. Z., Samin, A. M., Soumik, S. S., & Trianni, A. (2022). Energy management practices, barriers, and drivers in Bangladesh: An exploratory insight from pulp and paper industry. Energy Sustainable Development/Energy for Sustainable Development, 70, 115–132. https://doi.org/10.1016/j.esd.2022.07.015

Simon, R., Hugues, P., Levi, P., & Vass, T. (2023, July). Industry. IEA. https://www.iea.org/energy-system/industry

Simon, R., Hugues, P., Levi, P., & Vass, T. (2023, July). Industry. IEA. https://www.iea.org/energy-system/industry

Singh, V. K., Henriques, C. O., & Martins, A. G. (2018). Assessment of energy-efficient appliances: A review of the technologies and policies in India's residential sector. *Wiley Interdisciplinary Reviews Energy and Environment*, *8*(3). https://doi.org/10.1002/wene.330

SREDA. (2016). *Energy Efficiency and Conservation Master Plan up to 2030*. https://elibrary.sreda.gov.bd/public/admin/files/books_202104281990004944.pdf

SREDA. (2024). National Energy Balance 2021-22: (Improvement of Energy Efficiency and Conservation). https://sreda.portal.gov.bd/sites/default/files/files/sreda.portal.gov.bd/page/639366d4_9e29_4fcd_975a_b0f345a49cff/2024-04-30-06-11-1eefba07ac5af703bac17abc09d72a42.pdf

Thollander, P., Backlund, S., Trianni, A., & Cagno, E. (2013, November). Beyond barriers – A case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. Applied Energy, 111, 636-646. https://doi.org/10.1016/j.apenergy.2013.05.036

Tone, K. (2001) A Slacks-Based Measure of Efficiency in Data Envelopment Analysis. European Journal of Operational Research, 130, 498-509. http://dx.doi.org/10.1016/S0377-2217(99)00407-5

Tushar, S. R., Imtiazh, M. S. A., Noor, R. B., Alam, M. F. B., Bari, A. M., Islam, A. R. M. T., & Kabir, M. M. (2024). An Intuitionistic fuzzy approach to modeling the drivers to promote Energy-Efficient textile Manufacturing: Implications for sustainable development. Journal of King Saud University - Science, 36(6), 103214. https://doi.org/10.1016/j.jksus.2024.103214

Uddin, K. M. K., Rahman, M. M., & Saha, S. (2023, November). The impact of green tax and energy efficiency on sustainability: Evidence from Bangladesh. Energy Reports, 10, 2306-2318. https://doi.org/10.1016/j.egyr.2023.09.050

UNIDO. (n.d.). Industrial-Energy-efficiency-and-Climate-Change. https://www.unido.org/our-focus/safeguarding-environment/clean-energy-access-productive-use/industrial-energy-efficiency-and-climate-change

Wang, K., Wei, Y.-M., & Zhang, X. (2013). Energy and emissions efficiency patterns of Chinese regions: A multi-directional efficiency analysis. *Applied Energy*, *104*, 105–116. https://doi.org/10.1016/j.apenergy.2012.10.057

Wang, Z., & Feng, C. (2015). A performance evaluation of the energy, environmental, and economic efficiency and productivity in China: An application of global data envelopment analysis. *Applied Energy, 147*, 617–626. https://doi.org/10.1016/j.apenergy.2015.01.108

Wen, Z., Chen, M., & Meng, F. (2014). Evaluation of energy saving potential in China's cement industry using the Asian-Pacific Integrated Model and the technology promotion policy analysis. Energy Policy, 77, 227–237. https://doi.org/10.1016/j.enpol.2014.11.030

Working Group on Energy Balances (AGEB). (2023). *Energy consumption in Germany drops to the lowest level since 1990.* Retrieved from https://ag-energiebilanzen.de/wp-content/uploads/2023/07/AGEB_Jahresbericht2022_20230630_engl.pdf srv1.worldometers.info+15

Yan, D., Liu, H., & Yao, P. (2021). Assessing energy efficiency for economic and sustainable development in the region of European Union countries. *Frontiers in Environmental Science, 9*, Article 779163. https://doi.org/10.3389/fenvs.2021.779163

Zhang, D., Aunan, K., Seip, H. M., & Vennemo, H. (2011). The energy intensity target in China's 11th Five-Year Plan period—Local implementation and achievements in Shanxi Province. *Energy Policy*, *39*(7), 4115–4124. https://doi.org/10.1016/j.enpol.2011.03.085

Zhang, X.-P., Cheng, X.-M., Yuan, J.-H., & Gao, X.-J. (2011). Total-factor energy efficiency in developing countries. *Energy Policy, 39*, 644–650. https://doi.org/10.1016/j.enpol.2010.10.037

Zhou, G., Chung, W., & Zhang, Y. (2013). Measuring energy efficiency performance of China's transport sector: A data envelopment analysis approach. *Expert Systems with Applications, 40*(5), 2112–2117. https://doi.org/10.1016/j.eswa.2012.10.014

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