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# Drivers and Barriers to Industrial Energy Efficiency in Textile Industries of Bangladesh

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**Abstract:** Bangladesh faced a substantial growth in primary energy demand in the last few years. According to several studies, energy generation is not the only means to address energy demand; efficient energy management practices are also very critical. A pertinent contribution in the energy management at the industrial sector ensures the proper utilization of energy. Energy management and its efficiency in the textile industries of Bangladesh are studied in this paper. The outcomes demonstrate several barriers to energy management practices which are inadequate technical cost-effective measures, inadequate capital expenditure, and poor research and development. However, this study also demonstrates that the risk of high energy prices in the future, assistance from energy professionals, and an energy management scheme constitute the important drivers for the implementation of energy efficiency measures in the studied textile mills. The studied textile industries seem unaccustomed to the dedicated energy service company concept, and insufficient information regarding energy service companies (ESCOs) and the shortage of trained professionals in energy management seem to be the reasons behind this. This paper likewise finds that 3–4% energy efficiency improvements can be gained with the help of energy management practices in these industries.

**Keywords:** energy management; industrial energy efficiency; textile industry; energy policy; Bangladesh

## 1. Introduction

Bangladesh, a developing country, experienced sustained fiscal growth for the last few years due to increased industrialization, despite the lack of industry-friendly policies. Even with the insufficient energy production, the industrial index was upward over the last few years [1]. Due to a rapid economic growth, the requirement for energy is surging every day. However, the government of Bangladesh was not fully able to follow up this rapid economic growth with an equally large extension of the supply of electricity and energy, leading to a prevailing energy shortage situation in Bangladesh [1]. It is important to have a strong energy management policy for the industrial sector that accounts for nearly 30% of the aggregated energy use in Bangladesh.

Energy efficiency in industry is not only beneficial from the government perspective, but can also be advantageous for the business owners [2]. From the government perspective, energy efficiency measures could lead to reduced energy use from industry, which is highly important for a country like Bangladesh, considering the significant gap between demand and supply of energy, along with highly governmentally subsidized energy prices. Moreover, with the demand to mitigate global climate issues, it is important for industries to improve energy efficiency for reducing $CO_2$ emission, which is achievable by implementing proper energy management practices. In addition, this improved efficiency is also beneficial for business owners, as well as for an increase in production efficiency, cheaper production, higher productivity, and improved competitiveness [2,3]. The textile industry of Bangladesh is the highest export earner of Bangladesh, with this sector responsible for 81% of the aggregated gross domestic income of the country and also one of the major users of energy [4]. The textile industry is considered one of the major six target industrial sectors which have huge energy-saving potential in Bangladesh [4]; it is responsible for more than 27% of the total energy use in industry [5]. Currently, the textile industry in Bangladesh has more than 5600 factories, which is expected to increase further [6].

The Sustainable and Renewable Energy Development Authority (SREDA), an organ of the Government of Bangladesh, focused on industrial energy efficiency in recent times in Bangladesh. There are a few initiatives, such as an energy management scheme, standardization of energy efficiency measures and labeling, financial incentive scheme, etc., which were taken by SREDA for the industrial sector. However, large and energy-intensive industries are the key and preferred stakeholders for SREDA. To comply with proper initiatives, policies are important, and bottlenecks exist with regard to Bangladesh. There are several energy policies, and focus is mainly on power generation. The "Energy Efficiency and Conservation Master Plan up to 2030" features for the first time industrial energy efficiency in Bangladesh. This policy was initially implemented by SREDA in the recent past, although the policy is pending approval by the Government of Bangladesh. The inclusion of a dedicated energy manager at the industries, demand-side management (DSM), financial incentives, and favorable taxation and subsidies are the key features of the energy efficiency master plan.

There are numerous energy-efficient measures readily available, often times easy to implement and financially viable for different industries. However, these measures are not always implemented due to a number of barriers [7]. The nature of these barriers varies depending on a number of factors such as energy infrastructure, economic conditions, energy policy, market conditions, and types of industry [8,9]. One of the major objectives of this work was to identify the specific energy efficiency barriers for the textile industry in Bangladesh. A number of studies were already carried out to find out the barriers to and drivers for energy efficiency in different industries [9–11]. However, to the best of our knowledge, there were no other comprehensive studies conducted on the energy efficiency and energy management practices of the textile industry of Bangladesh. In previous studies, the barriers to and drivers for energy efficiency in the steel industry of Bangladesh were studied [12]. The textile industries that allocate 7% of their turnover toward energy costs are considered in this study. The relevancy of the steel and textile industry is significant, as both sectors represent an intensive usage of energy and contribute significantly to the gross domestic product (GDP) growth of Bangladesh.

In this work, we aimed to study current energy efficiency and energy management practices in large textile factories of Bangladesh. The aim of the study was to explore energy efficiency among large textile factories of Bangladesh regarding the following factors:

1. Energy efficiency potential among large textile factories of Bangladesh;
2. Energy efficiency technologies and measures presently taken by these factories;
3. Existing long-term energy management strategies (if any);
4. Drivers for energy efficiency;
5. Barriers to energy efficiency.

The organization of the rest of the paper is as follows: Section 2 illustrates the current energy generation and usage conditions of Bangladesh, along with details of the textile industry in Bangladesh. In Section 3, the concept of industrial energy management is introduced. The methodology of this study is presented in Section 4, and results of the study are presented in Section 5. The paper ends with a discussion in Section 6 and conclusions in Section 7.

## 2. Energy Situation and Textile Industry Context in Bangladesh

### *2.1. Use of Energy in Bangladesh*

Bangladesh, a country located in Asia, has an area of 147,570 km$^2$ [13]. The gross domestic product (GDP) of Bangladesh followed an upward trend for the past few years, despite a lack of sufficient energy generation and supply [14,15]. A strong relationship lies between a country's GDP and energy use [16–18]. In 2013, around 60% of the total population in Bangladesh had access to electricity [19]. The percentage of access to electricity since increased [1]. In June 2016, access of electricity reached up to 76% [20]. Recently, in 2018, with the installed capacity of 17,043 MW [21], electricity was accessible to 90% of the total population [19]. Figure 1 represents the installed capacity of power generation with different fuel types of Bangladesh.

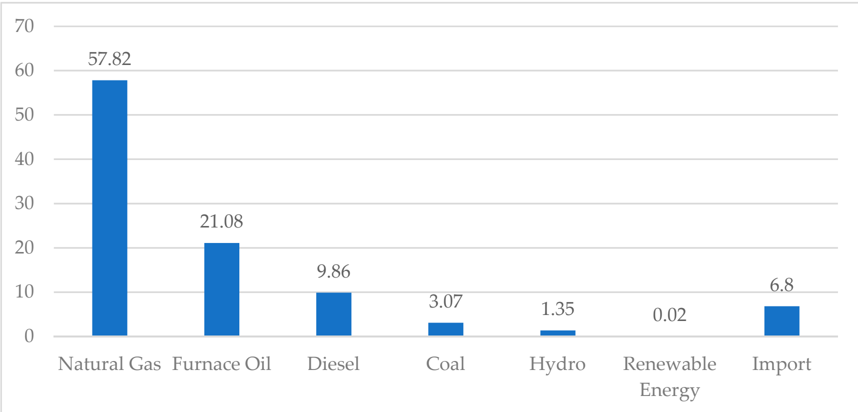


**Figure 1.** Power generation by fuel type (percentage) in Bangladesh [19].

According to the installed capacity, electricity generation is dependent on natural gas mainly, where 57.82% of the electricity is generated by natural gas, while 21.08% of electricity is sourced from furnace oil, 9.86% from diesel, 3.07% from coal, 1.35% from hydro, and 0.02% from renewable energy sources; furthermore, 6.8% is imported from outside the country, mainly from India [19]. Figure 2 shows the installed capacity of power generation by plant type in Bangladesh. The reciprocating engine type has the highest share (36%) in Bangladesh, followed by combined cycle (34%), steam turbine (14%), and gas turbine (8%).

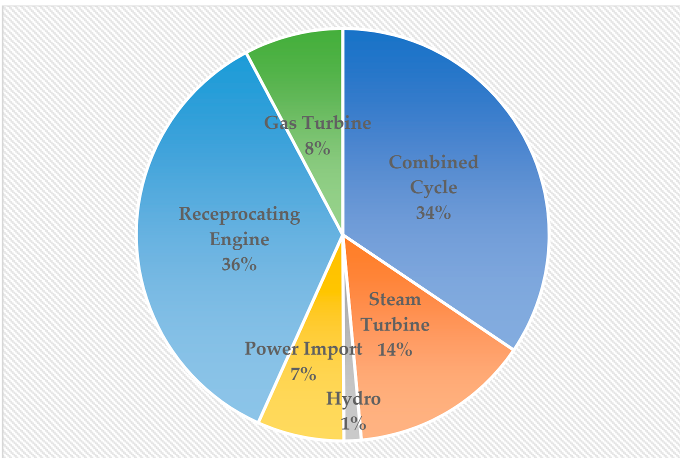


**Figure 2.** Installed capacity (17,043 MW) by plant type (percentage) [19].

Table 1 projects the total energy use of all sectors in business as usual (BAU) scenarios. It can be observed that the industrial sector has the highest energy use (27%) after use in residential sectors, and its energy use is estimated to rise further by 2041 [19]. It can be observed from Table 1 that the transportation sector is projected as the second highest energy user, followed by the industrial sector, and it is likely to reach 38% by 2041. The residential sector is assumed to have lowered its energy use compared to 2014.

**Table 1.** Total energy consumption—business as usual (BAU) scenario [19,22].

| Sectors | 2014 | | 2041 | |
|---|---|---|---|---|
| | ktoe | (Share) | ktoe | (Share) |
| Residential | 12,815 | (48%) | 22,797 | (17%) |
| Industrial | 7116 | (27%) | 54,526 | (40%) |
| Commercial and public service | 468 | (2%) | 1776 | (1%) |
| Transport | 3080 | (12%) | 51,187 | (38%) |
| Agriculture | 1409 | (5%) | 4197 | (3%) |

The total use of electricity in Bangladesh is reported as 48.98 billion kWh of electric energy per year, with an average per capita of 297 kWh per person [19,23]. The Government of Bangladesh stepped forward to mitigate the energy crisis; however, there are debates about the approaches [24].

### 2.2. Textile Industry in Bangladesh

The textile sector is considered as one of the highest energy users in the industrial sector of Bangladesh [25]. The textile industry of Bangladesh, which includes readymade garments (RMG) and knitwear alongside specific textile products, is considered as the number one export earner [26]. The sector represents 81% of aggregate income of the country [27]. Many clothing brands import from Bangladesh. The country now has 5.9% of shares of the global clothing market. Table 2 represents the list of famous brands that import from the Bangladesh textile industries.

**Table 2.** Renowned retailers and brands that import from Bangladesh [28–30].

| Brand Name | Remark |
|---|---|
| H&M | Swedish multinational clothing-retail company |
| Walmart | American multinational retailing corporation |
| C&A | Dutch chain of fashion retail clothing stores |
| Zara | Spanish multinational clothing and accessories retailer company |
| Gap | American worldwide clothing and accessories retailer |
| Levi's | American clothing company |

The expansion of the textile industry in Bangladesh is conceivable due mainly to cheap labor. However, others factors are also closely linked, such as supportive business conditions, freightage facilities, and so on. There are organizations such as the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA) which focus on reinforcing and promoting the textile sector. They take measures including ensuring an amicable atmosphere for business, educating the laborers, making an effort for the betterment of the laborers' social compliance, and building relationships among the concerned stakeholders, with the focus of expanding the trade income of Bangladesh. The textile sector is aiming now to achieve $50 billion in RMG exports by 2021 [31]. Figure 3 illustrates the yearly export of Bangladesh readymade garments in United States dollars (USD).

As of 2018, Bangladesh holds second place after China in apparel export [32]. In the financial year of 2017, the revenue from export recorded a 0.2% growth to $28.15 billion [27]. According to the Export Promotion Bureau (EPB) from the RMG sector, Bangladesh's export earnings raised to $30.61 billion, posting 8.76% growth in the last financial year (2017), which is 1.51% higher than the target of $30.16 billion for the financial year of 2018 [27]. Table 3 characterizes the process, technology, and equipment currently used in textile industries in Bangladesh. The Bangladesh textile industries depend mainly on imported equipment for production. Mainly, two types of stenter are used, one based on gas and the other on hot oil. Several types of boiler are available in the market, although mainly two types are used: two-pass and three-pass steam boilers. Considering the price, reconditioned air compressors are mostly used in the industries. Stand-by generators are kept at the industries to supply electrical power during times of load shedding.

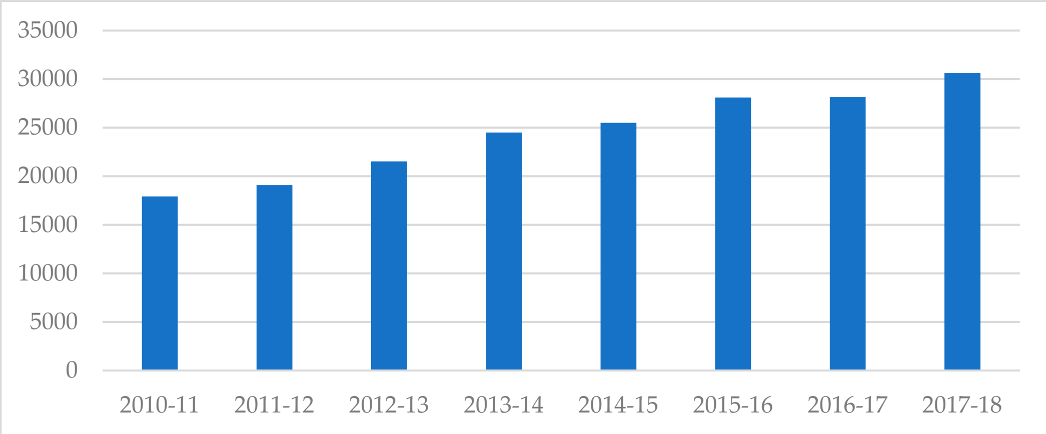


**Figure 3.** Yearly export of readymade garments (RMGs) in millions of United States dollars (USD) [6].

**Table 3.** Process, technology, and equipment in the textile industry in Bangladesh [33–35].

| Process, Technology, and Equipment | Remark |
|---|---|
| Production equipment in dyeing/washing and processing | Most units rely on imported equipment. |
| Stenter | Two types mainly: gas-based and hot-oil-based. |
| Steam boilers and thermic fluid heaters | Two types mainly: two-pass steam boilers and three-pass steam boilers. |
| Air compressors | Reconditioned air compressors are used mainly. Big units utilize the new screw compressors. |
| Water pumps | Most units use locally available submersible/centrifugal water pumps. |
| Stand-by power generators | Reconditioned power generators are mainly used, whereas large units utilize high-efficiency generators as base load. |
| Plant lighting | All of the major textile processing units utilize a large number of T8-type lights with electromagnetic ballasts. |

## 3. Energy Efficiency and Energy Management

### *3.1. Energy Efficient Technologies in the Textile Industry*

Energy efficiency means the usage of lower energy demand for completion of the same task [36]. Energy efficiency in an industry should be incorporated with process optimization and suitable replacement of current types of machinery [37]. Considering the high cost of changing machinery, process optimization is more preferable to the concerned stakeholders. However, the replacement of new machinery can be financially justifiable if water savings, material savings, and production quality are taken into account [37,38].

The significant amount of energy used among the textile industry manufacturers is accounted for in the spinning, weaving, wet processing, and man-made fiber production units. In the spinning unit, energy efficiency options are divided into five categories, which are preparatory process, ring frame, winding, doubling, and finishing process, air conditioning and humidification system, and general measures [37]. Table 4 presents the energy efficiency technology options and energy efficiency measures for the spinning process in the textile industries.

The weaving machines (looms) use 50% to 60% of total energy use in the weaving plant. The options for process optimization are very limited. However, the energy efficiency options of humidification and compressed air systems for the spinning process support the weaving plants to some extent, thereby achieving system efficiency. There are several energy-efficient technological options at the man-made fiber production unit, including the installation of a variable frequency drive (VFD), adoption of a pressure control system, use of a heat exchanger, energy-efficient high-pressure steam-based vacuum ejectors, etc. [37,39].

**Table 4.** Energy efficiency options for the spinning process [37,40,41].

| Energy Efficiency Options | Breakdown of Technologies/Options |
|---|---|
| Preparatory process | Installation of electronic roving end-break<br>Stop-motion detector instead of pneumatic system<br>High-speed carding machine |
| Ring frame | Use of energy-efficient spindle oil<br>Optimum oil level in the spindle bolsters<br>Replacement of lighter spindle<br>Synthetic sandwich tapes for ring frames<br>Ring diameter optimization<br>Energy efficient motor installation in ring frame<br>Soft starter installation<br>High-speed ring spinning frame |
| Winding, doubling, and finishing process | Installation of variable frequency drive on autoconer |
| | Intermittent mode of movement of empty bobbin conveyor in the autoconer/cone winding machines<br>Modified outer pot in two-for-one (TFO) machines<br>Optimization of balloon setting in two-for-one (TFO) machines<br>Replacing the electrical heating system with steam heating system for the yarn polishing machine |
| Air conditioning and humidification system | Replacement of nozzles with energy-efficient mist nozzles in yarn conditioning room<br>Installation of variable frequency drive (VFD)<br>Replacement of the existing aluminium alloy fan impellers with high-efficiency fiberglass-reinforced plastic impellers |
| General measures | Energy conversion measures at overhead traveling cleaner<br>Energy efficient blower fans<br>Power factor improvement plant (PFI plant) |

The wet processing unit is one of the largest energy-using units, as it uses both steam and heat energy [37]. The use of energy varies in this unit depending on several factors, which are product type (fiber, yarn, fabric, cloth, etc.), machine, and state of the final product etc. There are several energy efficiency options for the wet processing unit. Among them, the prominent options include energy efficiency improvements in stenters, conversion of thermal fluid heating system to a direct gas firing system in stenters, introduction of mechanical pre-drying, optimization of exhaust humidity, heat recovery of hot wastewater in waste autoclave, and so on. However, there are some cross-cutting energy efficiency options also that include electrical demand control, energy efficiency improvement opportunities in electrical motors, compressed air systems, pumping systems, fan systems, lighting systems, and steam systems. Figure 4 presents the cross-cutting energy efficiency measures for textile industries. Regarding the cross-cutting technologies, the improvement options of more energy-efficient electrical motors and steam systems are more significant compared to the other technologies [42].

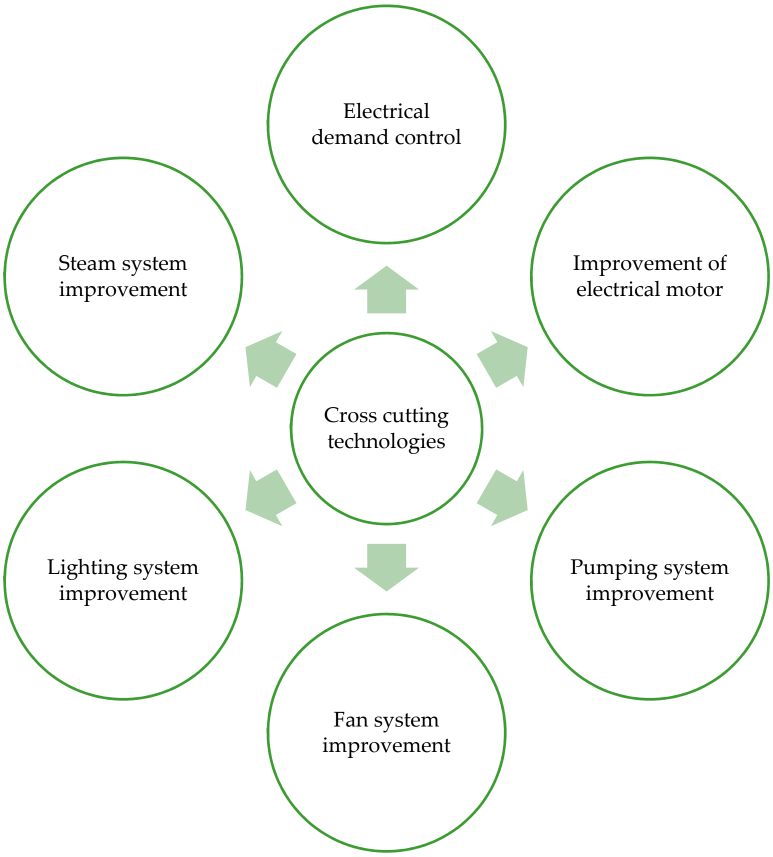


**Figure 4.** Cross-cutting energy efficiency measures [37,43].

### *3.2. Energy Management in Industry*

Energy management is viewed as a significant factor for the improvement of any organization's energy use [8,10]. It is an inside approach by the organization to be more cost-effective [25]. In addition, studies featured the relevance of inter-organizational aspects of energy management in industries. Considering the present standard of organizational wings, the supply chain approach can also support efficient energy management in industries [44,45]. In many cases, barriers toward energy efficiency can be tackled by a proper supply chain [44,46]. The definition of energy management varies from literature to literature [47]. Capehart characterizes this term by stating it as "the productive and successful utilization of energy to augment benefits (limit expenses) and upgrade focused positions" [10]. As per the German Federal Environment Agency, energy management aims to make sure that a minimum energy input is required for a predetermined bar of performance through the integration of the planned and executed actions [48]. Bunse et al. included controlling, monitoring, and the process to improve energy efficiency in the definition of energy management [8]. According to O'Callaghan and Probert, this term not only applies for resources, but also to the supply, conversion, and utilization of energy. They also stated that energy management aims to ensure that the least amount of power is required for a satisfactory performance, and this is done through carefully monitoring, examining, and redirecting energy and material flows through the system [8,49].

Ates et al. incorporated energy management with energy efficiency, as well as with the processes that mitigate the $CO_2$ emission [8,50]. Aziz et al. defined energy management as the inclusion of energy parameters that consist of energy monitoring and measuring, registration of energy-related data, and analysis and control of material flow via a system [7,51]. In this study, energy management is considered as energy's application to assets, in addition to the inventory, transformation, and usage of energy. An effective energy management framework not only ensures improved energy efficiency, but also optimizes the operational cost [25,52]. Scientific studies identified some factors (e.g., policy, energy cost allocation, strategy, management support, dedicated energy expert/manager, pay-off criteria, etc.) which are associated with a successful energy management scheme [12,48–54]. Figure 5 presents the criteria for a successful energy management system for an industry.

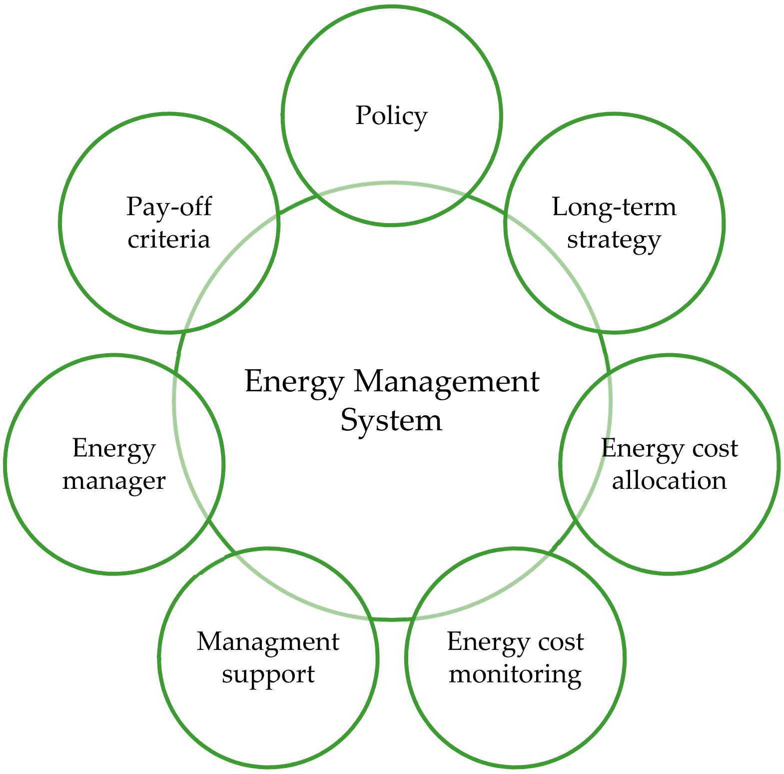


**Figure 5.** Criteria for a successful energy management system [11,12,55].

Improved energy efficiency will play a critical role, along with sustainable energy, thereby minimizing the anthropogenic greenhouse gas (GHG) emission by the industry as a major energy user [11,56]. Energy management is firmly connected with logistics and the production chain [48]. The terminology "energy management" incorporates the outlining and execution of energy production, as well as its utilization [10]. The objectives of adopting the energy management scheme at the industries involve the legitimate usage of assets, environmental sustainability, and savings of energy [57]. However, savings in energy cost are contemplated as the prime inspiration to apply energy management in industry [50,52,58].

## 4. Methodology

There are five types of strategies to pursue any research. They are classified as the experimental approach, surveying, archival analysis, histories, and analysis of case study [59,60]. This research was carried out as a case study considering the nature of the study. A case study strategy is an observational strategy to investigate a phenomenon in-depth in a practical context, where the connections between phenomenon and context are not clearly visible [60,61]. The case study helps understand such processes through uncovering a context for learning the characteristics of a particular problem being examined [62]. However, the case study analysis is accurate on the grounds that it is conducted with involvement and, furthermore, creates roots with the context [63]. The case study methodology holds the capacity to address any hypothetical development by the researchers [60,64]. Moreover, it gives a platform to perform casual argumentation on the basis of theoretical construction [60,65].

In this study, the data were obtained through a series of questions, thereby providing the general "perception" of the person being interviewed on behalf of the particular industry. The respondents of the questionnaire were either at the rank of plant manager or chief engineer, having more than 15 years of professional experience in the relevant industries. Considering the extensive experience of the respondents, the validity of the perception of the respondents can be considered as significant. Afterward, the data were validated over the phone. Furthermore, only arithmetic means were considered on the responses of the numbered Likert scale; hence, the differences in perceptions were not considered in this study.

The selections of the textile mills were done on a random basis, based on the list of registered textile mills of the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) [29]. Thus. the survey questions were forwarded to the textile mills by post and e-mail in the fall of 2018. The corresponding list of contacts was collected from the studied companies. It was found that there was no dedicated person for energy management. Therefore, the questionnaire was forwarded to the concerned plant manager or chief engineer. The total respondents were 31 out of the 78 asked to participate. This rate of feedback can be considered as good, considering Bangladesh's corporate and research community culture [12]. Respondents were requested to rank the perceived barriers to and drivers for energy efficiency in the range of 1 to 5, where 1 implies "not important at all" and 5 implies "very important". In the later phase, the results were normalized ranging from 0–1. Cronbach's alpha test was done to address the reliability issue of the respondents' answers/ feedback. This statistical test is considered as the measure of internal consistency of any data series. The value of Cronbach's alpha of 0.75 or higher is accepted as reliable for a dataset. An overview of the studied companies is presented in Table 5.

**Table 5.** Overview of the studied textile industries.

| Topic | Remark |
|---|---|
| Selection criteria of industries | Energy cost equal or higher than 7% of the turnover |
| Number of industries to which the questionnaire was sent | 78 |
| Number of respondents | 31 |
| Rate of response | 40% |
| Type of companies | Spinning, dyeing, and apparel |
| Designation of the respondents | Plant manager/chief engineer |
| Total questions in the questionnaire | 64 |
| Outsource facility | "No" for most of the industries. Few companies have an outsourcing facility in case of technical problems |
| Payback criteria | Payback criteria involve 3 to 4 years for the majority of companies. Few companies had a payback time of around 2–3 years. |
| Reliability check | Cronbach's alpha test |

The questions focused on energy management practices at the textile industries. A similar type of questionnaire was used in the energy management practice study for several European Union countries, Bangladesh, and Ghana [10,11,57,66]. The questions were short and convenient for the readers. In the questionnaire, the majority of the questions were in closed format. However, the questions related to energy efficiency potential were in open format. The company profile was asked at the beginning of the questionnaire, comprising turnover, energy use, workforce, etc. The set of questions was divided into several sections, such as barriers to and drivers for energy efficiency, energy management, energy efficiency options, and potential in energy efficiency.

The technical matters, financial and market challenges, and managerial factors were covered in the first section of the questionnaire. The second section covered the drivers toward energy efficiency. Energy efficiency potential at the industries was convened at the third phase. The policy- and institution-related issues were focused on in the energy management section of the questionnaire. The last section of the questionnaire incorporated the energy service companies.

## 5. Results

### *5.1. Barriers to Energy Efficiency*

The major barriers to energy efficiency in textile mills of Bangladesh were "inadequate capital expenditure" followed by "inadequate technical cost-effective measures". Eighteen textile mills identified these as the most significant barriers. "Poor research and development" and "inadequate technical experts" were marked by 11 textile mills. The other significant identified barriers were "inadequate financial incentives", "other preferences for capital venture", "unpredictability of energy parameters (prices, slow rate of return)", and "inadequate financial policy". It was found that the two lowest-ranked barriers were "time limitation or other significant work" and "complication in inter-divisional collaboration", which were rated by two respondents as important. The responses of the study are presented in Figure 6.

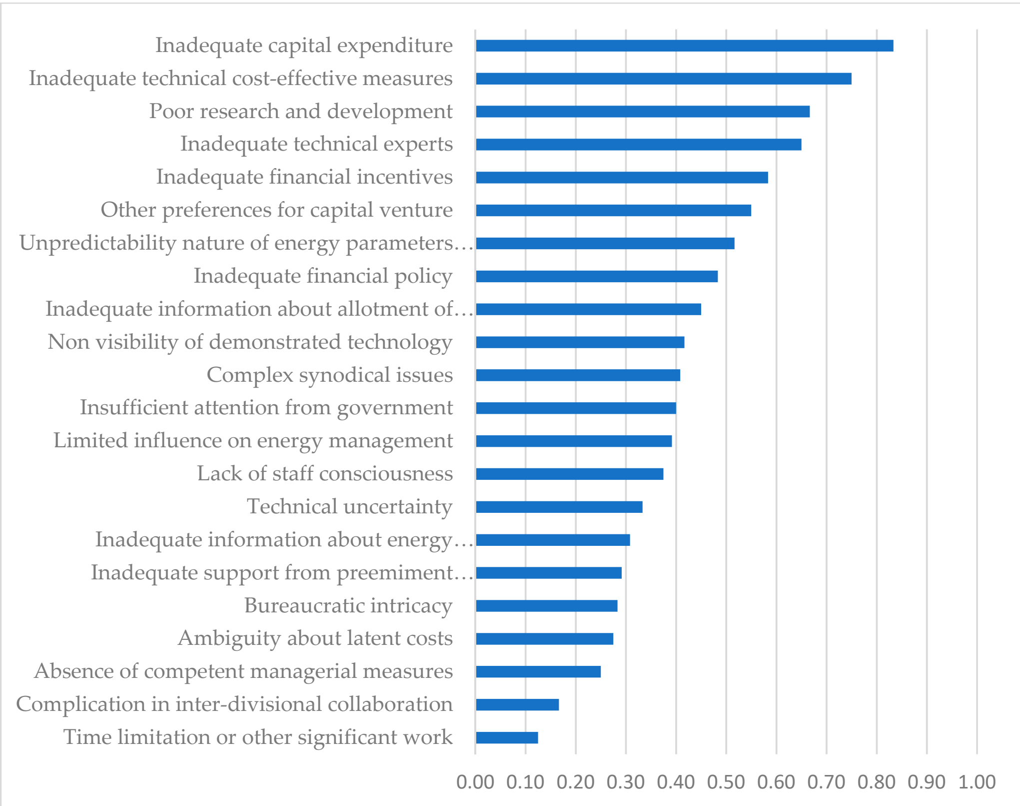


**Figure 6.** The perceived barriers to energy efficiency in the textile industries of Bangladesh.

### *5.2. Drivers for Energy Efficiency*

"Energy management scheme" was identified as the most important driver for energy efficiency among the studied textile mills, followed by "risk of high energy prices in future" and "assistance from energy professionals". The other important drivers were "owner's requirement", "expense minimization due to lower energy consumption", and "assurance from preeminent management". However, "favorable loans for efficient energy financing" and "organizational involvement in information and support" were also identified as important drivers, in addition to "energy blueprint", "high demand from consumer and non-governmental organizations (NGOs)", "subsidies for energy efficiency schemes", and "locally available energy consultancy". The lowest-ranked drivers were "acquaintances within the energy sector" and "agreements with tax dispensation". The detailed findings of this study are presented in Figure 7.

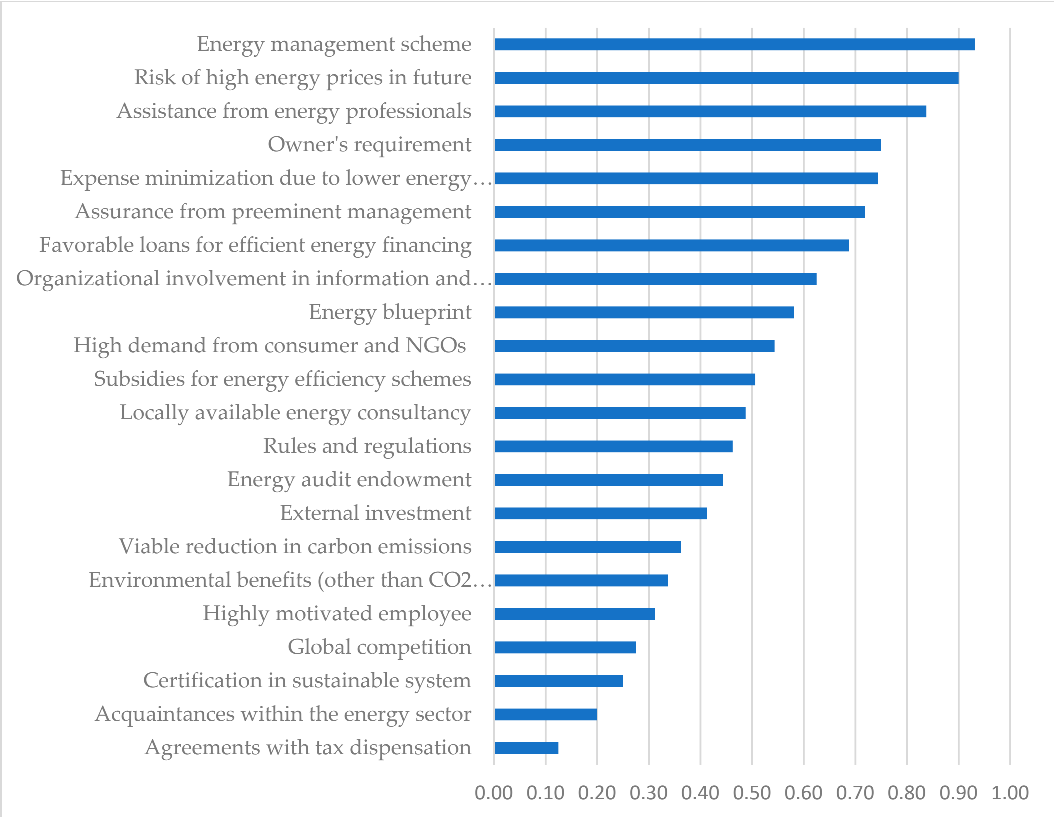


**Figure 7.** The perceived drivers to energy efficiency in the textile industries of Bangladesh.

## 5.3. *Energy Efficiency Potential*

The questionnaire started with improved energy efficiency, assuming all available economically viable technologies. The majority of respondents stated that 6–7% energy could be saved with the existing technology. The next question asked to the participants was about improved energy efficiency through energy management measures. On this note, 3–4% of energy efficiency improvements were perceived as possible, compared to current energy usage, with the implementation of energy management practices. The last inquiry was tied in with rating the significance of considering a framework point of view to assess alternatives for improved energy efficiency. Each respondent gave the most elevated score in this inquiry, recommending that a framework point of view for assessing choices for energy efficiency is absolutely critical.

## 5.4. *Energy Management*

In this study, the energy management matrix was used, consisting of association, strategy, data frameworks, consciousness or awareness, and investment [10,12]. Scientific literature was used to find the measuring aspects for various sub-classes of the energy matrix [11]. The inclusion of energy management aspects was ascertained by the weighted total of participants' responses to the distinctive purposes of survey questions. Figure 8 illustrates the energy management practices in Bangladesh textile industries. As seen in Figure 8, the textile industries have extensive potential for changes in each classification. However, the most significant factor for development was an increase in awareness by organizations about energy management. The stakeholders must be taught about energy optimization techniques and their capability to enhance substantial production. Moreover, the organizations ought to likewise consider energy efficiency speculation, actualization of energy management approaches, and integration of a dedicated energy manager into the organization structure.

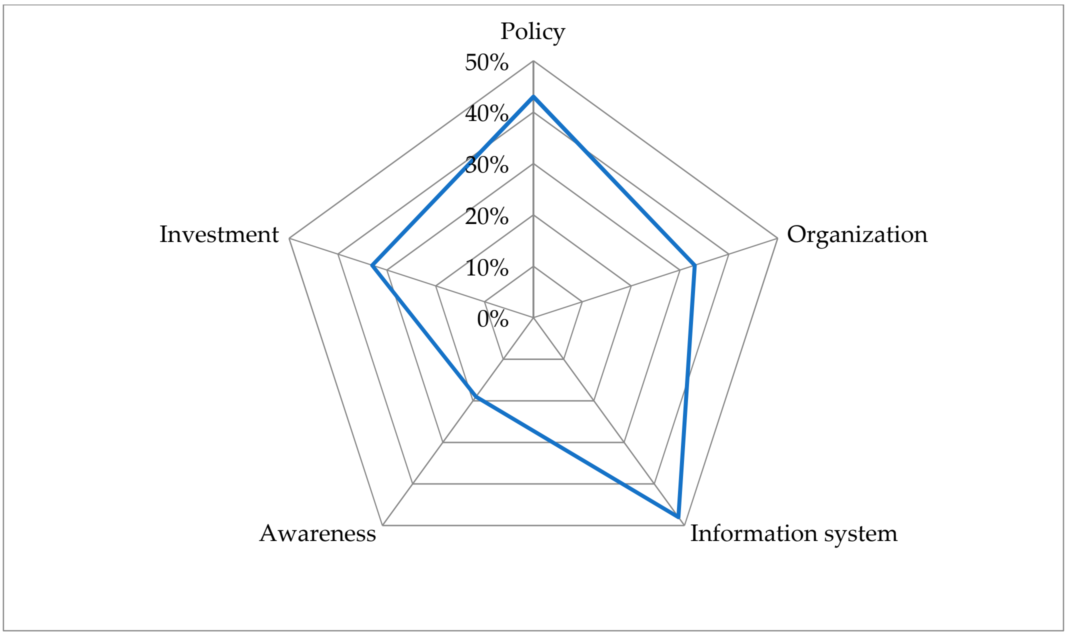


**Figure 8.** The matrix for assessing the energy management process in the textile industries of Bangladesh.

### 5.5. Energy Service Companies

The companies that work on energy savings and energy efficiency-related projects are known as energy service companies (ESCOs). ESCOs are considered as significant actors in the field of improved industrial sustainability. The textile industries of Bangladesh are not accustomed to the idea of dedicated energy service companies; rather, they tend to mainly utilize their own in-house resources. In this study, no participant acknowledged taking the service from ESCOs related to energy efficiency and energy management. Barriers were researched with regard to taking support from ESCOs. As per the participants' feedback, the major barriers were "insufficient information regarding ESCO" and "shortage of trained professionals in energy management", accompanied by "inadequate stakeholders" and "excessive service fees". However, "absence of regulated measures for energy parameters" and "lack of credibility" were also identified in this study, albeit to a lower extent. The aggregated responses of this study are presented in Figure 9.

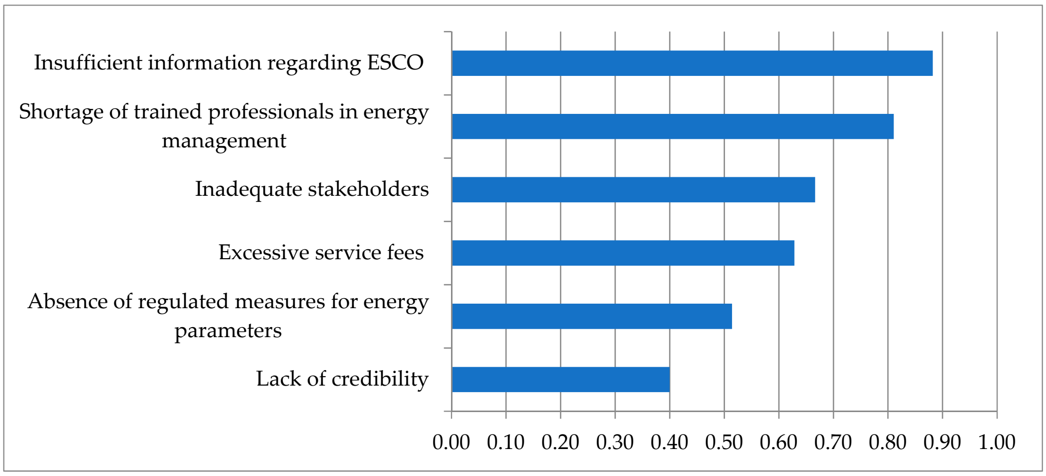


**Figure 9.** The perceived barriers for consulting with energy service companies.

## 6. Discussion

In this study, Cronbach's alpha test was conducted to address the reliability of the respondents' answers. The value of Cronbach's alpha for this study was 0.811, representing satisfactory internal consistency in the data series.

According to the results of the study, the primary barriers for energy efficiency were "inadequate capital expenditure, "inadequate technical cost-effective measures ", "poor research and development", "inadequate technical experts", and "inadequate financial incentives". Compared to the results of a similar study for the iron and steel industry of Bangladesh, the primary barriers for textile industry provide a highly contrasted result. Even with the same energy infrastructure, culture, and policy, the textile industry had significantly different barriers from the iron and steel industry. In the case of the iron and steel industry, the identified barriers to energy efficiency were mainly financial and technical, focusing on a slow rate of return and inadequate information about energy-efficient technology options [12]. Similar studies were conducted in another developing country, Ghana. The range of that study was not limited to a single industry, and inadequate funds and other prioritized options for investments were found to be the most significant barriers [10].

On the other hand, the main drivers for efficient energy management practices from the study were "energy management scheme", "risk of high energy prices in future", "assistance from energy professionals", "owner's requirement", and "expense minimization due to lower energy consumption". Similar to the barriers, there were significant differences between the iron and steel industry and the textile industry. In the case of the iron and steel industry, the primary drivers were related to the reduction of cost due to lowered consumption of energy, sustainability, competition with others, and energy price [12].

In addition, from the study, it is evident that it is possible to enhance the efficiency by 6–7% using existing energy technology. Moreover, with energy management practices, it is possible to improve energy efficiency by 3–4% according to the results of the study. From the comparison of the energy management matrix of the iron and steel and textile industries of Bangladesh, it can be found that there are significant differences in terms of policy and awareness among the stakeholders [12].

### *Policy Implications*

Energy efficiency is termed as "a wicked problem" due to the ambiguity of the problem itself. The meaning varies depending on the societal sector, modeling, and the research community [67]. In Reference [38], the authors indicated that, despite the proposal for effective technical policy approaches, the government introduced several neoclassical perspectives on the policy involving improvements on other mechanisms that are not rigorously connected to the energy efficiency plan. Another study on the Swedish Policy Program (PFE) showed that a large number of energy efficiency measures were not technical in nature, but rather related to management and operations of technologies and processes [68].

In comparison with the Swedish PFE program, Bangladesh, in 2015, introduced its policies for energy efficiency and energy auditing for the first time. The policy was derived from a number of strategic plans over a decade, with its inception in the form of the National Energy Policy of 2004. Most of the earlier policies dealt with the shortage of capital for the systematic development of power generation, transmission, distribution, data collection, research, and exploitation of energy resources, which caused an imbalance in the development of energy resources throughout the country. Bangladesh adopted its first renewable energy policy in 2008, developed by the Ministry of Power, Energy, and Mineral Resources (MPEMR) to provide electricity for the entire country by 2020 and to deal with the decline in fossil fuel, as well as energy security and climate change. The Sixth Five-Year Plan (2011–2015) was focused on mitigating the gap between electric power supply and demand through public—private partnership (PPP) and importing electricity from neighboring countries. There are several key measures outlined in the plan that facilitated the efficient use of energy, such as demand scheduling, diversification of fuel for electricity generation, cost reduction in importing power plant machinery, price adjustments, and so on. The Sixth Five-Year Plan (2011–2015) was heavily criticized for not discussing any other measures for energy efficiency except for the replacement of light bulbs with energy-efficient compact fluorescent light (CFL) bulbs [19].

A generalization of this comparison with the Swedish policy approaches may provide us with the indication that, for a developing country, improved energy efficiency as a policy means may not naturally be regarded as top priority or, as sometimes denoted, "first-fuel". Rather, it is the development of infrastructure, security of supply, and other issues that are far more urgent to deal with for the regarded country. From a global perspective, this may in turn have an impact on the mitigation of climate change, as, for a country like Bangladesh and other developing countries, they may be able to design their new infrastructure from the ground up with energy efficiency and sustainability.

It is likely that, at present, most people are aware of energy efficiency. Despite the fact that the global carbon emissions increased in 2018, global energy input was 1.3% lower than the last year, which indicates improvements in energy efficiency [69]. Bangladesh does not suffer from a shortage of nicely written and well-thought policies; rather, it lacks the implementation skills. According to a study conducted by UKAid (a British NGO) in October 2018, it was found that the comprehensive energy efficiency outline was passed by the Ministry of Law, Justice, and Parliamentary Affairs, Bangladesh, where it underwent some major revisions and a number of significant factors, such as tiering of energy auditors, mandatory provision of energy managers, financial penalty for non-compliance with the energy auditing process, were ignored. The removal of such critical factors resulted in the ineffectiveness of the overall energy efficiency framework and weakened the capability of enforcement [70].

A project completed in 2012 with the support of USAID, titled "Catalyzing Energy Efficiency in Bangladesh", later became a country-wide program to increase energy efficiency in the industries [71].

The Seventh Five-Year Plan (2015–2020) continued the demand-side management and the previously high-priority "energy efficiency and conservation map" and "energy efficiency action plan" were being prepared, supported by the Government of Japan. The Sustainable and Renewable Energy Development Authority (SREDA) proposed several programs for energy management and efficiency at both the industrial and residential level. The masterplan targets saving 5.3 Mtoe/year, equivalent to 100 billion Bangladeshi taka (BDT)/year. The masterplan also incorporated a few guidelines on an energy efficiency program to the stakeholders and provides carefully crafted incentives, subsidies, and tax exemptions to promote the use of energy-efficient equipment. SREDA's proposed mechanism was subjected to periodic energy auditing, which was the most influential factor for the improvement of energy efficiency. Considering the recently adopted policies by the Government of Bangladesh, financial incentives and subsidies are being offered, and carefully crafted policies offering lower taxes may facilitate the scheme. However, the dissemination of awareness could also improve the situation.

Keeping the implementation of the policy in mind, the Energy Auditing Regulations (EAR) is soon to be published, which emphasizes environmental issues correlating with the economy, e.g., global warming, transportation and population issues, waste management, resource depletion, and so on. The EAR will be applied to a few carefully selected "designated customers" as pilot projects. Compared to Bangladesh, the two neighboring countries, Pakistan and Nepal were relatively late bloomers in the context of energy policy, but presently could be considered at a similar level as in Bangladesh. India is the most advanced player among the neighboring countries in this game, with its Energy Conservation Act of 2001 having similar approaches proposed by SREDA in Bangladesh [72,73].

In 2018, the energy demand in Germany dropped by 2.2% due to increased energy efficiency, where the demand for oil decreased by more than 6% [74], having one of the largest and most developed markets in the European Union. Such a competitive and diverse market suits well for the boosting of energy efficiency potentials, and it grew significantly; services are now being segmented into categories such as energy auditing and consultation, management, metering, and so on [75]. However, large-scale textile industries are more likely to implement energy-efficient technologies compared to small- and medium-size industries [76].

Even though energy service companies can play a significant role in increasing energy efficiency and even though they are used in developed countries [8,54,56], in Bangladesh, there seems to be no use of energy service companies in the textile industries. A similar result was also found from the study of the steel industry in Bangladesh, where no use of ESCOs was found [12]. Being a developing country, the concept of energy service companies is quite novel in Bangladesh. Our findings of this study also indicate that the major barriers can be overcome through consultation with ESCOs, calling for this means to be a potentially promising policy approach in the country.

## 7. Conclusions

The objective of this work was to study different aspects of energy efficiency and energy management practices of the textile industry in Bangladesh. This study of energy efficiency is novel for the textile industry in Bangladesh, as the only other similar work was carried out for the steel industry in Bangladesh by the same authors [12]. The outcome of this work involved applying our method to study the barriers, drivers, and energy management practices for the context of an Asian developing country. However, this study only stands for a section of the industry of Bangladesh and, to incorporate the whole energy management scenario for Bangladesh, other industrial sectors need to be studied with a similar approach. According to the results of the study, there is a semi-high potential for improving energy efficiency of the textile industry by implementing more energy-efficient technologies, along with the implementation of energy management practices. Results of the study also revealed that there are a significant number of barriers for energy efficiency, which differ from other industries such as the steel industry of Bangladesh. Following a similar trend, the same conclusion can be drawn for the drivers, which also have significant differences from the iron and steel industry of Bangladesh, as well as being dissimilar to the drivers from the industries of developed countries. From the results of this study, it is evident that the policy-makers both from the government and the in-house management must be specifically aware of the barriers and drivers of the textile industry, which is significantly different from the iron and steel industry. The study shows that the main barrier for the textile industry is the lack of cost-effective technical measures, which are closely related to the lack of research and development both from the government and industry itself. Almost all of the technical measures implemented for energy efficiency in Bangladesh are imported from developed countries, and Bangladesh neither possesses any technical ability nor has any policy to acquire that technology through local research and development. On the other hand, as importing technology is expensive, the industry owners may not have the mindset and capital to spare for the energy efficiency purpose. Thus, based on the results of the study, the suggestion to the policy-makers of Bangladesh would be to invest a larger portion of the money to increase research for developing local technology for implementing energy efficiency measures. Similarly, the policy-makers should also consider providing incentives for energy efficiency measures, along with subsidies to encourage energy-efficient practices. Another important factor that also needs to be considered is the lack of energy service companies in Bangladesh. Thus, the policy-makers should also be aware of that fact and provide proper incentive to increase the number of energy service companies in Bangladesh.

Based on the results of the study, the recommendation for the policy-makers of Bangladesh would be to invest a larger portion of the public policy expenditure into increasing the research for developing local technology for implementing energy efficiency measures, considering the recently adopted energy efficiency policy. Given the Energy Auditing Regulations from SREDA, the periodic collection and analysis of the collected data will provide insights to the policy-makers for fine-tuning. The outcomes of the study could be the benchmark for fine-tuning a customized policy for different industrial sectors of Bangladesh, as in the textile industry at this moment. Considering the size, growth, and contribution of the RMG sector in the national economy, the perceived increase in energy efficiency is worth digging deeper. There were other studies on a technical increase in efficiency, and combining the artefacts from these studies produces an overall picture, clarifying the policy-making and proposing better solutions to the existing problems of energy efficiency. This study is a piece of a larger puzzle in the context of improved energy efficiency in Bangladesh in general, as well as for the nation's industry in particular.

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