Auditing and Energy Efficiency of a Ready-Made Garment Factory in Bangladesh: A Case Study

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Abstract

The possibilities for improving energy efficiency in ready-made composite garment factories in Bangladesh are assessed in this study. This work aims to understand the impacts of energy consumption on garment production and determine the scope of energy efficiency improvement based on energy-related data collected from a garment factory over a three-year period (2018-2020). Data from 2018 is used as the baseline and is compared to data from 2019 and 2020. It has been discovered that energy consumption has a seasonal impact. Despite the fact that electricity consumption decreased significantly during the 2020 pandemic, the energy consumption pattern in 2020 was found to be similar to that of 2018 and 2019. To improve energy efficiency, recommendations are made to modify the boiler, water pumps, gas generators, electrical motors, and lighting systems in specific ways. These suggested actions could save BDT 95 million (1.15 million US dollars) on power generation and BDT 20.5 million (0.25 million US dollars) on natural gas used for power and heat generation. These would result in a 3.75 percent reduction in the unit (kWh/kg) production energy requirement and a 3.65 percent reduction in natural gas usage per unit production, respectively, when compared to current conditions. Furthermore, these changes will provide an opportunity to reduce greenhouse gas emissions by 9.78%.

Keywords

Energy Efficiency, Energy Audit, Readymade Garment, Washing Plant, Natural Gas, Greenhouse Gas

1. Introduction

One of the most important components of any industrial activity is energy. However, the supply is not limitless. The global energy crisis, as well as high fuel

prices, prompted more activities to conserve energy to the greatest extent possible. The global energy crisis, as well as high fuel costs, prompted more activities to conserve energy to the greatest extent possible [1]. The textile industry is one of the largest energy consumers and has the lowest energy utilization efficiency. In the textile industry, energy is typically used in the form of electricity, which is a common power source for machinery, cooling and temperature control systems, lighting, equipment, etc.; oil is also commonly used as a fuel for boilers that produce steam; liquefied petroleum gas; and coal. This has paved the way for energy conservation, which can be achieved through process and machinery modifications, as well as the implementation of process-related technological advancements. In garment industries, energy efficiency is very important as it depends on the survival of the industries in this competitive global garment products/market. To find the cost-effectiveness of products, first the energy usage of the factory has to be studied, which energy is auditing. Then only the possibilities of energy savings can be found.

An adequate and consistent supply of energy is required to ensure long-term development. The growing rate of environmental problems associated with energy use has sparked increased interest in issues of sustainable development. This necessitates the prudent use of resources, technology, appropriate incentives, and strategic policy planning [2].

The ISO defined energy audit [3] as a systematic analysis of energy use and energy consumption within a defined energy audit scope to identify, quantify and report on the opportunities for improved energy performance. The energy audit is also defined as the process of inspecting, surveying, and analyzing energy flows to achieve industry energy conservation and proposes to reduce the amount of energy entering the system without negatively affecting the output [4]. According to ISO, Energy Efficiency [5] is defined as a ratio or other quantitative relationship between an output of performance, service, goods, or energy and an input of energy. Energy efficiency means using less energy to perform the same task – that is, eliminating energy waste. As a result, energy efficiency brings various benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering the costs on a household and economy-wide level [6].

A number of studies agreed that the textile industry is energy-intensive, that textile production frequently necessitates high levels of energy consumption, and that energy usage is inefficient. Additional studies recommend increasing energy efficiency through energy conservation techniques and energy management [7] [8].

As a developing country, Bangladesh has sustainable economic growth due to increased industrialization in recent years. Therefore, the improvement of energy efficiency in the industry is advantageous for the country. Therefore, the Government of Bangladesh has taken the initiative for energy efficiency named "Energy Efficiency and Conservation Master Plan up to 2030", which is being supervised by the Sustainable and Renewable Energy Development Authority

(SREDA) [9].

The foundation of the textile sector in this country lay in the early 60's. During 1965-66 first export of men's shirts started to the European market. Entrepreneurs started their ready-made garments (RMG) business in Bangladesh, following the beginners. The RMG sector of Bangladesh was developing rapidly. The growth of the country's RMG industry is attributed to competitive prices, a vibrant population, fast learning and dedication, irresistible and resilient entrepreneurial spirit, tax-free market access in the most developed countries, quick adoption of the green concept and environmental protection, and the factory produces different types of products with versatility. Organizations such as the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) and Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA) focus on promoting the textile sector. However, currently, BGMEA has 4381 members [10]. In the RMG sector of Bangladesh, there are more than 5000 garment factories (private statistics) at the current time, employing more than 1.2 million laborers, where 85% of the labor force is women. Bangladesh now exports garments to 150 countries.

In the financial year, 2018-19 and 2019-20, the RMG industries exported US$ 40.535 Billion and US$ 33.674 Billion, respectively. These amounts are 84.21 and 83.00 percent of the total export earnings of Bangladesh for the respective fiscal years [10] [11]. However, the target of 2021 of US$ 50 Billion may not be achievable due to the COVID-19 pandemic.

The textile industry has considerable energy-saving potential in Bangladesh [12]. The efficiency is the Key Performance Indicator (KPI) of the ready-made garments industry [13]. By the end of the 2018-19 financial years, the total sale of gas in the industrial sector is 15.79% (164.51 billion cubic feet (BCF)) [14]. Out of this 15.79%, the garment industry consumed 22.7% (1844 Ton of Oil Equivalent, TOE), and the textile industries consumed 19.5% (1586 TOE). Thus, in total, garment and textile industries consumed 42.2% (3430 TOE) of total industrial sector consumption [9]. Garment factories, specifically composite garment factories are energy intensive and water usage is very high. Also, the effluents pollute the environment.

In this study, a ready-made composite garment factory is considered for energy auditing. The studied factory is located near Dhaka city on the bank of river Shitalakhya. The study mainly concentrates on the usages of electrical energy, gas usage for heat and power generation, water usages, heat recovery system, GHG emission of this export-oriented garment factory.

2. Theoretical Background and Methodology

This section describes the methodology of this work with proper block and system diagrams. Necessary theoretical explanations are also being discussed.

2.1. Energy Audit and Energy Efficiency

Typically, three types of energy audits are introduced in the energy audit stan-

dard established by ASHRAE (American Society of Heating, Ventilation and Air-conditioning Engineers) and AEE (Association of Energy Engineers), USA. In this study, Level 2 and Level 3 types are used. These are walking through and quick check inspection, detailed energy usage and bill analysis, quantification, and evaluation of energy efficiency of boiler, generator, and pump motor set, identify the cause of heat loss, as well as energy and cost-saving opportunities. In addition, the scope of improvement with the implementation method should calculate the payback period of the improvement plan. Finally, an overall energy management plan should be proposed [15].

Industrial energy efficiency is a key factor in the transition to a more carbon neutral energy system. Although the potential field of energy efficiency is quite broad, there are many obstacles to energy efficiency. However, there are some cross-cutting energy efficiency options. Figure 1 shows the energy efficiency measures of the textile industry [16].

The energy audit is also defined as the process of inspecting, surveying, and analyzing energy flows to achieve industry energy conservation and proposes to reduce the amount of energy entering the system without negatively affecting the output [6].

Depending on the type of audit, the size, and the purpose of the facility being examined, a variety of tasks are included in an energy audit. As a result, doing an energy audit is an iterative process rather than a linear one. The audit described in this article was completed based on the functional activities listed below.

- Walk-through survey;
- Baseline for factory energy use;
- Assessment of energy-saving solutions;
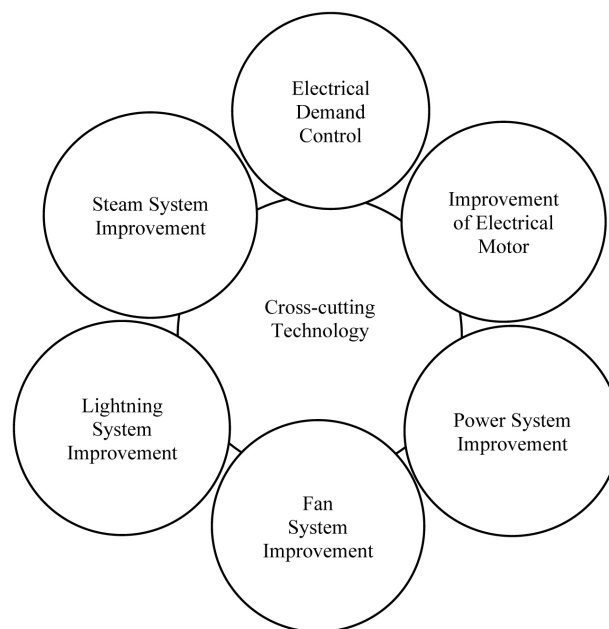- Analysis of factory and utility data.

Figure 1. Cross-cutting energy efficiency measures [11].

2.2. Relevant Theory

This study requires some equations to calculate different parameters and outputs. Energy consumptions, energy savings, energy payback period, the operating time of a pump, steam savings, etc., are required to calculate [17].

- Energy consumption per day (kWh/day) = *Operating time* (hr/day) × *power consumption* (kW)　　　　　　　　　　　　　　　　　　　　(1)

- Total saving of lighting = *Energy saving per lamp* (kW) × *Number of fittings* × *Cost of power consumption* (EGP/kWh) × *Lighting duration within the year* (*8 hr per day* × *365 days per year*)　　　　　　　　(2)

- *Pump Operating time* (hr/day): *Daily water requirement of a plant* (m^3/day)/ *Pump flow rate*　　　　　　　　　　　　　　　　　　　　　　　(3)

- *Payback period* = *Expenditure/ Total savings*　　　　　　　　　(4)

- *Steam Saving* = (*Heat loss* × *engine load*)/ 2651 (*Steam Enthalpy*)　　(5)

3. System Description

3.1. Processes of the RMG Industry

In the studied factory, the yarn selection process is completed in the first stage. After the yarn selection process, wet processing is used to treat and dye the yarns. Then denim fabric is produced through a weaving process. While the fabric is completed, it is cut and sewed to get the finished goods. Finally, in the washing plant, the garment goods again undergo wet processing and then dry out. The finished product is then ready for packaging and shipping. This process is depicted in **Figure 2**.

Figure 3 shows the washing process of the studied factory. Usually, two major washing processes are carried out, one is stone wash and the other is enzyme
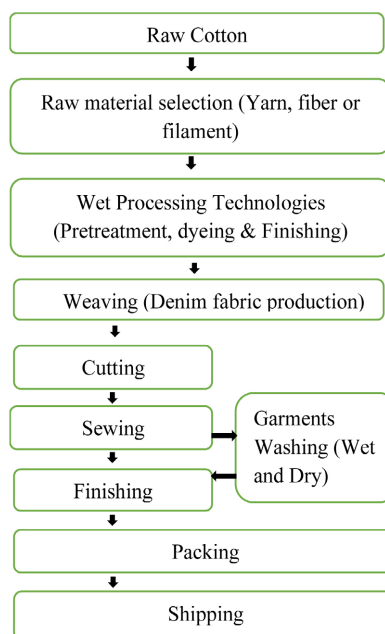

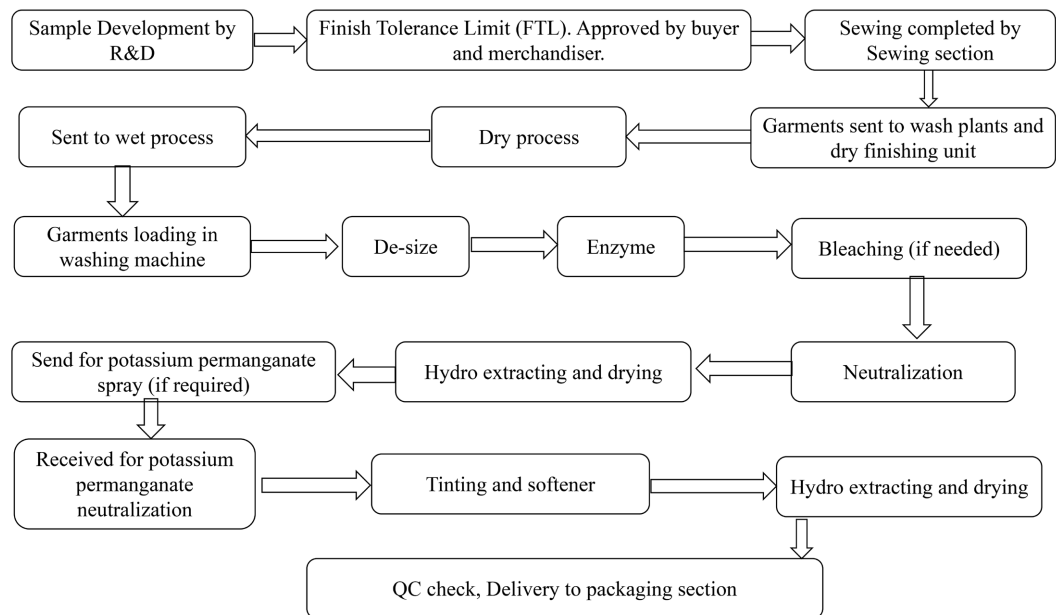**Figure 2.** Process diagram of a composite textile factory.

Figure 3. Process diagram of washing plant.

wash. Wet softeners are used for the garment softening process. Normal washing processes have about 8 - 15 steps of wet washing processes, including cold wash with a Denim Material Ratio (MLR) of 1:08 or 1:10. The number of steps and MLR varies depending upon the buyer's requirement, design, and quality. In many existing washing machines, the MLR is remarkably high—more than 1:10. For the Drying and Finishing Process, the stitched garments are subjected to several surface treatments. Surface treatments include hand scraping, grinding, whickering, pin tag, and potassium permanganate (PP) spray. The selection criteria of surface treatment are based on the style and look of the finished garment as required by the customer.

In the factory, there are six submersible pumps and six river water pumps. They supply the water required for the processes like (washing and finishing, gas engines, boilers, denim section, and other sections) and domestic use. The river water pumps are used during the rainy season to get soft water, with a flow rate of 150 m³/h each. Other six submersible pumps are used during the dry session, and their flow rate is 200 m³/h. Drained water from washing machines is recycled in the effluent water treatment plant. The water distribution system is shown in **Figure 4**.

There are 200 motors of IE1/IE2 class with derated capacity and efficiency of 800 kW and 79% respectively.

3.2. Utility Baseline of the Studied Factory

To do the energy auditing, the base line of the factory has to be studied first. This section mainly covers the observations from the energy consumption and load data. There are in total 19 natural gas engine generators with a combined capacity 22,126 KVA, 415 V. Out of these 6 (six) are 1125 KVA (900 kW), 5 (five)
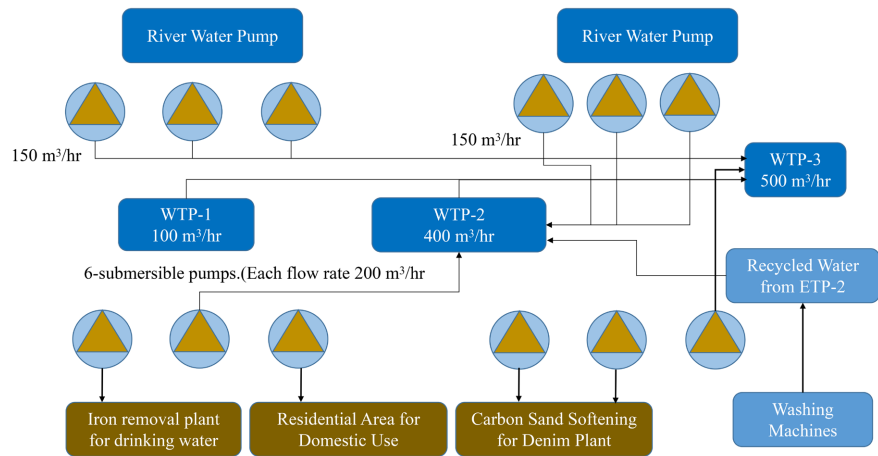
Figure 4. Diagram of water distribution system.

are 1150 KVA (920 kW), 5 (five) 1287 KVA (1030 kW), 2 (two) 1064 KVA (1064 kW) and 1 (one) 1063 KVA (1063 kW). There is a 512 kW Diesel Generator (DG) set which is seldom used, except for an emergency. Additionally, there is a grid connection from the Rural Electrification Board (REB) at 11 kV through two transformers of capacity 1250 kVA, 11/0.415 kV each. REB electricity is utilized only to meet critical loads during the partial or full shutdown.

Electricity generation requires natural gas as the factory uses the gas engine generator. Furthermore, the production-related equipment uses natural gas to produce heat, steam, etc. **Table 1** presents the equipment list which consumes natural gas in the studied factory. From **Table 1**, it has been seen that natural gas consumption is required to get the power generation and heat as the outcome. The heat is used in different processes of the factory. The total number of the equipment in the factory is 319 units.

Moreover, as an energy source, natural gas is also used to produce steam by the boilers that have a cumulative capacity of 75 Ton/Hour. Steam is distributed through an internal grid system by three different boiler houses. Some amount of natural gas is used directly through production processes, mainly for industrial heating equipment. Those are used where heat transfers are desired instead of pressure.

It is found that 99.47% of natural gas is used as primary energy. Out of this 58.15% is used for heating and 41.32% for power generation [18]. The remaining primary energy is received as electricity from the grid. In 2018, the total electricity consumption was 51.30 million kWh. Much (99.47%) of the total electricity demand was met by own generation and the rest 0.53% by grid. In 2018, the total energy (Electricity and Natural Gas) cost was 6.58 million US$.

This study focuses on identifying the saving opportunity of the utility system and the cost of implementation of the identified issues. It also studied the reduction of overall electricity consumption and process water for washing plants and its impact on production cost. The breakdown of various energy use for different applications in the factory is shown in pie charts (the charts are prepared based

on the monthly data taken from logbooks, meters, indirect calculations, and discussions with technical personnel.

Figure 5 shows the percentage of electricity consumption of different utilities of the factory. The compressor plant consumes major (35%) portion and then the washing plants (15%).

The supply of natural gas for different utilities of the factory is shown in Figure 6. To produce steam, the washing plants receive 10% natural gas as thermal energy. However, steam boilers consume a major portion of natural gas (66%) as thermal energy. Fabric dyeing and finishing use 19% gas.

Figure 7 depicts percentile use of steam by different utilities. It shows that the highest (48.9%) steam is consumed by the washing plant for finish product wash. The rest of the steam is used in knitting, dyeing, and finishing stages.

Percentile use of water consumption by different utilities is shown in Figure 8. The highest (49%) consumption of water is from washing plant and second highest (41%) by fabric dyeing and finishing, rope denim, and knitting.

Table 1. Number of the equipment's that consume natural gas.

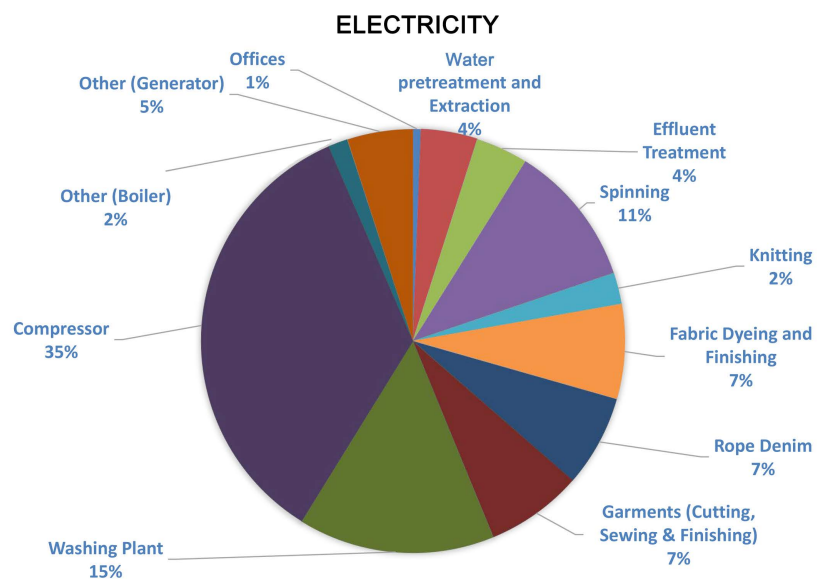| Equipment	Numbers	Out come
Boiler	7	Heat/Steam
Generator	19	Power Generation
Stenter machine/Heat setting machine	4	Heat/Process
Thermic Fluid Heater (Thermo)	2	Heat/Process
Dyeing Machine + Dryers	12	Heat/Process
Gas engine + Gas Stove/Gas Burner	275	Heat/Process
Total	319	

Figure 5. Electricity consumption in percentage of utilities of the factory.

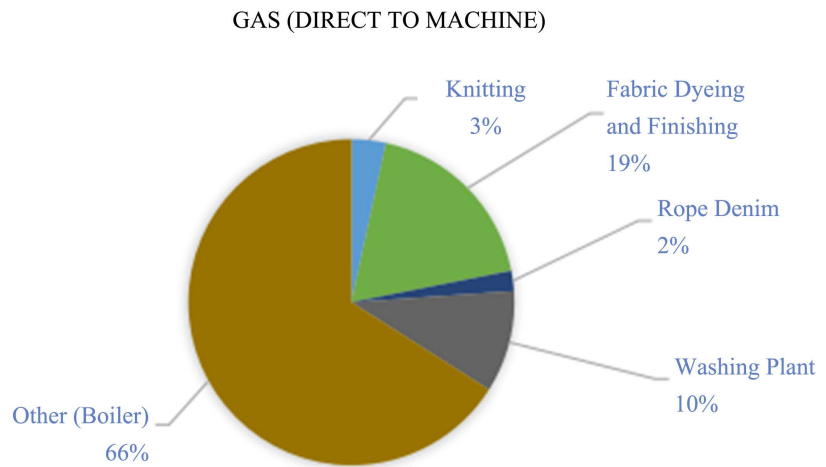GAS (DIRECT TO MACHINE)

Figure 6. Natural gas consumption (direct) in percentage of utilities of the factory.
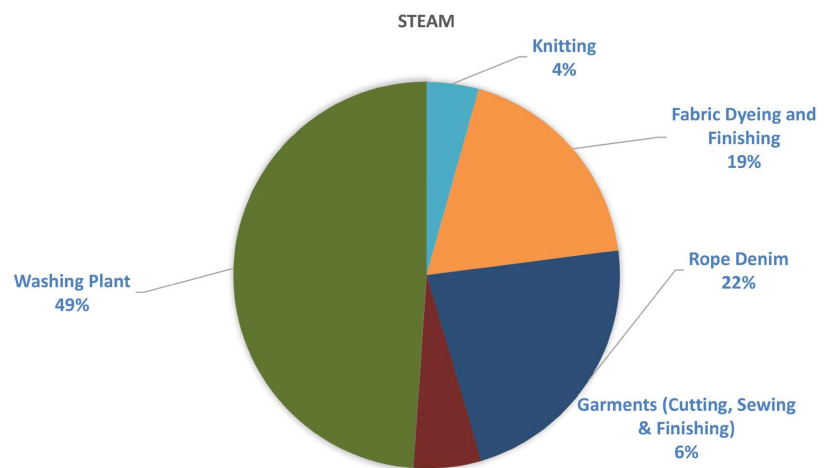
STEAM

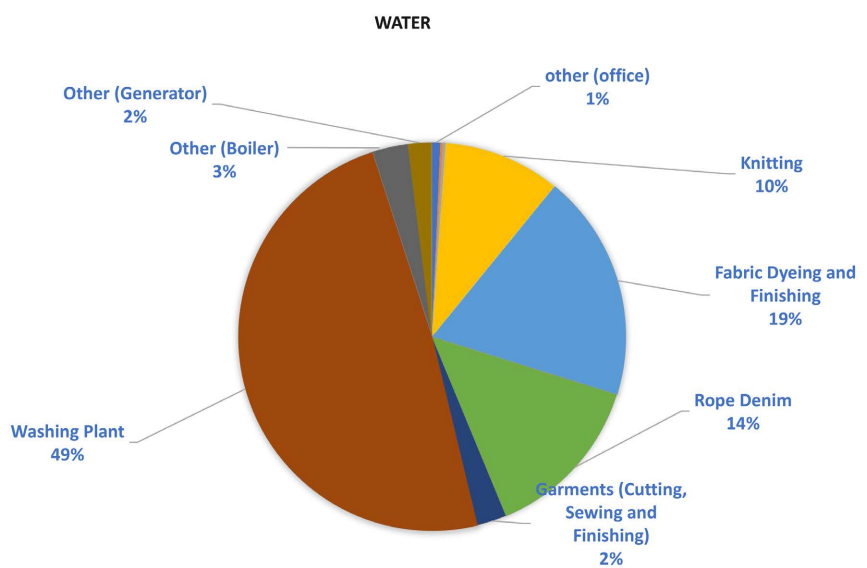**Figure 7.** Steam consumption in percentage of utilities of the factory.

WATER

Figure 8. Water Consumption in percentage of utilities of the factory.

4. Results and Discussion

In this section, the result of this research is explained and at the same time is given a comprehensive discussion and recommendations on the findings.

4.1. Data Analysis

In this section, actual data of energy consumption and water usage are collected for the base year 2018, as well as up to 2020. Conceptualization of the study includes identifying measures to reduce end-use demand for energy and water, identifying measures to improve the efficiency of utility service, to enhance heat recovery or heat generation efficiency. The critical estimations of this study are the annual energy savings (kWh), natural gas savings (Nm^3), process water savings (m^3), GHG emission (tCO_2), and the costs. Besides, the simple payback period is calculated.

Figure 9 shows total electricity consumption for 2018-20. In 2018 consumption peaked in January, April, July, and December. In between months there is variation in consumption. In 2019, almost similar pattern was observed to 2018 *i.e.* peaks in January, May, and October. These variations in power consumption are related to the volume of production and order received from buyers. In 2020, COVID 19 spread throughout the nation. The government declared lockdown, and the industries had to shut down. The outbreak of the pandemic decreased the order, and buyers canceled considerable numbers of orders. The lowest electricity consumption of April 2020 reflects the scenario during the lockdown.

Figure 10 shows the total volume of washed products in kilograms for the year 2018 and the few months of 2020. July has the highest production value in a base year (2018) which is correlated with electrical energy consumption of own generation and electricity from grid shown in **Figure 5** and **Figure 6**. The correlation between production and energy consumption is verified in **Figure 9** and **Figure 10**. At the beginning of the pandemic in January 2020 the production decreased and became zero in April when the lockdown is imposed in the
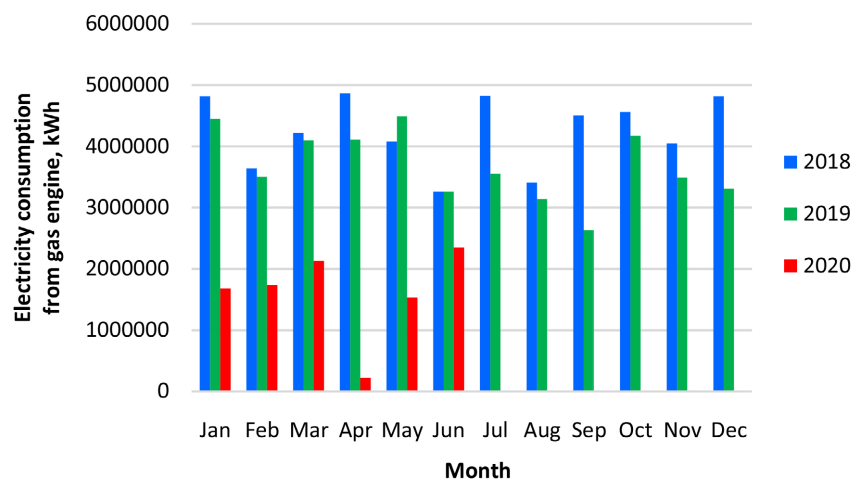

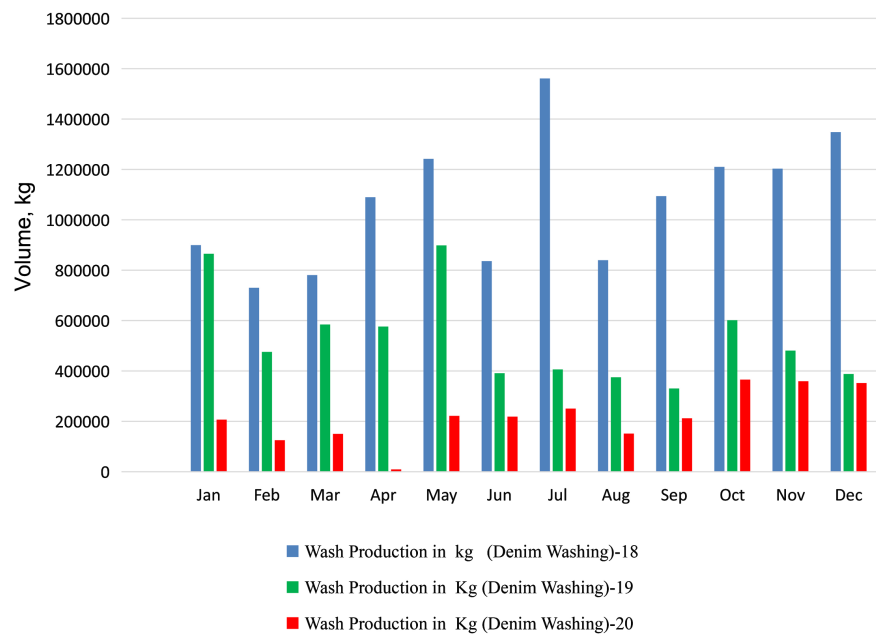**Figure 9.** Electricity consumption from gas engine generator.

Figure 10. Washed production from washing plant of the factory.

country. Figure 10 shows the production in May 2020 is almost 80% less than in May 2018.

Figure 11 shows the month-wise consumption of gas along with denim production. The Specific Natural Consumption (SNC) per kg of production is also represented on the right axis. There is a relationship between natural gas consumption and production volume. In February, production volume is the lowest, but gas consumption is the highest, 4.60 Nm^3/kg. However, the production volume is highest in July and the specific gas consumption rolls down to 2.67 Nm^3/kg. The reason for this anomaly is that the factory requires more heat to start up the process.

Table 2 presents the total energy consumption data and the corresponding cost. Gas tariff (m^3) for power generation and heat generation are different. Unit cost for electricity generation is BDT 10.70 and for heat, generation is BDT 13.85. The use of natural gas and electricity generation data are shown in Table 2. From Table 2, it is seen that own generated electricity is costlier that grid electricity. Even then, own generation is necessary for self-dependency and reliability.

Water is extensively used in textile industries. Average textile production in Bangladesh consumes 200-250 liters of water per kilogram (kg) of fabric production, which is almost five times higher than international best practices. Therefore, the industry discharges 12,713,500 cubic meters of wastewater every year, which represents 85% - 90% of the groundwater extracted for fabric processing. Overall, 20% of freshwater pollution comes from textile processing and dyeing [18].

Table 3 shows the baseline indicators of water consumption in the year 2018. The table shows that the factory utilizes 113.7-liter ground and surface water per kg of production. The amount of recycled water used is 38.9 liters/kg.
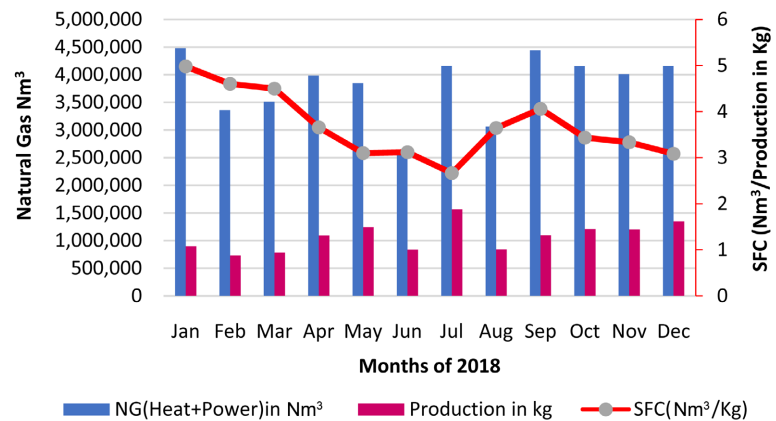
Figure 11. Plot of the specific gas consumption (heat + power) at the right axis and production in kg at the left axis.

Table 2. Total energy consumption and costing.

Resource	Consumption	Energy Cost (US$)	Specific Energy Rate
Electricity (REB Grid)	243,138 kWh	25,778 US$*/y	0.106 US$/kWh, 8.80 BDT/kWh
Natural Gas (Heat generation)	26,629,056 Nm³/year	3,432,902 US$/y	0.129 US$/Nm³, 10.70 BDT/Nm³
Natural Gas (Power generation)	19,162,319 Nm³/year	3,197,567 US$/y	0.166 US$/Nm³, 13.85 BDT/Nm³

* 1 US$ = 83 BDT [2018 baseline year value].

Table 3. Baseline indicators for water consumption.

Resource	Value (m³)	Production (kg)	Key Performance Indicators (KPI)
(Ground + Surface) Water	1,459,156	12,835,095	113.7 liter/kg
Recycled Water	499,089	12,835,094	38.9 liter/kg
Process Water	1,878,486	12,835,094	146.4 liter/kg

4.2. Findings and Recommended Actions

This study uses the actual data collected from the factory. During the data collection phase, some deficiencies are observed. Based on those observations, recommended actions are suggested in this section.

Out of 19 gas engine generators, 10 units do not have any heat recovery system. By installing Exhaust Gas Boilers (EGB), exhaust flue gas temperature could be reduced to 120°C - 130°C, instead of present 500°C - 540°C.

It was found that the average fuel consumption of the generators is 0.37 Nm³/kWh, but the manufacturer specification is 0.33 Nm³/kWh. By doing periodical maintenance gas consumption could be reduced. It is recommended to ensure periodical maintenance.

It is found by actual measurement of water flow, head, and power consumption that the efficiency of river water pumps is in the range of 33% - 41.5%. It is recommended to overhaul or replace existing pumps with energy efficient (70%) pumps. The existing 200 motors of IE1/IE2 class should be replaced by IE3 class, then the efficiency [19] could be increased to 93%.

It is recommended to replace existing 36W FL lights, which runs 16 - 18 hours/day, with a high color rendering, efficient LED lights, which will save energy by 50%.

The recommended actions would improve the overall efficiency of the factory. Besides, it will increase production and increase cost-savings. A simple cost-benefit analysis points out the overall improvement scope and shed light on the potential investment and payback period. Table 4 depicts the summary of the cost-benefit analysis based on the issues mentioned in Table 3.

From this case study, it is found that by performing regular maintenance of the generators, 1.020 million/Nm^3 gas consumption and 2.19 K tCO$_2$ GHG emission can be reduced. There are 200 old IE1 and IE2 class motors in use. There will be a savings of 645,120 units of electricity per year, when replaced by efficient IE3 class motors. For river water pumps, the electricity of 0.889-million-unit electricity would be saved, if replaced by energy-efficient pumps. Replacing 36 W (T12) lights by 18 W LED lights will same 82,944 units of electricity per year. Recent research shows that, eco-friendly and free, source of day lighting has the

Table 4. Cost-benefit summary and payback time.

Issue	System Savings	Financial Benefit	Environmental benefit	Investment	Payback period
Heat recovery from gas engine:	Steam Saving = (Heat loss × engine load)/2651 (Steam Enthalpy) = 1222.3 kg/h, Yearly Steam Saving = 8,448,570 Kg.	BDT 5,711,233 (US$ 67,990)	1400 tCO$_2$ annually	Cost of Waste heat recovery system for 1 MW Gas Engine (US$110,000)	19 Months
Reduce gas consumption	Annual average natural gas saving for Power generation: 1,020,968 Nm^3	BDT 14.1 million/ (US$ 0.17 million)	Equivalent 2199 tCO$_2$ emission reduction.	BDT 50 million (0.60 million US$)	4.6 Months
Efficiency improvement of river water pumps	Annual Saving = 83,980 kWh. (Per day running about 12 hours)	BDT 4.37 million (US$ 0.053 million)		BDT 3 million (0.036 million US$), US$-1785 (Pump Set A and B)	7.65 Months
Efficiency improvement of induction motors.	Saving per year of operation: 645,120 kWh	BDT 5.20 per kWh for GEG, BDT 8.80 kWh for REB) BDT 3.366 million (US$ 0.041 million)		(BDT 2500 per KW) Total: BDT 2 million (0.024 million US$)	7 Months
Energy efficient lighting system	Energy savings: 82,944 kWh/y	value BDT 4.318 million (US$ 0.052 million)		Investment BDT 1.849 million (0.022 million US$)	5 Months.

potential to reduce the consumption of 20% of lighting load of a garment factory [20] [21]. There are various models of daylight harvesting for various production floors. It is recommended to apply such kind of technology in the studied factories.

These are the recommendations for energy efficiency found in base line study. If the recommended actions are taken, the overall efficiency of the studied factory would be improved. Besides, it will create a significant amount of annual savings. It will also decrease the greenhouse gas emission. Table 5 summarizes the utility baseline performance indicators and the annual savings opportunity of the factory. The table shows that percentage of the reduction in energy per kg production would be 3.75% less than the present scenario, which is equivalent to BDT 95 million.

Furthermore, gas requirement per kg production would be 3.65% less than the present condition. Therefore, it would save BDT 25 million annually. Alongside, greenhouse emission would be reduced to 14,932 tCO_2 annually.

4.3. COVID 19 Impact on RMG

The changes in demand, the slowdown in the global economy, store closure, and production stoppage due to the COVID-19 outbreak have negatively impacted the global supply. The textile and garments supply chain has encountered similar impacts due to COVID 19. China is one of the largest suppliers of textile inputs. Hence, when the global pandemic erupted from China, the impact consequently extended throughout the global market [22] [23].

The Bangladesh Rural Advancement Committee (BRAC) conducted a national survey of 2675 respondents from low-income backgrounds (March 31-April 5, 2020). It shows that the potential outcome of COVID19 is that it affects low-income garment workers.

The BGMEA gave a declaration on the re-opening of the garments from 26 April 2020 with the government's permission [24] [25]. The return to work was made more troublesome as public transport was not available. Hence, workers had to organize their travel to return to work, and these arrangements are making them more vulnerable to disease transmission. In expansion, it has as of now been reported that social distance is not entirely maintained inside the industrial

Table 5. Performance indicator of the utility baseline in terms of production and environment.

Resource	Baseline Performance Indicators				Annual Saving Projection	
	Unit	Existing	To be	Reduction (%)	Impact (Reduction) Unit	BDT (Equivalent US$)
Power	kWh/kg of Production	4	3.85	$[4 - 3.85] = 0.15/4 \times 100 = 3.75\%$	18,442,368 kWh	95 M (1.14 M)
Natural Gas (Heat + Power)	Nm^3/kg of Production	3.56	3.43	$[3.56 - 3.43] = 0.13/3.56 \times 100 = 3.65\%$	1,671,114 Nm^3	20.5 M (0.246 M)
GHG emission	tCO_2	152,615	137,683	9.78%	14,932 tCO_2	

facilities, and satisfactory protective measures are not taken to secure workers [26] [27].

The COVID 19 situation has also affected the mental health of ordinary people who work during this pandemic. Fear of infection or death due to the COVID19 pandemic will affect mental health, and RMG staff are no exception. [28] [29] [30].

5. Conclusions

This paper presents a case study of a ready-made garment factory in Dhaka, Bangladesh. The assessment was based on energy auditing, and from there, opportunities for energy efficiency were discovered. Beginning with the details of the factors and a description of the components of the studied zone, it moves on to the utility baseline, which shows that the compressors and the washing plant consume 35% and 15% of the electricity, respectively. Natural gas consumption by the boiler and the washing plant is 66% and 10%, respectively. For its process, the washing plant uses 49 percent steam and 50 percent water.

According to the audited data, electricity consumption decreased during the pandemic in 2020. However, the energy consumption pattern was discovered to be similar to that of 2018 and 2019. Furthermore, the COVID 19 has had a significant impact on the production of the studied factory. According to the findings, May 2020 production was 80% lower than the same month in 2018.

This study discovered some energy efficiency opportunities and recommended some actions. A cost summary and payback period have also been discussed. As a result, the recommended actions would reduce the energy requirement (kWh/kg) by 3.75 percent compared to the current condition. Furthermore, natural gas consumption per unit of production would be reduced by 3.65%. It will also allow for a 9.78 percent reduction in greenhouse gas emissions from the current operating condition. Furthermore, the impact of COVID 19 on the garment factory has also been presented. In future work, implementation of the recommended actions may be studied to assess the performance of the studied factory.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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