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

By

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A project submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of
Master of Engineering in Electrical and Electronic Engineering

Electrical and Electronic Engineering Department
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Declaration

It is hereby declared that

1. The thesis submitted is my own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
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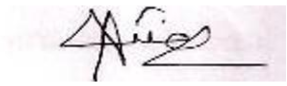

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Approval

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Abstract

In this study a ready-made composite garment manufacturing and processing factory of Bangladesh is audited to measure the energy efficiency. The energy data and the auditing data are collected from the factory for the year 2018. The aims of this work is to understand the energy consumption impact on production and find out the scope of energy efficiency improvement. The source of energy are natural gas and electricity purchased from the grid. Almost 99.47% of primary energy consumption is in the form of natural gas for heating 58.15% and 41.8% for power generation. The remaining primary energy is used for commercial purpose. Result shows at utility mapping, that the compressor plant consumes 35% of electricity. Washing plant consumes on average 30.71% energy (electricity, natural gas, steam and water) which is the second highest. Data shows that there is a seasonal variation on energy consumption pattern. January shows the highest energy consumption and June shows the lowest consumption of natural gas. It is recommended that boiler, pump, gas generator, electrical motor and electrical lighting systems should be checked, and appropriate measure should be taken to improve the efficiency.

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

DEDICATED

TO MY

BELOVED PARENTS

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List of Acronyms

NEP-	National Energy Policy.
ASHRAE -	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
EAC-	Energy Audit Cell.
SREDA-	Sustainable & Renewable Energy Development Authority
EECMP-	Energy Efficiency and Conservation Master Plan
GDP-	Gross Domestic Product
UNFCCC-	Nations Framework Convention on Climate Change
INDC-	Intended Nationally Determined Contribution
COP-	Conference of Parties
RMG-	Ready Made Garments
SME-	Small and Medium Enterprise.
LED-	Light-Emitting Diodes
HEM-	High Efficiency Motor
VSD-	Variable Speed Drive.
DSM-	Demand Side Management.
DG-	Diesel Generator.
REB-	Rural Electrification Board
KVA-	Kilo Volt Ampere
TPH-	Ton per Hour.

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Chapter 1

Introduction

1.1 Background

Bangladesh, a country located in Asia, has an area of 147,570 km^2. 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. A strong relationship lies between a country's GDP and energy use. In 2013, around 60% of the total population in Bangladesh had access to electricity. The percentage of access to electricity has increased. In June 2016, access to electricity reached up to 76%. Recently, in 2018, with the installed capacity of 17,043 MW, electricity was accessible to 90% of total population [1].

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. The reciprocating engine type has the highest share (36%) in Bangladesh, followed by combined cycle (34%), steam turbine (14%), and gas turbine (8%) [1].

The textile sector is considered as one of the highest energy users in the industrial sector of Bangladesh. The textile industry of Bangladesh, which includes Readymade Garments (RMG) and Knitwear along with specific textile products, is considered as the number one export earner. Several world-renowned clothing brands are placing their order in Bangladesh. The country now has 5.9% of shares of the global clothing market [2]. The expansion of the textile industry in Bangladesh is imaginable mostly due to cheap labor. However, other factors are also closely linked, such as supportive business conditions, freight 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 laborer's 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 [2].

1.2 Ready-Made Garment Sector

Bangladesh has maintained a six percent of average annual GDP growth rate with its limited resources. The RMG industry, which is the biggest export earner, has become a significant industry of the country. The Bangladeshi RMG industry acts as a catalyst for the prosperity of the nation and its competitiveness in the international RMG market [3]. In the financial year 2017-2018 the RMG industry generated $30.61 billion, which was 83% of the total export earnings and 12.36% (2016-2017) of the GDP. Now Bangladesh has more than 4500 factories of which are members around 40% of BGMEA members. These are knitwear, sweater and woven garment manufacturers. BGMEA member factories account for 100% woven garment exports of the country and over 95% sweater exports [4].

The RMG industry of Bangladesh started its journey in the 1980s and has come to the position it is in today [4]. The major issues of success in the RMG industry in Bangladesh must depend on backward linkage condition, support, and strategy formulation. The issue of developing backward linkage is discussed with reference to the desirability of having control over the supply of inputs of RMG industry, mainly, fabric, yarn, and processing status [5]. The Bangladeshi RMG industry has huge energy-saving potentiality [6]. There is a need to ensure that the growth in the RMG sector does not come at the cost of environmental degradation and inefficient usage of resources. Issues such as energy efficiency, waste water treatment and green renewable technologies will be of paramount importance to long–term success and sustainability of this sector in Bangladesh [7].

1.3 Scope of the project

The project study mostly concentrates usages of electrical energy, water treatment system, heat recovery system, GHG emission reduction with an overall energy efficiency program of export-based garment industries. Furthermore, issues related to improving efficiency have been identified and recommendations regarding energy efficiency have been given. Data is collected from different meter reading, logbook and technical experts of utility engineer and washing plant process specialist. In this study, it is identified how to use utility, washing and finishing outputs in RMG sectors with more efficient and less wastage of water.

There is an opportunity to improve energy and water management systems by identifying all the major problems with their solutions. So that good manufacturing practice is very important for every garment and textile industry. Bangladeshi garment factories and mills every year consume 1500 billion liters of water for the finish product dyeing and washing [8]. This affects lowering of ground water level. They also discharge toxic effluent in waterways and surroundings areas, which contaminate crop fields and health hazard. In addition, many apparel industries use inefficient generators which emit high levels of greenhouse gases.

IFC (International Finance Corporation) experts provide in-depth, tailored advice and technical assistance that enable mills and garment factories to lower water, energy, and chemical usage, reduce pollution, and cut operational costs. IFC-led “Partnership for Cleaner Textile (PaCT)” has provided more than 200 factories with on-site assessments, and advice on easy, low cost solutions and larger capital investments that helped slash water use by 21 billion liters per year in Bangladesh. These investments also reduced greenhouse gas emissions by 460,000 tons annually equivalent to removing 100,000 cars from the road. IFC has invested $12.3 million in garment suppliers [8] who implemented cleaner production measures.

1.4 Aims and Objective

The aim of the project is to explore energy efficiency of a large composite textile factory of Bangladesh considering energy usage in production and some efficiency improvement measures. The specific objectives of this project for identified factories are to:

(a) Assessing the present usage of commercial power, self-generated power as well as captive power and steam in the form of natural gas, water consumption, and GHG emission in the factory.

(b) Identifying the saving opportunity in the utility system.

(c) Identifying the saving opportunity by assessing wet dyeing process i.e., washing, drying, and finishing operations in forward linkage of textile units for supplying water and energy in a less wasteful manner.

(d) Identify opportunities for improving energy management to bridge the present energy efficiency gap.

1.5 Organization of the project

The organization of the project work is as follows: Chapter 2 provides an overview of Case study. Chapter 3 discusses the Theoretical background and methodology; Chapter 4 analyze the Data and provide Recommendations. Conclusion and future work is discussed in Chapter 5.

Chapter 2

Overview of Case Study

2.1 Process of RMG Industry

In this project a ready-made garment factory is chosen to do the energy audit and efficiency. It is a composite textile factory. The factory is situated near Dhaka city on the bank of river Shitalakhya. RMG products are being produced in stages by multiple manufacturers. The industry which supplies raw materials to another industry to produce the final product is known as backward linkage and the industry which uses the output of different industries to produce the final product is known as the forward linkage industry. In backward linkage of RMG, the basic raw materials are cotton and fiber. Cotton is the main source of making yarn and fabric. Almost 95% yarns are made from cotton [9]. Bangladesh imports raw cotton from different countries and continents like China, Egypt, Turkey, India; Africa, America [9]. In 2018 Bangladesh imported 8.2 million bales of cotton [10]. In spinning mill yarn is produced for sewing, weaving, and knitting [11]. According to the studied factory, after the yarn selection process, wet processing technology is used to treat and dye the yarns. Then denim fabric is produced through a weaving process.

While the fabric is completed, it is needed to cut and sew to get a complete goods. In the washing plant the garment goods again undergo a wet processing and then dry out. The finished product is then ready for packaging and shipping. Fig 2.1 represents the process diagram of the composite textile factory.

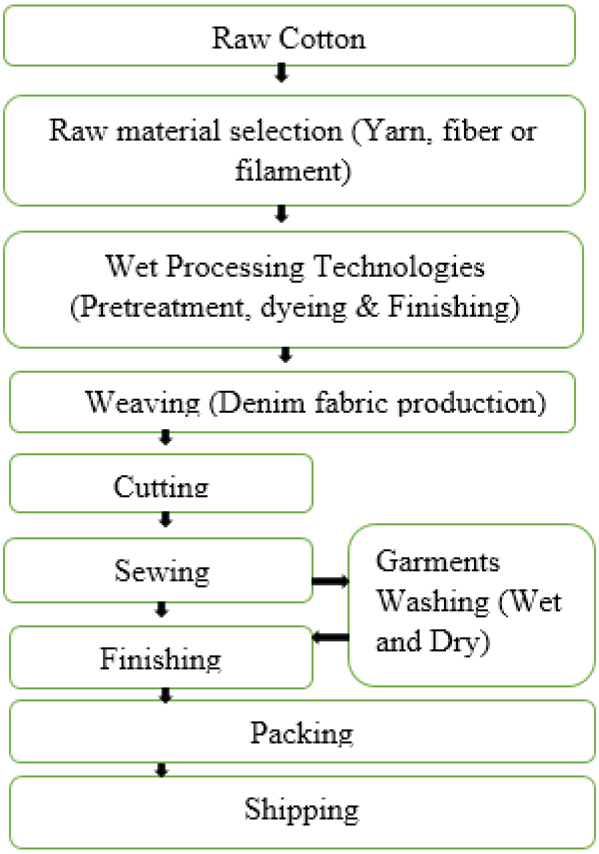

Figure 2.1. Process Diagram of Composite Textile Factory

2.2 Operation of washing plant

In view of above Fig. 2.1, through a composite process, the washing plant and related utility system is selected to study for this project work. The washing process operation and control level is extremely poor and process parameters are not followed for the washing process. The strategies are not monitored; batches are run for extra time for correction/modification and additional process. There is no systematic record or information available to investigate and control the quality issues. The overall work practices and process control supervision is poor and process is run by operators based on their own skill and experience. Supervisory control for process parameters monitoring is poor and batch-wise production records are not available.

Normally two major washing processes are carried out**,** one is stone wash and other is enzyme 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 denim Material Ratio (MLR) of 1:08 and 1:10. The number of steps and MLR is found varying depending upon the requirement of the buyer; design and quality. In many existing washing machines, the MLR is extremely high - more than 1:10.

For Drying and Finishing Process, the stitched garments are subjected to a number of surface treatments. Surface treatments include mainly hand scraping, grinding, whickering, pin tag and potassium permanganate (PP) spray. The selection criteria of surface treatment are based on style and look of the finished garment that is required by the customer.

The washing plant process flow diagram is shown in Fig. 2.2.

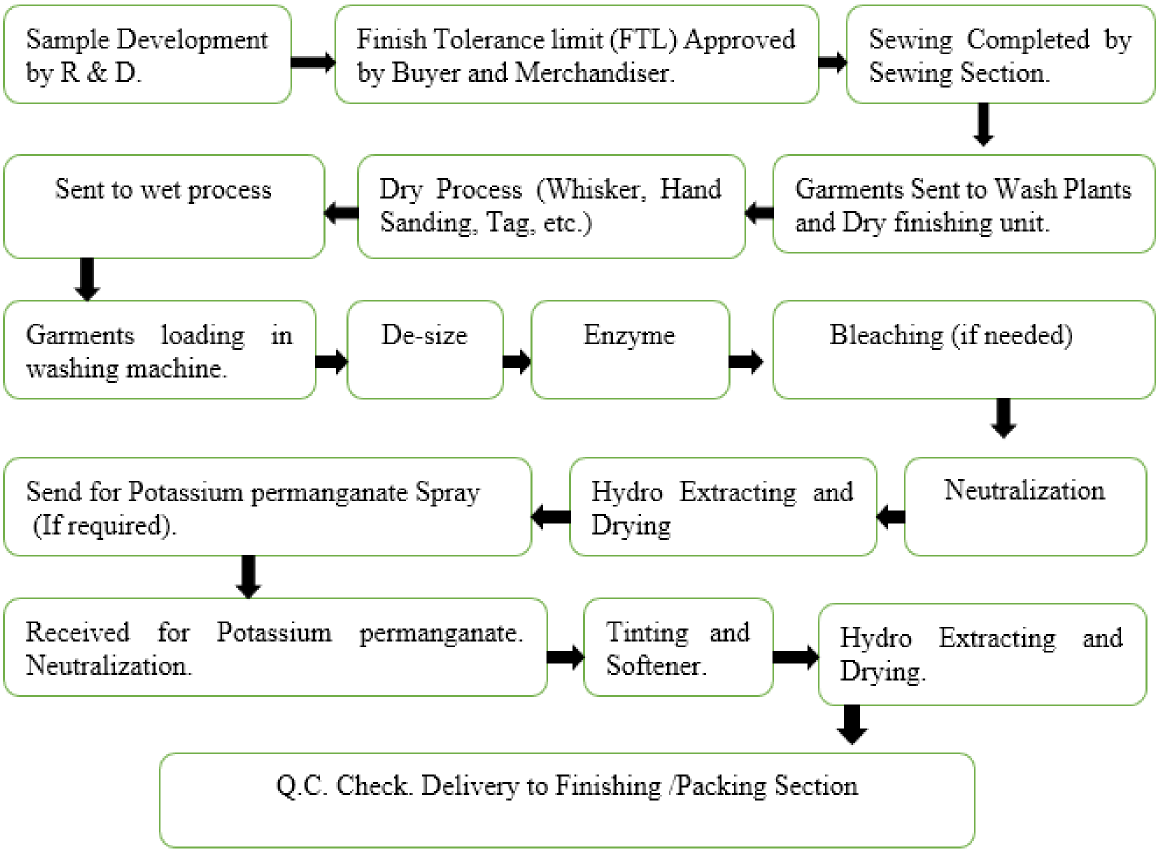

Figure 2.2. Process flow diagram of washing.

The surface treatments are one of the problematic areas of the production processes. The dust emissions arising from the hand scraping treatment can pose health problems. Closed water circulated cabin is used for Potassium permanganate (PP) spray, having 4-5 drums in each cabin. Use of PP sprays also poses serious health hazards, so the water flow can be increased to reduce its hazardous effects. The finishing process means final treatment and process of every kind of garment for better appearance and serviceability.

2.3 Energy baseline of the Plant

This section mainly covers the observations from the energy consumption and load data shared. At present, to meet the electricity demand, the factory has 19 nos. natural gas generators of cumulative capacity 18,154 kW connected at 415 V voltage level. Out of 19 nos., 6 nos. of 900 kW, 5 nos. 920 kW, 5 nos. 1,006 kW, 2 nos. 1,030 kW and 1 no. 1,064 kW gas generators are situated in 5 different power houses located at different places of the factory. Generators are internally synchronizing with each other in same powerhouse, but not one powerhouse with another. Additionally, there is a 930-kW capacity grid connection from REB (called Grid Power/Electricity) at 11 kV and a 512 kW DG set for backup power supply. Grid electricity is utilized during partially and full shutdown of gas generators. DG set is not usually used as power source. The grid power supply from the rural electrification board at 11 kV level passes through two transformers of capacity 1,250 kVA each.

In case of gas unavailability or breakdown of gas generator, grid electricity is used to meet critical load demands. Moreover, as energy, natural gas is used to meet steam generation by the boilers that of cumulative capacity 75 TPH (Tons Per Hour) and distributed through an internal grid (steam) system by 3 different boiler houses. Some amount of natural gas is used directly through production processes mainly for the industrial heating equipment. Those are used where heat transfers are desired instead of pressure.

It is observed that 99.47% of natural gas is used in the form of primary energy, of which 58.15% for heating and 48.15% for power generation. The remaining primary energy is received as electricity from the grid. In 2018, the cumulative electricity consumption was 51,304,393 kWh. In 2018, 99.5% of total electricity demand was met by gas generator and remaining 0.5% by commercial source. In 2018, total energy (Electricity and Natural Gas) cost has been calculated as Tk. 54,58,91,498 (USD 65,77,006).

This study focuses on identifying the saving opportunity of the utility system as well as the cost of implementation of the identified issues and the efficiency development of the process operation of washing plants for supplying water and energy as the impact on production. Breakdown of various energy sources for different applications in whole premises is shown in pie chart (the chart is prepared based on the monthly data from logbook, meter, calculation and mutual discussion with senior technical management of facility).

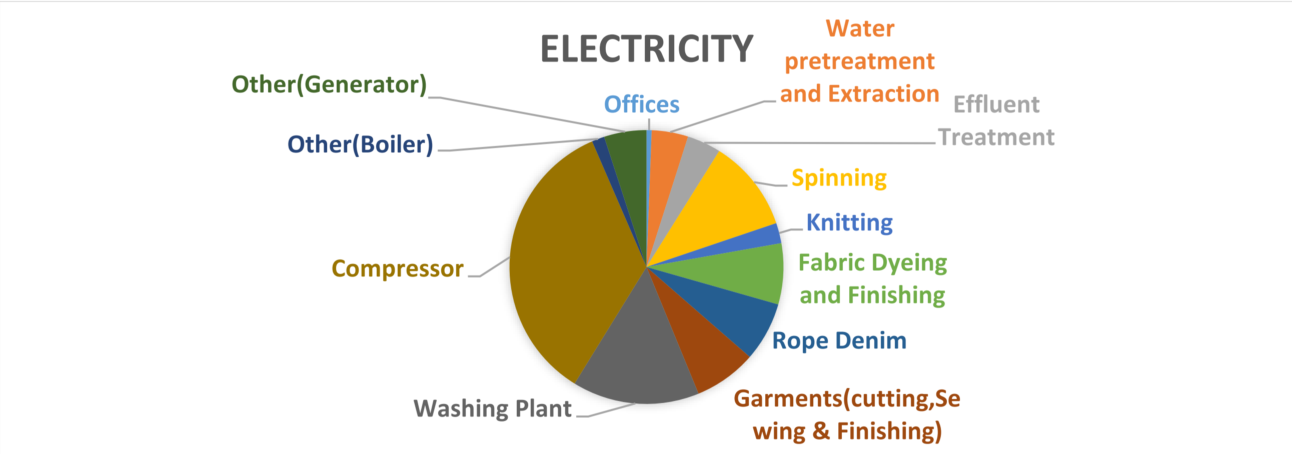

Figure 2.3. Pie chart of electricity consumption in percentage of utilities of the factory.

From the chart it found that the compressor plant consumes a major portion of electricity (35%). Also washing plant takes the second highest position at 15% in consumption of electricity among the entire zone.

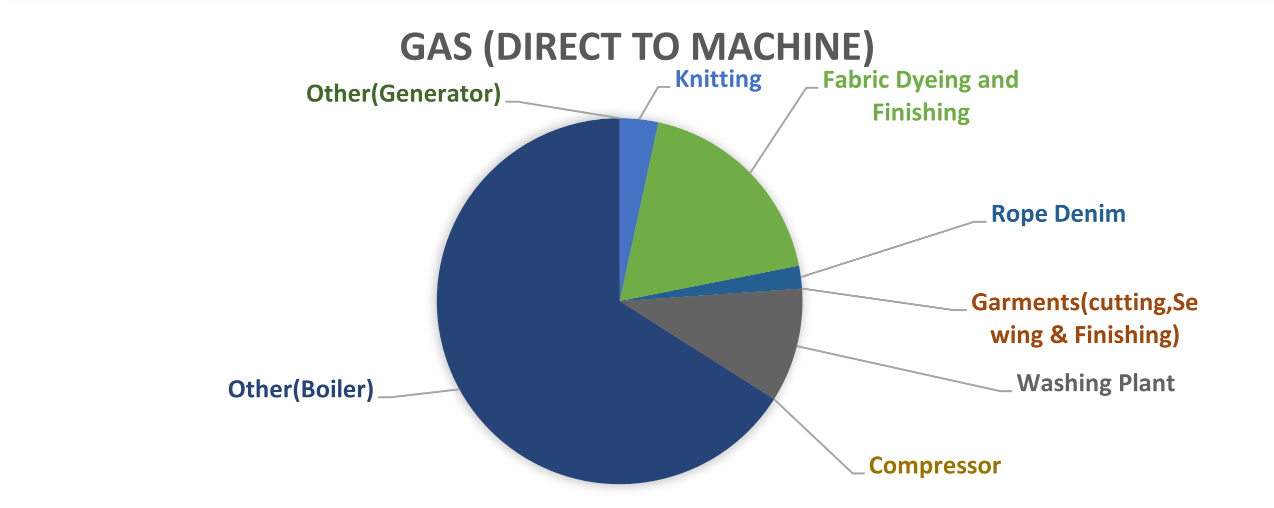

Figure 2.4. Pie chart of natural gas consumption (direct) in percentage of utilities of the factory.

The figure (Fig.2.4) depicts that steam boilers consume a major portion of natural gas (66%) as thermal energy. And the washing plant also receives natural gas as thermal energy in the process system which is 10%.

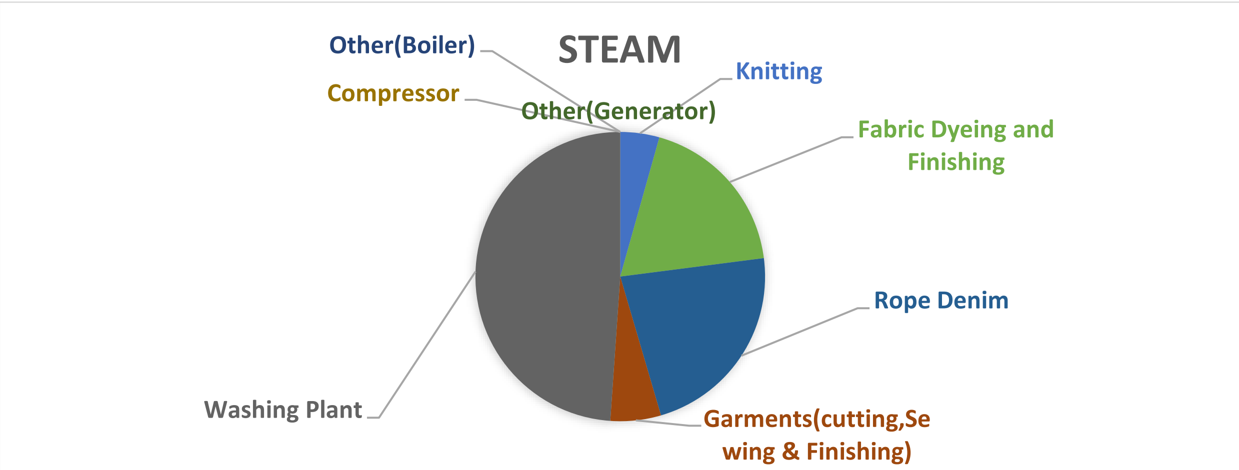

Figure 2.5. Pie chart of steam consumption in percentage of utilities of the factory.

Figure 2.5 shows percentage of steam of different utilities of the factory. It shows that the highest (48.9%) steam is consumed by the washing plant for finish product wash.

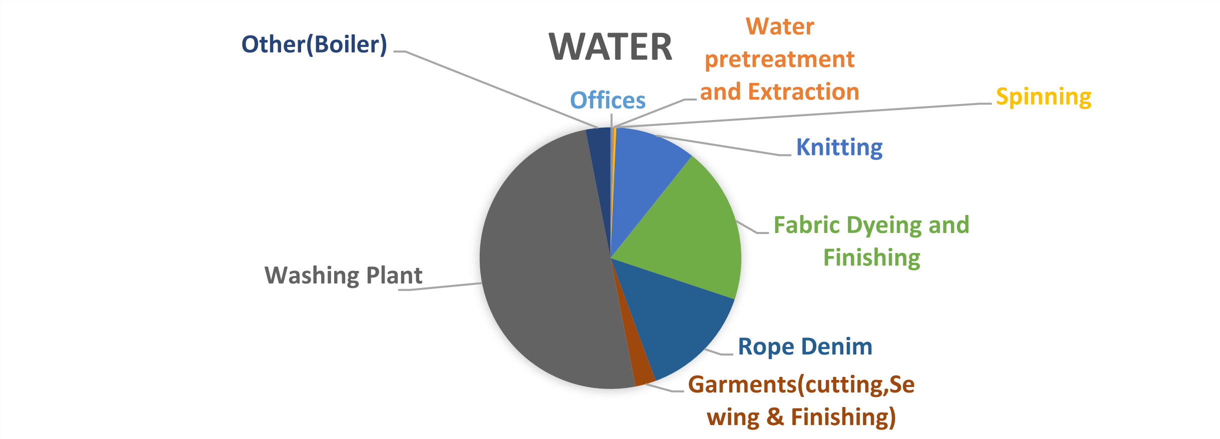

Figure 2.6. Pie chart of water consumption in percentage of utilities of the factory.

Highest (49%) water is consumed by the washing plant and about 41% water is used at fabric dyeing and finishing, rope denim, knitting and is the second highest in water consumption.

2.4 Statement of the problem

Whilst there is a clear imperative for reducing energy consumption in the RMG industry, there are also certain barriers to realizing this that will need to be addressed. As for example, competing priorities for investment, such as expanding production capacity instead of making existing capacity more efficient. In so far as the payback period is shortened by them, low or zero interest rate loans would tend to improve the attractiveness of energy efficiency projects. Also lack of awareness amongst the industrial players regarding modern technologies and their near term pay-off with the lack of expertise for implementing energy saving opportunities. From the mapping (Figs. 2.3-2.6) of entire zone washing plant consumes 15%,10%, 48.9%, and 49%, electricity, natural gas, steam, and water respectively of the entire zones. It is recommended that boiler, pump, gas generator, electrical motor, production process and electrical lighting systems should be modified to improve the energy efficiency.

Washing production goods consumes huge amounts of water, chemicals, and energy across the globe. Also the discharge of waste water into the water bodies are highly alarming for environment and aquatic lives. Technologies are invented day by day to reduce the resource consumption and make the process sustainable. Global energy crisis, as well as the high cost of fuels resulted in more activities to conserve energy to maximum extent. The textile industry retains a record of the lowest efficiency in energy utilization and is one of the major energy consuming industries. About 34% of energy is consumed in spinning, 23% in weaving, 38% in chemical processing and another 5% for miscellaneous purposes [12]. It is known that thermal energy in textile mills is largely consumed in two operations, in heating of water and drying of water. Fuel consumption in textile mills is almost directly proportional to amount of water consumed. Hence, if consumption of water can be reduced, it will also save energy [12].

Chapter 3

Theoretical Background and Methodology

3.1 Energy Audit

An energy audit is defined as an inspection, survey, and analysis of energy flow for energy conservation in an industry and suggesting a process to reduce the amount of energy input into the system without negatively affecting the output(s) [13]. Usage of energy efficiency approach, the energy loss can be minimized, and energy audit is a fundamental technical procedure for implementation of energy efficient operation in the industries.

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. The “Energy Efficiency and Conservation Master Plan up to 2030” features for the first-time industrial energy efficiency policy in Bangladesh [14].

3.1.1 Types of Energy Audit

Typically, three types of energy audits are introduced in energy audit standard established by ASHRAE (American Society of Heating, Ventilation and Air-conditioning Engineers) followed by of AEE, USA (Association of Energy Engineers) as stated below:

LEVEL-1

- Walk through and quick check inspection.
- Review and Testing of protection device/system of all electrical installations in the structure.

LEVEL-2

- Detailed energy usage and bill analysis.
- Evaluating existing efficiency and conditions.
- Quantification of energy streams into different equipment such as boiler, generator, pump motor set, and furnace, etc.
- Evaluation of energy efficiency of boiler, generator & pump motor set.
- Evaluate the thermal efficiency of the energy consuming equipment.
- Identify the cause of heat loss as well as energy and cost saving opportunities.
- Identifying scope of improvement with implementation method.
- Detailed benefit and simple pay back calculation
- Pre-implementation measurement and verification
- Energy Management Plan to prevent heat loss and ensure energy efficiency.

LEVEL-3

- All criteria of level 2 audit
- Economic evaluation and life cycle costing
- Depreciation cost analysis
- Net Present Value (NPV) and Internal Rate of Return (IRR) analysis.

3.2 Energy Efficiency

Energy efficiency is the most promising means to reduce greenhouse gases in the short term- said Executive Secretary of the United Nations Yvo de Boer in 2007. Later on, in the World Energy Outlook 2013, Executive Director of the International Energy Agency Maria Van Der Hoeven also aligned herself with the statement that Energy efficiency is the only fuel that simultaneously meets economic, energy security and environmental objectives [15].

Industrial energy efficiency is the key factor in the transition towards more carbon-neutral energy systems. While the energy efficiency potential area is quite vast, there are many barriers to energy efficiency. However, there are some cross-cutting energy efficiency options. Fig. 3.1 presents the cross-cutting energy efficiency measures for textile industries.

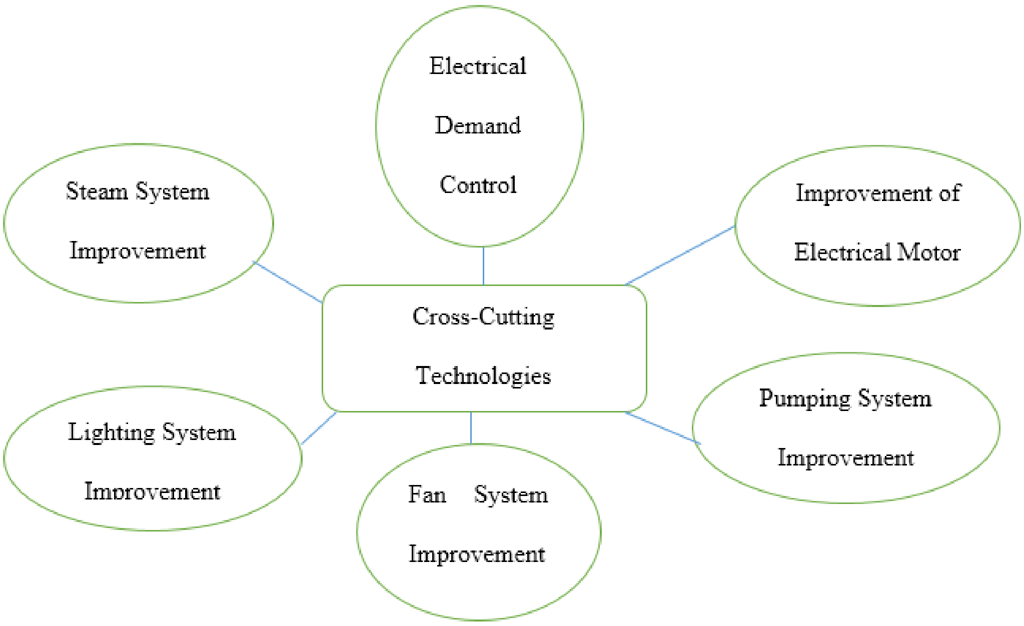

Figure 3.1. Cross-cutting energy efficiency measures [6]

Definitions of energy management vary in the literature. According to the German Federal Environment Agency, Energy management comprises the total of planned and executed actions in order to ensure a minimum of energy input for a predefined performance" [15]. The term energy management includes the planning and operation of production of energy and its consumption units. There are many factors related to successful energy management operations. The factors are policy, long-term strategy, energy cost allocation and monitoring, top level management support, pay-off criteria and energy manager as shown in Fig. 3.2.

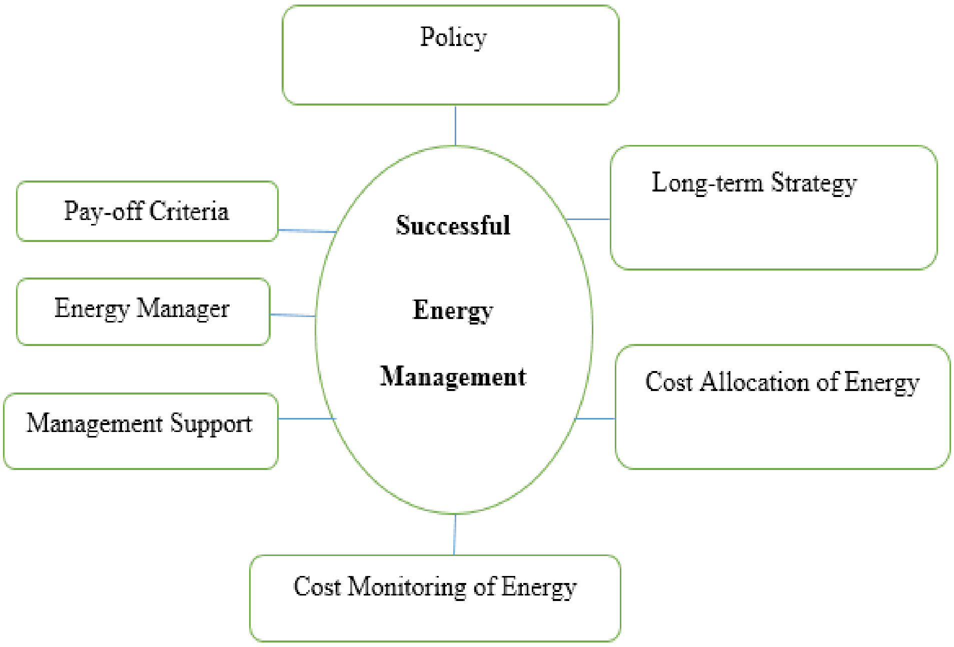

Figure 3.2. Criteria for a successful energy management system.

There are various energy efficiency opportunities in textile plants and RMG factories, many of which are cost-effective. However, even cost-effective options often are not implemented due mainly to limited information on how to implement energy-efficiency measures, especially given the fact that the sector is made up of units categorized as Small and Medium Enterprises (SMEs) i.e., their production capacity is less than 1 million pieces per month. Majority of the industrial enterprises in Bangladesh are in the SME size-class. These SMEs have limited resources to acquire Industrial Energy Efficiency information. SMEs require the most help in identifying and implementing energy efficient measures and the resulting improvement in competitiveness will help grow this important industrial sector.

Almost all Industrial Energy Efficiency literature on Bangladesh includes textiles and garment industry not because they are the most energy intensive but because of their size and scale. Some of the prescriptions are generic–for example changing lighting systems, switching to efficient boilers and industrial motors, Variable Frequency Drive (VFD), etc. This case-study will not make prescriptions as the interventions only but also tend to be feasible following investment grade audit at the factory level. However, best practices in Industrial Energy Efficiency experienced so far in the context of Bangladesh textile and garment sector are listed as:

- Installing Heat Recovery in Cloth Driers
- Using Servo Motors for Sewing machines instead of Clutch Plate motor in RMG factories
- Steam Management using Steam Traps and Condensate Recovery
- Combined Heat and Power Generation
- Using flue gas economizer to preheat feedwater before entering boiler
- Changing lighting systems in RMG factories to Light Emitting Diodes (LEDs)
- Insulation of pipes, valves, and flanges
- Improving power factor (PFI) in RMG factories.

3.3 Modelling of the Study

There are five types of strategies to pursue in any research. They are classified as the experimental approach, surveying, archival analysis, histories, and analysis of case study [16] this research was carried out as a case study considering the nature of the study. All the collected data of the industry is recent data (2018).

In this study a ready-made composite garment factory is audited to measure the energy efficiency. The aim of this work is to understand the energy consumption impact on production and find out the scope of energy efficiency improvement. Study shows that the washing plant consumes electricity, natural gas, steam, and water 15%, 10%, 48.9%, and 49% respectively of the entire factory. Various garment factories use a combination of electricity from the national grid and captive sources by using gas engines. Mostly uses natural gas engine generators for the most part of the energy requirement. Fig. 3.3 shows the conceptual energy uses of RMG industry.

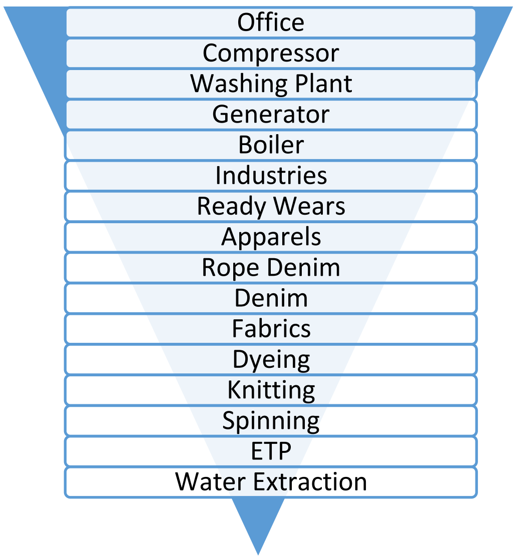

Figure 3.3. Conceptual Model for Energy Efficiency in RMG Factory

For the conceptual model of this study, it is identified the current status of electricity and gas supply in the RMG sector of Bangladesh. Implications of inadequate power supply on RMG Business. From the physical survey it is noticed that most of Ready-Made Garments factories have no reflection about the ratio of open space and built space. Several of the factories have less than 30-40% open green space and no consideration about the future expansion.

Most of the factories have no efficient indoor plumbing fixture and water harvesting system. There is less use of water that comes from ETP and no consideration about water efficient remodeling. By now, the building envelope serves multiple roles. It protects the occupants from changing weather conditions, and it plays a key part in meeting the occupants comfort needs. In Bangladesh even now there is no consideration about sustainable ventilation, lighting, building envelope, etc. From the field survey, it is noticed that most of the occupants who sit beside the evaporative cooler often suffer from various health hazards. Many factories are using LEDs in the sewing section for effective lighting. But here some problems are created. This is due to incorrect Color Rendering Index (CRI) of LED lights. Better to replace T12 by T5 FL lights with correct efficacy.

3.4 Data Collection and Analysis Method

In this study the data have been collected from field survey at utility and washing plant. process That is to find out whether there is any potential approach to apply energy efficiency and reduce consumption of water. Walk through assessment was considered to gain the process, practices and base line condition of the studied plant.

During the assessment, reviewed of production operation and supporting utility system such as gas engine generator, gas fired boiler, waste heat recovery systems, insulation systems, pumps, lightning systems and water treatment plant was carried out. Through field observations and interactions with plant personnel, opportunities for potential savings in electrical and thermal energy usage and improvement of process operations were identified. Water treatment plants were studied to understand and identify the possibility of improving the washing process and reduce water consumption.

To establish the baseline, historical data of all resources are required. To do this, measure and monitor all resource consumption (electrical and thermal) data of the wet processing units including water treatment plant. These collected data helps to create a resource map of energy and water sources. This resource map is used in the RMG processing facility analysis and develop an energy as well as water balance.

Conceptualization of the study: Identify measures to reduce end –use demand for energy and water; for example by improving equipment or system, improving process system,etc. Identify measures to improve the efficiency of utility service; for example by steam distribution system improvements, reduction of heat loss, water consumption reduction potential, use of high-efficiency luminaries/motors, etc. Also Identify measures to enhance heat recovery or heat generation efficiency and process.

For each saving opportunity that simplified through the project. Estimated the annual saving energy (kWh), annual natural gas saving (Nm^3) water saving, avoid water discharge, GHG emission (tCO_2) cost (BDT and USD) for the measure. Also estimated the project cost or cost of implementation and calculate the simple payback period.

Chapter 4

Data Analysis and Recommendations

4.1. Energy Study

The factory uses mainly gas engine generators for electrical energy. The commercial power from the grid is less than 1% and most of the power requirement is met from the gas engine generator as a captive source numerically it is about 99.5%.

The month-wise variation in electricity consumption is shown graphically in the Fig. 4.1.

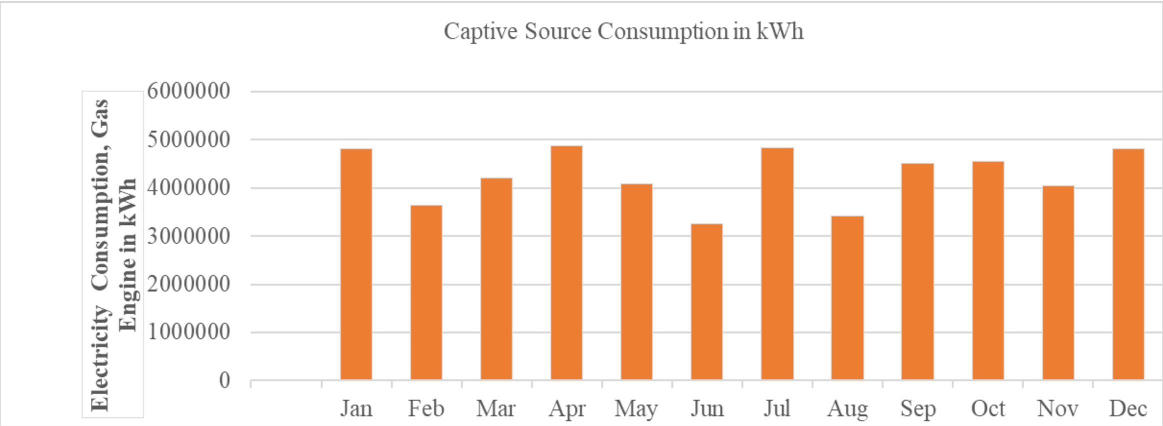

Figure 4.1. Plot of Electricity Consumption of 2018 from Gas Engine Generator of the factory

The common measures for the energy conservation and energy efficiency in the RMG industries are high-capacity utilization, fine tuning of equipment and technology up gradation and other kind of re-engineering initiatives. Figure 4.1 demonstrates total electrical generation from self-power sources which are gas engine generators. Data shows fluctuations on different months. January, April, July, and December have the highest generation. Also decrease pattern is observed from February to June. It shows, after January consumption decreases and from March it starts to increase. April shows the highest consumption peak. After that consumption starts to decrease and June shows the lowest consumption values. During these months from

February to June, data from Figure 4.2 shows opposite scenario. That means when the self-generation decreases, grid dependency increases.

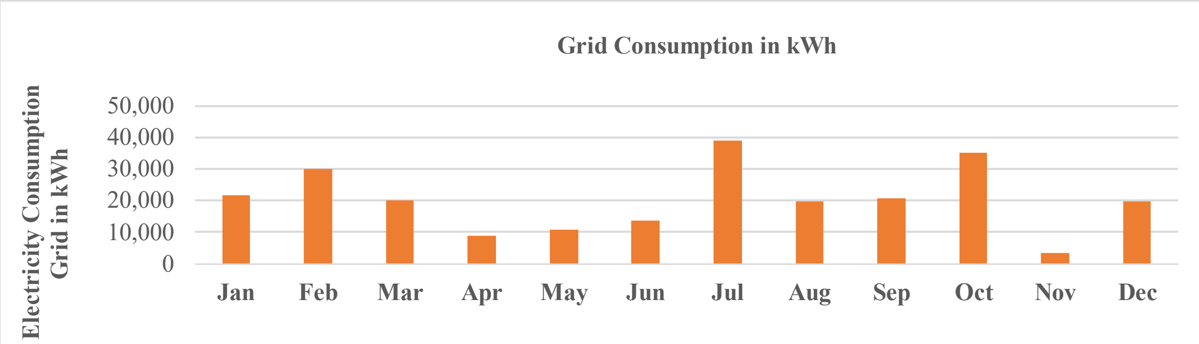

Figure 4.2. Plot of Electrical Consumption of 2018 from grid of the factory

Since energy management is relevant to a wide range of departments within a company, it is necessary to enhance the awareness, improve the knowledge and obtain the participation and cooperation of everybody involved in the production process. Figure 4.2 shows that grid power is the highest in July. Almost in the middle of the year, from the very beginning of the summer season, grid usage is increasing from April and reaches the highest peak in July 2018. Also, the graph shows the grid usage is minimum in November.

Due to its nature of operations, the share of lighting in electricity use is relatively high. It is important to re-examine whether the light source is utilized in the most efficient way and take electricity saving measures. The RMG industry uses a vast number of relatively small electric motors. While a conventional machine was driven by a single motor with the generated mechanical power transmitted to various parts of the machine in a collective manner, many modern machines utilize multiple motors with a control board controlling the movement of each motor, which is directly coupled to a machine part to drive it independently from others.

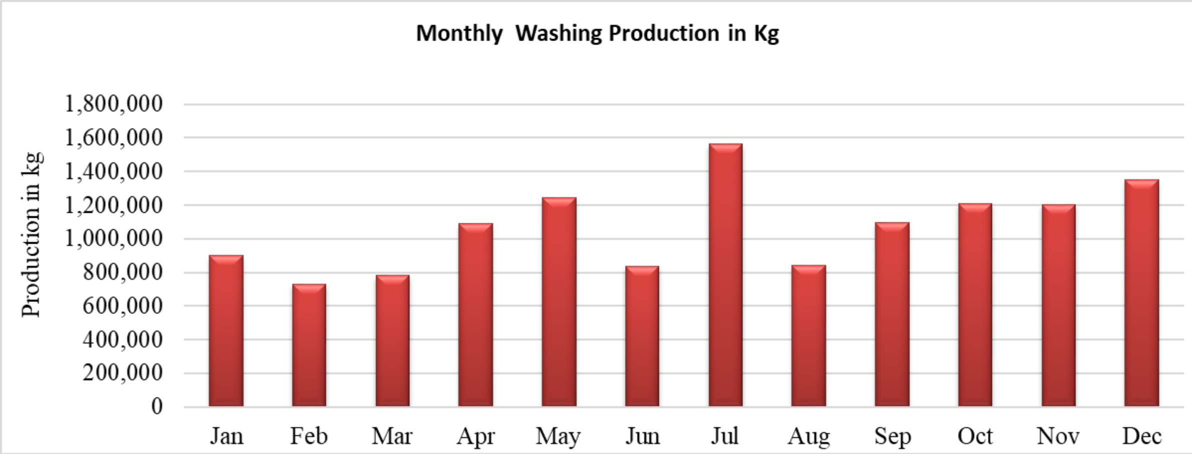

Figure 4.3. Plot of washed production (2018) from washing plant of the factory

Figure 4.3 shows the total washed products in kilogram. It shows that July has the highest production value. That is confirmed from the electricity consumption from grid and the self-generation values from Figs. 4.1 and 4.2. Also, it shows, production is moderately high from September to December and shows less fluctuations. During summer season, from April to July production fluctuates. But the starting three month of the year 2018 comparatively production is low.

4.2. Thermal Energy Study

Thermal energy in the form of steam is generated from boiler and thermic fluid heater. These equipment's raw materials is mainly natural gas. Steam generated is mainly utilized in process for generating hot water and for steam dryers. Table 4.1 shows the natural gas consuming equipment's in studied factory.

Table 4.1. Natural Gas Consumption equipment's

Equipment	Quantity (Numbers)	Output
Boiler	7	Heat/Stem
Generator	19	Power Generation
Stenter machine/Heat setting machine	4	Heat/Process
Thermo	2	Heat/Process
Dyeing Machine + Dryers	12	Heat/Process
Gas singeing + Gas Stove/Gas Burner	275	Heat/Process
Total	319	

Fig. 4.4 shows the month wise consumption of gas. It depicts the specific consumption that has a relation with the production volume. For the month of February 2018 when production volume is lowest, specific gas consumption is 4.60 Nm^3/Kg and when production volume is higher in the month of July 2018 specific gas consumption is down up to 2.67 Nm^3/kg. So it represents the lowest specific gas consumption for the month of July when production is highest. So, production is high, efficiency is high and gas consumption is low. Highest natural gas consumption in the month of January and lowest in June. The production volume is also depends on the nature of plant operation and types of goods. Those items of dresses as well as finished goods are needed for the winter season, it is made throughout the summer season for shipment before the winter period.

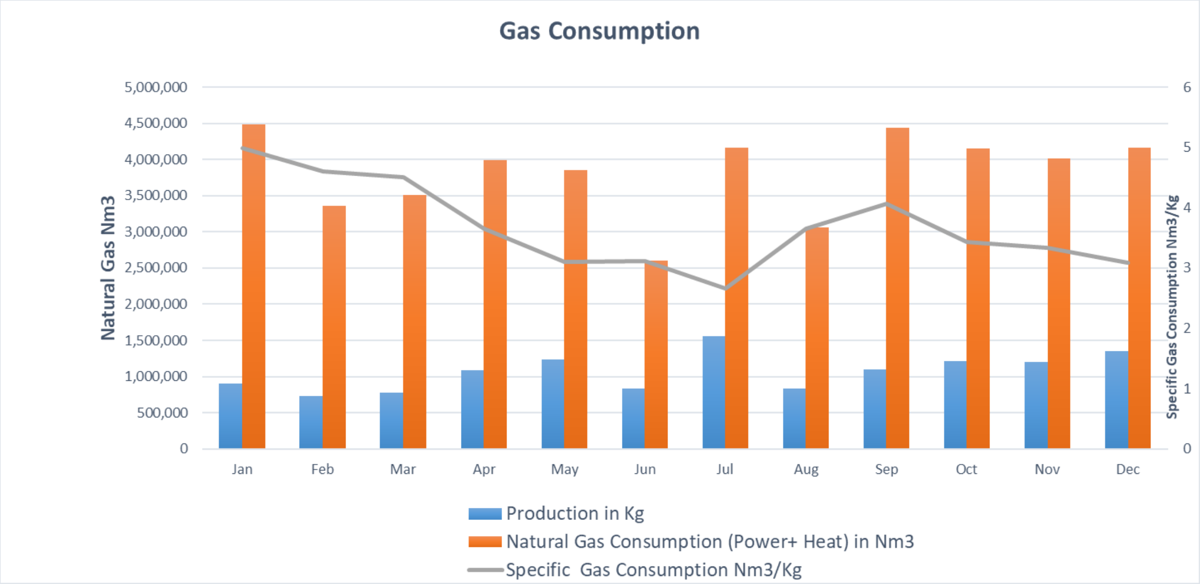

Figure 4.4. Plot of the Specific Gas Consumption of the factory from Gas Consumption (Heat +Power) right axis and Production in kg left axis during the months of 2018.

4.3. Annual Energy Consumption

Table 4.2 presents the total energy consumption data and the relevant tariff of the factory. Table shows the commercial electricity consumption 243,138 kWh which purchased at 8.80 BDT per kWh. Moreover, natural gas consumption for heat is 2,629,056 Nm^3/year and which is purchase at 10.70 BDT per cubic meter and natural gas for power generation is 19,162,319 Nm^3/year which costs 13.85 BDT per cubic meter. Natural gas tariff is different for power generation and heat production.

Table 4.2. Total Energy consumption and costing:

Resource	**Energy consumption**	**Energy Cost (USD)**	**Specific Energy Rate**
Electricity (Grid)	243,138 kWh	25,471 USD/y	0.105 USD/kWh
Natural Gas (Heat)	26,629,056 Nm^3/year	33,92034 USD/y	0.127 USD/Nm3
Natural Gas (Power)	19,162,319 Nm3/year [51,048,417kWh/year]	31,59,501 USD/y	0.165USD/Nm3

4.4 Water and Water Treatment Plant

Water is the most vital element among the natural resources and is crucial for the survival of all living organisms. Of the estimated 1.386 billion cubic kilometers of water available in the world, with 97.5 % being salt water and 2.5 % being fresh water [16]. Readily accessible water for human use is about 0.0007 percent of all the water on the planet. Although the total water available is sufficient to meet estimated demand at present, distribution is not uniform. America, Australia, and Oceania have the highest per capita water resources whereas Asia has far less. Asian countries must therefore think more seriously about conservation because the available per capita water is decreasing every year while the consumption has been growing at more than twice the rate of population increased [17].

Agriculture, fisheries, commerce, and navigation are all dependent on sustainable use of water resources. Deteriorating water quality has become a great concern, linked to population growth, untreated discharge of sewage, unplanned urbanization, and industrialization. Water is used extensively throughout textile processing, but it is not used efficiently. Average Bangladeshi textile production consumes 200-250 liters of water per kilogram (kg) of fabric production, nearly five times more than international best practices. The industry discharges 12.7-13.5 million m^3 of wastewater annually, representing 85-90% of the groundwater it extracts for fabric processing. Overall, 20% of freshwater pollution comes from textile treatment and dyeing [18].

The amount of water used varies widely in the industry, depending on the specific processes at the factory, the equipment used and the prevailing management philosophy. Cotton yarn and fabric require the largest amount of water. Conventional preparatory processes (de-sizing, scouring, bleaching, and washing) are highly water and energy intensive. Wastewater from dyeing creates the greatest pollution load. Water conservation techniques in textile processes would help to prevent pollution from this sector.

In the studied factory there are six submersible pumps and six river water pumps supplying the water requirements of process (washing and finishing, gas engines, boilers, denim section and other plants) and domestic use. River water pump basically is used during the rainy season to get hardness less water and each river water pump flow rate is 150 m^3/h. Others six deep pump are used during the dry session those flow rate is 200 m3/h. Drained water from washing machines is recycled from effluent water treatment plant in this factory. Water distribution are shown in Fig: 4.5.

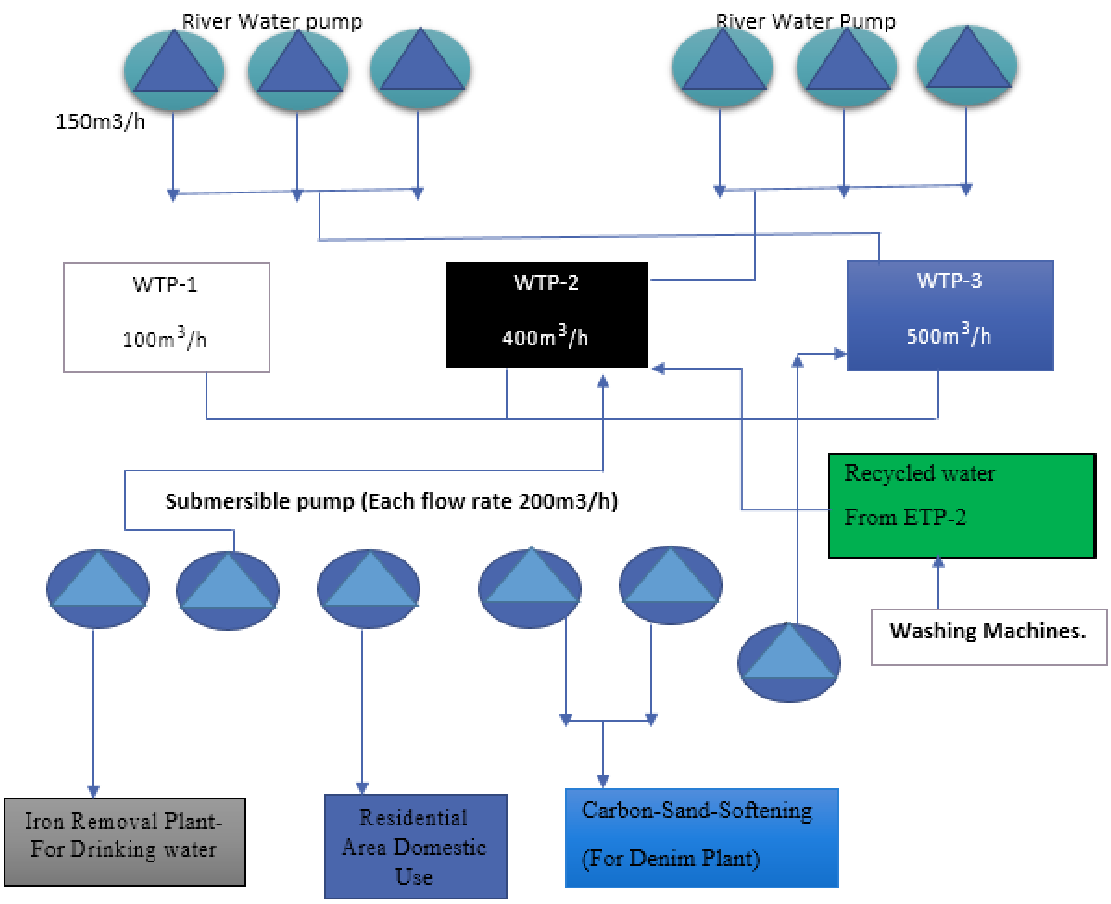

Figure 4.5. Water Distribution diagram.

From Fig. 4.5 softeners are installed only to meet zero hardness water requirements of boilers and gas engines. Installation details of submersible pumps and river water pumps are shown in Table-4.3.

Table 4.3. Pump Installation Details

Parameters	Unit	**River water**		**Submersible Pumps**				
		1-3	4-6	1	2	3	4	5-6
Flow Rate	m^3/h	150	150	200	200	200	200	200
Head	m	50	50	50	50	50	50	50
Motor Rating	kW	22	30	37.5	46.2	46.2	56.2	55
Quantity	numbers	3	3	1	1	1	1	2

Water consumption data in the year of 2018 of various sections has been received from the washing plant. Table -4.4 shows the baseline indicators for water consumption in the studied factory.

Table 4.4. Baseline indicators for water consumption

Resource	**Value (m^3)**	**Production(kg)**	**Key Performance Indicators**	
(Ground + Surface) Water	1,459,156	12,835,095	113.7	l/kg (Unit for KPI)
Recycled Water	499,089	12,835,094	38.9	l/kg (Unit for KPI)
Process Water	1,878,486	12,835,094	146.4	l/kg (Unit for KPI)

Transparency International Bangladesh (TIB) and Bangladesh Water Integrity Network (BAWIN) commissioned Environment and Resource Analysis Center (ENRAC) have conducted a study on the use and effectiveness of effluent treatment plants (ETP) in the garments industry of Bangladesh from a water sector integrity perspective and to make recommendations to improve governance to promote sustainable textile and RMG production in Bangladesh.

4.5 Recommendations

Recommendations and Cost Analysis of Utility:

Based on the practical analysis in studied factory, some of issues have been identified for energy efficiency improvement which are described in Table 4.5

Table 4.5. Utility recommendations for improvement

SL No.	Potential Area	Observations	Recommendations/ Remarks
1	Periodical Maintenance	It is observed and calculated that the logbook for energy consumption, expressed as an average specific fuel consumption 0.37 Nm^3/kWh which violates the generator operating catalog. Mentioned that the total annual Gas consumption from gas engine is 19,162,319 Nm^3 and Power generation is 51048,417 kWh.	It is recommended to take maintenance for spare parts (spark plug, lube oil, Different types of filters, etc.) as per catalog recommendation
2	Gas Engine	There is no heat recovery from 10 Gas Engines. Flue gas is released into the atmosphere at a temperature of 500-540^oC.	Recommended to recover this high-grade heat by installing EGB.
		There is no heat recovery from jacket water of Gas Engines from all the engines. Jacket water is at a temperature of 80-85^oC. This heat is un-utilized and is released through the cooling tower.	Recommended heat recovery from Jacket water for generating hot water.
3	Boiler and Steam System	At present flue gas from boilers is released into the atmosphere without any heat recovery. Economizers are installed in boiler house, but they have been bypassed. Flue gas is released into atmosphere at a temperature of about 210^oC	It is recommended to install an economizer for preheating feed water supplied to the boiler.
		Blow down is done manually at present. Blow down is done at 12times/day and the Blow down duration is 3 minutes.	Recommend installing auto blow down control system to reduce fuel and water losses due to manual Practice.
		Surface temperature of the steam header and steam valves is >130^oC.	Recommend insulating and hence reduce surface heat losses
4	River water pump	River water pump-B and pump-A are operating at 23m and 1m head respectively and delivering flow of 150m^3/h. Operating efficiency is 41.6% and 33.8% respectively.	Efficiency can be improved up to 70% either by replacement of pumps or by renewal of Pumps.
5	Lighting Retrofit	36w fluorescent lights are installed at different locations. These lamps are operating for about 16hours/days.	It is recommended to replace these lamps by LED. This will reduce power consumption by up to 50%.

In the powerhouse of the factory, in 2018 average specific fuel consumption is 0.37 Nm^3/kWh. In this situation per unit (kWh) cost is 5.20 BDT as on present natural gas government price of 13.85 BDT/Nm^3. According to the manufacturer manual by doing periodical maintenance this value could be 0.35 Nm^3/kWh. It is mentioned in the catalog that gas consumption is 0.33Nm^3/kWh. By replacing minimum number of old spare parts of the generators, annual saving could be 10, 20,968.34 Nm^3 of natural gas. This reduced amount of gas is equivalent 2199 t CO_2 emission to the atmosphere. Table 4.6. Shows the cost analysis.

Table 4.6. Saving projection on natural gas consumption.

Parameter	Unit	Existing	To be	% Of Natural gas reduction	Annual resource saving	Annual energy cost savings in BDT
Natural Gas (Power)	Nm^3/kWh	0.37	0.35	5.40	10,20,968 Nm^3	14,140,406
Investment in BDT 50,00,000						
Simple payback period is 4.4 month						
GHG Emission	kg CO_2	0.796	0.753		2199tCO_2	-

(Emission factor natural gas kg of CO_2/Nm^3 is 2.154)

In RMG plant, most of the sewing machine is clutch types and their number is 235.these sewing machines consume around 2,03,040 kWh per year. These types of sewing machines production capacity is also too low compared to the servo type sewing machines. The factory should replace the clutch type sewing machine with new energy efficient servo type sewing machines. Low power consumed servo motors are used with modern machines. That is operated only when the operator needs to sew. These machines have particularly good starting torque and immediately provided power to the machine needle. Although initial investment would be high, but the saving can have a significant positive impact on the factory's energy cost. Table-4.7 represents the saving and cost benefit assessment of sewing machines.

Table 4.7. Saving and Cost benefit assessment for providing the Servo Motor at Sewing Machine.

Parameter	**Units**	**Values**
The number of M/Cs	Nos	235
M/C rating	kWh	0.250
Annual power Consumption (at the rate (12h/dayx288 Days/Year)	kWh	235 x0.25x12x288 =203,040
Annual saving 60 % for servo motors	kWh	203,040x0.6=121,824
Annual monetary Saving (@ BDT 5.20/kWh for GEG BDT 8.80 kWh for REB)	BDT	121824x(5.20x0.995 +8.8x0.005) =6,35,678

During the study and investigation in the factory, 36 W tube-lights with conventional ballast are installed at many locations in the unit and these lamps are running for about 16-18 hours. It is recommended to replace existing 36 W tube lights by LED lamp. LED lamps would consume less power, and savings to the tune of 50% can be achieved. Table 4.8 shows comparisons of various energy saver lamps.

Table 4.8. Comparisons of various lamps

Type of Lamp	**Diameter of lamp (mm)**	**Lumens/Watt**	**Typical Life(hr)**	**Color Rendering (%)**
T12	38	60	5,000	65
T8	26	68	8,000	72
T5	16	104	20,000	85
LED	18/22	104	50,000	80

The cost-benefit analysis of the studied factory is as shown in the Table 4.9 as a practical study on a RMG factory. From this Table it is evident that it will save 82,944 kWh energy annually. It is equivalent to about USD 5000. The probable payback time would be 7 months.

Table 4.9. Saving and Cost benefit for energy efficient tube lights.

Parameter	**Unit**	**AS IS**	**TO BE**
Type of Fixture		**FTL**	**LED**
Type of Choke if Applicable		Electronic	Electronic
Type		36W	18W
Rated Power of Fixture	Watt/Unit	36	18
Consumption of Choke		6	0
Operating Power	Watt/Unit	42	18
Operating Days per Year	d/y	288	288
Operating Hours per day	h/d	16	16
Annual Energy Consumption	kWh/y	145,152	62,208
Annual Energy Saving	kWh/y		82,944
Equivalent NG Saving	Nm^3/y		31,181
Cost of NG (Power)	BDT/Nm^3		13.85
Annual energy cost savings	BDT/y		4,31,844
Investment	BDT		2,55,000
Simple Payback Period	Months		7

The induction motors are used broadly at different level. These levels are classified on the basis of their efficiency as per the international efficiency level 60034-30-1[19]. Based on the efficiency levels, the induction motors are classified into 4 categories which are IE1, IE2, IE3 and IE4. The IE1 motors invention as the standard efficiency range. The IE2 motors invention as the High-efficiency range. The IE3 motors invention as the premium efficiency range. The IE4 motors invention as the super-premium efficiency range. The efficiency range of each motors shows that the efficiency of the next series is better than the previous series [19]. The studied plant has around 66 numbers of old IE1/IE2 classes motors with a total rating of 800 kW with average efficiency around 48%. By replacing old IE1/IE2 class motors with energy efficient IE3 class motors, a lot of energy can be saved. If the IE1/IE2 classes motors with IE3 Class motors will increase the efficiency to 93.5%. Table 4.10 shows the saving analysis of IE3 Class Motors.

Table 4.10. Saving and cost benefit for IE3 Class Motors.

Parameter	**Units**	**Values**
Number of motors	-	66
Efficiency of old motors	%	48
Efficiency of New motors IE3, motor loaded as 75 % of rated load.	%	93.5
Total rating of the motors (around)	kW	800
Saving per year operation (@ (16h/dayx288 Days/Year)	kWh	(800 x (0.935-0.48) x 16 x288) =1677312
Annual monetary Saving @BDT 5.20 per kwh for GEG, BDT 8.80 kWh for REB	BDT	1677312 * (5.20x0.995 +8.8 x0.005) = 8752214
Investment @ BDT 2500 Per kW as per present market Price.	BDT	20,00,000
Payback Period	Months	3

It was observed that 10 out of 19 numbers of gas engine generators flue gases into the atmosphere at a temperature of 500-540^{o}C without any heat recovery. Exhaust Gas Boiler (EGB) is recommended to be installed at the outlet of the gas engine to recover heat content in the flue gas. Further at the outlet of EGB, economizer can also be installed. Final flue gas temperature can be 120-130^{o}C. Table 4.11 shows the saving analysis of the exhaust system of the gas engines. It shows if EGB is installed, it will reduce GHG emission by 1400 tCO_2 annually.

Table 4.11. Saving and cost benefit for installation of exhaust gas boiler for gas engines.

Parameter	Unit	Values
Temperature of flue gas (Engine)	°C	540
Expected flue gas temperature	°C	130
Temperature difference of the flue gas	°C	410
Fuel consumption in Gas Engine	m^3/h	1,500
Actual Load on Engine	%	55%
Calculated load on Engine	%	90%
Stoichiometric ratio of fuel to flue gas, relished into atmosphere at 23.2% of inlet air. (Flue gas per m^3 of natural gas**).**	Nm^3	17.2
Calculated the flue gas flow rate	m^3/h	42218
Density of flue gas	kg/m^3	0.80
Specific heat of the substance	kCal/kg/°C	0.26
Heat Loss	kCal/h	36,00,367
Steam Saving= (Heat loss * engine load)/2651(Steam Enthalpy)	kg/h	1222.3
Operating hours (24 x 288)	Hours/y	6912
Steam saving (1222.3*6912)	kg/y	8448570
Cost of waste heat recovery system for 1 Mw Gas Engine	USD	110,000
Financial saving (average cost of Steam 676 BDT/Ton)	BDT	57,11,233
	USD/y	67,990
Payback Period	Month	19
Steam Savaging equal to natural gas (stem to fuel ratio around 13 kg/Nm^3)	m^3/y	6,49,890
GHG emission saving (CO2 emission factor 2.154 kg/Nm^3 natural gas)	tCO_2	1400

It is observed during the visit that the back side of a boiler (12Ton/hrs.) is not properly insulated. In this situation a significant amount of energy is being wasted through heat radiation. The back surface of the boiler should be insulated with proper insulating materials (Ceramic wool/ ceramic fiber.). Table 4.12 shows the cost and benefit analysis.

Table 4.12. The cost and benefit analysis for boiler back side insulation system

Parameter	**Unit**	**Values**
Ambient temperature	°C	29
Surface temperature during audit	°C	127
Surface temperature after installing proposed insulation	°C	80
Surface Area	M^2	66
Reduction in heat lost through surface	kW Kcal/h	26 =26 x860=22,360
Natural Gas Calorific value	$Kcal/Nm^3$	8400
Boiler Efficiency	%	75
Natural Gas Saving	Nm^3/h	(22,360)/ (0.75x8400) =3.54
Natural Gas Saving/Year (@24 x288)	Nm^3/y	3.54x 24x 288=24,466
Financial saving (@10.7 BDT/Nm^3)	BDT/y	2,61,782

During the field visit, it was observed through measurement of flow, head, and power that the efficiency of existing river water pumps was in the range of 33-41.5% and these pumps are running for about 10-12 hours. It is recommended to renovate or replace existing river water pumps. Table-4.13 sows the cost and benefit analysis.

Table 4.13. Saving and cost benefit for replacement of river water pumps by energy efficient pump.

Parameters	Unit	Pump B Set	Pump A Set
Existing Water Flow	m^3/h	150	150
Existing Pump Head	M	23.0	11.0
Existing Pump Power	kW	32.2	21.7
Pump Efficiency	%	41.5	33.8
Proposed Flow	m^3/h	182.0	208.0
Proposed Head	m	22.5	15.0
Proposed Efficiency	%	70.0	70.0
Proposed Power	kW	19.2	10.5
Saving Potential	kW	13.1	11.2
Saving Potential	kWh/y	45,273.6	38,707.2
Saving Potential	Nm^3/y	17,020.15	14,551.57
Cost of NG	BDT/Nm^3	13.85	13.85
Saving Potential	BDT/y	2,35,729	2,01,539.24
	US$/y	2,806.29	2,399.27
Investment	BDT	1,50,000	1,50,000
	US$	1,807*	1,807
Simple Payback Period	Months	7.5	8.5

* 1USD=BDT83 in 2018

In this project during the study period, it was observed that washing plant process operation need to optimize by removing the existing process. There is no control of water level and process is carried out separately. According to logbook at present 146.4 liters of water is **co**nsumed to produce 1 kg of washing product. To consider baseline water consumption a combined process is recommended where all steps of washing (De-sizing, enzyme wash and bleaching process) in one bath can be completed to save water. If we can do so, then according to utility mapping, 10% water will be saved. At the same time consumption of electricity and gas will reduce by 3% each.

Table 4.14 shows in detail the cost benefit analysis of resources. In this process, exact cost benefit calculation is difficult as there are multidimensional impacts of saving in all resources: improvement in productivity, reduction in water, chemical and energy, etc. It can be estimated only on normative basis as follows:

Table 4.14. Saving and Cost benefit for processing performance improvement (combined pre-treatment)

Parameters	**Unit**	**Values**
Present annual production	kg	1,28,35,095
Present baseline process water consumption	Liter(L)/kg	146.4
Baseline power consumption	kWh/kg	4.00
Baseline NG fuel consumption	Nm^3/kg	3.56
Considering combining pretreatment processes for optimization		
Operating Days in year	d	288
(1) Water savings potential @10%	L/kg	14.60
Annual Water saving potential	m^3/y	1,87,848
Annual water cost saving for washing process@6x(2+4) BDT/m^3 [BDT 2 for deep water & BDT 4 for river water]	BDT/y	11,27,088
(2) Electricity consumption reduction @ 3% [Annual electricity consumption from gas engine 51,048,417 kWh and Grid 243,138 kWh.]	kWh/y	15,38,746
Equivalent NG Saving for power generation.	Nm^3/y	5,69,336
Estimated annual electricity cost saving @13.85 BDT/Nm^3	BDT/y	78,85,304
(3) NG consumption reduction for heating @3 % [Annual Natural gas consumption for heating 26,629,056 Nm^3/y**]**	Nm^3/y	7,98,871
Estimated annual NG cost saving @10.70 BDT/Nm^3	BDT/y	85,47,920
Estimated total saving potential (water+ electricity+ and heat)	**BDT/y**	1,75,60,312
	US$/y	2,11,570
Estimated investment for suitable chemicals for optimization of process.	BDT	80,00,000
	USD*	96,386
Simple Payback Period	Months	5.5

*Conversion rate 1USD=BDT83

4.6. Chapter Summery

It is found from this study that natural gas saving up to 10, 20,968 Nm^3 and 2,199 tons of CO_2 emission will be reduced per year if periodic maintenance of in-house generators are done as per manufacturers catalogue.

For sewing machines, if it uses servo type motors instead of clutch types then 1,21,824 kWh energy will be saved annually, which is around 60%. If 66 numbers old IE1 and IE2 class motors are replace by IE3 class, then 16,77,312 kWh energy will be saved per year. Using Exhaust Gas Boiler (EGB) can save natural gas up to 6,49,890 Nm^3/year and steam saving 8,44,48,570 kg/year. By back side insulation In the studied four 12 ton fired tube boilers, if back side is insulated 24,466 Nm^3/year natural gas can be saved. For river water pumps, if energy efficient pumps are used then electricity 83,981 kWh/year would be saved. Replacing 36W tube lights by 18W LED lamps which will save 82,944 kWh/year. Doing the process optimization of washing by removing de-sizing or combining de-sizing, enzyme wash, and bleach process, 1,87,848 m^3 /y,15,38,746 kWh/year, and 798871 Nm^3/year respectively of process water, electricity and natural gas for heating can be saved. The impact on the baseline indicators of different resources with annual saving projection are shown in Table 4.15. .

Table 4.15. Impact on the baseline indicators and saving projection for the studied project.

	Baseline Performance Indicators				Annual Saving Projection		
Resource	Unit	**Existing**	**To be**	% Impact (Reduction)	Impact (Reduction)	Unit	BDT
Power	kWh/kg of Production	4	3.73	[4-3.73] =0.27/4x100= 6.75	32,20,826	kWh	1, 77, 88,29
Natural Gas (Heat + Power)	Nm^3/kg of Production	3.56	3.37	[3.56-3.37] =0.19/3.56x100=5.33	24,94,451	Nm^3	2,66,90,626
Process Water	L/kg of production	146.4	131.70	[146-131.7] =15/146x100 =10	187,848	m^3	11,27,088
GHG emission	tCO_2	98,634	91,332	7.40	7,302	tCO_2	

GHG emission reduction is a must to installation of heat recovery equipment's on gas engines, ensure periodical maintenance as per catalog, and reducing most of the thermal losses, insulation, lighting optimization, energy efficient pumps, Process optimization by combining process steps.

From Table 4.15 the measurable saving potential of resources for the electricity is 6.75 %, natural gas 5.33%, and process water 10%. Monetary saving for electricity, natural gas and process water are BDT 1, 77, 88,29, BDT 2,66,90,625.7, and BDT 11, 27,088 respectively.

Chapter 5

Conclusions and Future Work

The objective of this work was to study different aspects of energy efficiency and energy management practices of a RMG industry in Bangladesh. The outcome of this work involved applying our method to study the barriers, drivers, and energy management practices in the context of an Asian developing country which is an example for the RMG industries. In this project work, some observations are placed such as improve our regular maintenance activity, replacing old technology to new technology and new innovations. The study shows that the main barrier for the 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 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 imported technology is expensive, the industry owners may not have the mindset and capital to spend for the energy efficiency purpose. The outcomes of the study could be the benchmark for fine-tuning a customized policy for the 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.

As a conclusion of the study, some of its findings should be implemented in RMG industries of Bangladesh. These are like electrical modification, thermal loss reduction, water treatment plant improvement and its energy diversities with implementation, changing conventional lights to proper LED lights and so on. The whole study has discussed the exciting new developments in the framework and the policy steps that would make electrical integration to the benefits of green growth into the economic success that Bangladesh has been enjoying.

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Annexure.

Annexure-1

Heat Recovery from Generator Exhaust

Temperature of flue gas (Engine) 540°C (Based on Practical Reading) released into atmosphere.

Expected flue gas temperature to install Exhaust Gas Boiler (EGB) at the outlet of gas engine and further at the outlet of EGB, economizer can also be installed. Final flue gas temperature after economizer can be 130°C.

Temperature difference of the flue gas (540 -130) °C =410°C.

Fuel Consumption in Gas Engine 1500 m^3/h, Real load on Engine 55%, and Designed load on Engine 90% (Based on logbook data & machine catalog).

Now, **the Flue gas per m^3 of Natural gas**= 17.2 [Stoichiometric ratio of fuel to flue gas at oxidation reaction of methane

$$CH4+2(O_2) \longrightarrow CO_2 +2(H_2O)$$

Molecular weight of methane = 12.01 x 4 x1.008=16.042

And Molecular weight of oxygen =16 x 2=32 (Atomic weight of reaction: Carbon (C)=12.01, Oxygen (O) = 16, and Hydrogen (H) = 1.008)

Now, oxygen fuel mass ratio = (2 x 32 / 16.042) or 3.991 kg

As we know, 23.2 % of Air is actual O_2, So Air required (3.991 x100)/23.2) or 17 kg to burn 1 kg of fuel]

Calculated flue gas flow rate= 1500 x 17.2 x (0.9/0.55) or 42218 m^3/h [Fuel Consumption for the generator x Flue gas per m^3 of Natural gas x (Real load/ Designed load on engine)]

Density of flue gas = 0.80 kg/m^3, Specific heat of the substance = 0.26 Kcal/Kg/ °C

Heat loss = (410 x 0.26 x 0.80 x 42218) or 3600367 Kcal/h [Temperature difference X Specific heat of the flue gas X density of flue gas X flue gas flow rate

Annual running hours of engine = (288 x 24).

Steam Saving = (3600367 x 0.9) / 2651 or 1222.3 kg/ h [(Heat loss x Designed load on Engine)/ Steam Enthalpy]

Yearly Steam Saving = 8448570 Kg/y [1222.3x6912]

Annexure- 2

Monthly Gas Consumption

Month	NG (Power) in (Nm^3)	NG (Heat) in (Nm^3)	Power Generation(kWh)	Specific Fuel Consumption Nm^3/kWh	Specific power Generation kWh/Nm^3
Jan	1,831,538	2,649,612	4,819,837	0.380	2.632
Feb	1,383,113	1,978,508	3,633,779	0.381	2.627
Mar	1,604,051	1,909,356	4,215,189	0.381	2.628
Apr	1,826,825	2,159,861	4,870,435	0.375	2.666
May	1,550,540	2,300,106	4,080,355	0.380	2.632
Jun	1,218,565	1,388,876	3,260,749	0.374	2.676
Jul	1,832,974	2,328,176	4,823,617	0.380	2.632
Aug	1,296,290	1,765,198	3,411,314	0.380	2.632
Sep	1,732,648	2,709,099	4,502,698	0.385	2.599
Oct	1,514,535	2,641,504	4,559,600	0.332	3.011
Nov	1,539,709	2,471,748	4,051,026	0.380	2.631
Dec	1,831,531	2,327,012	4,819,818	0.380	2.632
Total	19,162,319	26,629,056	51,048,417	0.375	2.664
	Total (Power& Heat)	**45,791,375 Nm^3**			

Annexure- 3.

Monthly Electricity Consumption:

Month	Electricity Consumption, Grid (kWh)	Electricity Consumption, Gas Engine(kWh)	Production in kg (Denim Washing)	SPC (kWh/Kg)
Jan	21,786	4,819,837	899,618	5.381
Feb	30,013	3,633,779	730,238	5.017
Mar	20,136	4,215,189	780,670	5.425
Apr	8,801	4,870,435	1,089,870	4.476
May	10,748	4,080,355	1,241,991	3.293
Jun	13,656	3,260,749	836,119	3.916
Jul	39,034	4,823,617	1,561,211	3.114
Aug	19,813	3,411,314	839,800	4.085
Sep	20,694	4,502,698	1,094,065	4.134
Oct	35,228	4,559,600	1,210,192	3.796
Nov	3,473	4,051,026	1,203,113	3.370
Dec	19,756	4,819,818	1,348,208	3.589
Total	243,138	51,048,417	12,835,095	3.996
G. Total	**51,291,555 kWh (Self + Grid)**			

Annexure-4

Monthly Water Consumption Details

Month	Ground Water (m^3)	Surface Water (m^3)	Recycled Water (m^3)	Process Water (m^3)
January	136,351	0	48,360	158,706
February	117,324	0	39,808	138,657
March	149,728	0	41,836	169,250
April	124,530	0	43450	194,389
May	37,902	88,807	42,640	168,008
June	27,386	60,290	32,944	122,214
July	41,191	94,588	46,147	155,989
August	28,428	66,661	32,926	113,525
September	39,070	90,338	45347	151,090
October	39,070	89,943	45,130	193,815
November	38,386	79,148	41,943	157,600
December	37,225	71,132	38,558	155,243
Total	818,249	640,907	499,089	1,878,486

Annexure-5

Reduced Gas Consumption to Ensure Periodical Maintenance as assessed by the manufacturing manual.

Yearly power generation by gas engine= 51,061,255 kWh

Yearly natural gas consumption for power generation=19,162,319 Nm^3 [N= Normal Pressure & temperature]

Average Specific fuel consumption by gas engine. = (19,162,319 /51,061,255) or 0.375 Nm^3/ kWh.

Manufacturing Catalog declared average specific gas consumption initially is 0.33 Nm^3/kwh. But considering the engine operational length it can be around 0.35 Nm^3/ kWh, if periodically spare parts and measure overhauling is done [It is assumed on good practice].

Studied factory natural gas can be saved if periodically maintenance action is accomplished thus, annually resource will be saved = (19,162,319 - 18,141,350.66) or 10, 20,968 Nm^3 [Existing specific gas consumption is 0.37 Nm^3/ kWh and recommended 0.35 Nm^3/ kWh, then natural gas consumption for power generation will be 51,061,255 x 0.356 = 18,141,350.66Nm^3]

Monetary saving = (10, 20,968 x 13.85) or BDT 14,140,406 or $USD 168,338

[Natural gas tariff rate BDT 13.85/ Nm^3 for power generation]

To replace the old spare parts with new one and yearly overhauling cost would be required as an investment around BDT 50 lac.

Simply payback period = (50 lac /11, 78367) or 4.4 month

[Monthly saving BDT (14,140,406 /12) or BDT 1178, 367]

Green gas emission will be reduced from atmosphere= (1020, 968 x 2.154) or 2199165.07 kg or 2199 tCO_2 [Emission factor natural gas kg of CO2/Nm3 -2.154].

Annexure-6

Light (Illumination) inventory in Wash Plant

Location	Type of Lamp	Wattage (W)	Quantity (numbers)	Remarks
Washing Plant -3	36 W FTL	36	148	
	Energy Light	40	5	
Washing Plant -4	36 W FTL	36	101	
	Energy Light	40	4	
	Incandescent	40	7	
Washing Plant -6	36 W FTL	36	69	
	Energy Light	20	5	
	Energy Light	40	6	
Hi-Fashion	36 W FTL	36	77	
Washing Plant-7	36 W FTL	36	72	
Dry Process Unit-1	36 W FTL	36	180	
	Energy Light	40	6	
P. P Unit	36 W FTL	36	31	
Washing Plant-8 & 9	36 W FTL	40	72	
	Energy Light	105	10	

Annexure-7

Energy efficient lighting System

Existing rated power of florescent tube light (T12) with ballast (36 + 6) W or 42 W/Unit

[The lamps are running for about 16-18 hours and operating days per year 288, Total light quantity 750 Nos]

Annual Energy Consumption, kWh/y = 145,152 [(42 x 16 x 288 x 750)/100]

Recommended LED light rated power= 18 W/Unit.

Annual Energy Consumption, kWh/y = 62,208 [(18 x 16 x 288 x 750)/100]

Annual Energy Saving = **(145,152 -62,208) or** 82944 or 83 kWh.

Equivalent natural gas saving = (82944 /2.66) or 31,181 Nm^3/y [Existing Specific gas consumption in the studied factory is 0.375 Nm^3 / kWh, so 1 Nm^3 is equal to 2.66 kWh.]

Annual energy cost savings = (31,181 x 13.85) or 4, 31,844 BDT. [Natural gas tariff rate BDT 13.85/ Nm^3]

Investment according to the present market price, LED 18 W light = (750 x 340) or 255,000 BDT. [Price per Unit BDT 340 & Quantity 750 Nos]

Simple Payback Period = (255,000 /35987) or 7 Month [Monthly saving 4, 31,844/12 or BDT 35987].

Annexure-8

Summary of All Process Machines in Wash Plant

Wash Plant Name	Wash machine Name	Wash machine Number	Load Capacity/Mac (KG)	Dryer machine Name	Dryer machine Number	Load Capacity/Mac (KG)	Hydro Extractor Name	Hydro Extractor Number	Load Capacity/ Mac (kg)
Wash Plant -03	Danish	16	220	Danish	6	250	Danish	2	250
	Topes a	2	220	Asian Star	7	100	GFK	1	120
				Green Mac	2	90	Green Mac	3	90
Wash Plant -04	Topes a	7	240	Topesa	6	200	Topesa	2	350
Wash Plant -06	Topes a	10	220	Topesa	4	300	Topes a	1	350
	Asian Star	4	150	Danish	1	250	Asian Star	1	150
				Asian Star	1	100			
Wash Plant -07	Danish	12	220	Danish	6	250	Danish	3	250
	Asian Star	2	150	Asian Star	1	100			
Wash Plant -08	Danish	8	220	Danish	4	250	Danish	2	250
				Asian Star	1	100			
				Ngai Shing	1	90			
Wash Plant -09	Danish	3	220	Danish	3	250	Green Mac	1	90
	Asian Star	3	150	Ngai Shing	2	90	Ramson Wash	2	90
	Green Mac	1	150						
Hi-Fashion	Brongo Wash	8	220	Danish	6	250	Danish	2	250
Total Machine		76			51			20	

Annexure-9

List of IE1 & IE2 induction motors with electrical load.

Total Power (kW)	**No. of Motor**	**Section**
140	7	Utility (Generator)
140	12	Wash plant 3
170	10	Wash plant 4
104	13	Wash plant 6
98	7	High Fashion
88	9	Wash Plant-8
80	8	Santex dryer

Annexure- 10

Efficiency developed by using IE3 Classes induction motors instead of old IE1 classes' motors.

IE1 Motors quantity around 66 Nos in studied factory.

Name plate specifications: 415 V, 39A (Delta) and 22.5 A (Star), 22 Kw (30 HP).

Field measured data = 407 V, 19 A.

P= (1.735 x407 x 19 x0.8) = 10.733 kW

Efficiency (%) = (10.73/22x100) or 48 %

Total rating of the motors (around) =800 Kw.

Efficiency of New motors IE3, motor loaded as 75 % of the rated load= 93.5 %

Saving per year operation=(800 x (0.935-0.48) x 16 x288) = 1658880 kWh

[Operation of the motor per annum 4608 Hours]

Annual monetary saving = (1658880 x (5.20x0.995+8.8 x0.005) or TK 86 55670

[BDT 5.20 per kWh for GEG, BDT 8.80 kWh for REB]

Investment @ BDT 2500 Per kW as per present market

Price. = 20 Lac

Payback Period = 3 Months.

Technical data

IE3 premium efficency cast iron motors

Technical data for totally enclosed squirrel cage three phase induction motors

IP 55 - IC 411 - Insulation class F, temperature rise class B, IE3 efficiency class according to IEC 60034-30-1:2014, IS 12615:2018

4-Pole, TEFC, 415V, 50Hz, IP55, IC411, Ambt. 50 deg, Rise Class B (70 deg)

Output KW	Frame Size	Speed r/min	Efficiency			Power factor cos Ø	Current		Torque			Moment of inertia $J=1/4GD^2$ kgm^2	Weight kg
			Full load 100%	3/4 load 75%	1/2 load 50%		I_n, A	I_s/I_n	T_n Nm	T_s/T_n	T_b/T_n		
1500 r/min = 4 poles				415V, 50Hz									
0.37	M2BAX71MLA4	1415	77.3	76.0	67.0	0.65	1.02	4.6	2.5	2.5	2.8	0.00098	12
0.55	M2BAX80MC4	1435	80.8	80.0	75.0	0.70	1.35	6.0	3.7	2.5	2.8	0.00195	17
0.75	M2BAX80MLA4	1445	82.5	81.1	77.1	0.70	2.05	4.5	5.0	3.5	3.9	0.00309	20
1.1	M2BAX90SB4	1435	84.1	83.7	81.0	0.70	2.60	6.0	7.3	3	3.7	0.00397	22
1.5	M2BAX90SLA4	1431	85.3	85.2	82.9	0.75	3.50	6.0	10.0	3.5	3.9	0.00486	25
2.2	M2BAX100LB4	1445	86.7	86.9	85.1	0.74	4.8	7.0	14.5	2.9	3.7	0.00919	34
3.7	M2BAX112MLA4	1450	88.4	88.5	87.0	0.76	7.7	7.5	24.4	3.3	3.9	0.01542	50
5.5	M2BAX132SMA4	1460	89.6	90.6	90.2	0.79	10.8	7.0	36.0	2	3.0	0.03505	72
7.5	M2BAX132MLA4	1462	90.4	90.9	90.3	0.75	15.4	7.0	48.8	2.1	3.2	0.04108	84
9.3	M2BAX160MLJ4	1470	91.0	90.9	89.5	0.77	18.5	7.5	60.4	2.7	3.5	0.105	130
11	M2BAX160MLA4	1470	91.4	91.5	90.5	0.78	21.6	7.5	71.5	2.6	3.2	0.11	134
15	M2BAX160MLB4	1470	92.1	92.2	91.3	0.80	28.8	7.5	97.4	2.6	3.4	0.135	159
18.5	M2BAX180MLA4	1475	92.6	93.0	92.5	0.80	34.7	7.5	119.8	2.5	3.3	0.219	192
22	M2BAX180MLB4	1475	93.0	93.5	93.0	0.79	41.5	7.5	142.4	2.9	3.5	0.243	205

Annexure- 11.

Chapter summary calculation:

1. Total Baseline power (Self+ Grid) = 51,291555 kWh.

Baseline annual product of denim goods=12, 835095 Kg

Now Specific baseline power consumption kWh/kg of denim production = 4.

After all recommendations regarding the electrical energy, it can be reduced as well as energy savings =3420826 kWh. Estimated value BDT 1,77,88,295.

[As on 5.20 BDT Per unit generation cost].

Thus, electrical energy consumption will be = (51291555-3420826) =47870729 kWh

After all, specific power consumption to be kwh/kg of denim=47870729/12835095=3.73 % . Percentage impact (reduction) = (4-3.73) =0.15/4*100= 6.75%

2. Natural gas consumption for heating and Power= (1,91,62,319+2,66,29,056) =4,57,91,375 Nm^3

Now, baseline fuel consumption=45791375 Nm3/1,28,35,095 kg of denim production=3.56

After all, given recommendation fuel consumption will be reduced as well as gas savings= (10,21,224+7,98,871+6,49,890+24,466) =24,94,451 Nm^3, estimated value is BDT 2,66,90,626

Thus, Fuel consumption will be= (4,57,91,375-24,94,451) =4,32,96,924 Nm^3

Specific fuel consumption to be kWh/kg of denim goods=4,32,96,924/1,28,35,095=3.37

Percentage impact (Reduction) = (3.56-3.37) =0.19/3.56x100=5.33%

3. Process water: Baseline process water consumption is 1,878,486 m^3

Baseline annual production of denim goods = 12,8,35,095 kg

So base line specific process water consumption l/kg=18,78,486/1,28,35,095=0.146^{m3}/kg of goods or 146.4 liters /kg.

Now, after all recommendation to combined pretreatment process instead of existing process what is carried out separately, Therefore, here exact saving assessment or cost benefit is difficult to calculate as there are multidimensional impact of saving in all resources, improvement in productivity, reduction in water and energy, etc. It can be estimated only on normative basis. So, allowing normative basis water saving potential @ 10%, it can be 18,78,486x0.1=1,87,848 m^3, estimated value is BDT 11, 27,088.

Thus, process water consumption will be = (18,78,486-87,848) =16,90,638 m^3. Now specific process water consumption will be m^3/kg =16,90,638/1,28,35,095=0.131 or 131.7 liters/kg of denim goods.

Percentage impact (reduction) = (146-131.7) =15/146x100=10%

4. GHG emission for natural gas:

Baseline, the quantity of GHG emission what has been released into atmosphere by use of natural gas.

Existing natural gas for (Heating and Power) =4,57,91,375x2.15

[GHG emission conversion factor of natural gas, Kg of CO_2/Nm^3 of natural gas=2.154]

So, the measures of CO_2 emission =98,451 tCO_2

After all recommendation the CO_2 emission it can be reduced around for natural gas =

24, 94,451x2.1545=5,373tCO_2

And for electricity 34,20,826x0.564 [GHG emission conversion factor of electricity, kg of CO_2/Nm^3 of natural gas 0.564= 1,929 tCO_2

Total=5,373tCO_2+1929 tCO_2 =7,302 tCO_2 emission will be reduced from atmosphere.

Percentage Impact (reduction) = 7,302/98,451x100=7.41%.