Evidence-based energy conservation potentials and policy implications in the textile and garment industries of Ethiopia

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Detailed Energy Audit and Policy Implications in Ethiopian Textile and Garment Industry

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Abstract

Energy is one of the primary inputs in textile and garment processing industries and its cost share is reported between 5-10 % of the total production cost in developed countries but is far higher in developing countries. . Textile and garment sector is one of the fast growing economic sectors in developing nations like Ethiopia have very limited scientific data particularly in the industries where there is no clear and concise information about the energy consumption pattern as well as the energy conservation practices. Thus the main purpose of this study was to understand the energy usage pattern, conservation practices, and to recommend evidence based conservation measures and policy directions. The aim of this comprehensive study was therefore to conduct a detailed energy audit in MAA garment and textile industry, in the town of Mekelle, at the northern part of Ethiopia to analyze the major energy consuming areas and implementation of evidence based energy conservation solutions. This was achieved through primary and secondary data collected from the company. Accordingly, a total of 15 energy conservation recommendation was identified and proposed for possible implementation that have the potential to save a total cost of around $ 214600 per year but requires nearly $ 98300 investment leading to a payback period of 5.5 months. These recommendations include in the utilities of boiler, Thermic fluid heater, air compressors and lightings. In addition, key policy directions are recommended to support the sectors to reduce their energy consumption.

Keywords: Textile and garment industry; Energy audit; Utilities; Energy savings; Policy implications

1. Introduction

Ethiopia is well positioned to become the textile and apparel-manufacturing hub of Africa. Because of suitable agro climatic condition for cultivation of surplus raw material, lower labor cost, shifting of international textile industries to least developed countries and availability of international market privilege through free trade agreement [1]. Because of this reason textile and garment sectors are mainly focused 100 % to be export oriented and become competitive at international market [2]. Next to beverage industry, leather industry, textile and garment industry is the third largest manufacturing industry in Ethiopia. In Ethiopia, 52 factories are located in Addis Ababa out of 189 large and medium scale garment factories. Textile and garment industries in Ethiopia are uncompetitive in domestic and international market. Low levels of productivity and under capacity utilization are the cause for un-competitiveness [3][4].

Energy is one of the key needs of human beings, and is the base for the world's development and will continue to grow to the minimum by one-third by 2035 [5]. The rapid economic growth in Africa has been generating high level of demand for energy. Meanwhile the recent volatility in fuel prices has encouraged emerging nations in Africa especially countries like Ethiopia to focus on energy security and reduce dependence on fossil fuels[6][7].Energy conservation is an essential step towards overcoming the problem of energy crisis and environmental degradation. Energy audit at commercial level targets is to reduce energy cost by reducing operational expenses and increasing profit [8] [9]. Most of the textile and leather industries are not implemented energy management scheme particularly in developing countries such as Ethiopia mainly due to the lack of enforcing mechanisms for the implementation of energy-efficiency measures.[10].

In the Textile and garment industrial sectors the main reasons for higher specific energy consumption are obsolete technologies in the operation, part load utilization, lower automation as well as embedded system, and lack of knowledge/awareness among the employees. Reducing wastage and losses, improving efficiency through technological upgrades and optimization of utilization and maintenance, can conserve the wastage of energy from the industries. [11] [12]. Therefore, improving energy efficiency in the industrial sector is being prioritized in many developing countries. The United Nations Industrial Development Organization (UNIDO) benchmarked the energy efficiency potential for some industrial sub-sectors in 2010 by looking at sector specific indicators of performance in terms of energy per unit of output [13].

The scope of this article is to empirically verify the relationship between energy consumption and economic analysis. This study provides energy analysis for the annual year between Dec 2017 and Nov 2018. The time scope of this study can be valid up to 2022 with respect to production details, investment on utilities, electricity bill and specific energy consumption. In addition, key policy directions are recommended based on the facts obtained from the case studies to enforce conservation measures at the Ethiopian industries. Results of this research will have significant contributions and co-benefits for both the research communities, industries and policy makers as it provides clear recommendations for the implementation of conservation measures in order to improve the international competitiveness of the textile industries of other African nations that are trying to expand their industries to this sector.

The importance of the study was to achieve and maintain optimum energy procurement and utilization, throughout the organization as to minimize energy costs / waste without affecting production and quality, but increasing profitability in long run. During preliminary energy audit (PEA) it was observed that in the energy share, the consumption of thermal and electrical energy is about 92.56 % and 7.44 % respectively whereas in the cost share the thermal and electrical cost is observed to be 70.3 % and 29.7 % respectively. In order to diagnosis the plant energy situation therefore we recommended it was mandatory to conduct detailed energy conservation audit in MAA garment. The objective of this energy conservation assessment was to assess the types of energy resources being extensively utilized, the technologies implemented, and the energy consumption with regard to the energy required by different processes of Textiles production to develop conservation measures

This paper is structured in different sections with section two detailing the methods employed in this research while section three presents the current energy profile of the company. Section four provides details of the research results with real time data based energy conservation recommendations. Section five presents details of the conclusions and key policy implications that can support industries to implement energy conservation measures.

2. Methods and Materials

2.1. Scope and description of the study area

Case study was conducted at MAA garment and textiles factory, which is emerging to be one of the leading apparel manufacturers not only in Ethiopia but also in East Africa and beyond. The company is located in Mekelle, which is the capital of the Tigray regional state in the Northern part of Ethiopia. Recently, the company has been observing increased specific energy consumption per unit of fabric and is aware about the challenges of huge energy losses and its consequences on the international competitiveness of their products. Therefore, detailed energy audit has been conducted in order to diagnosis the wastage of energy and energy conservation measures were developed and recommended. The company's key processes include: Blowing, Carding, Spinning, Knitting, Dyeing and Drying, and Garment. In addition, policy directions are suggested to support the industries and policy makers to make changes in the attitudes of all stakeholders towards energy conservation and management.

2.2. Methods

Most of the methodologies employed in this study were physical measurement in all utilities involved in the different processes. In addition to that, secondary data was collected from the company personnel such as bills of electrical, fuel, production details and to understand the pattern of energy consumption and its associated cost. Detailed energy audit has been carried out in two phases in MAA Garment, phase I and II.

2.2.1. Pre Audit Phase-I

The preliminary energy assessment study has been completed in MAA garment and actions and conclusions of walk through audit are listed below:

- Evaluated the major attention area
- Estimated the scope for energy and cost saving
- Identified immediate energy savings of nil or low investment.

From the preliminary study it was estimated that power and diesel consumption can be saved to an extent of not less than 18 – 20 % and 35 – 40 % respectively

2.2.2. Detailed Audit Phase-II

During the detailed energy audit, the entire production process was assessed through observations, interviewing of companies personals to understand the complete process of the company. The following activities have been undertaken during the detailed energy auditing:

- Performance evaluation of boilers and thermic fluid heaters
- Performance prediction of air compressors
- Measurements on loading of motors, pumps and fans etc
- Illumination survey and Lux level measurements at various locations
- Estimate energy conservation opportunities in the above areas

2.3. Data processing

After measurements taken from each process, the data was synthesized, analyzed and interpreted. The economics analysis of energy savings potential were calculated by the following expressions with respect to each utility as given below:

2.3.1. Compressors

Anticipated power consumption in bandwidth reduction can be calculated by the following equation

$$\left[\frac{P2^{0.36}-1}{P1^{0.36}-1}\right] \qquad \text{--- (1)}$$

where P_2 and P_1 is cut off and cut in pressure respectively

Leaks are the main cause of energy waste in compressed air systems. During the leakage test the following procedure was adopted as expressed below:

Step 1: Compressor was made to run at the actual operating pressure for the required task.

Step 2: All the utility points were closed and compressed air was allowed to flow to the respective sections.

Step 3: During the flow the compressed air on / off load time was noted and recorded

Step 4: The task conducted in step 3 was repeated three times to get the average values for accurate result

Quantity of air leakage in percentage of the total compressed air is estimated using the following equation.

$$\%\ \text{of Air leakage quantity} = \left[\frac{load}{(load+No\ load)}\right] x100 \qquad \text{--- (2)}$$

2.3.2. Boilers

Reduction of operating pressure in the boiler, the percentage of fuel savings can be calculated by the following expression:

$$\left[\frac{h_{9\ bar} - h_{7.5\ bar}}{h_{9bar}}\right] x100 \qquad \text{--- (3)}$$

where'h' is enthalpy of respective steam pressure

Heat Lost from the bare hot water pipeline is calculated by the following heat transfer formula:

$$h\ xA\ x\ \Delta T \qquad \text{--- (4)}$$

where h = Convection heat transfer coefficient ($W/(m^2K)$)

A = Surface area of the pipe line (m^2)

ΔT = Temperature difference (^0C)

Waste heat recovery from the flue gas and heat content in the hot waterof the boiler can be calculated by the thermodynamic relation given below:

$$Q_{fg} = m_{air} x Cp_{air}\ x\ (T_{hot\ air} - T_{amb\ air}) \qquad \text{--- (5)}$$

$$Q_{water} = m_w x Cp_w\ x\ (T_{hw} - T_{cw}) \qquad \text{--- (6)}$$

In each part of economic analysis, for calculation purposes it has been taken up as the average power cost of \$ 0.0275/ kWh and the working period of Spinning & knitting, Dyeing and Garment plants considered are 8450 hours, 7200 hours and 2400 hours respectively.

2.3.3. Motors

Actual readings of voltage, current, power factor formotors, fans, blowers, compressors and lightings were taken by using of power analyzer.

2.3.4. Economics analysis

In this study the energy economics analysis were obtained by simple payback period (SPP) method. In economic analysis, SPP as a first approximation: the time (number of years) required recovering the initial investment (First Cost), considering only the net annual saving that represents the returns on investment. The simple payback period is usually calculated as follows:

$$Simple\ payback\ period = \frac{First\ cost}{Yearly\ benefits - Yearly\ costs} \qquad --(7)$$

It is very well-known fact that a widely used investment criterion, the payback period seems to offer the following advantages such as it is a measure of a project's capital recovery, not profitability. It discriminates against projects, which bring substantial cash inflows in later years but not in earlier years. Despite its limitations, it may be useful for evaluating an investment. The investment cost was calculated which includes acquisition charges such as cost of brokerage, fabrication and installation, operation and maintenance, duties, interest rate, etc. Besides savings ratio was calculated by dividing annual energy savings by increase annual income of the plant. In this study, investment cost was projected put together, as included all parameters mentioned in the economics analysis part.

2.3.5. Materials used

- Power analyzer to measure electrical power
- Infrared analyzer for temperature measurement
- Digital Pitot tube for pressure measurement
- Ultrasonic detector for leakages
- Ultrasonic flow meter was applied to measure the water flow rate to the boiler
- Digital Anemometer to measure air velocity
- Non contact type infrared thermometer to measure temperature
- Digital pressure manometer to measure pressure
- Flue gas analyzer to measure flue gas composition

3.0. Benchmarking key results of textile industries in Ethiopia

Energy efficiency benchmarking mainly comprises in comparing the measured energy consumption with reference consumption of other similar type of companies or generated by simulation tools to identify excessive or unacceptable running costs. In this work the benchmark on the performance of textile and garment factories in Ethiopia was focused. The energy cost-share in Ethiopian cotton textile industries accounts for an average of 16.01 % of the total production cost of a fabric product. Spinning plant consumes the greatest share of electricity 36.8 % followed by weaving and utility energy consumption was 28.5 % and 26.1 % respectively. The specific electrical energy used for woven fabric manufacturing changes between 3.47 kWh/kg and 6.02 kWh/kg and for yarn changes between 2.65 kWh/kg and

4.58 kWh/kg. Spinning consumes the greatest share of electricity (36.8%) followed by weaving (28.5%) and utility (26.1%) [14].

4. Energy Profile of the Company

4.1.Energy utilization status of MAA Textiles Industry

To understand the energy consumption status of the factory, bills of both thermal and electrical energy for the plant were collected for the year Dec 2017 – Nov 2018. Highlights of the energy profile of the plant are summarized in Table **1**.

Table 1: Energy profile for the year Dec 2017 – Nov 2018

No	Particulars	Specifications
1	Transformer capacity of the plant	5250 kVA
2	Overall Electrical Energy Consumption	EPCO: 8,548,584 kWh / y
		DG Set: 12,720 kWh / y
3	Electricity Bill	$223,530 / y
4	Base Cost of Electricity (EPCO)	$ 0.0255 / kWh
5	Average Cost of Electricity (From bill)	$ 0.0275 / kWh
6	Landed cost of HSD	$ 0.507/ lit
7	Average Power Factor achieved	0.95
8	Specific Energy Consumption	5.25 kWh / kg of yarn and fabric
9	Specific Energy Consumption	0.84 kWh / kg of dyed yarn fabric

Total electricity consumption of the plant for the period Dec 2017 – Nov 2018 was 8.5 Million kWh. Energy usage pattern is given in Table 2 and distribution of energy and cost share for entire factory is graphically illustrated in

Figure 1. The result shows that the energy share for electricity and thermal is 7.4 % and 92.6 % respectively whereas cost shares for electrical and thermal is 29.7 % and 70.3 % respectively. It was revealed that thermal energy is extensively utilized in the textile unit.

Table 2: Energy usage pattern for the period Dec 2017 – Nov 2018

No	Energy source	Type of energy	Unit	Annual consumption (lit)	Direct energy equivalent 10^5 MJ / y	% Share	
1	EPCO	Electrical	kWh	8548584	30.774	7.32	7.433
2	DG		kWh	12720	0.457	0.10	
3	Steam boiler & Thermic fluid heater	Thermal (HSD)	lit	1096379	388.59	92.47	92.56
4	DG		lit	1080	0.383	0.09	

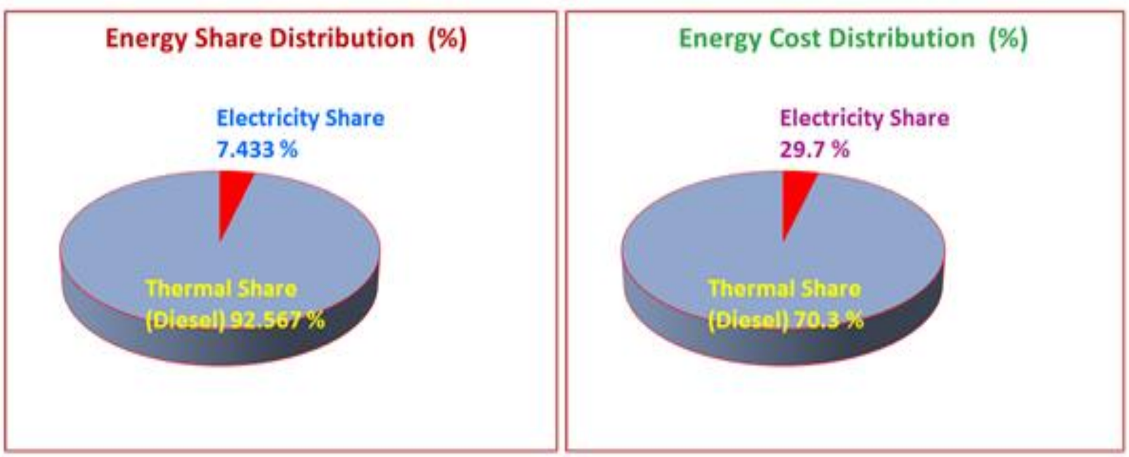


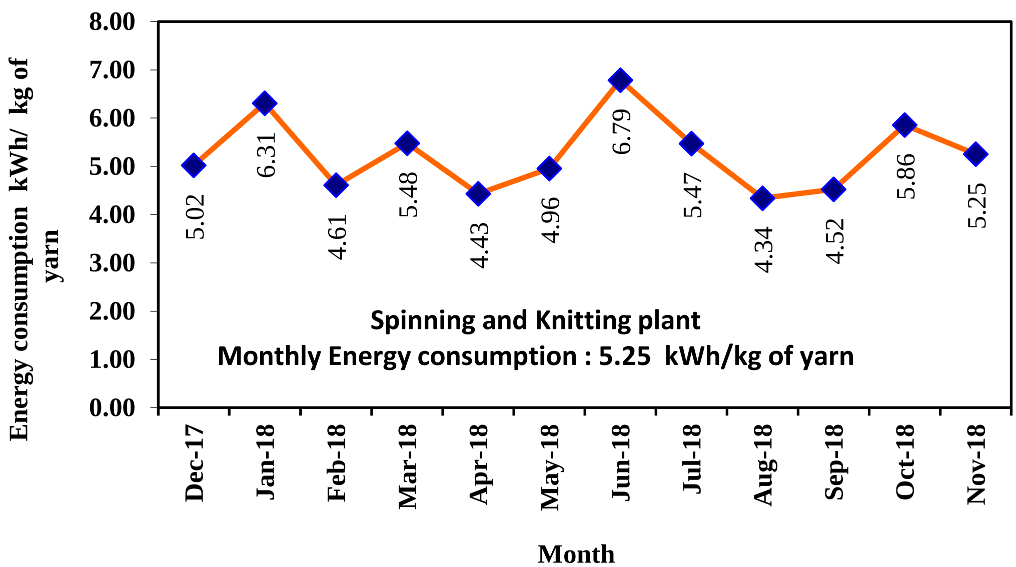
Figure 1: The distribution of energy and cost share

4.2.Specific energy and production cost

The electricity Bill details for the year Dec 2017 – Nov 2018 was collected and the variation in all the parameters is analyzed monthly wise. The specific energy consumption for spinning and knitting plant details are tabulated in Table 3. In the spinning and knitting plant, the average unit consumption and production, cost per month has been observed to be 5.25 kWh and $ 0.14 per kg of yarn as depicted in Figure 2.

Table 3: Specific energy consumption for spinning and knitting plant

Month	Production-kg	Power consumption (kWh)	kWh/kg of Yarn
Dec-17	144514	726000	5.02
Jan-18	103022	650040	6.31
Feb-18	104057	480000	4.61
Mar-18	96299	527820	5.48
Apr-18	113671	504000	4.43
May-18	130772	648000	4.96
Jun-18	88401	600000	6.79
Jul-18	101995	558000	5.47
Aug-18	121610	528000	4.34
Sep-18	137926	624000	4.52
Oct-18	106528	624000	5.86
Nov-18	123345	648000	5.25
Average	1372140	7117860	**5.25**



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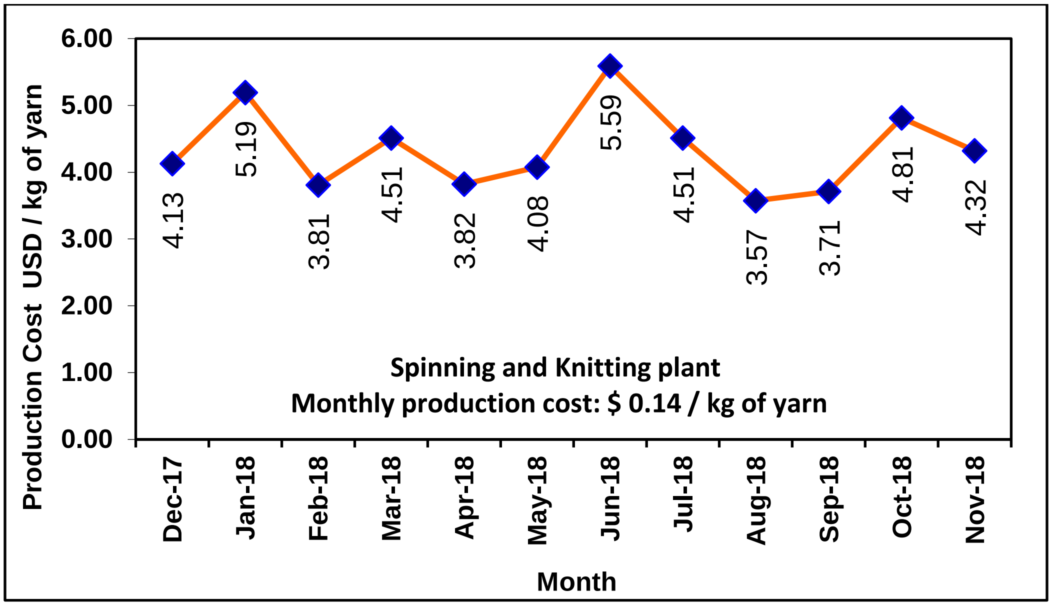
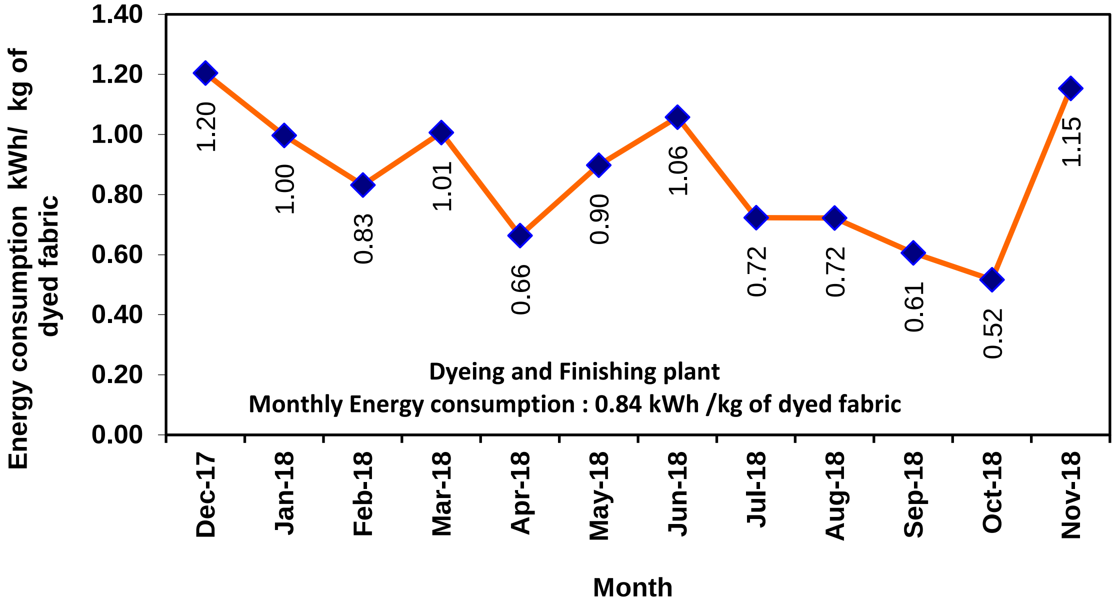


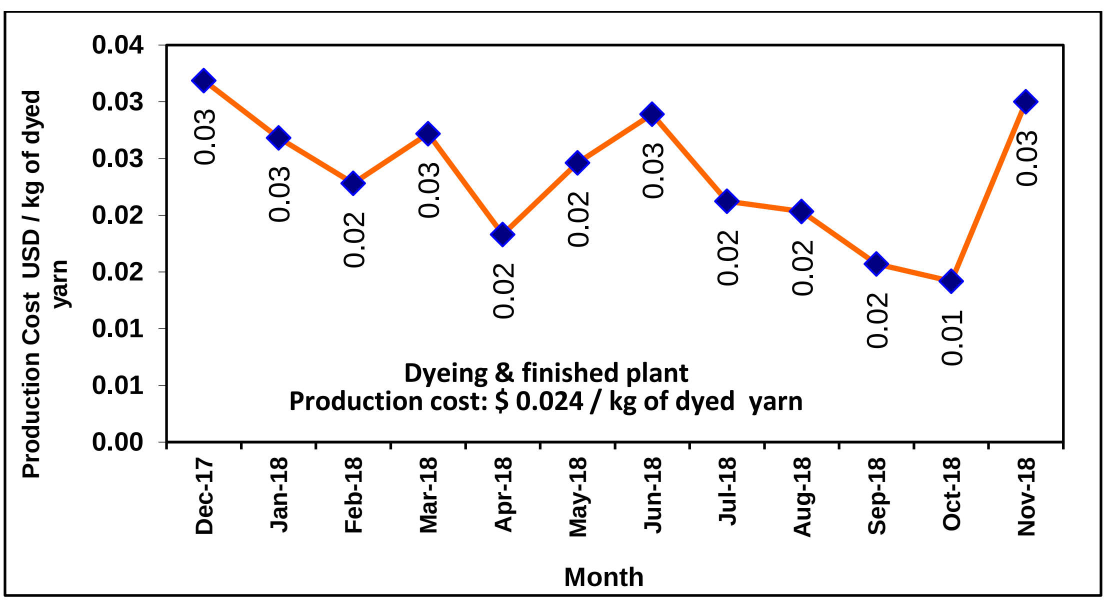
(b)

Figure 2: Spinning & Knitting plant (a) Energy consumption (b) Production cost

Similarly in dyeing plant the average unit consumption and production cost per month was recorded about 0.84 kWh and $0.024 per kg dyed fabric as shown in Figure 3 and specific energy consumption for dyeing plant details are shown in Table 4.



(a)



(b)

Figure 3: Dyeing plant (a) Energy consumption (b) Production cost

Table 4: Specific energy consumption for Dyeing plant

Month	Production-kg	Power consumption (kWh)	kWh/kg of dyed

			yarn
Dec-17	77235.5	93000	1.20
Jan-18	79762	79500	1.00
Feb-18	77517	64500	0.83
Mar-18	65590	66000	1.01
Apr-18	85949	57000	0.66
May-18	65195	58500	0.90
Jun-18	53873	57000	1.06
Jul-18	62240	45000	0.72
Aug-18	74775	54000	0.72
Sep-18	141146	85500	0.61
Oct-18	113248	58500	0.52
Nov-18	98788.5	114000	1.15
Average	995319	832500	**0.84**

5. Results and Discussions

5.1. Energy saving potential in boiler

MAA garment has two fire tube boiler fired by diesel for supplying steam at 8 - 10 bar for dyeing plant and one boiler is kept standby. During the audit, it was observed that currently the steam boiler is being loaded to only 885 - 1086 kg per hour against a designed capacity of 3 ton per hour (36 % loading) with maximum capacity of 12 bar pressure. Besides the plant has one thermic fluid heater having capacity of 2,000,000 kcal per hour with permissible working pressure of 10 bar for Stenter machine. The oil consumption was estimated as 103 liters per hour assuming that the price of diesel per liter is $ 0.507 and the operation period of the boiler is 5200 hours per annum.

5.1.1. Reduction in operating pressure

The existing pressure setting in the boiler was recorded as between 8 and 10 bar (average 9 bar) while the maximum steam pressure required for the process is in the range of 5.5 to 6 bar. This indicates that steam was generated at a higher pressure than required by the process, which leads to higher diesel consumption. Hence, it is recommended to operate the boiler pressure between 6.5 and 8 bar (average 7.5 bar) at boiler house. This would bring in notable savings in fuel with nil investment. As a result, more than $1370 can be saved annually by making the stated pressure setting corrections.

5.1.2. Effective condensate recovery

At present steam is used direct and indirectly in dyeing vessels for hot water generation. The condensate from dyeing vessels returns to a feed water tank. But condensate pipeline is not fully immersed in the water tank as shown in Figure 4.

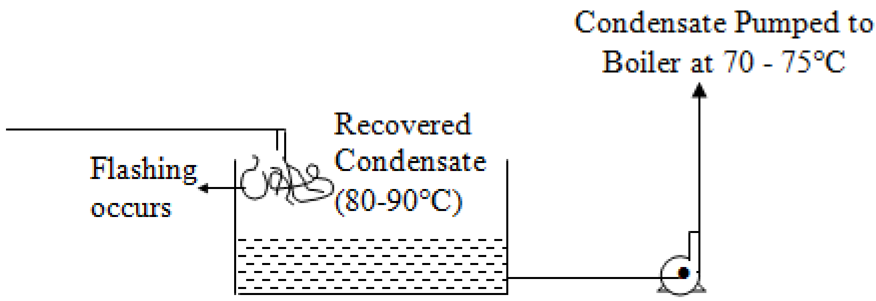


Figure 4: Existing condensate pipeline system in the boiler house

As the condensate return pipe is not fully immersed, a considerable amount of condensate is flashed as vapors into the atmosphere leads to high loss of thermal energy. Therefore, it was recommended to immerse the condensate pipe deep inside in the tank in order to effect proper heat recovery. For this purpose the condensate pipe line can be modified with an investment of $ 212. As a result of proper mixing of condensate with feed water, the fuel consumption can be saved 69 700 liter per annum and thereby possible cost savings of $ 34250 with payback period of less than one month.

5.1.3. Proper insulation of bare feed water pipe lines

In the Boiler house, it was observed that at the bottom of the feed water supply tank, 2 inch size mild steel pipe is connected and carrying hot water to feed water pump was not insulated and left bare at a distance of 13 meter. The entire hot surface of this bare pipeline varied from 60 - 65 ^{0}C results in considerable heat loss to the surroundings. Hence, it was recommended to insulate the left over part of hot water pipelines with an investment of $ 90 with a simple payback period of 5 months to minimize the convection heat loss and thereby cost savings $ 206 can be achieved.

5.1.4. Fuel additives for improvement of combustion of fuel oil

It is known that combustion of furnace oil (FO) or high speed diesel (HSD) is not effective due to their properties. The combustion of firing of the fuel oil can be enhanced by adding fuel additives. These fuel additives work by reducing the size of the fuel droplets through proper atomization thereby resulting in increase in total surface area. This in turn increases the combustion efficiency. The advantages of addition of fuel additives are includes ensure complete combustion, prevents pitting and corrosion of metallic components, quicker starting and smoke emissions. Hence, it is recommended to add fuel additives in requisite quantities to diesel for firing in boiler, thermic fluid heater and DG sets. The best fuel additives for diesel such as stanadyne, diesel kleen, lucas fuel, red line and opti-lube are available in the market. The anticipated fuel savings is about 2 % in high-speed diesel. From the economic analysis it was found that more than $10800 per year can be saved with investment of $ 16600 with payback period of less than 19 months.

5.1.5. Installation of Recuperator for heat recovery

In general, nearly 35 % of the input energy goes as a waste in the flue gas to the atmosphere, which could be easily utilized for pre-heating of the inlet combustion air. It is general principle that every 21°C rise in inlet air temperature reduces fuel consumption by 1 % [15][16]. During the energy audit, it can be observed that flue gas leaves the boiler as well as thermic fluid heater (TFH) at a temperature of around 190 ^{0}C and exhausted to atmosphere. Atmospheric air at temperature of 24 ℃ supplied to the furnace by FD fan into the furnace of the boiler and thermic fluid heater for combustion. Therefore it was recommended to install an recuperator alongside of the steam boiler and TFH. The proposed layout of installation of air preheater for boiler and TFH is shown in Figure 5.

It was noticed that heat gained by pre heated air was estimated as 0.2 million kJ per hour and raise in temperature was around 92^{0}C. Therefore fuel savings possible by preheating the inlet air through the outgoing hot flue gas would be around $26,000. Investment required for recuperator with ceramic plate & installation is around $28,000, which results to payback period of less than 13 months.

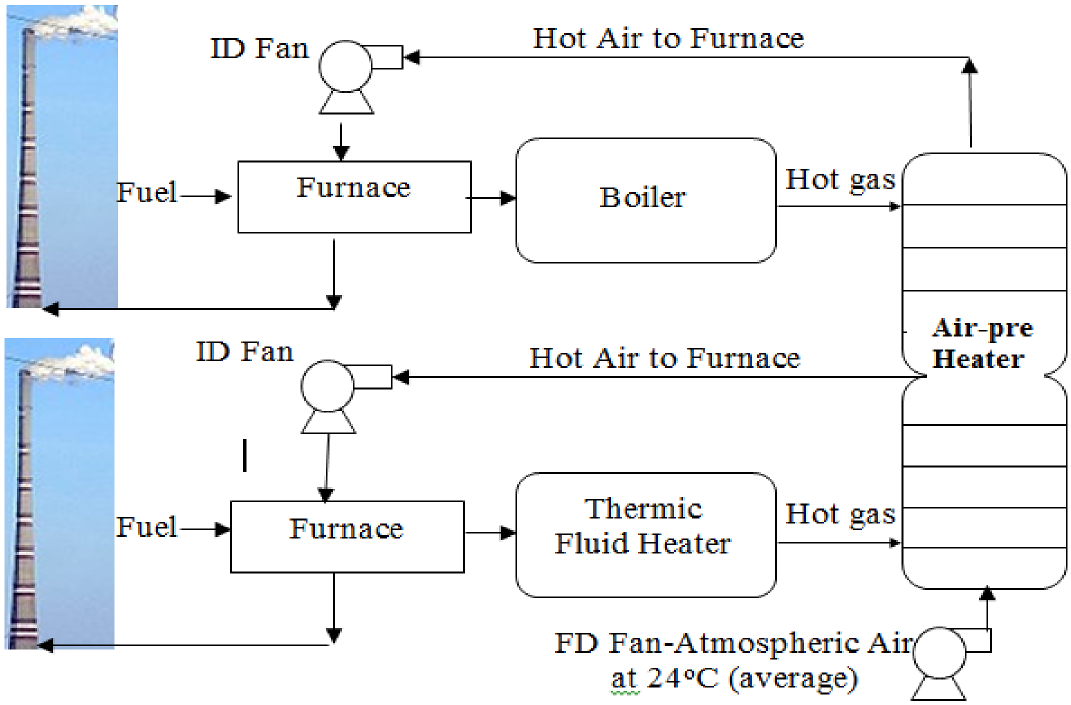


Figure 5: Proposed layout of installation of air preheater for boiler and TFH

5.1.6. Dedicated solar hot water generator for dyeing chamber

At present hot water is generated by the indirect heating of live steam generated in the boiler, which is used for dyeing of cloths in the dyeing chamber. For this purpose treated raw water at 21^{0}C is supplied and stored in the addition tank and stack tank separately. This raw water is heated indirectly by steam between 65^{0}C and 75^{0}C prior to injection in the dyeing chamber. Hot water requirement for addition tank and stack tank is 4,060 liter per day and 183,600 liter per day respectively. It was observed that live steam generated from the boiler is about 0.8 – 1.1 tons per hour. According to energy conservation concept, generation of steam at higher pressure for hot water production is not an energy efficient method.

Hence, it is proposed to use a dedicated solar-based hot water generator for hot water generation. Hot water can be supplied through the insulated pipeline to the respective addition and stack tank. The proposed scheme is shown in Figure 6.

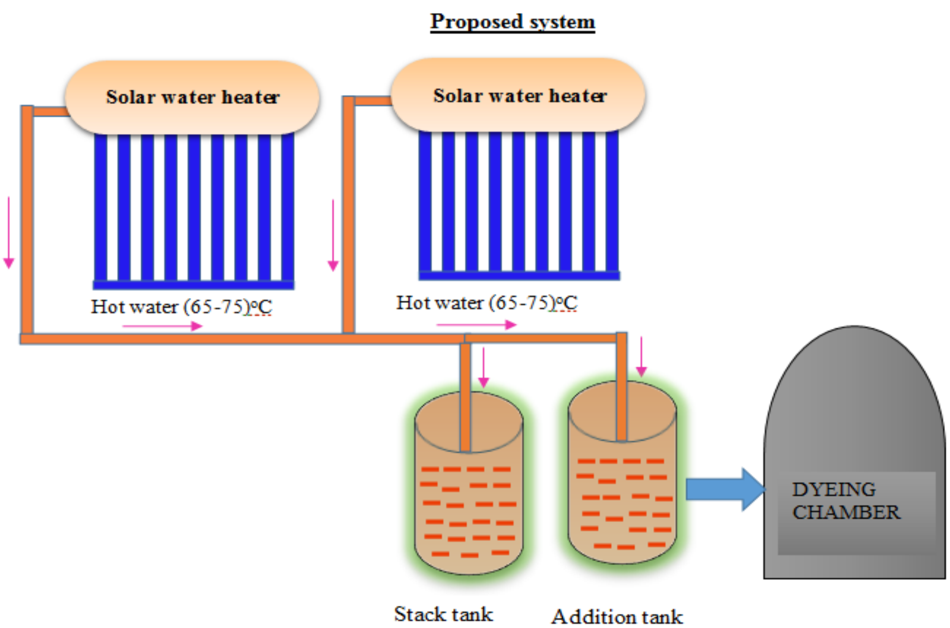


Figure 6: Schematic diagram for proposed installation of an economizer

Economic analysis has been done to understand its feasibility and the heat equivalent to hot water was estimated around 490 kW. Therefore, HSD fuel saving is around 412200 litre per annum and the equivalent cost savings possible by use of dedicated solar hot water generator could be around 24240 USD. Investment required for solar hot water generator and installation is approximately 24260 USD and hence the benefits and the payback period is about 12 months time.

5.1.7. Waste heat recovery through installation of an economizer

Normally increase in boiler feed water temperature can lead to substantial increase in boiler efficiency thus leading to reduction in specific fuel consumption. At present dyeing plant has installed four numbers of dyeing units, which are used for dyeing process. It was noticed that once the dyeing process is over, the hot dirty water is drained out of the chamber containing substantial amounts of heat energy and is send simply to the wastewater storage. Hence, it is recommended to install a heat exchanger to preheat the feed water going to the boiler by hot dirty water. Recovering the energy contained in the dirty water instead of throwing it away can lead to significant savings of energy. The proposed layout is shown in Figure 7.

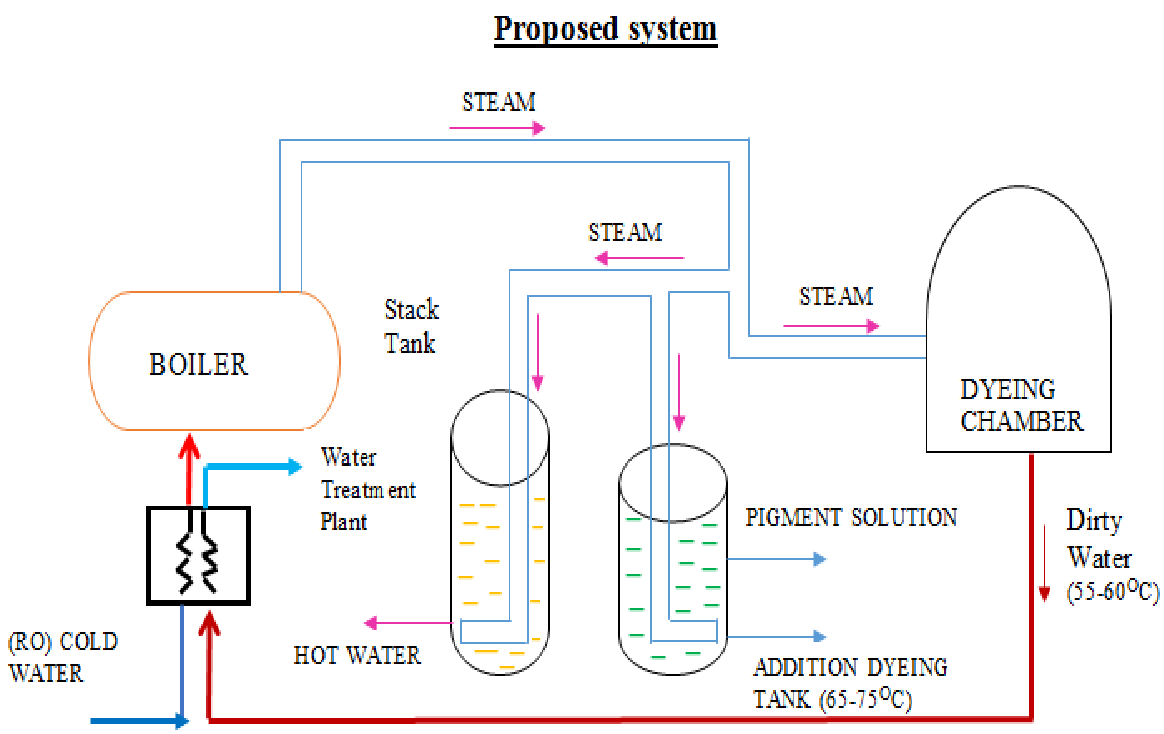


Figure 7: Schematic diagram for proposed installation of Heat exchanger

During the study, the hot wastewater was estimated as 7,650 litres per hour and detailed economics analysis has been made. Heat available for feed water preheating from wastewater has been observed to be 0.76 Million kJ per hour and hence diesel equivalent of heat recoverable was 123900 litre per annum. It can be inferred from the findings that the possible saving was around $ 60970. The investment needed is around $28,000, which is one time investment, and hence the simple payback period is around 6 months.

5.2. Energy saving potential in air compressors

5.2.1. Reduction of operating bandwidth

A cluster of compressors are installed in three locations to cater air supply for spinning & knitting plant, dyeing plant, and garment plant for various process requirements. It was noticed from the plant operation that the average maximum compressed air pressure required is only 5 to 6 bar for process requirement. Generally higher the pressure of compressed air higher would be the power consumption. Hence it is recommended to optimize the bandwidth of pressure setting in the compressor in order to reduce the power consumption. The proposed pressure setting and its anticipated power reduction for three units are given in Table 5.

Table 5: Details of proposed pressure setting for three units

Utilities	Existing pressure (bar)		Proposed pressure (bar)		Actual Power Consumption (kW)	Anticipated Power (kW)	Max. Press. needed (bar)
	Cut in	Cut out	Cut in	Cut out			
	Spinning & Knitting Plant						6 bar
Comp-1	8	8.9	6.5	7.5	11.43	10.32	
Comp-2	8.2	8.9	6.5	7.5	11.58	10.45	
Comp-3	8.1	8.9	6.5	7.5	11.80	10.65	
Comp-4	8	8.9	6.5	7.5	11.50	10.38	
Comp-5	9	10	6.5	7.5	97.15	87.69	
Dyeing Plant							6 bar
Comp-1	6.4	8	6.4	7.5	7.37	6.58	
Comp-2	6.4	89	6.4	7.5	7.52	6.71	
Garment Plant							5 bar
Comp-1	6.3	7.1	5	6	5.1	4.42	
Total					**163.45**	**147.21**	

With the proposed pressure setting for the three unitis, the power consumption can be reduced from the current 163.5 kW to 147 kW, which can save around $ 3150 per year without need for any investment.

5.2.2. Reduction of compressed air leakages in the system

As compressors are major energy guzzlers, it is utmost importance the compressed air is used optimally and judiciously allowing for very minimum unavoidable leakages. In any compressor plant, the major drain of energy is due to air leakage in the system.

Table 6: Analysis of compressed air leakage for three plants

Utility	Trials	I	II	III	Average	% of loading	Actual FAD (m^3/min)	Actual Air Leakage (m^3/min)
					Spinning & Knitting Plant			
Comp-1	Load	31	38	37	35.33	13.81	1.31	0.18
	Unload	238	242	231	237			
Comp-2	Load	32	29	35	32	11.94	1.29	0.15
	Unload	225	238	245	236			
Comp-4	Load	32	39	39	36.66	13.33	1.23	0.16
	Unload	241	234	240	238.33			
Comp-5	Load	38	39	34	37	10.53	1.52	0.19
	Unload	251	245	268	254.66			
Comp-6	Load	118	201	109	142.66	62.66	17.95	8.26
	Unload	189	201	112	167.33	167.3333		
					Dyeing plant			
Comp-1	Load	569	560	561	563.33	60	0.795	0.48
	Unload	352	390	375	372.33			
Comp-2	Load	425	339	412	392.00	61	0.885	0.54
	Unload	260	248	259	255.66			
Comp-3	Load	425	421	412	419.33	53	0.795	0.42
	Unload	352	390	375	372.33			
					Garment Plant			
Comp-1	Load	3433	0	0	3433	100	0.799	0.799
	Unload	0	0	0	0			
						Total	26.57	11.18

Besides compressed air leakage to an extent of 10 % of generation is normally permitted, as that would be very impossible to avoid[17]. During the energy audit it was observed that compressors are located three places to cater air supply for Spinning & knitting plant, dyeing plant and garment plant for various process requirements. All the compressors are operated at a time for delivering compressed air to the process for respective plants. To ascertain the compressed air leakage and for quantifying the same a leakage test was carried out in spinning, dyeing and garment plant. The quantity of air leakages in the three plants are summarize in Table 6.

From the total quantity of compressed air of 26.57 m^3 per minute supplied, 11.18 m^3 per minute was leaked. Therefore, with permissible of 10% leakage, nearly 10 m^3 per minute air leakage could be arrested resulting in a total cost saving of $ 48530 per year with zero investment.

5.2.3. Reduction of compressor air intake temperature

At present five compressors are housed in a separate shed and operate to supply air for process requirement of spinning and knitting plant. All these compressors operate on Load and No Load mode. It was observed that the air temperature inside shed was around 8° C to 10° C higher than the outside ambient air temperature of 31^0C. This temperature difference is expected to go higher during summer times. Any rise in suction air temperature of the compressor would increase the energy requirement for compression. It has been established that every 3° C rise in the suction air temperature would increase the compressor power consumption by 1 % [15][16]. Hence, it was suggested to provide ventilation for suction duct. It is possible to save at least 1.5 – 2 % of present energy consumed by the compressors. Hence if we provide ventilation arrangement, present motor power consumption of 144 kW could be reduced by 2 % leading to a minimum of $ 645 cost savings per year. The payback period would come negligible period due to very low investment.

5.2.4. Minimization of compressed air usage for cleaning purposes

In general compressed air is one of the widely used utilities for floor cleaning / personnel cleaning application. Although the cleaning through compressed air is an accepted practice in a factory, it does consume substantial energy. As such, the air pressure required for cleaning is only of 1.5 bar. However, the air pressure used in many industries is not less than 6 bar. During the energy audit, it is estimated that currently about 29 % of compressed air generation goes for cleaning purposes at the spinning and knitting plant section. Therefore, it was recommended that installing transvector nozzles in air cleaning hose pipe lines that could supply cleaning air at 2.5 bar, which is less than the currently used 6.5 bar pressure. The air consumption savings can be achieved from 70 % to 75 % depending on the air quantity used for cleaning application[18]. This could save nearly $1500 per year with an investment of around $300. This brings to a payback period of maximum of 2.5 months.

5.3. Energy saving potential in lighting systems

5.3.1. Installation of automatic occupancy sensor for lighting in identified toilets

Lighting survey was conducted during Energy Audit for possible Energy Savings. It was observed that toilets in spinning and dyeing plant tube lights were glowing continuously for 24 hours and 12 hours respectively, even though the usage was limited to about only 2-4 hour in a day. Hence, it is recommended to install automatic occupancy sensor for lightings in these identified toilets. The occupancy sensors would automatically put off the lights when there are no occupants. This method would result in a substantial saving of electrical energy. The use of automatic occupancy sensor for 22 lamps in the toilets could save more than $ 720 per year with an investment of $110 leading to a payback period of around 2 months.

5.3.2. Use of 36 W CF lamps in place of conventional luminaries in identified locations

The study shows that there is the possibility of power savings by replacing the existing conventional 58 W fluorescent tube lights (FTLs) with 36 W compact fluorescent lamps (CFLs) in the identified locations such as sample room, spare parts store, accessories store, fire fighter’s office and guard office. Illumination from 36 W CFLs is sufficient enough to maintain the Lux level requirements in these Locations. Hence, it is recommended to replace the existing 58 W Luminaries with 36 W CFLs in these Locations. The use of 88 number of 36 W CF lamps in place of conventional luminaries could save more than $150 per year with an investment of $200 leading to a payback period of around 16 months. This recommendation can be implemented as and when the existing 58 W Fluorescent lamps fail.

5.3.3. Replacement of High Pressure Mercury Vapor (HPMV) lamps by Sodium Vapor (SV) lamps in street lighting

At present 40 numbers of high pressure mercury vapor lamps 250 W (HPMV) are used in the street light for Passages illumination purposes. HPMV are generally used in places where color rendition is critical. These lamps can be replaced by high pressure sodium vapor (HPSV) lamps having lesser wattage when the color rendition is not important. Therefore, all these 250 W HPMV lamps can be replaced with 32 numbers of 100 W, HPSV. The replacement of by sodium vapor lamps could be possible saving of $ 800 per year with an investment of $ 250 leading to a payback period of around 4 months. This recommendation can be implemented as and when the existing HPMV lamps fail.

5.3.4. Installation of Servo Stabilizer in the identified lighting feeder

Power measurements were taken at various locations in the Lighting feeder. The plant has three lighting feeders in spinning & knitting, dyeing and garment plant for illumination purpose.

During this study, it was observed that the measured voltage in the respective lighting feeder was about 220 V, but the operating voltage required is only around 210 V for any types of lamps. It has been established by various studies [15][16] that a reduction in supply voltage by 5 % would result in

a) Proportional drop in power Consumption (5 %)
b) Insignificant drop in Illumination Level (2 - 3 %)

Hence, it was recommended to install three Servo Stabilizers (also known as Energy Savers) with capacity of 100 KVA, 50 KVA and 75 KVA for spinning & knitting plant, Dyeing plant and Garment plant respectively. These plants can operate the lighting load at a reduced voltage of 210 V. This would result in appreciable cost savings of $ 1,250 per year with an investment of $ 300, which gives a payback period in just 3 months.

6. Policy Implications and Conclusions

6.1. Policy Implications

The case study at the company shows that there are substantial energy saving potentials that could support the company in reducing energy bills and providing other associated benefits. However, it was understood that there is no any strategy being implemented by the company to implement energy conservation measures. At the policy level, the government has a strategy to lower power losses to a maximum of 11% [19]. Some of the key priority areas of the country’s policies are [20].

- To set, issue and publicize standards and codes which will ensure that energy is used efficiently and properly;
- To develop human resources and establish competent energy institutions;
- To take appropriate policy measures to achieve a gradual transition from traditional energy fuels to modern fuels

However, these policy and strategy directions are not properly materialized at the end users such as in the textile and garment industries and other energy intensive sectors. These policy directions are not detailed for easiness of implementation by the end users. The lack of regulatory and policy implementation and weak monitoring and evaluation of the energy consumption pattern at the industries is becoming the bottleneck to achieve the anticipated energy saving and its associated benefits. This condition is creating significant negative impact in the companies' international competitiveness and is straining the supply side of the energy sector affecting energy access and quality of power to the end users. Therefore, Ethiopia needs to take this seriously and implement different policies and strategies in order to stimulate and encourage end users particularly energy intensive industries to implement energy conservation measures. Considering the current context of the country and the lessons learned from the case study, the following internationally proven and effective policies and strategies are recommended.

6.1.1. Developing standards of energy management systems

Several industries are currently adopting the international standards such as ISO 50001 and ISO 50002 in order to standardize their energy management systems. Therefore, adoption and conformity to these international standards in Ethiopia could have huge positive impact considering the lack of energy management systems in the country. Therefore, policy makers should considering making utilization of these standards mandatory for the industries. In order to make it mandatory, appropriate legal framework should be developed in order to support enforcingindustries to implement these standards.

6.1.2. Developing effective regulatory framework

Ethiopia has several energy regulations but mainly focusing on the generation, licensing, electricity tariff, and ownership of generation, transmission and substations. This is mainly because of the lack of focus by policy makers consequently lacking enforcing mechanism to ensure the following international standards by all sectors. Therefore, developing specific legal framework to implement energy efficiency international standards should be given the highest priority by the government. The type of legal frameworks that could be implemented includes but not limited to:

- Inclusion of all international efficiency standards like ISO 50001 and ISO 50002as part of the licensing documentation of industries.
- Making energy efficiency progress and report the compliance is mandatory at certain frequency by the responsible body
- Publicizing and posting efficiency standards and codes as part of their business at all types of industrial premises mandatory

6.1.3. Developing and implementing incentive mechanisms

Incentives are internationally proven effective policy tools for changing the minds of implementers of any policies and regulations. The following policy directions could be enacted by the government in order to encourage industries to shift their current energy resources towards the utilization of energy resources.

- Reduction of income Tax for the implementation of proper energy conservation measures and associated reduction of energy losses
- Reduction of income Tax for diversifying their energy mix by shifting from fossil fuels to renewable energy resources.
- Reduction of income Tax for companies who establish training centers and provide awareness creation for their employees.
- Recruit energy managers to get training at well-known industries to explore the international experience.

6.1.4. Capacity building and awareness creation

The different studies conducted so far in the industries and other sectors shows that there is lack of skilled human power and lack of awareness on the energy conservation and management. Therefore, implementing awareness creation within the relevant sectors starting from all categories of employees could have significant effect in changing the attitudes of users. This can be achieved by:

- Publicizing energy efficiency standards and codes to the industries and their employees at large

- Developing apps that can remind end users at a specified frequency to establish simple energy conservation measures.
- Conduct workshop by the experts to share the experiencesand case studies to have successful implementation of energy conservation measures

6.1.5. Developing enforcing mechanisms to hire energy managers

Almost all industries in Ethiopia including the textile and garment industries have no energy managers. This means there is no bodies that have the skills and expertise to implement energy conservation measures in the industries. Therefore, the government should take drastic action to hire energy managers and establish in-house energy unit to implement energy measures. The manager shall also be responsible to report the regulatory body for the implementation of energy conservation measures in the companies based on the standards and codes.

6.1.6. Establishing strong monitoring and evaluation government unit

The energy sector in Ethiopia has well-established institutional structure from federal to regional levels. But there is no sector to take responsible to monitor the energy activities and enact policies and regulation to minimize energy losses at the end users. This is creating a huge gap between policy makers and end users. The absence of such units is the bottleneck and leads to loosing millions of dollars due to lack of advanced automation in the industrial sectors.

7.2. Conclusions

The study was conducted in MAA textile and garment factory as a case study to investigate the current energy conservation practices and to develop and recommend energy conservation measures and policy directions. Although the case study company is considered as a sample to understand the current context, most of the textile and garment industries in Ethiopia are not practicing any energy conservation measures mainly because of the lack of strong regulations, monitoring and lack of awareness on energy conservation. Therefore, the recommended energy saving measures could be widely implemented across all textile and garment industries in the country and beyond. Based on the study, suggestions have been made for conserving energy taking into consideration the techno economic viability and also the acceptance levels by the users. Accordingly, a total of 15 evidence based energy conservation recommendation have been identified and developed for possible implementation. Four recommendations are proposed with nil investment that could save a total cost of around $53,700 per year. A total of 11 other recommendations are provided but require investments. These recommendations could save a total cost of around $160900 per year but requires nearly $ 98400 investment. However, this investment could be recovered within a maximum of 7 months payback. This is a massive saving and all textile and garment industries could benefit by implementing these recommended solutions. The following Table 7 gives the list of ENCON proposals made along with techno economic viability of each proposal.

Table 7: Consolidated list of energy saving proposals

(a) Nil Investment Proposals – 4

No	Energy Saving Proposal	Investment Required ($)	Annual Savings ($)	Payback Period months
1	Reduction in operating pressure of the Boiler	Nil	1370	0
2	Reduction of operating bandwidth of the air compressor	Nil	3150	0
3	Reduction of compressed air leakages in the system	Constant Maintenance	48530	0
4	Reduction of compressor air intake temperature	Negligible	645	0
	Total	**0**	**53695**	**0**

(b) Investment Proposals - 11

No	Energy Saving Proposal	Investment Required ($)	Annual Savings ($)	Payback Period months
1	Effective condensate recovery	212	34250	0.06
2	Proper insulation of bare feed water pipe lines	90	206	5.2
3	Addition of fuel additives for improvement of combustion of fuel oil	16600	10,800	18.4
4	Installation of recuperator for heat recovery	28,000	26,000	12.9
5	Installation of dedicated solar hot water generator for Dyeing chamber	24260	24240	12
6	Waste heat recovery through installation of an economizer	28,000	60970	5.5

7	Minimization of compressed air usage for cleaning purposes	300	1500	2.5
8	Installation of automatic occupancy sensor for lighting	110	720	1.8
9	Use of 36 W CF lamps in place of conventional luminariesin	200	150	16
10	Replacement of High Pressure Mercury Vapor (HPMV) lamps by Sodium Vapor (SV) lamps	250	800	3.75
11	Installation of Servo Stabilizer in the identified lighting feeder	300	1250	2.88
	Total	**98322**	**160886**	**7.33**

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