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Research Article

Analytical Modeling of Specific Energy Consumption and Cost-share in Comprehensive Textile Industry: Case Study of Ethiopia

Dessie Tarekegn Bantelay[a,*], Muluken Zegeye[a], Betelhem Dereje[b], Robile Nigussie[a]

[a] *Faculty of Mechanical & Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, 26, Ethiopia*
[b] *Faculty of Electrical & Computer Engineering, Bahir Dar Institute of Technology, Bahir Dar University, 26, Ethiopia*
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Abstract

Energy is one of the primary inputs in textile processing industries that have a significant impact on the cost of a cotton product. The energy cost-share is reported between 5-10% of the total production cost of woven cotton fabric in textile factories of developed countries. However, it is far higher in developing countries. This study aims to contribute to the understanding of energy use and energy efficiency in Ethiopian cotton textile industries through multi-level comparisons and analyses. Determination of specific energy consumption, specific cost-share and specific energy consumption and cost estimation model is developed in cotton textile processing industries of Ethiopia to show the level of energy utilization practice effectiveness and to point out specific energy conservation measure. Actual and designed energy consumption data has been gathered from machine nameplate and factory design documents. Then important performance indicating data is collected through on-site measurement. This research pointed out that, the actual energy consumption per unit textile product is higher than the estimated consumption of each involved textile processing stage. The cost-share of energy in Ethiopian cotton textile industries accounts for an average of 16.01% of the total production cost of a cotton product and it is the second-highest cost of a product next to cotton. This indicates the existing of poor energy management practices in the textile industries. As a result, they face high production costs, poor product quality, and non-conducive working environment. This study shows that any productivity improvement measure in the textile industries of Ethiopia has to give more emphasis on the reduction of energy cost than any other production inputs.

Keywords: Analytical cost modeling; Energy cost-share; Energy efficiency; Energy consumption; Textile industry

1.Introduction

The textile sector is one of the large scale industries in Ethiopia. The government of Ethiopia gives high priority for the textile sub-sector considering its multiplier effect on the country's economy. The sector also serves as poverty reduction establishment, create huge job opportunity and generate foreign currency (Khalil, 2010). But it is suffering from low performance and encountered a high cost of manufacturing (Dedimas et al., 2019). The introduction of the Africa growth opportunity act (AGOA) by the USA and the end of the multi-fiber agreement in the European Union has opened a new market in Africa. Furthermore, textile industries have moved from Asia to other places, including Africa, where labor costs are relatively lower and raw materials are readily available. However, the rising of production costs due to higher energy consumption has been a major challenge provoked by textile industries in developing countries compared to developed nation industries (Khalil, 2010). The share of energy cost from total production cost in textile industries widely vary from country to country. Studies showed that in developed nations the cost of energy often comprises the third or fourth highest cost of the overall product cost (Khude, 2017).

*Corresponding author Email address: dessie2000ec @gmail.com.

The textile sector has comparatively high energy consumption compared to other small and medium industries in Ethiopia. The cost of a cotton product consists of several components. It includes the cost of cotton, chemical, spare part, electric & fuel, direct & indirect labor, and capital depreciation, etc. As the sector faced an increasingly competitive business environment, it is important to search for opportunities towards reducing production costs without affecting product quality. Investigations in different countries of the world have shown the existence of substantial cost-effective energy efficiency enhancement mechanisms. To improve energy generation, distribution, and consumption practice in the textile industries of Ethiopia, performance study is a precondition. Unlike the textile sector, there are well-developed productivity measurement and analysis frameworks in other manufacturing sectors of the country. These frameworks are simple to understand, can easily detect a problem, compatible with modern management systems and tools (Yilma et al., 2017).

Out of all the steps in the energy performance improvement process, measuring energy consumption for each particular product and compare with benchmarks is by far the most important step. After a complete and thorough understanding of energy cost-share and consumption by section and product. Then an energy improvement measure can be made deliberately. For this reason, the study utilizes high-resolution empirical energy data of two textile factories (Bahir Dar and Kombolcha Textile companies). This study aims to contribute to the understanding of energy use and energy efficiency in Ethiopian textile industries by considering the two case companies through multi-level comparisons and analyses. The gap between Ethiopian and leading countries' performance has been examined to notice the energy performance level.

2. Literature Review

Energy has a key role in the growth and development of a nation. Global energy crises, rapid population growth, increased production level, and growing energy cost is the main imposing factors for implementing energy conservation techniques. The world's population is forecasted to increase by about 35% at the end of 2050 (UN/DESA, 2012). The rapid growth of population and the continuing economic growth in developing countries will significantly increase in textile manufacturing. Consequently, will result in substantial growths in the textile industry's entire energy use. Ethiopian rapid economy development dependency on energy has increased. Besides, the shortage of energy progressively has become a serious problem for our economy (Lin and Tian, 2016). To solve the shortage, the country depends more on the worldwide energy market, which has not only affected energy security but also has made serious challenge to national stability (Lin and Ouyang, 2014). Therefore, to confront the mismatch between economic growths, environmental crises, energy shortage, energy conservation, and efficiency improvement programs have become an inevitable choice at present and in the future (Lin and Du, 2013). The textile industry encompasses many plants that together need a significant amount of energy. The share of the total production cost expended for energy in cotton textile industries varies by the country, production process, energy management practice and level of technology utilized. Table 1 shows general shares of energy costs in the textile industries of selected developed countries.

Table 1
Energy cost-share from total production cost in textile industries of several countries

SN	Cost factors	China	Korea	Brazil	India	Italy	Turkey	USA	Average
1	Raw materials	61%	53%	50%	51%	40%	49%	44%	50%
2	Capital depreciation	14%	21%	32%	23%	17%	26%	21%	22%
3	Labor	2%	8%	2%	2%	24%	4%	19%	9%
4	Energy	**8%**	**6%**	**5%**	**12%**	**10%**	**9%**	**6%**	8%
5	Waste	11%	8%	7%	7%	6%	8%	6%	8%
6	Auxiliary material	4%	4%	4%	5%	3%	4%	4%	4%
	Total	100%	100%	100%	100%	100%	100%	100%	100%

(Source: Khude P., 2017)

To implement an energy improvement project, it is mandatory to observe and analyze the existing energy consumption situation and trend in detail. Therefore, it is important, to begin with knowing the relationship between production, energy consumption, and cost-share to start an energy management system improvement project. Figure 1 shows the average production cost-share of the textile industries in developed countries. Raw material and capital depreciation take the first and second highest cost-share of 50% and 22% of the total production cost respectively, and they account for an average lump sum of 72% of the total production cost. While energy costs are mostly the third or fourth highest cost-share of total production cost accounts an average value of 8%.

Different research findings approved that the cotton textile industry is energy demanding, the fabrication of the textile sector usually needs high energy consumption and mostly associated with inefficient energy usage (Yacout et al., 2014). The energy efficiency venture is a sound business approach in current manufacturing situations (Worrell and Galitsky, 2008). A technical evaluation of newly innovated technologies in the cotton textile sector for energy and water efficiency has been conducted and the result showed a continual improvement (Ali and Price, 2015).

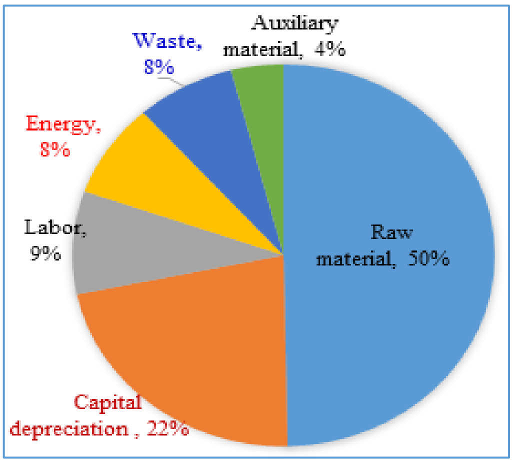

Fig. 1. Textile industries an average production cost-share of developed countries (Source: Khude P., 2017)

Even though researchers reported that broadly reviewed technologies have resulted in considerable savings in multiple aspects as compared to conventional technologies, but no single equipment will be the best or the only solution. A study reported that in the textile sector energy efficiency enhancement should be a core of innovation and technological growth (Lin and Zhao, 2016). In many countries, government policies and programs focused on a possible intervention that can increase manufacturing sector competitiveness through reducing energy wastage and preventing environmental impact. Improving production planning and controlling strategies highly impact on performances and competitiveness of manufacturing industries (Dametew et.al, 2019). However, in developing countries, like Ethiopia, there are no well-developed procedures on possible interventions.

The furthermost likely way of decreasing energy usage and associated costs are applying energy management system in the industries. Study about energy consumption has been done in the area of energy audit practices (Shen et al., 2012), assessment of energy audit plans (Fleiter et al., 2012b), energy management system or consumption practice optimization by analytical modeling (Giacone & Mancò, 2012), development and implementation of energy end-use programs and policy (Tanaka, 2011), as well as energy efficiency benchmarking (Saygin et al., 2011). The studies highlighted energy audits as a vital tool for efficient energy management of a firm to continuously trace out inferiorities and identify energy improvement potential. There are three types of energy audit practices in the manufacturing sector. Preliminary energy audit, general energy audit and detailed energy audit practice (Abdelaziz et al., 2011). It is a formal, logical way that investigates the existing energy generation and utilization trend of business. The objective is to investigate energy utilization processes, measure and quantify energy use in each production step and to trace out an energy improvement potentials (Gordić et al., 2010). On the other hand, studies proved that energy efficiency investments derived from survey work in less developed countries show high internal rates of return with a repayment period vary between 0.9 and 2.9 years (Alcorta et al., 2014). Similarly, energy management is considered as the approach of fulfilling energy demand at the right place and time. This can be accomplished by improving energy utilization processes. This will lead to a significant reduction in the total costs of manufacturing (Abdelaziz et al., 2011). A study has been conducted to indicate energy cost, energy usage and the association between energy consumption and production cost increment (Kemal, 2005). Various researches have been conducted on energy management practice. For instance, research in the area of energy audit practices and evaluation of energy audit programs has been conducted (Shen et al., 2012; Fleiter et al., 2012b). Furthermore, researches conducted on process optimization using analytical modeling (Giacone & Mancò, 2012), development and evaluation of energy end-use industries strategy programs and actions (Tanaka, 2011) and on energy efficiency benchmarking. The study result proved that the energy improvement project is a mandatory task in textile industries (Saygin et al., 2011). There are different research which developed a conceptual outline of an energy management system that demonstrates a comprehensive approach is necessary to successfully exploit the existing energy efficiency improvement potential in specific textile industries (Schulze et al. 2016).

There are three prevalent themes of energy management from a performance management perspective. These are energy accounting, performance evaluation and benchmarking. Benchmarking energy efficiency models is an important mathematical tool used to compare energy utilization, efficient (Chung, 2011). The main benefit of this methodology is that the model takes into account the factors that affect energy consumption (Wang et al., 2014). Similarly, there are three types of energy efficiency benchmarking: particular industrial benchmarking, historical benchmarking, and company-wide benchmarking (Peterson and Belt, 2009). During industrial benchmarking, each facility or procedures of companies' are compared with facilities or procedures of other similar companies, are generally difficult to realize as other companies are commonly unwilling to share their energy efficiency values as they considered sensitive. During historical benchmarking companies compare the actual energy consumption of a facility or a process against itself at an earlier time. In a company-wide benchmarking, numerous facilities and procedures of the same company are compared with each other. An industry benchmarking was taken from different studies. Figure 2 shows the breakdown of electricity use in a composite textile plant (Sathaye et al., 2005).

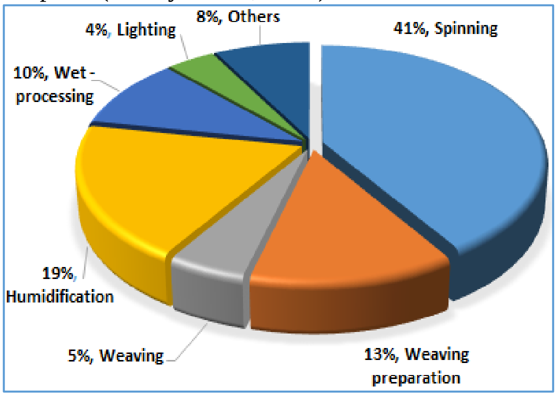

Fig. 2. Breakdown of typical electricity use in a composite textile plant (Sathaye et al., 2005).

As shown in the Figure, spinning and weaving sections consume the largest part of electricity with a share of 41% and 18% respectively. Wet process preparation (de-sizing, bleaching, etc.) and finishing collectively consume the smallest share of electricity (10%).

3. Methodology

To improve energy generation, distribution and consumption practice in the textile industries of Ethiopia performance studies are required. For any energy efficiency research, measuring the existing energy consumption quantitatively is a very important step. This study utilizes high-resolution realistic energy data of a case study textile industry including, any type of quantitative data required to determine energy use and to find out any fundamental efficiency improvement opportunities. Figure 3 presents the overall procedure of the study.

This work faced challenges in obtaining relevant historical data. Performance indicating data for Ethiopian textile industries are not organized and included in databases. The fact, that the relevant data is scattered, and is not available in literature and databases, we are forced to collect and reorganize and evaluate outdated companywide documents. To meet the study objective both secondary and primary data were collected, analyzed and interpreted. Initially, secondary data gathered from current records of case textile factories. Then primary data collected from on-site measurements.

Before conducting walk-through energy consumption inspection in the case textile plants, discussion meetings were held with production and utility divisions at managerial level; to have a common understanding of the data collection and survey process, to get data, to know the understanding of the management on energy conservation practice, etc. Monthly production and energy consumption data of the involved plants were gathered. A checklist to be used during an on-site measurement is developed and given to the energy measurement teams. On-site electric and steam consumption measurement were performed through the real-time measurement of the machinery using electronic equipment. Then energy intensity determined using:

$$\text{Energy intensity (EI)} = \frac{\text{Energy Use (EU)}}{\text{Production Volume (PV)}} \qquad (1)$$

Where EI denotes energy intensity MWh or GW/kg, EU denotes energy use in MWh or GJ and PV denote production volume.

Multiple linear regression analysis techniques used to measure the relationship between the production cost (dependent variables) and independent variables (representing the cost of cotton, chemical and related, spare and related, energy, labor, and capital depreciation). Production cost modeled using multiple linear regressions as:

$$Y_i = B_0 + B_1X_1 + ... + B_pX_p + E \qquad (2)$$

Where Y_i denotes the dependent variable (total production cost or total power consumption), B_0 denote Y-intercept, X_1 - X_p denote independent variables, B_1 - B_p stands for regression coefficients of X_1 – X_p and E denote random error in prediction. Finally, benchmarking and energy performance analysis were done.

4. Results and Discussion

4.1. Energy cost-share analysis

Producing better quality yarns and fibers with a fair price is a key factor in competing with other industries in today's complex market situations. Since the free market govern the price of products, obtaining extra profit depends on reducing the manufacturing cost of yarns and fibers regardless of the management of spinning mills. In particular, cheaper yarns produced by Far East countries, such as India, China, and Indonesia, attract the attention of consumers. This negatively affects other countries' yarn manufacturers, and factors such as cost estimation and minimization become very important (Kaplan, 2004).

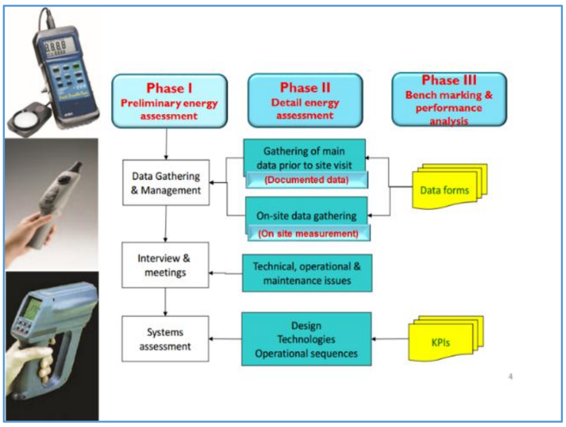

Fig. 3. Materials and methods used for the study.

Table 2.
The summary of percentage share of cost factors for five consecutive years in textile industries of Ethiopia.

Cost factors	Yearly cost-share in percent				
	2011/12	2012/13	2013/14	2014/15	2015/16
Cotton	51.1	45.3	47.4	47.9	49.2
Chemical & related	4.2	4.3	4.4	4.3	4.3
Spare and related	6.1	3.8	4.1	4.9	4.7
Electric	3.1	3.9	4.0	3.0	2.3
Fuel	16.9	15.6	11.9	12.8	7.3
Total energy cost	20.0	19.5	15.9	15.8	9.6
Direct labor	3.2	3.1	3.5	4.2	5.3
Indirect labor	9.0	9.5	9.9	10.1	12.4
Total labor cost	12.2	12.5	13.3	14.3	17.7
Capital depreciation	6.4	14.6	14.9	12.9	14.4

The cost of manufacturing consists of several cost factors, such as raw material cost, energy or power cost, labor cost, capital cost, etc. To evaluate the status of energy consumption, it is necessary to evaluate the share of energy cost from total production cost. To estimate the energy cost-share five consecutive years' data from Sep 2011 to Aug 2016 of the case companies used, from the survey and analysis result, it was observed that the cost-share of energy in Ethiopia textiles is high. Table 2 shows the percentage of cost-share of production inputs for five consecutive years. Energy cost-share varies significantly from year to year. It accounts for 9.6% in 2015/16 and 20% in 2011/12. This implies there is a great opportunity for improvement.

As shown in Figure 4 energy accounts for an average of 16.01% from total production cost and it is the second-highest share next to cotton. It could be noted that even though electric power cost is inexpensive compared to benchmarked developed countries, the share of energy cost is almost doubled to the average value of benchmarking countries.

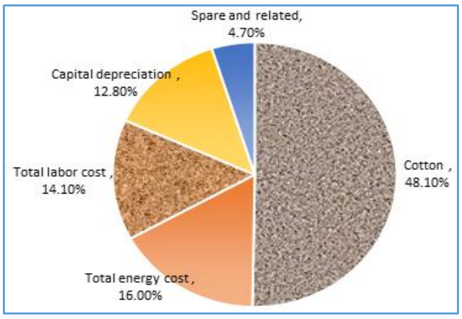

Fig. 4. Yearly average share of cost factors in textile industries of Ethiopia.

This shows that the existence of inefficient energy utilization practices. As a result of this, they face high production costs, poor product quality, and uncomfortable working environment. In today's global business environment, manufacturers face increasing competition both in quality and cost. As a result, they have to seek opportunities to reduce energy costs without negatively affecting product yield or quality and any productivity improvement measures in textile industries have to give better attention for optimization of power cost than any other.

Table 3
The percentage share of energy cost in textile industries of Ethiopia.

Cost factors	**Yearly cost-share in percent**					**Average Share**
	2012/13	2012/13	2012/13	2012/13	2012/13	
Electric cost-share from total production cost	3.1%	3.9%	4.0%	3.0%	2.3%	3.3%
Electric cost-share from total energy cost	15.3%	20.0%	25.0%	19.1%	24.1%	20.3%
Fuel cost-share from total production cost	16.9%	15.6%	11.9%	12.8%	7.3%	12.8%
Fuel cost-share from total energy cost	84.7%	80.0%	75.0%	80.9%	75.9%	79.7%
Total energy cost-share from total production cost	20.0%	19.5%	15.9%	15.8%	9.6%	16.0%

The total cost of energy highly depends on energy source and boiler effectiveness. The reliability and efficiency of boilers operation influenced by controllers used, boiler type, manufacturing machinery. But the operator and maintenance practice have an indispensable influence than any others (Putra et.al, 2018). Table 3 presents the share of electricity and fuel consumption from the total power consumption for five consecutive years. The table presents the relation between electric cost-share, fuel cost-share, and total energy cost. As shown in the table when the electric cost-share from the total energy cost increase and fuel cost-share from the total energy cost decreases the total energy cost from total production cost decrease. Similarly, when the electric cost-share from the total energy cost decrease and fuel cost-share of the total energy cost increases the total energy cost from total production cost increase. This implies using the electric boiler for steam generation is more economical than oil fired boiler in the context of Ethiopia.

4.2. *Energy consumption analysis by product*

The composite textile factories considered in this study produce two main products fabric and yarn. To estimate electric power consumption by product five years of data from Sep. 2011 to Aug. 2016 were collected and analyzed using eq. 2 and the result summarized in Table 4. The result shows that electric power consumption has no linear relation to the product volume and it didn't increase proportionally to production volume increment. The study shows that the electric energy used for unit cotton product manufacturing changes between 3.47 kWh/kg and 6.02 kWh/kg, whereas the specific electrical energy consumption for yarn has been changed from 2.65 kWh/kg to 4.58 kWh/kg. It is too much compared to other textile industries that exist in developed countries. Unless the specific energy consumption reduced, it is impossible to survive in the market competition.

Table 4
Yearly average production volume versus electric consumption/cost in cotton textile industries of Ethiopia

Year	Annual Yarn production (kg)	Annual Fabric production		Yarn annual consumption (MJ)	Yarn specific consumption (MJ/kg)	Fiber annual consumption (MJ)	Fiber Specific consumption (MJ/kg)	Total electric consumption (MJ)
		(m^2)	kg					
2011/12	2,280,167	12,071,493	1,822,795	10,098,585	4.43	10,595,735	5.81	20,694,320
2012/13	3,140,192	12,206,029	1,843,110	14,393,472	4.58	11,088,173	6.02	25,481,645
2013/14	3,070,269	10,938,308	1,651,685	13,032,194	4.24	9,201,688	5.57	22,233,882
2014/15	2,914,869	12,843,312	1,939,340	10,900,943	3.74	9,519,154	4.91	20,420,097
2015/16	2,723,780	10,317,456	1,557,936	7,207,664	2.65	5,410,924	3.47	12,618,588

4.3. Energy consumption analysis by section (production departments)

The composite textile plants considered in this study have blowing, spinning, weaving preparation, weaving/knitting, wet-processing and finishing all in the same compound. The textile machinery use huge amounts of electricity and fossil fuels. The amount and share of energy used within the textile sector depend on fuel cost, electricity cost, effectiveness of steam, compressed air & water production and distribution, the art of technology and energy management practices (ETIDI, 2014).

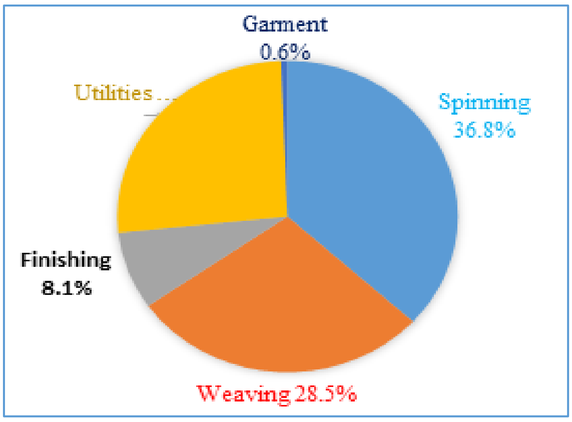

Fig.5. Energy Consumption share by section/end use in composite textile industries of Ethiopia

Figure 5 shows the average share of the usual electric power consumption in a complex textile industries in Ethiopia. As can be understood, spinning utilizes the greatest part of electricity (36.8%) accompanied by weaving (28.5%) and utility (26.1%). Finishing consumes the highest part of the thermal energy and least part of electricity (8.1%). The least amount of electricity is also consumed by garment (0.6%). These percentages slightly vary from factory to factory. Therefore, more emphasis could be given for spinning and weaving sections to reduce electricity consumption than any other section.

4.4. Energy cost determination model

Energy cost significantly affect the cost of a cotton product in the textile industries of Ethiopia. Determining energy cost-share for each product is used to evaluate the energy efficiency level and determine the unit cost of each product. Currently, the case textile factories have no models to estimate energy cost and consumption. In this study, energy consumption and cost during five consecutive years of fabric and yarn production has been used, then investigation of a chosen textile mills has been shown. A new approach, multiple linear regression analysis (eq. 2) has been used for quantifying the detailed energy utilization and unit cost for fabric and yarn production.

Table 5
Summary of regression output for energy cost as a function of product mix (Fabric and Yarn)

Regression Statistics	
Multiple R	0.99995
R Square	**0.99990**
Adjusted R Square	0.99971
Standard Error	162,438.45
Observations	4 years average (48months)

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	270,408,547,103,811.00	135,204,273,551,905.00	5,124.04	0.01
Residual	1	26,386,249,308.16	26,386,249,308.16		
Total	3	270,434,933,353,119.00			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-108,938,191.43	1,536,524.71	-70.90	0.01	-128,461,588.94	-89,414,793.92	-128,461,588.94	-89,414,793.92
Fabric (m2)	5.14	0.09	56.74	0.01	3.99	6.30	3.99	6.30
Yarn (Kg)	28.32	0.57	50.03	0.01	21.13	35.51	21.13	35.51

R Square equals 0.99999, which is a very good fit. 99.99% of the variation in the production cost of energy is explained by the independent variables Fabric and Yarn production volume. Closer to 1, the better the regression line fits the data. This implies the designed model (3) can work precisely.

Energy Cost (birr) = -108938191.43 + 5.14F + 28.321Y (3)

Where F denote Fabric production volume in m^2 (where 1 m^2 = 151kg) and Y denote yarn production volume in kg.

Table 6
Summary of regression output for energy consumption as a function of product mix (Fabric and Yarn)

Regression Statistics	
Multiple R	0.95
R Square	0.91
Adjusted R Square	0.73
Standard Error	2,538,797.00
Observations	4 years average (48months)

	df	SS	MS	F	Significance F
Regression	2.00	65,334,213,516,485.40	32,667,106,758,242.70	5.07	0.30
Residual	1.00	6,445,490,195,764.59	6,445,490,195,764.59		
Total	3.00	71,779,703,712,250.00			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-54,388,465.61	24,014,784.48	-2.26	0.26	-359,525,233.89	250,748,302.66	-359,525,233.89	250,748,302.66
Fabric (m2)	1.77	1.42	1.25	0.43	-16.23	19.78	-16.23	19.78
Yarn (Kg)	18.32	8.85	2.07	0.29	-94.10	130.73	-94.10	130.73

Similar to energy cost R Square equals 0.91, which is a very good fit. 91% of the variation in the amount of energy consumption is explained by the independent variables Fabric and Yarn production volume. Closer to 1, the better the regression line fits the data. This implies the designed model (4) can work precisely. Energy Consumption (MJ);

ECons. = -54388465.6 + 1.773f + 18.32y (4)

The energy consumption of a particular cotton product produced in the selected weaving mill has been calculated using the new technique, and the results obtained have been compared with the actual data given in table 4. To test the model validity the simulated result presented in table 7 Similarly figure 6 present comparison of actual energy cost and consumption to estimate energy cost and consumption using the models. Since the result has a very slight variation compared to the actual data the model could be used better for energy cost and consumption estimation precisely.

Table 7
Comparison of actual with estimated energy consumption based on the model

Year	Fabric (m^2)	Yarn (Kg)	Actual Energy cost (birr)	Model Energy cost (birr)	Actual Energy consumption (MJ)	Model Energy consumption (MJ)
2012/13	12,206,029	3,140,192	42,894,912	42,734,175	23,101,443	24,781,141
2013/14	10,938,308	3,070,269	34,188,019	34,237,800	22,776,762	21,252,483
2014/15	12,843,312	2,914,869	39,628,685	39,628,437	22,654,919	21,783,127
2015/16	10,317,456	2,723,780	21,325,783	21,233,706	13,068,680	13,804,033

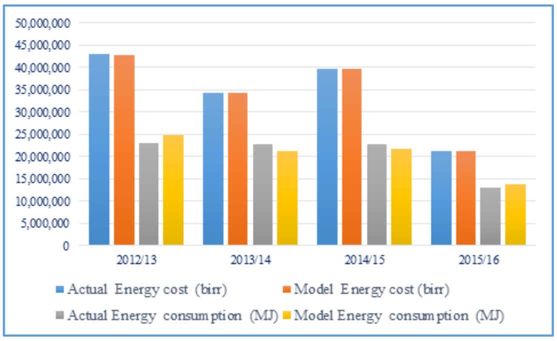

Fig. 6. Comparison of actual energy cost and consumption to estimated energy cost and consumption based on the model

5. Benchmark Analysis

Benchmarking has been accepted as an effective investigation system and management technique that supports to continually improve energy utilization efficiency and performance. Industrial energy consumption benchmarking is a process of measuring the energy consumption efficiency of each particular industrial plant compared to a reference plant (Saygin et al., 2011). Energy consumption benchmarking is important for understanding the energy use situation, identification of inefficiencies in energy use, assessing the potential for energy saving and designing strategies to enhance the energy economy. Energy utilization benchmarking for the industry is usually defined as the process of measuring the energy consumption performance of an individual plant against a common measurement that represents the standard or optimal performance of a reference plant (Worrell et al., 2006).

The benchmarking study aimed to obtain a set of performing actions that could be applied to assess the efficiency and effectiveness of operations, gain an understanding of the key cost drivers, gain empirical comparisons to peer companies, set goals for performance improvement and obtain an external perspective on performance.

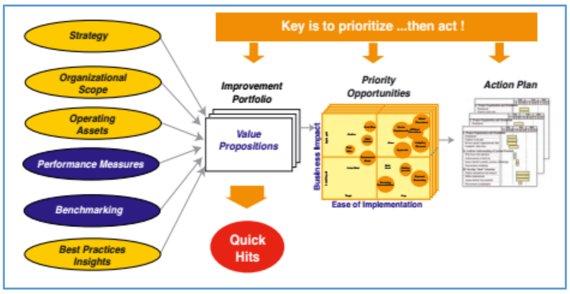

Fig. 7. Developing an improvement portfolio via benchmarking

Considering these as presented in table 8, the energy required for each particular cotton product in the textile industries of Ethiopia against similar investigations was analyzed. The result shows that the case factories' specific energy consumption is higher than similar benchmarked factories. This reveals that the sector suffers from poor energy management practices. An industry benchmark was taken from different studies. A study dealing with specific energy consumption in the textile industry shows that the specific electrical energy used for cotton product manufacturing varies 2.1 kWh/kg to 5.6. (Koç E., Çinçik E. 2010). Similarly, the specific electrical energy consumption for yarn has been changed between 1.60 and 3.00 kWh/kg (Kaplan and Koç, 2010). Different studies having specific energy consumption lower than these values were used for benchmarking study to alleviate the technological gap.

Figure 8 shows a comparison of average yearly energy consumption between actual and benchmarked companies. The result shows that in all years the textile factories of Ethiopia have high energy consumption. On average the textile industries consume 243.19% more electricity than the best models and 53.8% than the outer. This shows how the sector suffers from poor energy management practices.

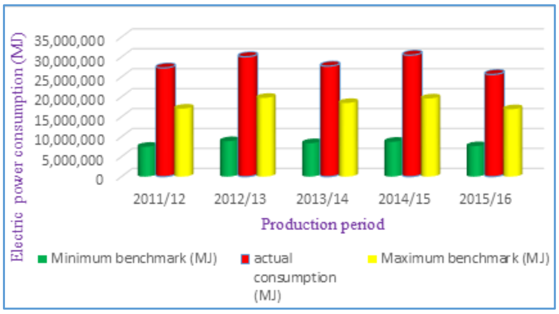

Fig. 8. Comparison of actual electrical energy consumption with benchmarked consumption.

6. Conclusion and Recommendations

The textile industry has comparatively higher energy consumption as compared to other small and medium industries. Five consecutive year's data (from Sep. 2011 to Aug. 2016) of the case companies are used to estimate the energy cost-share of the textile industry. From a detailed survey and analysis, it was observed that the cost-share of energy in Ethiopia textiles is high. As shown in Figure 4 energy accounts from 14.2% to 26.7% (on average 16.01%) of the total production cost and it is the second-highest share of total product cost next to cotton. It could be noted that even though electric power cost is inexpensive as compared to developed countries, the share of energy cost in Ethiopian textile industries is almost doubled. The specific energy consumption of Ethiopia textile industries against similar investigations was analyzed. As shown in table 8, the case factories' specific energy consumption is higher than similar benchmarked factories.

When the electric cost-share from the total energy cost increase and fuel cost-share of the total energy cost decreases the total energy cost from the total production cost decrease. This implies using the electric boiler for steam generation is more economical than oil fired boiler in the Ethiopia context. Also, power consumption has no linear relation to product volume. It doesn't increase proportionally to production volume increment. Rather, it depends on the type of boiler used for steam generation and energy management practice. This reveals that the sector suffers from poor energy management practices.

As presented in figure 5 the average share of electricity utilized in the complex textile plant of Ethiopia was evaluated. Spinning uses the greatest part of electric energy (36.8%) accompanied by weaving (28.5%) and utility (26.1%). Finishing consumes the highest part of thermal energy and less amount of electricity (8.1%). The insignificant amount of electricity is also consumed by garment (0.6%). These percentages slightly vary from plant to plant. The benchmark study result shows that the textile factories of Ethiopia have high energy consumption. As shown in figure 8, the textile industries consume 243.19% more electricity than the best models and 53.8% than the outer. This shows how the sector suffers from poor energy management practices.

Energy required for a specific cotton product produced in the selected textile industries has been determined using the new technique, and the result compared with the actual finding to test the model validity. Even though the result has a slight variation the model can use better for energy cost and consumption estimation.

Table 8
Summary result of calculated electrical energy consumption (minimum and maximum) based on the benchmark.

Year	Annual Yarn production (kg)	Annual Fabric production		Yarn annual consumption (MJ)		Fiber annual consumption (MJ)		Total benchmarked consumption (MJ)		Annual actual consumption (MJ)
		(m^2)	kg	Min	Max	Min	Max	Min	Max	
2011/12	2,280,167	12,071,493	1,822,795	3,648,267	6,840,501	3,827,870	10,207,654	7,476,138	17,048,155	27,255,809
2012/13	3,140,192	12,206,029	1,843,110	5,024,307	9,420,576	3,870,532	10,321,418	8,894,839	19,741,994	30,063,412
2013/14	3,070,269	10,938,308	1,651,685	4,912,430	9,210,807	3,468,537	9,249,433	8,380,968	18,460,240	27,709,673
2014/15	2,914,869	12,843,312	1,939,340	4,663,790	8,744,607	4,072,614	10,860,305	8,736,405	19,604,912	30,465,216
2015/16	2,723,780	10,317,456	1,557,936	4,358,048	8,171,340	3,271,665	8,724,441	7,629,713	16,895,781	25,620,222

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