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Specific Energy Consumption and Saving Analysis of Textile Production

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***Abstract*-**As our energy demand, which is indispensable for life, increases as well. In the textile industry, energy use and efficient use of energy and efficient use of energy instead of waste have become a very important issue in sectors that need and support the national economy. This study examines the energy saving research of a textile factory established in Mardin´s organized industrial zone in 2019 with the aim of providing energy savings for the textile industry, and reviewing the literature research and energy saving of textile companies.

In this study conducted based on these data, it was tried to reach general conclusions on a sectoral basis in the textile factory in Mardin.

Keywords- *Textile Industry, Energy Management, Specific Energy Consumption, Efficiency*

I. INDEX OF SYMBOLS AND ABBREVIATIONS

a: Specific variable
b: Specific variable
c: Specific variable
d: Specific variable
E: Energy [kJ]
P: Product [Number]
R: Pegression number
SET: Specific energy consumption
TEP: Ton equivalent oil

II. INTRODUCTION

The geography of Turkey, as a country with many different seasonal conditions, determines the heating and cooling energy needs at different levels. Particularly, the share of the textile sector adds special importance to this circulation. As an indispensable part of the production and export in both Turkey and the world, textile production and consumption supports the national economy with its power in this regard.

In his study Önöz suggests that: "The Turkish textile industry, is one of the country's leading socio-economic activity areas in terms of its technology level, economic efficiency and social interaction, and it is expected to maintain this position at the same level in the coming years. Our product quality and process technologies have global production standards " [1].

While the demand for energy is increasing day by day, the textile sector, which is the leading sector in our country, and the related Energy consumption factor are indispensable basic elements in this sector. Energy consumption is one of the most important expenditure items of textile factories and requires more efficient use. For this reason, efficient energy technologies should be diversified and increased. One of the most important goals of the textile industry is to take advantage of such technologies.

This study introduces basic concepts such as energy efficiency and the energy management system in the textile industry, and a textile factory located in the Organized Industrial Zone, Mardin, was examined based on a sample company for Mardin in terms of the importance of energy efficiency for the sector. With the incentives and supports given in recent years, it is observed that investments in the textile sector are more concentrated in the Southeastern Anatolia Region. In this case, first of all, the current situation should be reviewed and a a study should be performed to identify the situation in the factory before making operational savings plan. With energy saving it is aimed to leave a world that can be lived by proposing measures not only for the communities that exist today but also for future generations. It also plays an important role for our country in the development process due to the employment opportunities it provides, the added value it creates in the production process and its weight in international trade [2].

In his study, Güven emphasizes that, the largest share in the final energy consumption in our country, as in the world, belongs to the industry sector with 30-40%[3].

III. MATERIAL AND METHODS

A. Industrial energy management system

1) Energy and energy efficiency

Before explaining the importance of energy efficiency, it is necessary to examine the root of the word 'energy' and the definition of energy efficiency. Many different descriptions

were found during the literature review. The word energy comes from the Greek "energeia" as its origin, and its meaning is expressed as "acting force"[4].

The Energy perspective of Ören is defined as the results obtained from the input and output process follow-up of a workflow. Therefore, in energy efficiency terminology, we can express it as reduction of energy consumption in the industry without causing any decrease in the quality or quantity of the product [5].

Energy must be efficiently used and saved since its consumption increases rapidly and it also consumes natural energy resources in our age. In conclusion, the concept of energy efficiency emerges and gains importance in this context [3].

In general terms, energy efficiency involves efforts to reduce the value of energy density and it is considered as a way of minimizing the amount of energy consumed without reducing the quantity or quality in production or impeding development or social welfare. [6]. The industry sector, which has the highest share, is the leading one in terms of final energy consumption depending on the structure of the countries.

In another definition, "Energy efficiency means, first of all, producing more goods and services with less use of energy (coal, gas, electricity, etc.) without compromising comfort conditions, [7] and shows an improvement towards energy saving by using new technologies"[8].

The study by Sütas describs Energy Management as synergy created to ensure optimum and efficient use of energy, activities for efficient use of resources in a way that will not harm the nature, monitoring from the beginning to the end, not being wasted, making sufficient use, and a mode of using the money´[9]. In short, energy efficiency refers to the use of least possible amount of energy and to apply it without decreasing the standard of living and quality in production.

In this age of rapid changes, it is very important for our country to respond rapidly to these changes and conduct competitive studies at these standards. In implementation of energy management plan in the world, Turkey should properly identify the plans for efficient use of energy resources in the short and long term and work in a disciplined manner in this regard. These programs include training, legal regulations, campaigns and the activities carried out by universities in cooperation with industry. At the end, together with a decrease in the employer costs in the textile industry, energy imports will decrease as well as.

According to the regulation entitled "Measures for Industrial Enterprises to Increase Energy Consumption Efficiency" issued by the Ministry of Energy and Natural Resources in 1995, all factories with energy consumption equal to 2000TEP should establish an energy management system in order to increase their efficiency in energy consumption [10].

Keskin announced that this process will continue with the "Energy Efficiency Law" enacted in 2007. With the enforcement of the law, all activities covering energy efficiency research and environmental awareness in the country will form an integrated structure within the Energy Efficiency Coordination Board [11].

Energy efficiency is one of the fastest and most economical ways that affect the environmental performance developments of industrial enterprises. Özdabak et al. also explained the inevitability of providing continuity, quality and low cost in energy inputs in the industrial establishments where energy costs are high [12]. Therefore, industrial enterprises are obliged to establish energy management organizations that will direct use of energy within their organizations and increase the efficiency and profitability of the enterprises thanks to the energy savings to be provided [13].

2) Textile energy management system

In his work, S.Erden describes the Textile sector as a process starting from fiber, continuing with yarn and fabric, until ready-to-wear products [14].

Akyüz stated in his study that "As in all sectors, it is possible to save energy in the textile industry by reducing costs and increasing profit. This can be implemented by developing a systematic management program [15].

According to Çakal: "Energy Management System is a disciplined study that is structured and organized for more efficient use of energy without sacrificing product quality, safety or any other environmental condition and without slowing down the production. [16]. As a result of this study, the income of the factory is also increased. This should start by measuring the current level of efficiency. Every month, the specific energy consumption should be calculated taking into account the level of production.

Çınar states that: "In the textile sector, intensive energy consumption makes it compulsory to use energy efficiently. There are various applications in this area, including but not limited to insulation in machinery, boilers and transmission systems, using high-efficiency technologies, keeping the combustion quality and efficiency at a high level in the boilers used, efficient use of electrical energy, planning of production, recovery of waste work and waste water energy, prevention of energy losses caused by leaks and inadequate maintenance, and improvement of compressed air systems." [17].

With energy management and revisions in industry, productivity increases can be achieved under conditions that require planned, controlled, coordinated and disciplined work. It should be a more energy efficient work without reducing energy in production, and even factories should have energy policies and personnel training that can be implemented for them. In works carried out with simple operational measures without any specific program, up to 10% energy can be saved in some organizations. With the implementation of comprehensive energy management programs, energy saving efforts are made sustainable, and the saving rate can exceed 25% [18].

Below are listed some factors for the success of the system:

- To increase the efficiency of the manufacturer (boilers compressors

- Machines that breathe too much steam should be transported using separate pipelines.
- Connection of air hoses should be controlled,
- Leaks should be prevented,
- Valves should be insulated and air should not be used when edges are open
- Continuous control of high power consumption points to reduce consumer use,
- Energy should be used in the most economical way, setting up a heat recovery system, training for ironing.

B. Determination of energy consumption

1) Energy scan

Energy consumption varies depending on periodic processes, these can be daily or weekly and they are divided into two.

Specific variables determine the energy need according to the production amount of a part of the factory. These variables are used in standard equations employed to determine the energy need.

Controllable variables are variables planned by management to minimize energy consumption such as business practices, system control, production planning and maintenance standard. [13].

2) Determination of energy consumption standards

After collecting data, the standard line regarding energy consumption of each enterprise should be determined. This standard line is a linear equation showing that the energy requirement depends on specific variables (production, weather conditions, etc.). These types of equations are divided into 3 [13].

In the linear equation ENERGY = a + bP; a and b are constant values, and P is the specific variable of that section. The type of standard equation that can fit any part depends on the number of specific variables and the relationship between energy and these variables. This equation is

a) TYPE (1); E = a

That is, energy consumption is constant and there are no specific variable for the section under study. In this case, the energy consumption of that part is initially constant regardless of production.

b) TYPE 2; E=a+bP

Energy consumption depends on a single specific variable, P (production). The constant a in this equation is the amount of energy that is not related to production.

c) TYPE 3; E = a + bPl + cP2 + dP3 +...

Energy consumption in this equation depends on more than one specific variable. These specific variables P1, P2, P3 may be various variables such as production quantity, weather conditions etc., or various types of products produced in the same section. The constant a is energy consumption that is not dependent on production, which occurs under conditions where all specific variables are zero. The values of b, c, d constants depend on the importance of the relevant variables [18].

The targets are determined after the standard equation found. While determining the standard for each department, the target should be determined at the same time. The target is an equation in the same form as the standard. In order to evaluate the performance after the goal is set in the enterprise, the expected energy use should be compared regularly with the actual energy consumption values. To do this, Specific energy consumption (SEC) values can be used. Specific energy consumption is defined as the energy used per unit product [18].

IV. RESULTS AND DISCUSSIONS

A. Machines used in production and energy consumption

The factory, in operation since 2011, produces clothing for women - men - children (jeans, skirts, shorts, jackets and bustiers) in a major market in Turkey. The main production stages of the factory consist of cutting, stitching, embroidery, washing and ironing.

The number of machines used for production by the textile company in the organized industrial zone of Mardin is 200. The machines consist of electronic lock-stitch machines, electronic twin needle sewing machines, overlock machines, bartacking sewing machines and buttonhole machines. This study was conducted in a company established in 2011 and serving leading brands abroad. The main use of energy in the enterprise consists of the energy consumption made for textile production lines and machines. The factory uses electricity and natural gas as energy sources. Energy analysis of the textile production factory was made for 2019. Energy types and costs used in consumption are given in the Table 1.

TABLE I. ENERGY CONSUMPTION AND COST VALUES OF TEXTILE FACTORY

Type of Energy	Consumption				Cost			Unit Cost
	Quality	Unit	TEP	% Total	TL	TL/kwh	% Total	TL/ TEP
Electricity	827906,14	kWh	71,37	80,68	394332,95	0,48	58,79	5525,19
Gas	198201,84	kWh	17,09	19,31	276347,81	1,39	41,20	16170,15
Total	1026108	kWh	88,46	99,99	670677,76	1,87	99,99	21695,34

As seen in the Table 1, the share of electricity in total energy consumption is 80.68% while this ratio is 19.31% for natural gas. It was determined that the electricity consumed constituted 58.79% of the total cost of energy while remaining 41.20% is related to the consumption of gas.

Table 2 shows the energy production and consumption values of the factory by months for 2019.

Specific Energy Consumption (SEC) method was used to evaluate the energy efficiency and performance of the enterprise. Specific energy consumption (SEC) is simply the energy used per unit product.

$$\text{Specific Energy Consumption} = \frac{Total\ Energy\ Consumption}{Total\ Production}$$

Specific variable in a factory, i.e. production, is expressed in ton/kg/m2/piece etc. Energy consumption-production relations and SEC values are given below. Examining these values on a monthly basis is more suitable for analysis. Variable values are seen in monthly production and consumption amounts.

TABLE II. ENERGY PRODUCTION AND CONSUMPTION VALUES OF THE TEXTILE FACTORY BY MONTHS IN 2019

Electricity Gas		Electricity consumption (kWh)	Electricity cost (TL)	Gas consumption (kWh)	Gas cost (TL)	Total consumption (TEP)	Production pieces (TEP)
Total	2019	827906,148	394329,95	198201,84	27634781	1023,83	787251
2019	January	71980,13	27229,18	20619,05	33267,1	92,59	50987
	February	62113,3	28379,76	15283,54	24569,53	77,39	63342
	March	71520,05	33093,12	23375,77	26778,03	94,89	56837
	April	69843,318	28617,97	23103,66	26502,33	92,94	76270
	May	63225,55	28668,36	10881,4	12595,92	74,10	44665
	June	51570,6	30130,08	6627,83	7963,95	58,19	45598
	July	78052,8	40865,87	10930,65	12797,85	88,98	92211
	August	68296,2	34840,82	7146,3	9538,97	75,44	39957
	September	61327,2	29140,76	12563,63	19058,96	71,89	55638
	October	72477,6	35977,49	17696,25	26972,69	90,17	96017
	November	73871,4	37092,81	15937,1	24299,85	89,60	63522
	December	83628	40293,73	34036,66	52002,63	117,65	102207

TABLE III. SET VALUES FOR 2019

Energy		Total Energy (TEP)	Production (piece)	SET (TEP/piece)
Total	2019	1023,83	787251	0,001
2019	January	92,59	50987	0,001
	February	77,39	63342	0,001
	March	94,89	56837	0,002
	April	92,94	76270	0,001
	May	74,10	44665	0,002
	June	58,19	45598	0,001
	July	88,98	92211	0,001
	August	75,44	39957	0,002
	September	71,89	55638	0,001
	November	90,17	96017	0,001
	October	89,60	63522	0,001
	December	117,65	102207	0,001

Using the factory's 2019 production and energy consumption values, a chart was created between energy consumption and production and a standard equation was explored.

The points at the bottom of the line chart indicate that energy efficiency is increasing. The goal is to reduce the linear SET value by reducing energy consumption(SET) per unit product. Therefore, the similar line equation formed by the points below the standard line graph in Target Evaluation is the target SET value equation.

As can be seen in the Figure 1, according to standard graph, R^2 value was found to be 0,4995 and standard equation relation was found to be y = 0,0005 (x) + 52,942. In the target re-evaluation at the points under the linear graph of the standard

equation in the Figure 1, the R^2 value was found to be 0.7933 and the target equation was found to be y = 0,0005(x) + 46,601.

The closer the square root of theR^2 value found in the production-total energy consumption graph to the value of 1, the more linear the production-consumption relation.

Accordingly, the R value of 0.70 and the target R value of 0.89 show that the relation between energy consumption and production improved according the actual operating conditions of the factory.

Çakal stated that target energy consumption values are target energy consumption for standard product values calculated based on the target equation found [16]. The energy saving potential of the company was found by comparing the standard, target energy consumption and SEC values. The Table 4 shows these calculated values

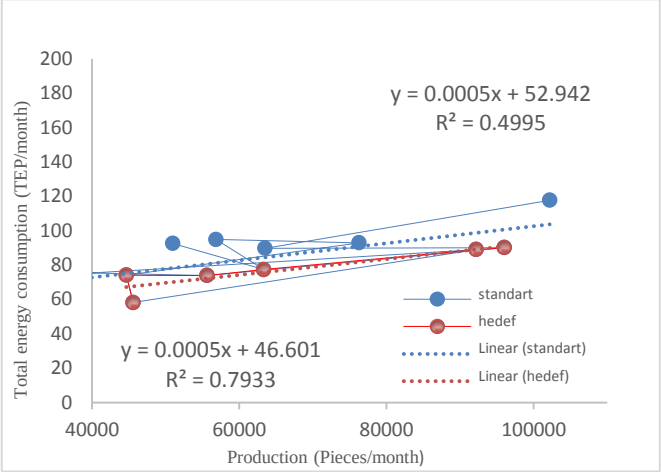

Figure 1. Total energy consumption and production of the factory

TABLE IV. PRODUCTION, ENERGY CONSUMPTION AND SET

Month	Production values (Piece)	Standart Electricity consumption (TEP/Month)	Standart SET value (TEP/Piece)	Target Energy consumption value (TEP/Month)	Target SET consumption value (TEP/Piece)	Target Energy Saving (TEP/Month)
January	50987	92,59	0,001	50,987	0,001	41,61218
February	63342	77,39	0,001	63,342	0,001	14,05484
March	56837	94,89	0,002	113,674	0,002	-18,7782
April	76270	92,94	0,001	76,27	0,001	16,67698
May	44565	74,10	0,002	89,13	0,002	-15,0231
June	45598	58,19	0,001	45,598	0,001	12,60043
July	92211	88,98	0,001	92,211	0,001	-3,22755
August	39957	75,44	0,002	79,914	0,002	-4,4715
September	55638	71,89	0,001	55,638	0,001	18,25283
October	96017	90,17	0,001	96,017	0,001	-5,84315
November	63522	89,60	0,001	63,522	0,001	26,2865
December	102207	117,65	0,001	102,207	0,001	15,45766
Total	787251	1023,83	0,001	409366,3	0,001	616741,7

V. CONCLUSIONS

The aim of the study is to make an energy scan to contribute to the energy saving studies of a textile production factory. By examining the energy consumption data and production data of the factory for 2019, standard energy consumption was calculated taking into account the production and consumption data, and the related target energy consumption was found.

In the research conducted; standard energy consumption equation was found to be E = 0,0005 x (P) + 52,942 and it was determined that the energy consumption value varies depending on the production variable by 58,19 to 117,65 TEP/Month. The target standard energy consumption equation for the next year was found to be E = 0,0005 x (P) + 46,601, and it was determined that the energy consumption value varies depending on the production variable by 45,59 ile 113,67 TEP/Month.

According to the specific energy consumption (SEC) values, it was calculated that the energy saving potential can be realized as 60,24 i.e. 616,741 TEP per year. Accordingly, it is seen that financial savings would be approximately TRY 260,340 for 2019.

Besides, in order to increase this saving at the factory, insulation of the fixtures and boiler surfaces in the boiler room may be improved, or a speed drive may be added to the compressed air compressor, or frequency controls may be used for the circulation pumps and electric motors.

There are also low temperature processes and solar energy can be used for such processes. In conclusion, since the drying process in the textile factory is an energy consuming process, it is stated that it will save energy and reduce the emissions that lead to environmental pollution.

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