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# ENERGY EFFICIENCY IN TEXTILE INDUSTRY FOR SMALL AND MEDIUM-SIZED BUSINESSES

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**Abstract.** In this study, research was carried out on how to prevent unnecessary energy in the textile sector, and solutions were presented in this context, identifying the main problems. The textile industry is one of the most beautiful examples in the globalized world. A product is not manufactured in a plant from start to finish, but instead, it is customized to be small and medium-sized enterprises (SMEs) for one task. Energy efficiency is especially important for SMEs to compete with businesses in Asian countries in the market. The purpose of examining the energy sources used in this study under the headings of electricity and thermal energy was to prepare a more detailed report and create a resource that could be used in the sector. As a result of our study, energy savings of up to 60% can be saved by changing most machines and working methods used in the sector with simple customizations or new ones that can be made in machines because of the lack of old or working methods designed to meet the old or needs.
***Keywords:*** textile industry, energy efficiency, energy management, thermal energy.

## INTRODUCTION

Textile industry is one of the areas with the most complex manufacturing chain, the biggest reason for this may be to show that small and medium-sized enterprises (SMEs) have a significant share in production. The variety of main methods used in the textile manufacturing industry and the different processes with them from the machines used are the main reason for this complexity. More than one type of fibers or yarns, different fabric production methods and final process processes (preparation, printing, painting, chemical / mechanical finishing and coating) is to keep an important place in the production of a finished fabric.

Energy prices are one of the main costs in the technical industry. Especially in the present day when energy prices change rapidly and enter the upward trend, increasing energy efficiency should be one of our main issues. We need to avoid unnecessary waste and energy consumption, which is important not only as cost, but also for solving the problem of the climate crisis. However, since the production facilities in the textile sector are generally in SME class, their knowledge of this issue is very limited because they do not have a special employee about energy efficiency. With this, there are opportunities to increase energy efficiency with low costs. Energy datamiliation programs, seminars and handbookes to be prepared by the states regarding the necessity of these methods and energy efficiency should be informed about energy efficiency technologies and applications.

Table 1

**Leading exporters of textiles in 2000/2010 and 2018** (WTO, 2018)

| **Top 10 Exporters** | **2000** | **2010** | **2018** |
|---|---|---|---|
| China | 10.3% | 30.4% | 37.6% |
| European Union (28) | 36.4% | 26.9% | 23.5% |
| Extra-UE (28) Exports | 9.8% | 8.1% | 7.2% |
| India | 3.6% | 5.1% | 5.8% |
| United State of America | 7.0% | 4.8% | 4.4% |
| Turkey | 2.4% | 3.5% | 3.8% |
| Republic of Korea | 8.1% | 4.3% | 3.1% |
| Chinese Taipei | 7.6% | 3.8% | 2.9% |
| Viet Nam | 0.2% | 1.2% | 2.6% |
| Pakistan | 2.9% | 3.1% | 2.5% |

In this paper generally we will focus to SME's companies energy efficiency problems because they have the highest percentage in the industry and because they don't have a direct energy management policy. With this resource, they can increase competition by managing energy use more rationally against the cheap labor force in Asia and Africa, and I wanted to help them fulfill their part in our step into a cleaner world.

Table 2

**Leading importers of textiles in 2000/2010 and 2018** (WTO, 2018)

| Top 10 Importers | 2000 | 2010 | 2018 |
|---|---|---|---|
| European Union (28) | 34.9% | 27.8% | 23.1% |
| Extra-UE (28) Exports | 9.8% | 10.0% | 9.7% |
| United State of America | 9.7% | 8.7% | 5.3% |
| China | 7.8% | 6.6% | 5.3% |
| Viet Nam | 0.8% | 1.7% | 3.3% |
| Bangladesh | 3.0% | 2.7% | 2.7% |
| Japan | 0.9% | 1.6% | 2.1% |
| Indonesia | 0.8% | 1.9% | 2.0% |
| Mexico | 3.5% | 1.9% | 2.0% |
| Turkey | 1.3% | 2.4% | 1.8% |

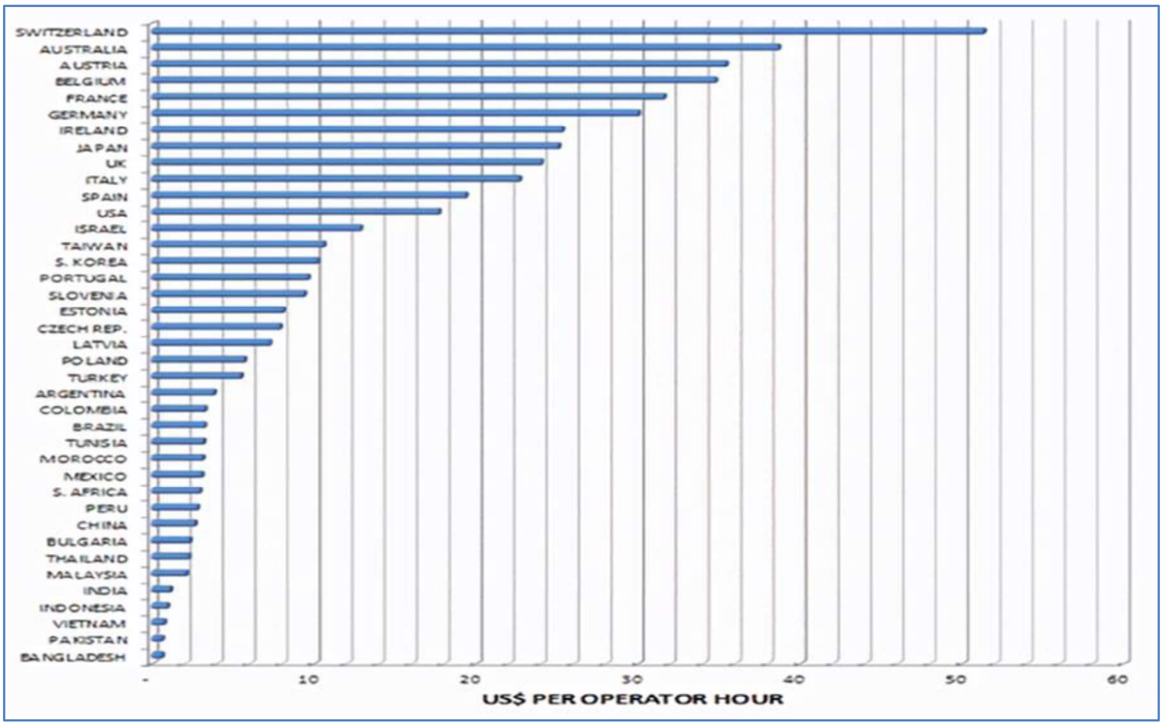



Figure 1. **Textile industry labor cost – 2014 Werner international** (Sheng, 2014)

## OVERVIEW OF THE TEXTILE INDUSTRY

Textile has played an important role in the progress of humanity since the early age. Thanks to the first clothes, the people who survived the ice age quickly adapted to the very different climates around the world. With the invention of steam machines, the textile industry has played the main role in the changing of countries and the world.

China, European Union (EU28), and India remained the world's top three exporters of textiles in 2018. The countries in the top three exported a total of 567 billion USD in 2018, including 234 clothing and 333 billion USD (WTO, 2018).

The textile industry is traditionally regarded as a labor-intensive industry developed on the basis of an abundant labor supply. The global workforce is estimated to be 3.4 billion people. 430 million are thought to work in fashion and textile production. The number of persons employed in the textile and clothing industry was around 6.4 million in China in 2010 (NBSC, 2010; ILO, 2010; Fashion United, 2020; Un Comtrade, 2020), around 2.3 million in the European Union (EU) in 2007 (Un Comtrade, 2020; Euractiv, 2020; European Commission, 2003a; European Commission, 2008; industriAll European Trade Unio, 2016; Report Linker, 2020; Invest in Eu, 2016), and 500,000 in the US in 2009 (WTO, 2018).

In 2014, the hourly work wage of workers working in the textile industry is comparative among 49 countries in U.S. dollars (Sheng, 2014; Euractiv, 2020; European Commission, 2003a; European Commission, 2008; industriAll European Trade Unio, 2016; Report Linker, 2020; Invest in Eu, 2016; Dodd et al., 2013; Verner International, 2006; Emerging Textiles, 2020; Berik & Rongers, 2008). Worker's and energy wages played an important role in the rise of production in Asian countries by the 2000s. Textile companies in Europe are predominantly SME and 70% of their employees are women (Euractiv, 2020; European Commission, 2003a; European Commission, 2008; industriAll European Trade Unio, 2016; Report Linker, 2020; Invest in Eu, 2016; Dodd et al., 2013). In these circumstances, energy efficiency is of great importance in order to compete with companies in Asia and Africa.

## TEXTILE PROCESSES

Although the textile industry is usually a production order as shown in the picture, in some special cases their order may change or not be done at all, and it is very difficult to do all these operations in a single facility. Operations are usually done in separate facilities in groups. This article will be briefly mentioned in the main processes that consume the most energy, as the procedures given here as the title are often very difficult to mention all of this, which usually includes many processes as subheadings. Studies will be done on the possibilities for increasing energy efficiency for these operations.

In some stages in textiles, multiple types of energy are used together. For example, during dying phase, we usually need steam and electrical injectors at the same time. In this article, we will examine these types of energy separately.

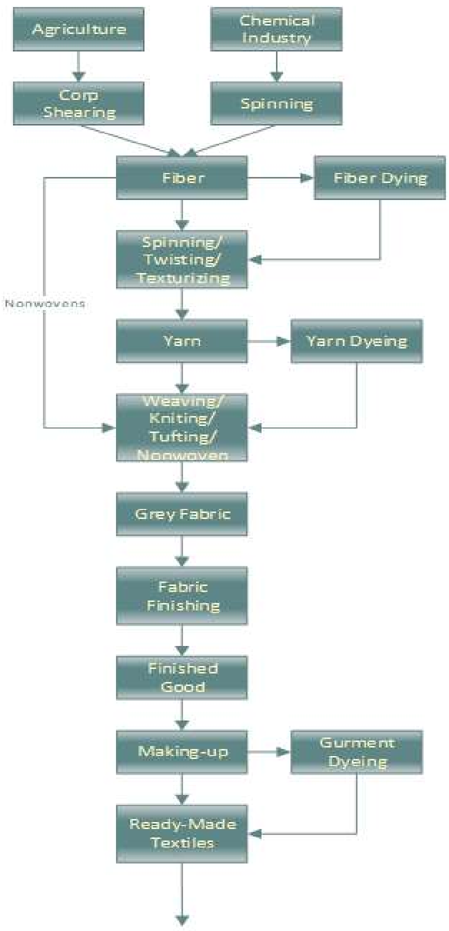



Figure 2. **The textile chain** (European Commission, 2003b)

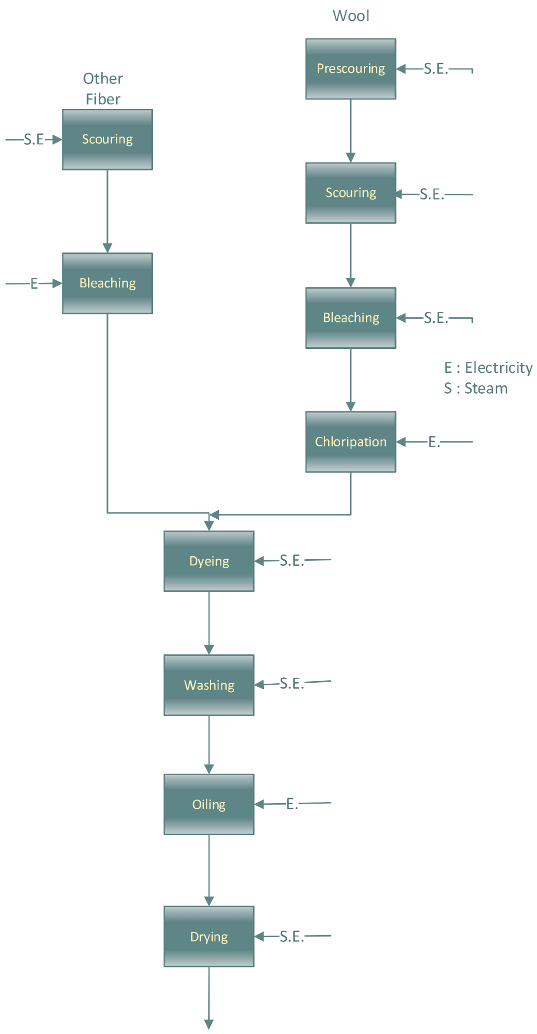


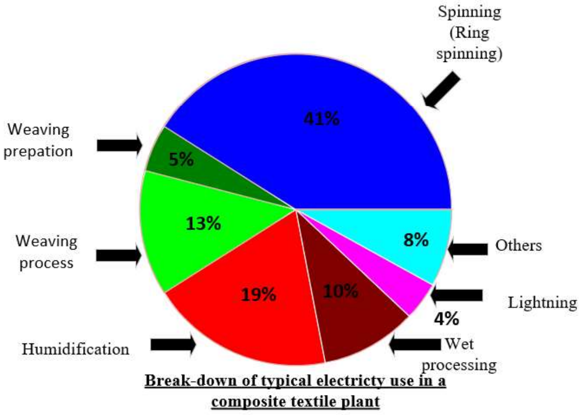

Figure 3. **Dyeing and finishing process for fiber and yarn and energy use** (Tang & Mohanty, 1996)

## ENERGY USE IN TEXTILE INDUSTRY

In the textile industry, productions do not take place in a single facility or with the diversity of production, the diversity of energy used in the variety stands out. That's why it's not defined as a very energy-consuming area at first glance. The difference in energy consumption and consumption occurs depending on the energy used in conjunction with this or what type of product it produces. Because of all this, some of the applications we recommend or do here may have different results.

A large amount of energy is used in the textile industry and is often used as follows: Electrical machinery, lighting, cooling, air conditioning systems, and so on are used as the main power source. Natural gas, oil, or coal are used for steam boilers. It is usually used together with electricity and steam (Tang & Mohanty, 1996). This research will focus on methods of improving electricity and fuel efficiency. For example, weaving is used together with a large amount of fuel and electricity in the dyeing and finishing operations.

The use of energy in a plant has spinning, weaving/ knitting, and wet-processing, which includes all the main steps of electricity and thermal energy together is in the graphic. Each step in textiles contains its own unique methods, and these steps are often used together with electricity and steam energy at the same time. If we look at the chart, thermal energy is used in a very large amount of wet operations (35%). During steam production and distribution, a significant amount of thermal energy is also lost (35%). These percentages will vary depending on the facility. If you look at the electrical energy graph, it has a consumption rate, such as Spinning (41%) (Tang & Mohanty, 1996). It is not surprising that the humidity, which has a significant impact on the quality of the structure and the products used, is in second place because it can also make an important contribution in preventing heat loss in wet processes. Therefore, in order to provide energy efficiency, the order and necessity of the operations need to be thoroughly understood.



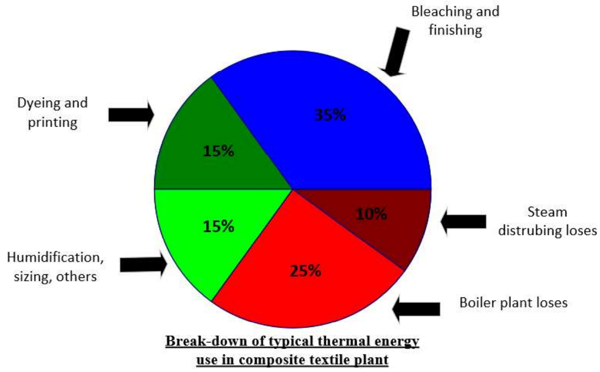




Figure 4. (a) **Break-down of electricity use in composite textile plant** (b) **Break-down of thermal use in composite textile plant** (European Commission, 2003b)

Having a specific energy management plan for the plant is very important for efficiency. It should be noted that since facilities in textiles are generally customized for a few steps, and features from climate and geographical coordinates can create huge differences (Hasanbeigi & Price, 2012). The best way to increase energy efficiency in a facility is to create an energy management program that contains detailed the use of all-inclusive energy that includes all stages and contacts in the institution. Such a program includes every step of the facility, including the management of the facility, the environment, health, safety and personnel, and is working with an energy engineer and those who are experts in that field.

It can be stated that the concept shown as the basic rule for the energy management system consists of the plan-build-check law philosophy of the ISO quality management system. It is important to consult and brainstorm with department managers and key engineers at the factory to get the necessary inputs when creating a detailed action plan. A detailed action plan creates a systematic process to ensure energy efficiency. An action plan is regularly reorganized at the end of each year to reflect achievements, performance changes, and changing priorities. The following steps outline a basic starting point for creating a plan action plan:

1. Define technical steps and objectives.
2. Identify roles and resources.


Figure 5. **Energy management strategy** (Hasanbeigi & Price, 2012)

In general, the amount of electricity consumed in each piece of equipment varies by machine type and factory scale so it cannot be handled in a standard way, so they must customize the energy efficiency management of each company (Abdel-Dayem & Mohamad, 2001).

## ENERGY-EFFICIENCY IN THE TEXTILE INDUSTRY

We can collect and examine the types of energy used in the textile sector under 2 main headings. This article will discuss efficiency recommendations and methods on Thermal Energy and Electricity. First, we will work on the possibilities of increasing energy efficiency in plants that contain very high lost energy and use thermal energy that we can get the reward of our investment in this area in a very short time by applying some basic principles. Although the technology and methods in general will include recommendations on improving or rearranging however sometimes new machines with high energy efficiency of state-of-the-art can offer less time and more efficient solutions. After that, we will talk about renewable technologies and ways of generating electricity and thermal energy for the plant more cheaply.

### A. 1. Thermal Energy

In the textile industry, it is often necessary to heat or cool the gases and liquids in preparation of the product for processing or directly in these processes. We can briefly call this need thermal energy. As you can see in the chart, wet process and finishing demand half of this energy. Along with that there is a huge loss of as much as 35%. We will work on how to eliminate this loss as a priority and then I will address the methods of reducing energy consumption in wet processes and finishing processes. With the use of heat recovery systems in production facilities, some of the need for hot water and steam can be met and energy loss can be avoided. It is important to reduce the amount of lost energy while reducing the plant's carbon footprint and reducing costs. Gas turbine with recovery boiler and thermal fluid heater. Since exhaust gas contain a large amount of excess air and the exit temperature is high, a thermal fluid heater can be incorporated in order to improve the system thermal efficiency. Post-combustion is required in both thermal fluid heater and boiler.

#### *A.1.1. Energy Losses and Solutions*

When producing or using them while playing an important role in hot water and steam in the textile industry, a large amount of waste heat occurs. Steam condensate discharges are hot and clean water flows and we can use these flows as boiler feeding water or for the preparation of paint baths. It is not only provided with a large amount of energy and also helps the plant reduce water consumption and produce less wastewater. If the steam rate is over 5% continuously blown, we can use waste heat recovery systems in any boiler. With pressure ratio, energy savings are directly proportional. Some of the water exposed as a result of these operations were clean, while others were contaminated with numerous chemicals and paints. These wastewater flows are usually discharged at temperatures of 60-70 C. These waters can be heated and cooling indirectly with heat exchangers instead of a direct heat exchange. It is important to find the right heat exchanger here and customize and use it for the intended process. In this way, it can reduce contamination or chemical reaction to the mass and control the pollution level of the wastewater flow due to direct contact. It also contains a significant amount of heat from boiler shaft gases. This energy can be used to preheat boiler feeding water with economizer.

Steam is widely used in the textile industry, the pressure and loss of steam caused by heat radiation from Steam during transport is not to be underestimated. To prevent this, the boiler and pipeline must be insulated with insulated materials. Thanks to thermal insulation in boilers, we can get safety and performance advantages. Generally, the insulation process and the material to be used varies depending on the age of the boiler, its design and the canteens in which it is made. The materials used in insulation should be regularly controlled and repaired as needed because they are subjected to high heat and pressure during use. Boiler control systems are important for monitoring performance and ensuring that the gain is in safe ranges. These systems must include a combustion control system, flame protection, water level control and fuel control to use energy efficiently (CADDET, 1993).

Due to the improperly installed pipelines and equipment or the installation of the plant without taking into account, leaks occur with a path or loss of pressure. If transportation is to be carried out at long distances, high-pressure pipes should be preferred instead of low pressure and large diameter pipes.

Excessive valve and pipe blocking in the plant causes pressure and energy loss. Since the pressure losses in the corners are large, it may be a wise choice to reduce pressure by increasing the radius around here. With this, all broccoli and steam condensates should be properly insulated and their maintenance should be done by experts. In general, the importance of preventive care is not understood or neglected to stop production, resulting in large-scale energy losses due to leaks every year. Steam traps do not work functionally due to mismanagement or neglect. In addition, there are no significant losses in the old machines still in use in the facilities when there are no steam control valves or energy controllers. As a result, if the boiler and pipeline are improved and the system is under regular control and routine maintenance, we can achieve an important energy saving and a cleaner working environment (Textiledigest, 2009; European Commission, 2003b).

### *A.1.2. Opportunities to Increase Energy Efficiency in Production Processes*

Weaving machines (weaving looms) consume an average of 50 to 60% of the energy collected in a facility that only works on weaving. The remaining energy varies according to the lighting, humidification, compressor, and type of machine used (Worrell & Galitsky, 2004). Since the weaving thesis is customized according to the product used, the main issues to improve energy efficiency depend on the productivity of the machine, the humidity of the environment, the pressure air system used, lighting and maintenance, and so on.

In addition to these, we can use the following primarily to increase the efficiency of the weaving process on the counters.

We can use counterflow currents for washing in this method, while the fabric continues on its way to washing normally, we can make the cleanest part of the clean water outlet to the entrance into contact with the cleanest washing solution in the plant. With this, the washing solution is 40 C warmer than the exocellular system, thus demanding less energy in the next stage of building. In addition, use less water and energy in washing. This process consists of washing equipment, washing and dehydration mechanism, filter equipment, sensors, and pumps. Washing water is fed in the opposite direction of fabric flow, and the sensor detects water pollution to automatically adjust the feeding speed of the water (Sivaramakrishnan et al., 2009). After inspections and tests at many facilities where this process began to be used, a water-saving of 50% and steam savings were provided (Sivaramakrishnan et al., 2009; ECCJ, 2007; Textiledigest, 2009).

A heat recovery equipment, a heat exchanger, can be installed in the continuous washer machine. This process which is actually quite simple, can save huge amounts of energy, so we can remove the water tank by matching the flow of water in and out of the system. Of course, due to the washing phase, we can use a self-cleaning heat exchanger or a heat exchanger with a pre-filter that can remove the fibers that come with the waste water.

In wet processes, it is necessary to rinse the fabric or yarn with high temperatures of water before proceeding to the next step (up to 80° Celsius). Sometimes the amount of rinsing water can be up to 25-30 times that of the product used. The water used in rinsing can be used to preheat the water to be used for the next rinsing and also helps to cool the waste water before treatment, resulting in a double-sided gain.

Steam coils can be used instead of direct steam usage used to heat bulk painting machines used in textiles. Paint paths on older machines are more inefficient in terms of energy efficiency than directly heated by raw steam in the central system. We can provide condensation by submersing a steam coil into a paint bath so that a large fuel design is possible (Carbon Trust, 1997).

Microwave dyeing equipment uses fast, efficient and energy-saving dispersion and microwaves to penetrate the fabric of paints and chemicals. This equipment has a very different operating principle than traditional painting equipment. Since microwave irradiation generates heat through dielectric losses, the heat is absorbed by objects with large losses, thus heated without heating the moisture-containing fabric, surrounding air and equipment, which significantly reduces losses from environmental factors. In addition, in the case of fabric piercing (paint solution) moisture, the steam generator with internal heating of paint and chemicals and penetration and distribution quickly and fairly, mass production ensures the suitability of the fabric for continuous painting (Sivaramakrishnan et al., 2009).

Steam is widely used in almost every area in the textile sector. In many plants, especially older ones, steam use is manually controlled in many parts of the process. This often results in a significant waste of steam. An automatic steam control system controls the supply of steam to each piece of equipment according to the requirements of the process preset in the system so that we can prevent excessive amounts of steam being delivered to the machines.

Heat recovery from exhaust gases of stents can be achieved using surface-to-air systems such as plate heat exchangers, glass-tube heat exchangers, or heat wheels. Their efficiency is usually about 50-60%, with which problems with air bypass, contamination and corrosion can arise (CADDET, 1993; Hasanbeigi & Price, 2012).

Stenter machines use energy intensively, so it is important to remove the moisture and excess water before the fabric enters the oven. We can achieve this using mechanical equipment such as mangaes, centrifuges, suction slots and air blades etc. and drying can be obtained by passing over heated cylinders before entering the fabric oven. If the moisture content of the fabric is reduced from 60% to 50% before entering stenter (depending on the type of substrate), up to 15% energy savings can be achieved in stenter (CADDET, 1993).

In general, it is common to maintain energy efficiency by regular maintenance or by regularly checking machine accents and adapting new technology products to machines and manufacturing processes.

### A. 2. Electricity

Electricity is required for all side operations from operation of textile machines, ventilation, pumping, lighting, humidification and etc. It is used at all stages, making it difficult to find unnecessary use or lost use. As mentioned above, the most consumption in the textile sector is at the spinning stage. On the other hand, the total consumption rate of humidification, lighting and other processes seen as auxiliary processes or elements can be 31%. Of course, the rates here can reveal big changes according to the operations performed in the facility, the methods and machines used. Therefore, in this article we will examine the textile processes and auxiliary elements separately.

#### *A.2.1. Energy Saving Opportunities in Textile Processes*

A large amount of electricity is used in Spinning operations, especially in cotton bending systems, we can easily see this in the chart. Thermal energy use may vary according to the plant's multiplex coordinates. Thermal energy is generally required to provide the moisture needed for the plant and the process, and sometimes for the dyeing or fixing of the yarn produced.

The old types of a simplex machine have a pneumatic suction pipe in the roving end cutting system, and if we replace it with a photoelectric stop-motion end-cutting detector system, we can save energy. Investigations in two of the factories using this measure showed that an average of 3.2 MWh/year/machine electricity savings was achieved per machine and the installation of this system was made at a very low cost (EMT, 2008a).

The weight of the spindles inside the ring frames directly affects the energy consumption of the machine, ring frames are the largest energy consumer in the ring spinning process. High efficiency spindles that are lighter than normal can be used in the market. An average saving of 23 MWh / year / ring was achieved by applying this method at a spinning plant (EMT, 2008b).

We can replace the cotton bands on the ring frames with synthetic sandwich spindle bands, which are made from a mixture of polyamide, cotton yarn and a special synthetic rubber. Sandwich tapes are made of soft and flexible tape bodies that work more stable, resulting in less weakly twisted yarn, unbreakable, not fiber adhesion. Thanks to all these features, 5-10% energy saving is achieved with the use of these bands. A case study conducted at one plant showed that two average 8 MWh/ring frame/year energy savings were achieved (Palanichamy & Sundar, 2005). Together with this, there may be differences in energy saving values as the number of spindles in these machines may be different from each other (EMT, 2008c).

Energy saving excel fans can be installed in the suction system of ring frames. The purpose of use of these fans is to absorb the fibers formed when a thread break. The average cost of these fans is US$ 19 - 310, giving us an average annual electricity saving of 5.8 to 40 MWh/year/fan (EMT, 2008b).

The light coil can be used in ring frames. The yarns are collected on coils and they make period movement through the spindles on which they are seated in coils. Spinning the spindles is the most energy-consuming step in the ring machines and this energy consumption is directly proportional to the weight of the coils on the spindles (EMT, 2008c).

Autoconer machines are usually used to wrap small coils of yarn into larger cones. It can help save energy if variable frequency drives (VFDs) are installed in the Autoconer's main engine to maintain a constant vacuum. Electricity savings of 331.2 MWh/year were achieved in a plant implementing the method (but no Autoconer number applied to this method is specified) (EMT, 2008d). It can also be switched to an intermittent mode of motion instead of the continuous movement of empty coil conveyor belts. The results obtained from the facility implementing this measure provided maintenance cost savings and waste reduction and electricity savings of 49.4 MWh/year (we don't have Autoconer number applied to this method is specified) (EMT, 2008d).

Wet operations are generally the most energy-consuming process in the textile industry and in the textile industry, which is because it uses large amounts of thermal energy and is high in electricity consumption. The amount of energy consumed may vary greatly due to the method used, which type of product (fiber, yarn, fabric, fabric) depends on many variables, such as the type of machine used, the last product we obtained. With this, it is possible to save significant electricity by making small changes, even by applying appropriate maintenance and instructions. Some of the methods that can be followed at the loom are explained:

• Machines must be regularly edited and more than 90% of use. If the utilization rate on these machines is reduced by 10%, this energy consumption will increase by 3-4% (Worrell & Galitsky, 2004).

• The electric motor of the machine can be replaced with an energy-efficient engine or the engine with which is regularly maintained.

• The type of weaving machine plays an important role in energy consumption. Therefore, it can make a difference in getting a new machine with high energy efficiency. Therefore, we cannot make a general recommendation for the type of bench that should be used; rather, it should be recalculated for each operation. In the meantime, raising or replacing old equipment makes a difference, with lower costs and energy savings.

• When high-speed painting machines and high-speed spinning frames are used, a certain amount of thermal energy and electricity can be saved.

• The quality of the threads used for warp and weft directly affects the efficiency and energy consumption of the weaving process. In fact, although these yarns have a higher cost, this leads to less thread breakage and stopping in the weaving process, and in other statements, it may be more costly to use cheap and low-quality yarns in weaving.

• All parts of a machine are not used until the end of the process, so significant savings can be achieved even if only used when necessary. I'm going to try to explain this with a few examples and their solutions.

When a machine is stopped in textile facilities, auxiliary units working with it continue to work and cause energy waste. We come across a situation like this in the operation of fabric singeing machines. In many facilities, cooling blowers are constantly running even after the singeing machine is stopped. As a solution, energy saving can be achieved by locking the cooling fan motor with the main engine of the singeing machine. This measure resulted in the implementation of an average of 2.43 MWh/year/machine electricity savings with the implementation of a plant in India. The investment cost of this measure is zero or very small (EMT, 2005a). We can use the same method in fabric cutting machines, the blower motors can be connected with the engine of the machine. This measure has not been implemented before in a textile factory in India and based on this, 2.43 MWh / year/machine energy savings can be achieved. The investment cost of this measure is zero or very small (EMT, 2005a). Exhaust fans, which are usually fitted to hoods used to smoke in yarn roller machines in facilities, remain open throughout the process. With this, the exhaust output occurs only during the washing if we automatically close these fans with the forward movement of the water tray, the use of the fan will save electricity. A case study of 12.3 MWh/year/machine showed that electricity savings were achieved through this method. Again, the cost of investment for this measure is very small (EMT, 2006).

In the textile industry, large differences may occur according to the type of product used, the preferred method and the quantity of the product to be used. If you use variable frequency drives (VFDs) instead of general and manually controlled systems here, energy consumption can be provided as much as requested. In the case of studies, the average electricity savings and average electricity savings are as follows:

• Upper painting machines allow the wool to be painted before spinning. If we install VFD in the pumps of these machines, we can degrade the speed according to the situation, so the average electricity savings were approximately 26.9 MWh/year/machine (EMT, 2008e).

• Control of circulation pumps, which still ensures the flow and management of chemicals in the textile sector, is usually controlled by global valves. If we can install and use VFDs instead of spherical valves. It can also be installed in mixers used to mix colors. These two methods were implemented in a plant and provided with 38 MWh/year electricity savings (EMT, 2005b).

• Solvents are a machine that is required in the production of viscous filament and usually operates at a constant speed throughout the entire process, while speed varies depending on the processing. In India, VFD was installed on solvent engines and an average of 30.3 MWh/dissolver/year electricity savings were achieved (EMT, 2008f).

• In the washing machines, especially those used after treatment, on average 40.4 MWh/pump/year electricity can be saved by using pressure-controlled variable frequency drives to washing pumps. The amount of energy savings here can change variability because the speed of washing pumps is changed according to the denier (thickness) variation of the thread (EMT, 2007).

If we adjust the balloon size of the TFO (one-to-two) twister machines to the optimal level based on thread bends and the number of different threads, we can save energy because research shows that electricity consumption is less in low thread balloon setting. This method was applied at a facility to save 205 MWh/year electricity, but it is not specified which type of products or how many machines this is applied (GTZ, 2007).

Using high-speed multi-yarn line yarn production equipment to produce nylon and polyester filament, 6,000 min high speed completely retreated filament (FDY) or partially directed filament (POY) melts, rotates and improves productivity and energy efficiency by making wrapped in the same process. The new equipment continuously continues the spinning process and filament construction process, reducing electricity consumption by 55% (NEDO, 2008).

Energy-saving can be achieved by drying coil products with Low Pressure (LP) microwave dryers. LP microwave drying method has better drying efficiency and preventing products from drying excessively. 107 kWh/ton yarn thread is achieved in electricity saving (NEDO, 1997).

### *A.2.2. Electric Motors*

The electric motor is used extensively in textiles, and the majority are in the small to medium size class. The machines used in conjunction with this usually consist of old type engines with no single engine and speed adjustment since they are older. Generally the engines are efficiently in the operating range of 50-100% of the nominal load, also their maximum efficiency is considered to be 75%. Research has shown that the best choice for the textile sector is a two-speed motor with variable loads, adjustable speed drives and an acceptable range of different loads. This is important because a machine is not always produced with the same type of product and the same amount, so we have to choose an engine that can give us flexibility. In addition, if we choose an engine that is too large or too small, it will force the nominal values of the engine and reduce the efficiency. This is why energy efficient engines should be replaced because they reduce their losses with improved design, better materials, tighter tolerance ranges. With the right installation, energy-efficient motors can stay cooler, have a longer insulation life and less vibration. In some special cases, instead of buying a new motor, our energy-efficient motor with Rewind and reuse it we can, but we need to be careful here, the costs of a new engine rewind 60% of the cost should not exceed, otherwise to buy a new motor would be a better choice (CEE, 2007).

The primary objectives of engine maintenance are to predict failure and extend engine life. Care allows us to take preventive measures. These are generally to minimize voltage imbalance, to lower engine temperature by engine ventilation, to control energy consumption by load assessment, to prolong life by engine alignment and lubrication (Barnish et al.,1997). With the engine maintenance program, a savings of between 2 - 30% of the total energy used in the engine system can be achieved (Efficiency Partnership, 2004).

### *A.2.3. Air Compressor*

In the textile industry, compressed air is used extensively in many stages and leakage in air compressor systems is a common problem. Leaks often occur in ports, used pipes, seals, valves, and old pneumatic equipment. It is also commonly seen in the knitting process, and its cost cannot be calculated precisely because it cannot be fully identified. Together with this, the compressor has to work over time to maintain the pressure in the compressed air line, which means excessive electric consumption (Trygg & Karlsson, 2005). More than 85% of the air entering the air compressor is discarded as waste heat, and only about 15% of the electrical energy consumed is used as compressed air energy (USA) (DOE-ITP EM, 2008). System controls therefore play a central role in the efficiency of air compressor systems. The system should be used with minimum amount of compressed air for a short time and must be constantly re-arranged according to the needs of the system. As usual, it can monitor air leaks or pressure changes with maintenance and allow us to take precautions based on changes in operating temperature or humidity status.

When there are large differences in ambient temperature, humidity rate and load, there will be large oscillations in compressor load and efficiency. In these cases it can meet itself in a short time by installing adjustable speed drives (Heijkers et al., 2000). With the application of adjustable speed drives in rotary compressor systems, it is possible to save 15% of the system's annual energy consumption (Radgen & Blaustein, 2001).

When the condensate is removed from the system, electronic condensate evacuation traps (ECETs) offer improved reliability and are very efficient as almost no air is wasted when the condensate is rejected. Normally a receiver tries to take the air out of the system by forcing the drain valve to open, but this method is extremely wasteful and costly.

The pipes to be used in the system can be designed optimally and reduce pressure losses, leaks and production costs. The increased pipe diameter generally reduces the energy consumption of the annual compressor by 3% (Radgen & Blaustein, 2001).

If all ports in a system are not installed correctly, they can be considered compressed air leak points. In addition, leaks not only can cause increased energy consumption, they can make pneumatic systems/equipment less efficient and adversely affect production, Shorter equipment life, lead to additional maintenance requirements and unscheduled downtime. A typical plant if it is not well maintained that can have a leakage rate of between 20 and 50% of total compressed air production capacity (Ingersoll-Rand, 2001).

Industrial air compressors emit a very high amount of heat when operating, for example a 150 hp compressor may reject as much heat as a 90 KW electric-resistant heater or a 422 MJ/H natural gas heater when operating (Trygg & Karlsson, 2005). In fact, we can convert this waste heat into thermal heat with a heat recovery unit and use it in water heating, air heating, Vanity water boiler to recover 50 -90% (Parekh, 2000). Recovery efficiency of 50-60% with large water-cooled compressors is typical (U.S. DOE, 1998). When used for field heating, the heat recovered is equal to 20% of the energy used annually in compressed air systems (Radgen & Blaustein, 2001).

#### *A.2.4. Air Conditioning and Fan Systems*

Heating, ventilation, and air conditioning (HVAC) should be carefully designed to create the optimum environmental conditions necessary for the comfort and more efficient production of weather conditions in factories. For example, the optimum temperature for weaving should be approximately 30 C and relative humidity should be approximately 80%. To save energy and use energy efficiently, electricity consumption can be reduced by using it with fresh air after filtering some of the air-conditioned air to avoid unnecessary delivery of too much fresh air. Of course, we can keep the system close to the nominal value by monitoring the sensors to specific locations to control all this airflow with the help of the computer that is evolving today.

We can get more opportunities to reduce energy costs by controlling pressure (Kim & Kim, 2007). We can manage system pressure with a system with good airflow properties (channel speeds and sizes optimized) that match with the appropriate controller, pressure monitors, and variable frequency drives. Caution should be taken about channel inefficiencies and fan system effects (elbows in and out, etc.). These shortcuts increase static pressure and operating costs throughout the life of the system (Lanham, 2007). The key to any design is the appropriate fan selection. The design of the fan and knife type can significantly affect efficiency and power requirements. While the wing profile wheels are more efficient, it may not be a good choice when using particulate-laden air (Lanham, 2007). Significant energy savings can be achieved even if the system is operated on medium-sized systems by installing adjustable speed drives that control volumetric flow speed. A fan system powered by ASDs can save between 14% and 49% of annual energy use (Xenergy, 1998).

#### *A.2.5. Pumps*

In the textile industry, a large amount of hot or cold water is used to aggravate yarn and fabric, paints and water used to wash and wash. It is the duty of the pumps to provide enough bass and the desired amount of all of these. Although it does not consume a large amount of electricity in general, energy savings can be achieved with a few simple changes to the needs of the plant. If the system is not adequately maintained, the efficiency of the pumps will decrease and cause it to heat up faster. It is possible to avoid these events while increasing energy efficiency with the right maintenance. Proper maintenance can be fed up as follows (U.S. DOE, 1998):

• Replacement of worn wheels.

• Oil ingenue or replacement in addition to bearing inspections and repairs, regularly between 6-12 months.

• Inspection and replacement of mechanical seals, wear rings and wheels.

• Pump/engine alignment control.

On the other hand, we can obtain the biggest gain by designing leaks, unnecessary use, and the system that is most suitable for the facility. Using holding tanks, it can emit the flow in the production cycle, reduce the need for a new pump at a certain rate, and perform all these operations more efficiently. In addition, if bypass loops and other unnecessary flows that may occur or may occur in the system are removed, energy savings for each of them can be approximately 5-10% (Easton Consultants, 1995). It would be a wise choice if you need a large flow in the system and there are more loads that change in general and to use multiple pumps in a system dominated by static head either static head. By establishing a parallel pump system, the U.S. industry found that the average electricity consumption decreased by 10 – 50% (Easton Consultants, 1995). Again, by trimming at the end of the propellers, we can reduce the amount of energy given to the pumped liquid by reducing the end speed of the propeller. With a smaller or cut propeller, the pump's flow rate and pressure can be used efficiently in applications where the normal-sized propeller generates excessive heat because of both reduced (U.S. DOE, 2005).

#### *A.2.6. Lighting System*

Making the most of daylight and seeing it as an alternative source of illumination and being used in this context will reduce electrical energy consumption (U.S. EPA, 2007). With this, it is generally thought that there is consumption due to excessive lighting as there is no work done on lighting control or optimal working range in production facilities. To prevent this, heat-sensitive sensors and/or remote-controlled systems can be used (Hasanbeigi & Price, 2012).

In the textile industry, T-12 tubes are typically used. The first output for these lights is high, but the energy consumption is also high. They also have extremely low productivity, lamp life, lumen depreciation, and color generation index. Therefore, maintenance and energy costs are high. If we replace them with T-8 tubes, it can have a life span of close to 2 times and light quality. In a study, 1196 ordinary tube light was replaced by energy-efficient tube lights, saving 114 MWh /year electricity (U.S. DOE, 2005).

In a critical case of color delivery in the section, we will use, metal halide lamps can save 50% energy instead of mercury or fluorescent lamps, while high-pressure sodium lamps save 50-60% energy compared to mercury lamps when color representation is not an important criterion (EMT, 2008g). With this, we can consider it as high-density fluorescent lighting systems as lamps with the highest efficiency. These systems bring us advantages such as lower energy consumption, better dimming options, lower lumen depreciation during the life of the lamp, options, faster launch, better color presentation, less glare, and reducing maintenance costs. High-density fluorescent systems save 50% more electricity than standard metal halide lamps (EMT, 2008g).

## RENEWABLE ENERGY TECHNOGIES IN TEXTILE INDUSTRY

Energy and labor wages are generally higher in Europe and the United States. It is vital to buy energy cheaply or consume less in order for textile companies here to fight against other competitors and among themselves without reducing product quality. For this reason, we can generate our own electricity and thermal energy in plants. Two methods stand out here are cogeneration systems and roof-top solar panels systems. Which system the plant will choose here depends entirely on what type of production they do and geographical conditions. For you, we have examined these two systems with an outline.

### A. 1. Cogeneration Systems

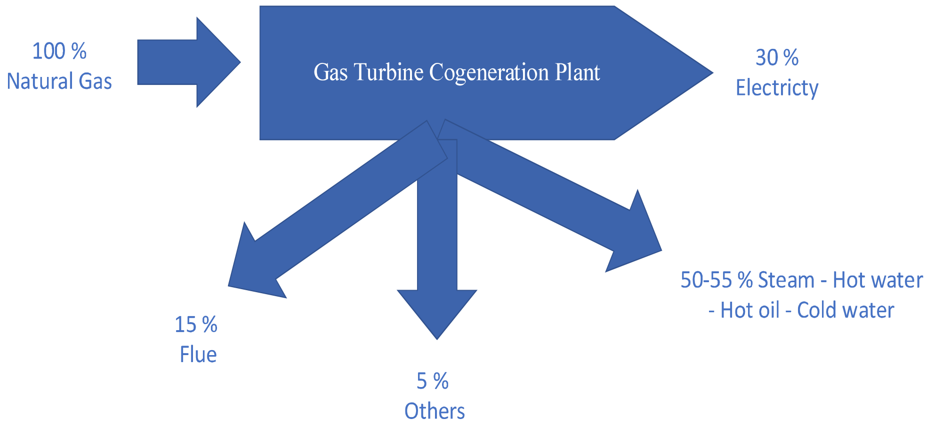
Electricity and heat consumption of a textile plant can be achieved to a certain extent by cogeneration to be installed in an environment where electricity and heat consumption is high and energy costs are relatively burdened. The main reason why cogeneration facilities are preferred especially in the textile sector is that electricity and heat provide the possibility of beneficial consumption when producing together from a single fuel source (Hasanbeigi, (2010). There are 3 main criterias for maximizing the system:

1. Maximum Compensation of Electricity Consumption
2. Maximum Rate of Cooling and Heating Need
3. Should Work with Maximum Capacity of The Cogeneration System

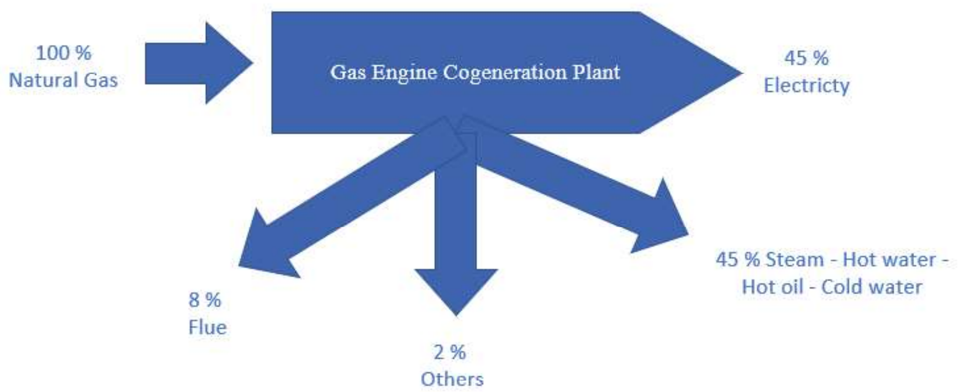
Cogeneration systems increase the chance to compete by using up to 90% energy and simultaneously performing electrical, heating and cooling (The trigeneration) operations at the same time, while meeting the energy needs of larger-sized manufacturing facilities, and generating electricity and heat from the market to a lower cost. In addition, with the realization of production directly within the plant, transmission and distribution loss is minimal and ensures clean uninterrupted quality electricity generation. The plant's carbon footprint shrinks as you produce low greenhouse gases along with the use of natural gas as the fuel of the system.

Cogeneration facilities are classified in 2 different ways: Gas Turbine Cogeneration Plant and Gas Motor Cogeneration Plant. Which type of plant should be preferred is determined entirely according to what type of production the plant produces and the energy requirement arising from it (Ashok & Banerjee, 2003; WatElectrical, 2019).

If the demand for heat/electricity > 1 the appropriate power gas turbine should be preferred, if the heat demand/electricity requirement < 1, the appropriate power gas engine should be preferred. Here, the appropriate power is the facility's monthly and annual energy consumption data and a graph is created, and accordingly the optimum value is usually the most repetitive value (WatElectrical, 2019).




(a)




(b)

Figure 6. (a) **Gas turbine energy scheme,** b) **Gas engine energy scheme** (WatElectrical, 2019)

**A. 2. Solar Panel Systems**

Many conditions are very important to avoid using solar energy systems. There are many factors, such as the general operating frequency of the plant, vegetation or other structures around which the plant is in the climate, so pre-feasibility tests should be carried out before a decision is made. In contrast to what is thought about solar energy panels, it continues to operate not only on sunny days but also in cloudy or other weather conditions. Solar panels need heat, not light, to generate electricity, so the panels work at an average of 60 to 70%, even on a day when the sun rays are very low. But on rainy days, panel efficiency can fall below 50%. In this way, we can provide a direct production of electricity to the plant by using panels or we can use it in producing hot water. Because there is a high demand for low-temperature hot water, especially in wet processes, and we can produce this water partially using solar energy.

There are two main methods for the use of solar panels for hot water. The first of these is connected directly to panels to produce low temperature water (up to 85 ° C) and to make this water available directly in wet processes. The second method is to heat all the water with panels for preheating before entering the boiler. When these two systems are examined in a textile company in Egypt and the results are compared, it is more efficient and economical to use the low temperature water directly in the system that is required for the first systemin i.e. wet processes (Abdel-Dayem & Mohamad, 2001).

## CONCLUSIONS

The main purpose of this article is to ensure that small and medium-sized enterprises (SMEs) which are very heavily in the textile sector are as little as possible affected by rising or already high energy prices while ensuring that the plant operates more efficiently. Because energy prices are one of the main costs of these facilities. In addition to obtaining products cheaper without making any changes to the amount of the product produced with energy efficiency, we can reduce the carbon footprint of the plant. With this, the amount of energy obtained by the implementation of the proposed methods there may vary depending on the production method, the coordinates, and the size of the plant produced at.

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