THE EFFECT OF ECONOMIZER APPLICATION ON ENERGY ECONOMY IN STENTER MACHINES USED

Kenan KARACAVUS[1], Furkan HAMZAOGLU[2]

[1] *Trakya University*
[2] *Termo Isı Sistemleri A.Ş.*

Abstract

This study investigates the impact of economizer application on reducing energy consumption in the textile industry. It starts by analyzing the influence of traditional drying methods on both energy usage and operational costs. Next, it explains the operation of ramie machines and economizer technology.

The primary focus is on the contributions of economizer application to energy efficiency. This includes highlighting the reduction in energy consumption and cost savings in operations. The study also underscores the importance of economizer application for environmental sustainability by helping to reduce greenhouse gas emissions.

Furthermore, it discusses the investment cost and payback period of economizers, emphasizing how they can enhance a company's economic competitiveness. Real-world examples and success stories are provided to demonstrate the practicality of implementing economizers.

In conclusion, this research underscores the significance and potential of economizer applications in improving energy economics within the textile sector. This technology not only enables energy savings but also contributes to environmental sustainability, supporting the creation of a more sustainable future in the textile industry. It also compares the energy consumption of a single-pass ramie machine with and without economizer use, assuming a 24-hour daily operation for 300 days, while thoroughly evaluating the associated advantages and disadvantages.

Keywords: Drying, Textiles, Stenter Machine, Economizer, Energy Efficiency

INTRODUCTION

Energy efficiency is the use of less energy to produce the same amount of goods or services. It is an important way to reduce energy use and emissions.

Energy efficiency can be improved in a few ways, including:

- Using more efficient equipment: More efficient equipment uses less energy to do the same job. For example, new washing machines use less water and energy than older models.
- Reducing waste: Waste materials can be used to produce new products. For example, textile companies can recycle or reuse waste materials.
- Optimizing production processes: Production processes can be designed or modified to use less energy. For example, companies can use more efficient lighting and heating systems.

Energy efficiency provides a number of benefits, including:

- Saving money: More efficient equipment and processes can save money on energy costs.
- Protecting the environment: Energy efficiency can help slow climate change by reducing greenhouse gas emissions.
- Improving business productivity: More efficient equipment and

processes can improve production efficiency.

The textile industry is a major consumer of energy. It is estimated that the industry accounts for 2% of global energy consumption. There are a few ways to improve energy efficiency in the textile industry. For example, companies can use more efficient heating and cooling systems, more efficient machines, and more efficient production processes.

The most important factor in energy efficiency is energy conservation. Energy conservation is often perceived as using less energy. For example, turning off one of two light bulbs can be perceived as energy conservation. However, in this case, we are also giving up outputs that require energy, so it cannot be called energy conservation since only one bulb will provide lighting instead of two. The most basic changes that can be made to achieve this are to evaluate energy waste and prevent energy losses in existing systems.

We can evaluate energy conservation in two different ways. The first is to take concrete measures such as saving money by using more efficient products with high technology in homes, cars, and other technological products, and organizing daily habits and behaviors to use energy more efficiently. The second option is to provide indirect energy savings, such as reducing the production of new products by extending the lifespans of existing products; arranging settlements in a way to minimize energy costs; using technologies that consume less energy; and transitioning to activities that can be produced using methods without direct material consumption.

In the textile industry, liquids can be found in the fabric in several different ways. Depending on the presence of these liquids in the fabric, the methods used to eliminate moisture may vary. After mentioning which drying method can provide better drying performance in which situations, we will touch on our main problem, stenter machines.

In this study, the effect of changes that can be made on the stenter machine, one of the most important machines in the textile industry, on energy efficiency was examined.

DRYING AND DRYING IN TEXTILE

The amount of energy spent for drying processes in industry worldwide constitutes approximately 10% of the total energy consumption.

In 2022, approximately 1.2 trillion kWh of energy was spent on industrial drying processes worldwide. Approximately 70% of this energy was consumed by heat pump dryers. The remaining 30% was consumed by conventional ventilated dryers and other methods.

The largest share of the energy spent for drying processes in the industry is used in the paper, wood, food, textile and chemical industries.

In the textile industry, the amount of energy spent for drying processes constitutes approximately 5% of the total energy consumption. This also accounts for a significant portion of global greenhouse gas emissions.

In 2022, approximately 60 billion kWh of energy was spent for drying processes in the textile industry. Approximately 80% of this energy was consumed by conventional ventilated dryers. The remaining 20% was consumed by heat pump dryers and other methods.

The largest share of the energy spent for drying processes in the textile industry is used in drying cotton fabrics. This industry consumes approximately 40 billion kWh of energy for drying processes. Other important applications are drying of woolen fabrics and ironing of synthetic fabrics.

DRYING METHODS IN TEXTILES

Mechanical Drying

One of the ways to save energy in the drying process is to perform mechanical drying before convection drying. Depending on the fabric type, 7% to 90% of the water on the product can be removed by mechanical dehumidification systems.

Mechanical dehumidification methods can be examined in 4 categories.

Crimping Method
Centrifugation Method
Vacuuming Method
Blowing Method

Crimping Method: Fabric in the squeezing process in textile; It is made by passing it between two rubber-coated cylinders under a certain pressure. This method is an easy and cheap way of working that can work without interruption. Depending on the fabric type, 7% to 43% of water can be removed. There is a risk of it breaking and not being able to tighten properly. This problem that occurs in the squeezing system is the curvature that occurs in the squeezing rollers as the fabric width increases. This curvature unbalances the pressure applied on the fabric, causing water to drain away irregularly, and the middle part of the fabric remains more moist than the edges. This imbalance in water distribution reduces the efficiency of the convection drying process.

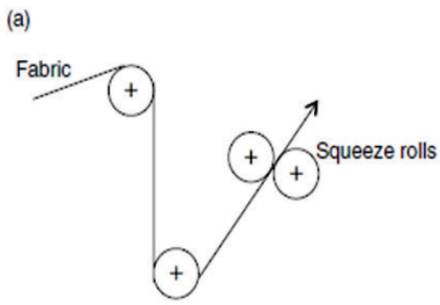


Fig. 1. *Crimping Method Line Diagram*

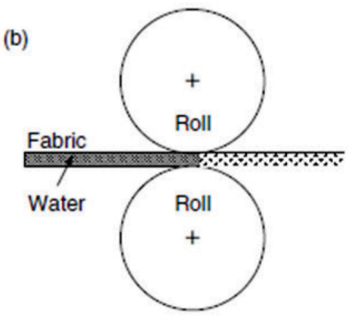


Fig. 2. *Spinning Method Dehumidification Method*

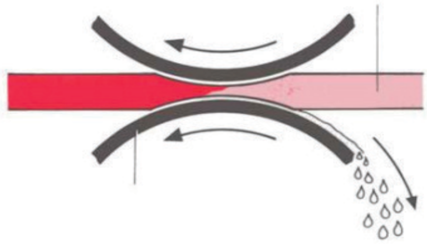


Fig. 3. *Crimping Method Working Principle*

Centrifugation Method: In the centrifugation method, the water on the product placed in a perforated basket is thrown out of these holes by the centrifugal force that occurs when the perforated basket rotates. This method provides more effective pre-drying than the squeezing method. By centrifugation, 35%-55% of the water on the fabric can be removed, and the water removal capacity varies in proportion to the number of revolutions. The speed of centrifuges used in textiles is generally between 500 and 1500 rpm. Although mechanical drying is an effective method, it has significant drawbacks. The advantage of centrifugation; It can be applied to all kinds of textile products such as fiber, yarn, fabric and ready-made clothing. However, intermittent and limited working capacity, unbalanced tension and tension applied to the fabric during filling-unloading, and unbalanced water removal are the most important problems for centrifugation.

Fig. 4. *Centrifugation Machine -1*

Fig. 5. Centrifugation Machine -2

Vacuuming Method: Vacuuming is the process of removing the water on the fabric by vacuum suction. Along with the air rapidly absorbed through the fabric, water is also absorbed and removed. The figure shows the vacuum water removal process on a fabric as a representation.

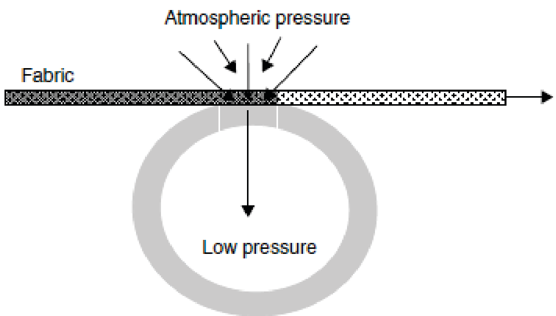


Fig. 6. Vacuum Method Line Diagram -1

Vacuuming is especially used for pre-drying fabrics that are at risk of wrinkling and are sensitive to pressure. The transversely open fabric is passed over one or more suction slits. Air in amounts up to 5000-6000 1/min is sucked through these slits with the help of vacuum pumps. Some of the water is also removed along with the air absorbed through the fabric.

Vacuuming: Basically, a vacuum unit consists of a suction chamber, separator and vacuum pump. However, for the system to work properly, main parts such as a centralizer, wastewater pump, valve to adjust the vacuum power or an electronic control system are also needed.

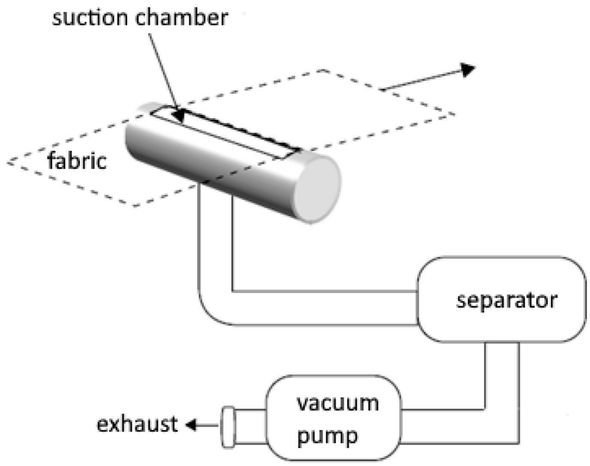


Fig. 7. Vacuum Method Line Diagram -2

Tab. 1. Amount of Water That Cannot be Separated From The Fabric

Fabric Type	Residual Water Percentage (%)
%100 Viscose	70 - 75
%100 Polyester	25 - 30
%100 Cotton	50 - 55
%100 Wool	33 - 38
%80 Polyester / %20 Cotton	25 - 30
%65 Polyester / %35 Cotton	30 - 35
%50 Polyester / %50 Cotton	35 - 40
%50 Viscose / %50 Cotton	55 - 65
%50 Viscose / %50 Polyester	40 - 45
Acrylic	23 - 28
Lyocell / Tensel	43 - 47
PA Flament	10-15
Polyester Flament	5-10

In Table 1; The required amount of heat was given by vacuum drying a fabric weighing 1000 kg and with 88% moisture.

By removing a very small amount of water, such as 50 kg/h, from the fabric using the vacuum method, 36 kW/h energy savings can be achieved. This means 59.616 € / year profit for a business that works 24 hours a day, 300 days a year. If the amount of water is an average value of 150 kg/h, the profit for the business is 178.848 € / year.

Blowing Method: Blow drying is basically the opposite of vacuuming. Water on the fabric is removed by blowing air at high pressure. Operating costs and installation costs are less than the vacuum system. It is claimed that it theoretically reduces the moisture content of cotton and cotton-containing fabrics to 40-50%.

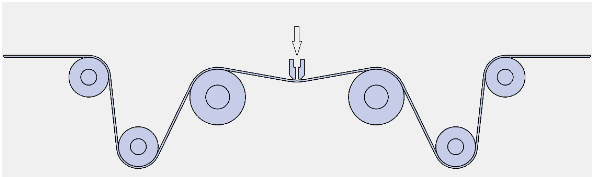


Fig. 8. *Drying by Blowing Method*

Heat Drying

Removing the water contained in the textile product with the help of heat is called primary drying. It is a process that requires a high amount of energy and is therefore expensive. This process occurs through heat transfer. The drying process carried out by heat transfer can be examined as five main principles:

Contact Drying
Drying with Radiation
Drying with High Frequency/Microwaves
Burning Drying
Convection Drying

Contact Drying: The drying process, which is carried out by evaporating water as a result of contact of the wet textile product with a heated surface with the help of oil or superheated steam, is called contact drying. Roller dryers are the most used dryers in contact drying.

Examples of contact drying are roller dryers and felt dryers. Cylinder drying machines are generally designed for pre- and post-press drying of fabrics such as towels, velvet, and woven fabrics.

Drying with Radiation: In this drying, the textile product is passed through a vertical channel with irradiators on both sides and IR rays are absorbed by the product. Depending on the type of product to be dried, the temperature can reach up to 500oC. However, in order not to damage the wet product, this process is preferred in drying where the amount of water is reduced to 25-35% by pre-drying instead of main drying.

Drying with High Frequency/Microwaves: In the high frequency drying process, water molecules under alternating current constantly release heat due to friction while their settlement patterns change. Thus, electrical energy turns into kinetic energy, and kinetic energy turns into heat energy.

Burning Drying: If some of the liquid that needs to be removed from the product is flammable, the vapors of the liquid are burned and heat is released around the product to be dried. It cannot be used in cases where the product is sensitive. For this reason, it is not a preferred method.

Convection Drying: Principle of convection drying; It is a method applied by contacting warm, low-humidity air with the moist textile product, and there is no contact with the dryer surface. With this drying, bilateral heat and mass transfer occurs. It occurs as water vapor transfer from the moist textile product to the hot air and as heat transfer from the hot air to the moist textile product. Water vapor passes into the air.

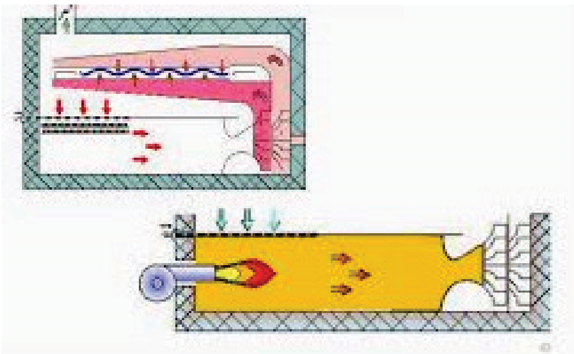


Fig. 9. *Convection Drying*

Convection drying method is the most used drying method in the textile industry. Many machines used in industry work on this principle.

In machines operating on the principle of convection drying, the room is heated by the following methods:

- With pressurized steam,
- With hot oil,
- With indirect fuel oil,
- With directly fuel oil.

The efficiency of dryers that dry using the convection method is quite high. Efficiency can be further increased with good insulation and sufficient air circulation in a closed system.

DRYING METHODS IN TEXTILES

Stenter Machine

Fig. 10. *Stenter Machine*

Stenter machines are drying machines in which the fabrics are attached to the edges of the machine with the help of needles or pallets in a transverse manner, the movement of the fabric is carried out with the help of a double moving chain, and in the meantime, hot air is sent to the fabric. Although the initial investment and operating costs are very high, stenter machines are the most preferred drying machines due to their advantages such as being able to control the dimensional forms of textile products and being used in condensation, drying and thermosetting processes.

Desired width and length settings can be given to the fabric on the stenter machine. Thanks to the holders on the edge of the fabric, transition can be made without the fabric coming into contact with the machine. In addition, wrinkles in the fabric can be removed with this system.

Stenter machines work on the principle that the water in the moist fabric turns into steam with the help of hot and pressurized air sprayed from the nozzles on the upper and lower surfaces of the fabric, and the air containing this water vapor is removed from the fabric with a special suction device. In this way, the fabric leaves the machine dried.

Stenters have cabins that are 1.5-3 meters long and whose number can be determined according to the desired drying performance. For a more effective drying system, the fabric is dried quickly at high temperatures in the first sections, the temperature is kept constant in the middle cabins, and lower temperatures are used in the last cabin. Between the cabins, the fabric is carried by an air cushion by holding only its edges and without touching anything. Meanwhile, pressurized hot air is sprayed from the nozzles onto the upper and lower surfaces of the fabric.

Stenter machines can be divided into two types according to their construction and the number of fabric passes. These types are single-pass and multi-pass stenter machines. As the name suggests, in single-pass stenter machines, the fabric is passed through the drying environment once and the cabins are arranged horizontally. In multi-pass stenter machines, the fabric is passed more than once in a drying chamber (cabinet). Additionally, cabinets can be lined up

If the distribution of heat energy consumed in a stenter machine is examined on an example, it can be more easily understood at which points improvements can be made.

For example, if you want to dry a 1000 kg, 88% moist fabric at 160°C in a stenter machine with 6 cabins in 1 hour, the amount of energy used is (ambient temperature 30°C, fabric exit humidity 8%);

Tab. 2. *Amounts of energy consumed in a stenter machine*

Heating the fabric	54 kW
Evaporation of water	577 kW
Heating fresh air	398 kW
Insulation losses	35 kW
Other	5 kW

As seen above, almost all of the energy consumed is used for evaporating water and heating fresh air. The amount of energy used can be reduced by making various improvements on these two points. In addition, fabric advancement speed can be increased by making improvements in the factors affecting heat and mass transfer. In this way, as the production amount will increase, the machine efficiency will also increase.

Economizer in Stenter Machines

When integrated into stenter machines, economizer units heat fresh air with the heat of the exhaust air, allowing it to enter the system at a higher temperature. Thus, the energy required to heat fresh air is much lower. This increases the efficiency of the stenter machine and saves energy.

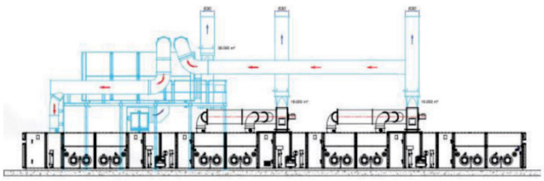


Fig. 11. *Line drawing of a stenter machine with economizer on it*

The picture above shows the placement of the economizer on which work will be done on a stenter machine. The economizer integrated into the chimney lines takes the hot air discharged from the air outlet pipes into the system, passes it through the pipes without mixing it with fresh air and gives the fresh air to the system at temperatures higher than room temperature. Since the economizer application will be used at the exit point of the system, it provides energy savings independently of other systems.

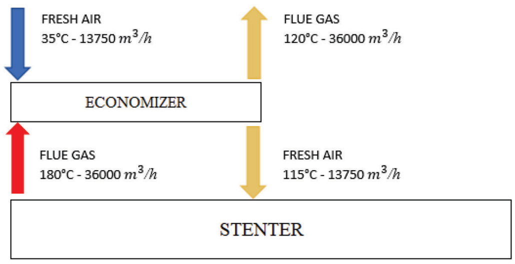


Fig. 12. *Stenter - economizer air passages*

In the line drawing of a stenter machine, the positioning of the economizer is as shown in Figure 11.

Fig. 13. *A stenter machine with economizer installed*

Fig. 14. *Image of economizer on stenter machine*

MATERIALS AND METHODS

Economic Advantages of Economizer Application

Fresh air at 35°C is heated up to 120°C in the heat recovery exchanger. Accordingly, the amount of savings made from natural gas use is:

$$Ha = 8250 \text{ kcal/m3} \quad (1)$$

$$Q = m \,.\, cp,av \,.\, \Delta T \quad (2)$$

$$= 16.843,75 \,.\, 0.241 \,.\, 85$$

$$= 345.044,22 \text{ kcal}$$

$$V = Q / Ha \rightarrow V \quad (3)$$

$$= 345.044,22 / 8250$$

$$= 41,82 \text{ m3 / h}$$

$$Vt = 300 \,.\, 24 \,.\, V \quad (4)$$

$$= 301.104 \text{ € / year}$$

$$Png = 1,02 \text{ € / m3} \quad (5)$$

Monetary value of annual savings

$P_{ng,year} = P_{ng} \times V_t$ (6)

$= 307.126$ € / year

Ha : Natural gas net calorific value

V : The amount of natural gas required to heat the air from 35°C to 120°C

Vt : Amount of natural gas to be saved for 300 days 24 hours working time

Pd : Natural gas unit price (October 2023 European Countryaverage price.)

Pt : Amount of monetary savings

Validation of energy savings through field tests

The set values used in the calculations for the drying process and the variables that arise depending on these values are listed in the table below. After these studies, the hydraulic padder continued to operate actively. In order not to affect the accuracy of the calculations, post-scarf pick-up tests were performed, and these values were integrated into the table. The variables kept at constant intervals in all tests carried out in the drying process are:

Padding pressure: 5 bar
Cabin temperature set value: 135 °C
Nozzle fan value: 90-80 %
Chimney fan values: 70-80 %

Speeds of 35 and 40 meters/minute were used as the machine advancement speed, and two tests were carried out for both speeds. Each thesis mentioned here includes calculations made for two different situations. For each set value, the machine was operated with the economizer open for a while and with the economizer closed for a while. We tried to keep the run times as long as possible to obtain results with higher accuracy. The fabric type used during these tests is a fabric containing 53% CO, 44% PES and 3% EL.

All tests were repeated under the same conditions with the economizer closed and open, and comparisons were made.

Tab. 3. *Comparison of natural gas consumption when economizer is closed and open*

Case	Natural gas meter difference (Nm^3)		Natural gas comsumption for per meter fabric (m^3/m)		Percentage Consumption Difference (%)
	Economizer		Economizer		
	Off	On	Off	On	
1	82	77	0,045	0,032	28,89
2	47	52	0,037	0,031	16,22
3	65	39	0,038	0,023	39,47
4	71	50	0,039	0,027	30,77

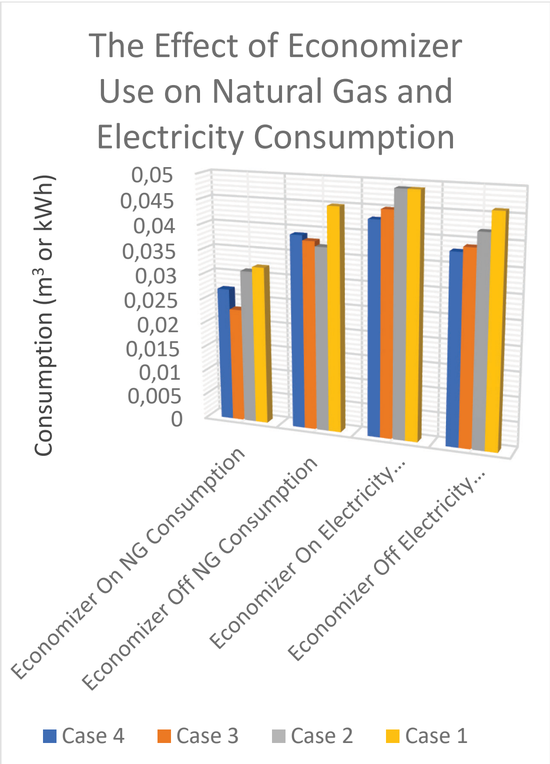
Tab. 4. *Comparison of electricity consumption when economizer is closed and open*

Case	Electricity meter difference (kWh)		Electricity comsumption for per meter fabric (kWh /m)		Percentage Consumption Difference (%)
	Economizer		Economizer		
	Off	On	Off	On	
1	101	119	0,046	0,049	-6,52
2	53	82	0,042	0,049	-16,67
3	65,5	76	0,039	0,045	-15,38
4	69	80	0,038	0,043	-13,16

All natural gas consumption is written in m^3 and all electricity consumption is written in kW. Additionally, since numerical differences will vary under all circumstances, percentage differences are also included.

If we compile the results obtained in the table above as graphics for a better understanding of the subject, we will encounter the following results:

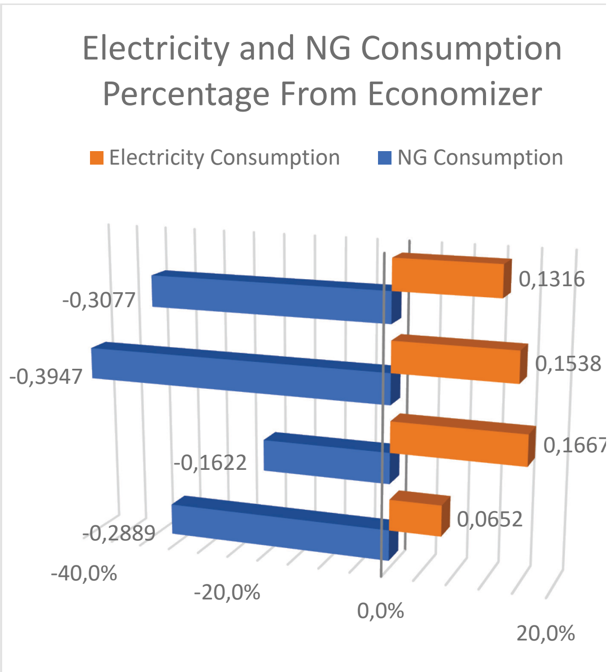
***Tab. 5.** The Effect of Economizer Use on Natural Gas and Electricity Consumption*



***Tab. 7.** Economical Analysis for Economizer Application*

Factor	Unit	Case 1	Case 2	Case 3	Case 4	Average
Natural Gas Consumption Gain	(%)	28,89	16,22	39,47	30,77	28,84
Loss of Electricity Consumption	(%)	6,52	16,67	15,38	13,16	12,93
Natural Gas Cost	€ / m	0,0459	0,0377	0,0388	0,0398	0,0406
Cost of Natural Gas with Economizer	€ / m	0,0326	0,0316	0,0235	0,0275	0,0288
Electricity Cost	€ / m	0,0106	0,0097	0,0090	0,0087	0,0095
Electricity Cost with Economizer	€ / m	0,0113	0,0113	0,0104	0,0099	0,0107
Total cost	€ / m	0,0565	0,0474	0,0478	0,0485	0,0500
Total Cost with Economizer	€ / m	0,0439	0,0429	0,0338	0,0374	0,0395
Economic Savings Percentage	%	22,26	9,44	29,22	22,89	20,95

***Tab. 6.** Electricity and NG Consumption Percentage From Economizer*



If we summarize the values we obtained in a table and perform profit-loss calculations as a percentage, the result we will encounter is that we will save an average of 20.95% in the drying process. The savings amount mentioned here is our net savings figure because the electrical energy that the economizer will lose to us was integrated into these calculations and the calculations were made.

CONCLUSION

As a result of the calculations made in this study, it was seen that an amount of 301,104 €/year would be saved on natural gas consumption. This amount also indicates that energy is used much more efficiently. Being able to use technologies that cause less environmental pollution and use less fossil fuel has to be one of our most important choices in our time. Some studies have been carried out in the industry, including both natural gas and electricity consumption, with and without economizers, in order to reinforce the accuracy of the studies and to evaluate the effects of electricity consumption. The results obtained as a result of these studies are of serious importance.

Results obtained in tests carried out in the industry; It shows that 20.95% monetary gain is achieved in the drying process.

As a result of these studies, it has been seen that economizer applications, in which waste heat and fresh air are heated, have high returns in terms of energy efficiency. In future studies, there are options such as increasing the efficiency of the economizer design with structural changes, reducing the amount of lost energy, and even providing more efficient working environments by making experiments on application areas. In addition, it has been seen that significant energy savings can be achieved with other efficiency-increasing changes, the advantages and disadvantages of which are examined in this study. It is envisaged that the performance of these methods will be increased as a result of future studies, and much higher energy savings can be achieved by using one or more of them in stenters and other convection dryers.

REFERENCE

[1] Cabak, B. (2018). Tekstil Fabrikasında Enerji Verimliliği Uygulamaları, (Master's Thesis). Trakya Univercity/Institute of Natural and Applied Sciences, Edirne

[2] Çay, A., Tarakçıoğlu, I., Hepbaşlı, A. (2010). Exergetic Analysis of Textile Convective Drying with Stenters by Subsystem Models: Part 1—Exergetic Modeling and Evaluation. Drying Technology, 28(12), 1359-1367.

[3] Çıtır, H. (2013). Endüstriyel Tav Fırınında Ekonomizer Tasarımı, (Master's Thesis). Karabuk Univercity/Institute of Natural and Applied Sciences, Karabuk.

[4] Demir, K.C. (2017). Baca Gazının Ekonomizere Giriş ve Çıkış Tasarımının Isı Geri Kazanımına Etkisinin İncelenmesi, (Master's Thesis). Namık Kemal Univercity/Institute of Natural and Applied Sciences, Tekirdağ.

[5] Gelir, B.Ç. (2017). Tekstil Sektöründe Kullanılan Ramöz Makinelerinde Isı Geri Kazanımı ile Enerji Tasarrufu, (Master's Thesis). Namık Kemal Univercity/Institute of Natural and Applied Sciences, Tekirdag.

[6] Genceli, O.F., (2017). Isı değiştiricileri. Istanbul: Birsen Yayınevi.

[7] Güngör, A., Özbalta, N. (1997). Endüstriyel Kurutma Sistemleri, Teskon Program Bildirileri. Ege Univercity, Izmir.

[8] Kutlu, N. (2012, 19 Aralık). Gıdalarda Kurutma Teknolojisi. https://www.gidagundemi.com