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Energy Efficiency in the Competitiveness of the Textile Industry

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Abstract

The aim of this scientific contribution is to show the ways in which efficient energy management influences the competitiveness of companies in the textile industry. To achieve this objective, the present investigation carries out a bibliographic review of the scientific contributions socialized by the Scopus database, and the information detected in the databases of the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) was analyzed in Excel spreadsheets. In this scientific contribution, the following topics of results are found: 1) Bibliometric analysis of published research related to Energy efficiency in the competitiveness of the textile industry. 2) Energy use in the textile industry and breakdown of energy use by end use. 3) Opportunities to improve energy efficiency in the textile industry. There are several options for implementing efficient energy management in textile plants, many of which are profitable. However, even cost-effective options are often not implemented in textile mills mainly due to limited information on how to implement energy efficiency measures, especially given that most textile mills are classified as small and medium-sized enterprises. Furthermore, it is a reality that these particular plants have limited resources to acquire this information. This fact means that technical knowledge on energy efficiency technologies and practices must be prepared and disseminated among textile plants.

Keywords

Efficient Energy Management, Renewable Energy Sources, Innovation, Competitiveness, Textile Processes

1. Introduction

The use of energy carriers and their efficient management, to some extent and in various ways, could be said to have marked the evolution of humanity (Hidalgo

& Hernández, 2021). The textile industry has played an important role in the development of human civilization for several millennia (Bravo Hidalgo, Jiménez Borges, & Valdivia Nodal, 2018). The main raw materials that supported the industrial revolution were cotton, steel, and coal. In this context, technological development from the second part of the 18th century onwards led to an exponential growth in cotton production, beginning first in the United Kingdom and later spreading to other nations on the European continent. The production of synthetic fibers that began at the beginning of the 20th century also grew exponentially (Bravo Hidalgo & León González, 2018; Jensen, 1993).

Throughout history, the textile industry has been considered a labor-intensive process industry. The number of people employed in the textile and clothing industry was around 2.45 million in the European Union (EU) in 2006, around 500,000 in the US in 2008, and around 8 million in China in 2005 (Phetrak, Westerhoff, & Garcia-Segura, 2020).

China is the world's largest textile exporter with 40% of world textile and clothing exports. The textile industry is the largest manufacturing industry in the aforementioned country, with around 32,400 companies. This does not include the clothing industry. In 2008, the total export value of China's textile industry was US $65.4 billion, an increase of 16.6% compared to 2007. China is also the largest importer of textile machinery and Germany is the largest exporter of textile machinery (Sultan, 2013).

EU textile and clothing processing accounts for 29% of global textile and clothing exports, not including trade between EU member countries, placing the EU second after China. In 2006 there were 220,000 textile companies in the EU employing 2.5 million people and generating a turnover of €190 billion. The textile and clothing sector represent around 3% of the total industrial value added in Europe (Jiménez-Marín, Zambrano, Galiano-Coronil, & Ravina-Ripoll, 2021).

The objective of this scientific contribution is to demonstrate the ways in which efficient energy management influences the competitiveness of companies in the textile industry. To achieve this objective, the present investigation carries out a bibliographic review of the scientific contributions socialized by the Scopus database. In addition, information from databases such as the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) is analyzed. In this scientific contribution, the following topics of results are found: 1) Bibliometric analysis of published research related to Energy efficiency in the competitiveness of the textile industry. 2) Energy use in the textile industry and breakdown of energy use by end use. 3) Opportunities to improve energy efficiency in the textile industry.

2. Materials and Methods

This scientific contribution is based on a critical review of scientific publications focused on efficient energy management of textile industry processes. Only publications contained in the Scopus database or academic directory are considered.

Scopus is a bibliographic database of abstracts and citations of scientific journal articles. It covers approximately 24,500 titles of serials (journals, conferences, research book series) from more than 5000 publishers in 140 countries, including peer-reviewed journals in the fields of science, technology, medicine, and social sciences, including the arts and humanities. The technology platform is developed by Elsevier and is accessible on the Web for subscribers, but index entry and revaluation are managed by an editorial committee independent of Elsevier.

Scopus also offers author profiles that cover affiliations, number of publications and their bibliographic data, references, and details of the number of citations each published document has received. It has alert systems that allow the registrant to track changes to a profile. Using the Scopus Author Preview option, you can search by author, using the affiliate name as a limiter, verify the author's identification, and set up an automatic notification system that alerts you to changes in the author's page via RSS or e-mail.

On the other hand, analysts and studies the information detected in databases of recognized relevance such as the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA).

The search criteria used in these databases and academic directory were "energy efficiency, competitiveness, textile industry". With these search criteria, a total of 1041 documents were detected, between the years 1974 and 2021. The information detected in the databases of the International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) was analyzed in spreadsheets. Excel.

3. Results

3.1. Bibliometric Analysis of Published Research Related to Energy Efficiency in the Competitiveness of the Textile Industry

The international scientific community shows great interest in research focused on increasing the competitiveness of the textile industry through energy efficiency and the use of renewable energy sources. Figure 1 shows an increase in scientific publications related to this topic. It can be seen that as of 2005 the number of publications has increased notably.

Currently, the scientific journals contained within the Scopus academic directory, which offer more diffusion to publications related to the incidence of energy efficiency in the competitiveness of the textile industry, are (See Figure 2):

- Journal Of Cleaner Production.
- Desalination And Water Treatment.
- Izvestiya Vysshikh Uchebnykh Zavedenii Seriya Teknologiya Tekstil Noi Promyshlennosti.
- Journal Of Hazardous Materials.
- Energy.

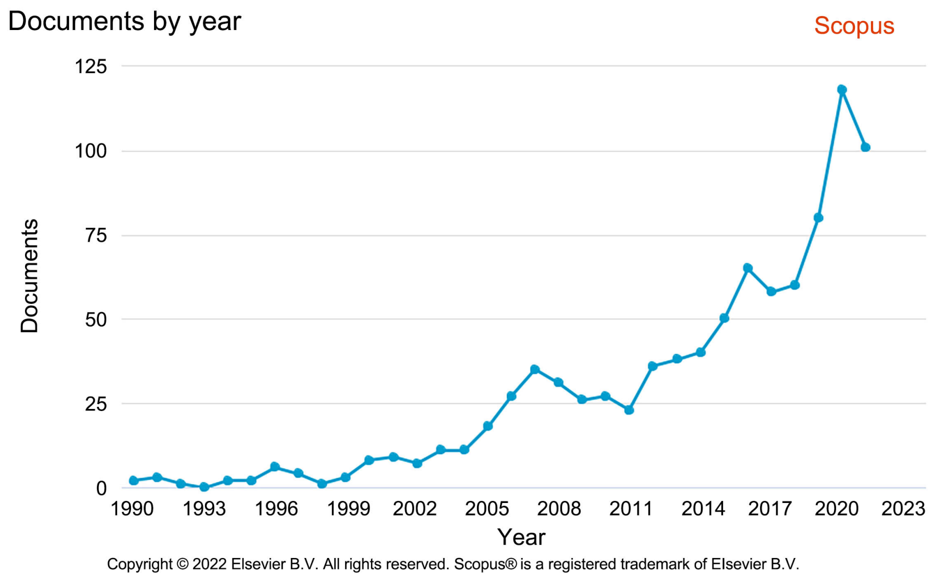

Figure 1. Quantitative evolution of publications socialized in Scopus.

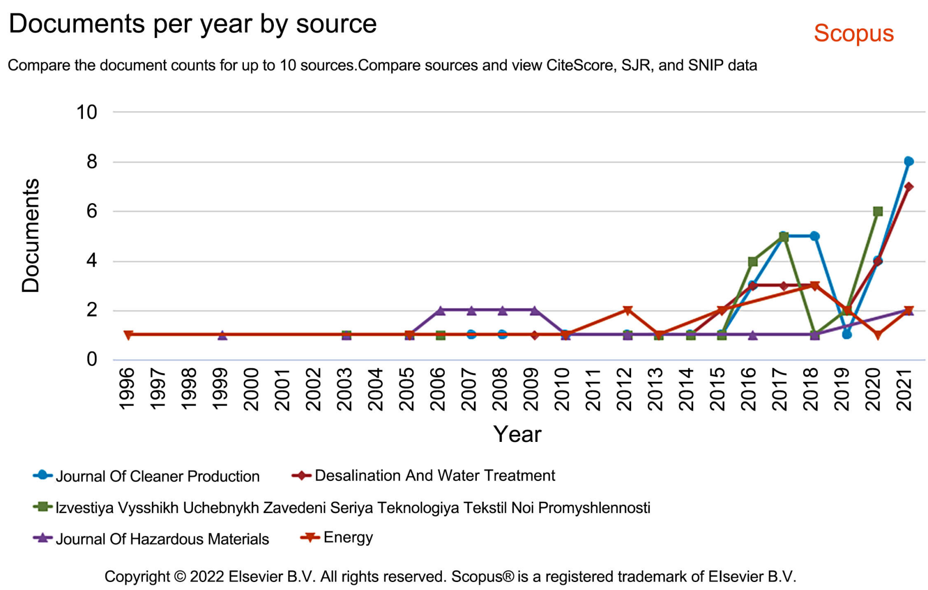

Figure 2. Journals that most frequently publish research related to energy efficiency in the competitiveness of the textile industry, within the academic research directory Scpus.

Figure 3 shows the most abundant thematic areas in research related to the role of efficient energy management in the competitiveness of the textile industry; which are:

- Engineering.
- Environmental Science.
- Materials Science.
- Energy.
- Business, Management and Accounting.
- Chemical Engineering.

India, China, the United States of America, Turkey and Germany are the nations that have published the most research in journals contained in the Scopus database. Figure 4 shows the number of documents published by nations or territories.

The largest volume of scientific contributions related to this topic is of the scientific article type. Figure 5 shows that 75% of the scientific contributions socialized by the Scopus database are of the scientific article type.

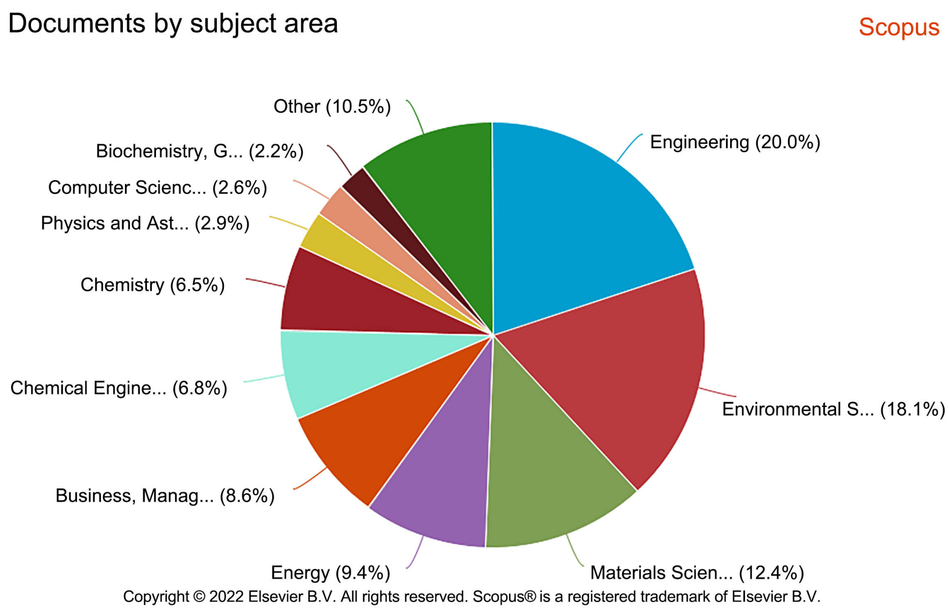

Figure 3. Documents published by research areas within the academic directory or Scopus database.

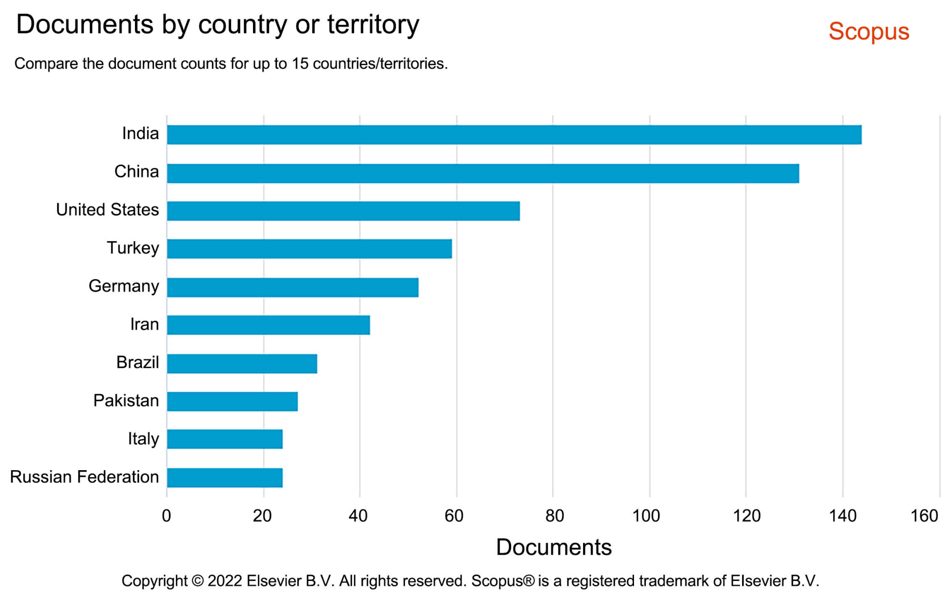

Figure 4. Most productive nations or regions in terms of scientific publications related to this topic.

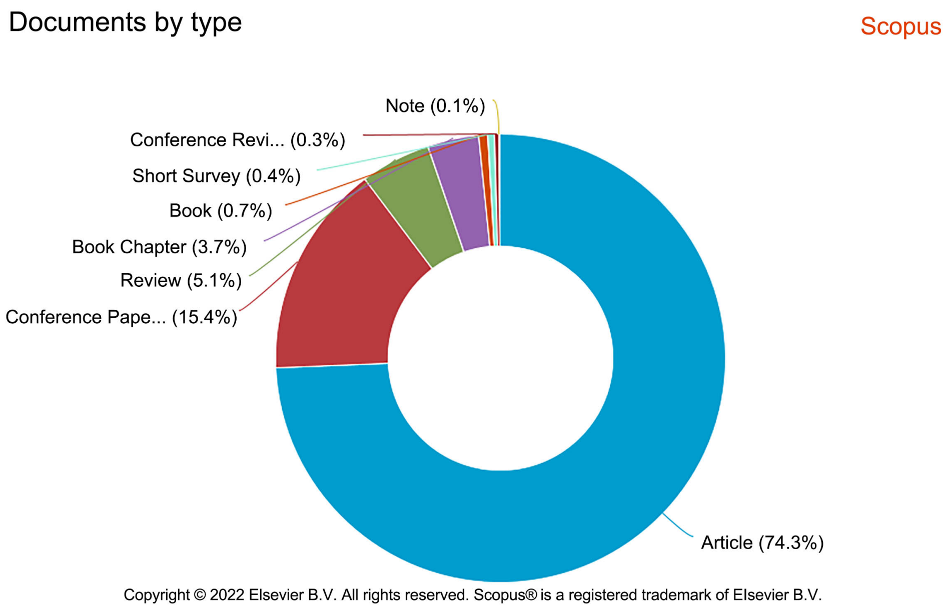

Figure 5. Percentage distribution of the different types of document published in the Scopus database and related to this topic.

3.2. Energy Use in the Textile Industry and Breakdown of Energy Use by End Use

If the energy consumption of the textile industry is compared with the metallurgical, food or chemical industry; it can be assumed that the textile industry demands little energy. But the reality is that the textile industry comprises a large number of plants that together consume a significant amount of energy. The total manufacturing energy consumed by the textile industry in a particular country depends on the structure of the manufacturing sector in that country. For example, the textile industry accounts for about 4% of final energy use in manufacturing in China, while this proportion is less than 2% in the United States of America (Isaac & van Vuuren, 2009). The total cost of energy consumed in the textile industry is different in various nations or territories. **Figure 6** shows the general proportions of cost factors for cotton yarn in the United States of America and China. The cost of energy is usually a third or fourth of the total cost of the product.

The processes of the textile industry use large amounts of electrical energy and energy carriers such as fossil fuels. The share of electricity and fuels in the total final energy use of the textile sector in any country depends on the structure of the textile industry in that country (Bravo Hidalgo, 2015). For example, in yarn spinning, electricity is the dominant energy source, while in wet processing the main energy source is fossil fuels. Data from the paper (Khan, Hou, Zakari, & Tawiah, 2021) from 2021 on a global scale, show that 61% of the final energy used in the textile industry was fuel energy and 39% was electricity. The textile industry is ranked as the fifth largest consumer of steam among the 16 main industrial sectors. The same study showed that around 36% of the energy input to the textile industry is lost on site (e.g. in steam generators, engine systems, distribution, etc…).

Evidently, in the textile industry processes, energy is used in different end uses for different purposes. Figure 7 shows the breakdown of final energy use by end use in the textile industry. Although the percentages shown in the graph may vary from country to country, this figure gives an indication of the final use of energy in the textile industry. However, it should be noted that the textile industry in developed countries is more likely to not include as many labor-intensive processes (e.g. spinning and weaving) as it does in some developing countries, where the cost of labor it's lower. As shown in Figure 4, in the textile industry, steam-driven systems and motors (pumps, fans, compressed air, material handling, material processing, etc.) have the largest share of energy end use and each account for 29% of the total final energy use in the textile industry on a global scale.

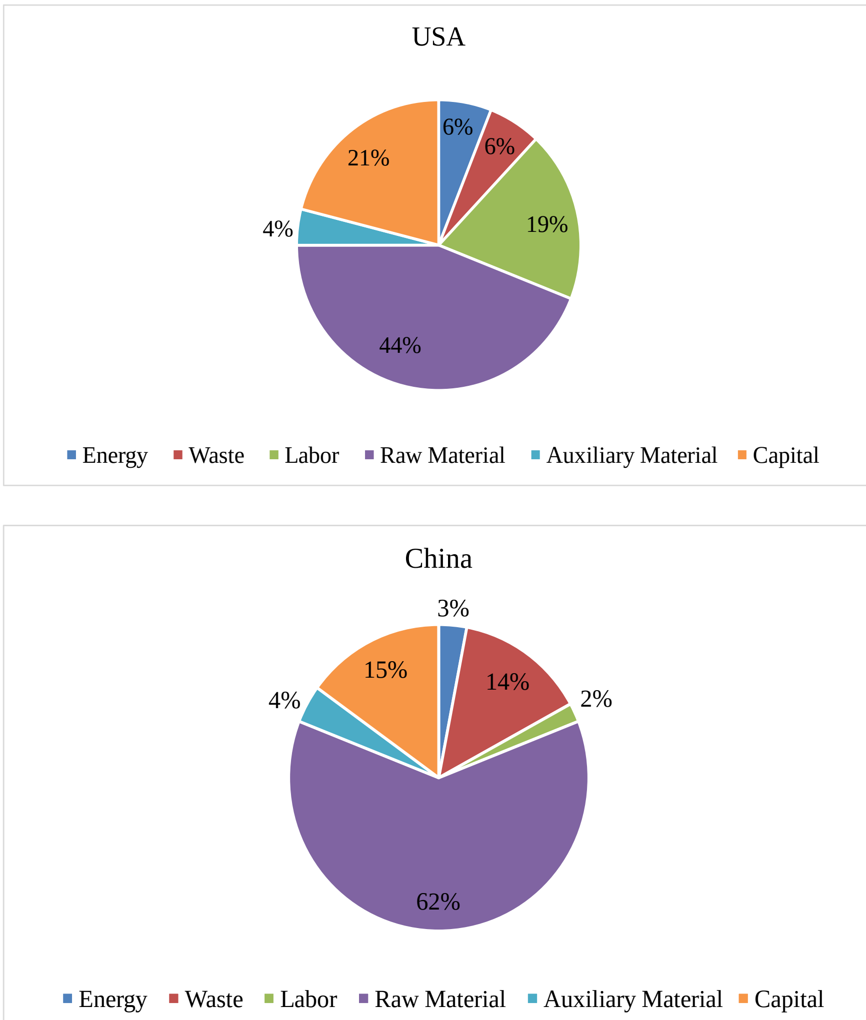

Figure 6. Participation of manufacturing cost factors for combed cotton yarn in the USA and China.

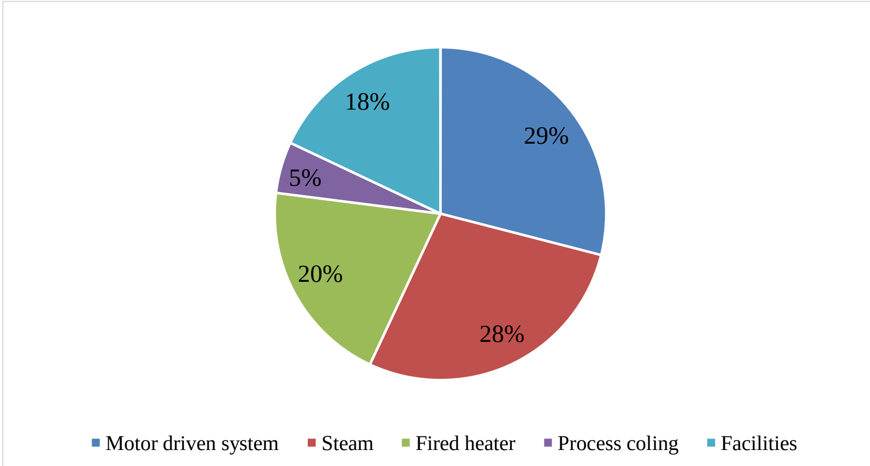

Figure 7. Final use of energy in the textile industry on a global scale.

Considering the laws of thermodynamics, it is presumable the existence of losses in the different energy transformations that occur in the processes of the textile industry. **Figure 8** shows the site energy loss profile for the textile industry. [120]. About 39% of the energy input to the textile industry is lost on site. Engine-driven systems have the highest proportion of on-site energy waste (15%), followed by distribution at 9% and boiler losses at 7%. The proportion of losses could vary for the textile industry among various nations, depending on the structure of the industry in the country being analyzed. However, **Figure 8** illustrates where losses occur and the relative importance of each loss in the textile industry.

3.3. Real Possibilities of a Total Efficient Management of Energy in the Processes of the Textile Industry

The real possibilities of a total efficient management of energy in the processes of the textile industry are made up of both real possibilities of modernization and optimization of processes as well as the complete replacement of the current machinery by new state-of-the-art technology. In this context, the present investigation focuses on modernization measures, since the new state-of-the-art technologies have high initial capital costs and, therefore, the energy savings that result from the replacement of the current equipment with new equipment in many cases may not justify the cost. However, if all the benefits received from the installation of the new technologies are taken into account, such as water savings, material savings, waste and waste water reduction, rework reduction, higher product quality, etc., the new technologies are more economically justifiable (Nunes, Matias, & Catalão, 2015).

On the other hand, this scientific contribution evidences measures for which quantitative values can be found for energy savings and cost. Adding that, in some cases it was not possible to find such quantitative values, but since some measures are already well known for their energy saving value, we decided to

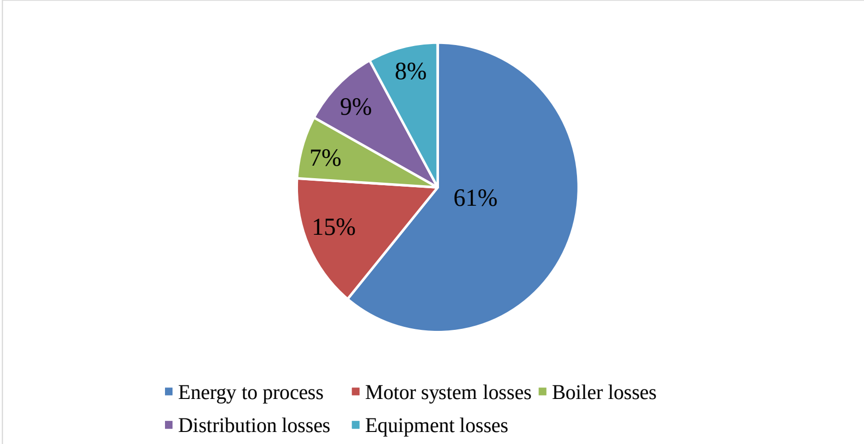

Figure 8. In situ energy losses in the textile industry on a global scale.

include them in the document despite the lack of quantitative metrics of their potential. We believe that knowledge about the existence of these technologies can help textile plant engineers to identify available opportunities to improve energy efficiency and therefore the competitiveness of the sector (Ghituleasa et al., 2016).

The energy cost and savings data provided in this document should be assumed to be typical cost/savings data or plant/case specific data. The savings and cost of the measures may vary depending on several factors, such as plant and process specific factors, type of fiber, yarn or fabric, quality of raw materials, specifications of the final product and raw materials. (for example, fineness of the fiber or yarn, width or specific weight of the fabric g/m^2, etc.), the geographical location of the plant, etc. For example, for some of the energy efficiency measures, a significant part of the cost is the cost of labor; therefore, the cost of these measures in developed and developing countries can vary significantly (Jiménez-Marín et al., 2021).

- Efficient energy management practices in the yarn spinning process:

A detailed explanation of each energy efficiency technology/measure provided in this document can be found in (Heijkers, Zeemering, & Altena, 2000). The aforementioned research provides the list of measures/technologies included in this document for the yarn spinning process. Energy efficiency measures are given for five subcategories for the spinning process: preparatory process; ring frame; winding, folding and finishing process; air conditioning and humidification system; and general measures for spinning mills.

- Efficient energy management practices in the weaving process:

Weaving machines or commonly known as looms represent around 50% - 60% of the total energy consumption in a weaving plant. Humidification machines, blowing machines or compressors and lighting systems represent the rest of the energy demand, depending on the types of looms and the wet insertion techniques. Since a loom is just a machine, there are not many physical modifications that can be made to existing looms to improve their efficiency. Of course, looms differ in their energy intensity (energy use per unit of product). However, for a given type of loom, most energy efficiency improvement opportunities are related to the way the loom is used (productivity), the auxiliary utility (humidification, compressed air system, lighting, etc…) and maintenance. of the looms (Larioniv & Viktorov, 2017).

4. Discussion

The authors' research Cagno & Trianni (2012) establishes that governments are pursuing a variety of measures to reach common and more efficient environmental and energetic policies: Nonetheless, the effort has shown to be not sufficient, since the objectives stated in the European Union (EU) Directive 2009/28/EC on energy efficiency seem quite distant to be reached. A greater attention has obviously been paid toward the industrial sector, which utilizes a major share of primary energy consumption: Till now several actions have been taken to achieve the energy performance of buildings, but very few are in operations. Nonetheless, in order to be most effective, governments should focus their attention not only on energy intensive large enterprises (LEs) but also on nonenergy intensive small and medium enterprises (SMEs) that represent the majority of the total number of industries, cover a consistent share of the energy consumption of a whole domestic industrial sector, and are usually less efficient than LEs. This paper aims to highlight the most effective energy savings opportunities (ESOs) for reducing energy consumption in industrial operations that have been successfully implemented in a large number of SMEs case studies investigated in North America and Italy, showing a correspondence (in terms of savings and costs) between the two databases. This paper analyzes the ESOs, characterized by the best available technologies and practices (BAT/Ps), with a cross-analysis within three manufacturing sectors, i.e., primary metals, plastics, and textiles, and considers different subsidizes among SMEs, in order to show commonalities and differences among the sample. The ESOs have been analyzed and ranked according to different criteria of importance, highlighting the most diffused, those having the highest energy savings, and those with the shortest pay-back time. The scope of the elaboration of these criteria is twofold: on one side, it allows to be closer to the entrepreneurial sensibility, guiding entrepreneurs in evaluating a possible investment in energy efficiency; on the other side, it provides important suggestions for a public local authority that, through financial support and/or other policies, aims at diffusing the adoption of BAT/Ps and increasing the sectors' energy efficiency and competitiveness.

The document of the authors Demessinova, Aidarova, Maulenkulova, & Mamutova (2020) explains that, currently, textile industries consume a large amount of fuel and energy resources in the production of products. Energy security is an integral part of the economic security of the enterprise, as the dependence of production on the supply of fuel and energy resources in the required time, the necessary quality and quantity at economically feasible prices can put under threatening the competitiveness of the company's products, as well as its survival in general. To improve the energy security of the industry, it is necessary to introduce less energy-intensive processes, introduce more productive equipment, improve the efficiency of energy logistics in the enterprise of the industry, etc.

This research (Jiménez-Marín et al., 2021) states that strategic and tactical factors come into play in shop competitiveness where, in addition to the products sold, other marketing mix variables must also be considered. There are also subjective factors, such as perceptions through the senses. This became even more important when, as a result of the COVID-19 crisis and the forced closure of certain establishments with physical sales, it was necessary to increase profitability and efficiency. The aim of this study was to determine the exact role of sensory marketing in shop efficiency and profitability, based on the guiding principles of technology, innovation, and respect for the environment. We conducted an exploratory and experimental study consisting of the creation of a sensory strategy through the adaptation of the Hulten, Broweus and Van Dijk model on a specific establishment in the current era of Industry 4.0. The results indicate an increase in sales as well as customer satisfaction and happiness after implementing the relevant strategies. The conclusions show that this model is valid and reliable for physical retail establishments, and that these business strategies can significantly contribute to the optimisation of energy resources.

From the analysis carried out, it can be deduced that there is no standard solution to minimize the obstacles to energy efficiency. In the process of disseminating and adapting measures that help achieve efficient energy use, not only do the individual decisions of the controllers and entrepreneurs of the textile industry converge, but various types of actors must intervene and interact. (Joshi & Singh, 2010) state that the proper use of energy represents a promising market for energy technologies and services, where textile companies could benefit from transferring from a model of pure energy supply to a model of provision of integrated services. of energy. However, these mutual gain relationships, users-companies, could be limited due to the existence of economic, political, social, organizational and behavioral barriers, and the absence of functioning energy service markets. According to the multi-criteria analysis, different types of barriers converge to explain the non-adoption of cost-effective energy efficiency measures.

In this sense, a specific solution can show results in a certain period of time, so it is clear that the implementation of energy efficiency measures will not necessarily be carried out by economic agents. This means that what is really important to strengthen decision-making at the local and national level is the constant need to monitor, evaluate and update the changing consumption patterns of consumers, in order to achieve permanent feedback that produces sustainable changes in time (Demessinova et al., 2020).

5. Conclusion

This document is a review of the use of efficient energy management applicable to the textile industry. Actual cost and energy savings of measures will vary, depending on plant size and configuration, plant location, plant operating characteristics, production and product characteristics, local supply of raw materials and energy, and various other factors. Therefore, for all of the energy efficiency measures presented in this paper, individual plants should conduct further research on the economics of the measures, as well as the applicability of different measures to their own unique production practices, to assess the feasibility of the measure implementation. Energy is one of the main cost factors in the textile industry. Especially in times of high volatility in energy prices, improving energy efficiency should be one of the main concerns of textile mills. There are several options for implementing efficient energy management in textile plants, many of which are profitable. However, even cost-effective options are often not implemented in textile mills mainly due to limited information on how to implement energy efficiency measures, especially given that most textile mills are classified as small and medium-sized enterprises. Furthermore, it is a reality that these particular plants have limited resources to acquire this information. This fact means that technical knowledge on energy efficiency technologies and practices must be prepared and disseminated among textile plants. The real possibilities of total efficient management of energy in the processes of the textile industry are made up of both real possibilities of modernization and optimization of processes as well as the complete replacement of the current machinery by new state-of-the-art technology.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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