THE NECESSITY OF ENERGY TRANSITION IN TEXTILE INDUSTRY

Njegoš Dragović[1*]

[1] Nezavisni istraživač, Beograd, Srbija
[*] E-mail: njegdr@gmail.com

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Abstract: *The textile industry should play an important role in the development of the economy, but it is limited due to the negative impact on the environment, which can be solved by switching to sustainable and renewable energy sources (RES). A successful strategy for the production of textile products includes a set of environmental, economic and energy, technological and health factors. Clothing and home textiles are the basic products of the textile industry, but with new materials and technologies, the use is expanding in the field of agrotechnical nets, applications for building structures or military materials. Textile products are created in long technological processes in production halls so that natural resources and water are used for processing, into which harmful substances flow. Following these negative sides, the textile industry has to reform in the field of application of materials on inputs to sources of electricity supply.There is a technological and energy transition that can contribute to increasing production efficiency, work effectiveness and reducing electricity consumption, sustainable use of nearby energy resources such as RES. In this way, water pollution is directly reduced, and the forced use of resources that cannot be renewed or cleaned of pollution is indirectly reduced. The advantage is that the energy transition can save materials, the aesthetic appearance of textiles and products improves, and the economic savings are significant. Funds can be invested in the replacement of acceptable materials, which are recycled and do not pollute. RES such as solar energy and wind energy can be placed on the roofs of halls, and natural fibers can be washed, bleached or thermally treated with geothermal water and thus create sustainable materials in the textile industry.*

Keywords: Energy transition, renewable energy sources, textile industry, consumption, savings.

NEOPHODNOST ENERGETSKE TRANZICIJE U TEKSTILNOJ INDUSTRIJI

Apstrakt: *Industrija tekstilstva treba da ima važnu ulogu u razvoju privrede, ali je ograničena zbog negativnog uticaja na životnu sredinu, što se može rešiti prelaskom na održive i obnovljive izvore energije (OIE). Uspešna strategija proizvodnje tekstilnih proizvoda uključuje skup ekoloških, ekonomskih i energetskih, tehnoloških i zdravstevnih činilaca. Odeća i kućni tekstil su osnovni produkti tekstilne industrije, ali uz nove materijale i tehnologije širi se upotreba u oblasti agrotehničkih mreža, primene za građevinske strukture ili vojne materijale. Tekstilni proizvodi se stvaraju u dugim tehnološkim procesima u proizvodnim halama tako da se koriste prirodni resursi i voda za preradu u koju otiču štetne materije. Prateći ove negatvne strane, tekstilna industrija mora da se reformiše u oblasti primene materijala na inputima do izvora snabdevanja električnom energijom. Postoji tehnološka i energetska tranzicija koja može da doprinese povećanju efikasnosti proizvodnje, efektivnosti rada i smanjenju potrošnje struje, održivom korišćenju bližih energetskih resursa poput OIE. Na ovaj način se direktno smanjuje zagađenje voda,*

1 https://orcid.org/0000-0003-3634-4545

a indirektno se smanjuje usiljeno korišćenje resursa koji ne mogu da se obnove ili očiste od zagađenja. Prednost je što se energetskom tranzicijom mogu uštedeti materijali, estetski se poboljšava izgled tekstila i proizvoda, a ekonomske uštede su osetne. Mogu da se ulažu sredstva u zameni prihvatljivih materijala, koji se recikliraju i ne zagađuju. OIE poput solarne energije i energije vetra mogu da se postave na krovovima hala, a geotermalnom vodom mogu da se ispiraju, obeljavaju ili termalno tretiraju prirodna vlakna i tako stvore održive materijale u tekstilstvu.

Ključne reči: energetska tranzicija, obnovljivi izvori energije, tekstilna industrija, potrošnja, uštede.

1. INTRODUCTION

Natural resources are all around us, but humanity faces difficulties in continuous supply, as well as rational use of resources and destruction of rivers, land or air. For industrial development, it is necessary to set strategies aimed at reducing pollution, energy efficiency and the transition of energy supply in production. The textile industry is important for the economy, which has a long tradition, but in addition, it must bring more benefits than investment, i.e. costs for long-term survival. The production of textiles and yarns, as well as new materials, is growing because the range is expanding. Starting from clothing, as a basic product in textiles, the existence of packaging, construction or agricultural products derived from fibers, textile elements for defense purposes, protective purposes, aeronautics and nanomaterials that are resistant to water or fire, sand or with elastic must be considered properties. It is noticeable that the interest of science and business in innovations in the field of textiles is increasing, and more efforts are being made in saving and replacing sources of energy supply in the process of production and processing of textiles, in order to achieve the smallest ecological footprint on the natural environment.

The textile industry is considered to be a major polluter, as large volumes of waste water from chemicals and dyes are concentrated, and water and energy consumption increases, as the standards are clear about the participation of heavy metals and additives in composite materials for textiles. An increasing number of clothes are produced every year, and the warehouses are full of unsold clothes that later have to be recycled, put on waste and decompose slowly, emitting harmful gases.

2. TEXTILE SECTOR AND ENERGY

The value of the textile sector in the world is moving from the current 480 billion to 700 billion dollars. The global status of textiles shows the intention in the energy transition, with the current reliance on non-renewable sources, such as fertilizer for growing cotton, the use of oil for the production of synthetics, chemicals for the production and dyeing of fibers, but also the use of fossil fuels for the production of electricity.

The share of electricity and fuel in the total energy consumption in the textile sector of any country directly depends on the structure of the textile industry. The textile industry is considered to be an extremely labor-intensive branch of industry that develops on the basis of a diverse supply of labor. The production of textiles and clothing is the most important branch of the European manufacturing industry, which in 2016 had 177,700 textile companies in the EU and employed over 1.7 million workers [1].

In recent years, the industrial production of textiles has decreased, as a result of the world crisis in finance, economy and health, so that clothes were used again. The highest influence on the demand for textiles is the price, as well as the inputs in the final product, where energy prevails. In the textile industry, energy sources are divided into electricity that drives machines, air conditioners, lighting, office equipment, as well as coal, oil and petroleum gas resources as fuel for boilers.

Energy is an important factor that affects production efficiency, productivity and economy, and in the textile industry, reducing the consumption of electricity and thermal energy is considered a way for greater acceptance and environmental sustainability. Not only does energy efficiency increase with renewable energy sources, but production processes are technologically modernized, production time is shortened, accessible sources are used, and lighting and heating in production halls can be obtained from solar panels and mirrors.

The prerequisites for using renewable energy sources in the textile industry [2] are:

1. Existence of awareness of cost reduction caused by energy,

2. Existence of eco-eco (ecological, economic) analysis of the use of RES,

3. Technological improvements and innovations,

4. The existence of renewable energy sources in the vicinity,

5. Neutralizing the barriers to accepting the energy transition,

6. Strengthening support through directives, institutions and finances.

Two categories that decisively affect the environment of textile production are the release of harmful substances and the high consumption of water and energy [3].

2.1 Environmental problems of the textile industry

There are direct and indirect sources of pollution originating from the textile industry, and they are related to higher consumption and fast trends [4]. Some clothing companies are trying to reduce costs, to shorten the supply chain, which leads to lower prices for more affordable clothing [5]. In the environmental sphere, the main focus is on the use of energy, water, chemicals, direct CO2 emissions and solid waste [6]. The ecological footprint of the mentioned resources has different intensity depending on the stage of the product life cycle in the textile industry (Table 1).

Table 1: Environmental problems in textille industry

Environmental problems	**The most impactful stages in product life cycle**
Energy consumption	Production of man-made fibers, yarn manufacturing, finishing processes, the washing and drying of clothes in the use phase
Water and chemicals consumption	Fiber growth, wet pre-treatment, dyeing, inishing and laundry
Solid waste	Mainly the disposal of products at the end of their life, textile/clothing manufacturing
Direct CO2 emissions	Transportation within globally dispersed supply chains

Source: Created by the author based on [6]

Every year, the fashion industry produces half a million tons of microfiber plastic that ends up in the ocean. Likewise, this industry is one of the largest, consuming millions of tons of water for washing fibers, bleaching, dyeing and cleaning the final product. The problem arises because wastewater is not filtered and treated to reduce pollutants before it enters the environment. As a result, we have 20% of drinking water pollution caused by the processing and dyeing of textiles, and the toxicity comes from formaldehyde, chlorine and heavy metals.

A noticeable environmental problem caused by the textile industry is water, air and solid waste pollution. The global textile and clothing industry used 79 billion cubic meters of water in 2015 [7], and a lot of land is needed to grow cotton and other fibers needed for textile production.

2.2 Water as an endangered resource from the textile industry

By 2030, the world's textile industry will use 50% more water, emit 63% more carbon dioxide and produce 62% more waste compared to 2015 [8]. The goal is to reduce the use of water capacity, but also to use this resource more for energy production, because the hydroelectric plant is technologically acceptable and represents a renewable form of energy.

Wastewater in the textile industry is generated in the process of preparing raw materials, dyeing fibers or fabric, in the finishing and special processing of finished fabrics (See Table 2). For this reason, they contain a high content of organic or inorganic pollutants, high coloring, various minerals and metals, and often toxic and carcinogenic substances. Before discharge into the recipient, they must be reduced to the maximum permitted values prescribed by law. The problem of water purification needs to be solved as soon as possible because the underground water, which is the main source of drinking water, is polluted to alarming levels [9].

Another solution to reduce water consumption and pollution of textile industries is the reuse of water for

Table 2: Waste water (refined and non-refined) according to treatment method and activity (thousands of cubic meters), 2023 year

	Discharged wastewater in total	**Discharged precise effluents**	**Precise waste water (example treatment)**	**Precise waste water (secondary treatment)**	**Precise waste water (tertiary treatment)**	**Tested imprecise waters**
Textile industry	457	367	10	15	342	90

Source: Wastewater [10]

washing floors, rinsing containers, as well as "Air Dyeing Technology" (ADT), which uses air instead of water for wet dyeing. ADT dyeing emits 84% less greenhouse effect, requires 87% less energy, enables new designs and does not require sorting clothes when washing.

2.3 Technological processes in the textile industry

Production facilities in the textile industry can be optimized to reduce electricity costs, through energy efficiency from the fiber treatment process, entering the processing plant, processing technological operations, and all the way to market placement. In this way, money is saved, pollution is reduced, and investments are made in the replacement of processing technology and the energy transition is carried out.

The input elements in the technological process of textile production are dyes, additives, water and energy, which affect all stages of raw material processing, which can be seen in Figure 1. The stages are the production of natural and synthetic fibers, the production of yarn (threads, fabrics and knitting), wet processing (pretreatment, dyeing, printing, finishing), sewing, use of finished products. During all these stages, some waste occurs, as well as emissions, with the fact that the waste itself can create pollution emissions.

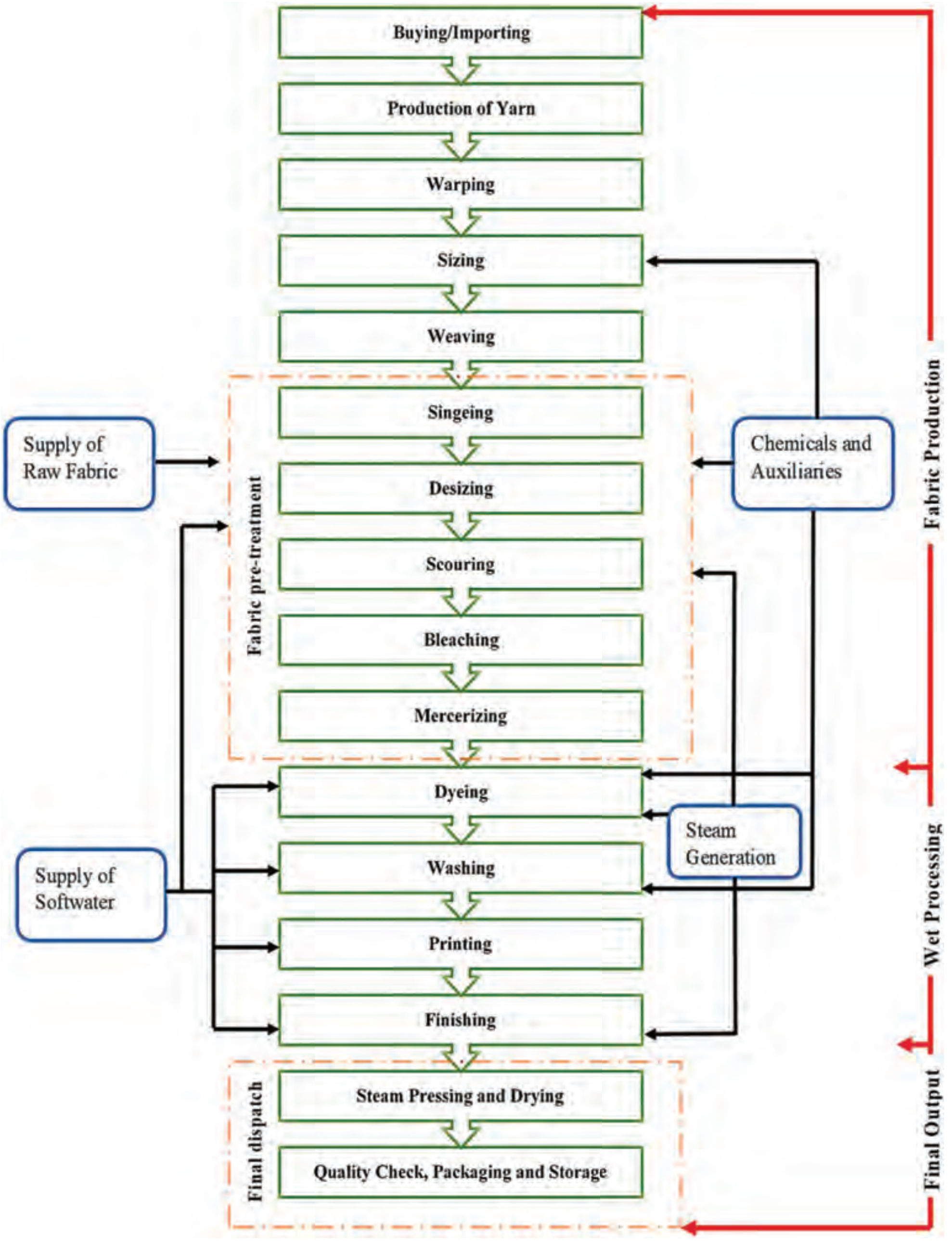

Figure 1: Typical manufacturing process flow diagram [11]

2.4 Application of new materials that can reduce the energy input

Textile materials can be natural or artificial, and the complexity of the weaving process depends on the business ambitions of manufacturers who incorporate new materials or technologies in order to obtain textiles and a final product that will be accepted by users with as little investment as possible.

In 2017, natural fibers had a share of 28% in global fiber production. If artificial fibers or yarns were used instead of natural ones, the method of fabric production would change and the finishing processes would include preparation, printing, dyeing, chemical and mechanical finishing and coating. Artificial fibers in the non-woven industry have a share of 90%, while natural fibers such as cotton, jute, kenaf, flex, hemp, coconut are not widely used [13, 14, 15].

Wearable textiles come in a variety of styles and sizes, and there are textiles for sports, protection or intimate wear. Home textiles have properties that satisfy functional needs, for pillows, bed linen, towels or carpets. Composite materials are reinforced with natural textiles and are used where high mechanical resistance is not required, in automotive panels and upholstery, noise insulation panels, interior furniture panels or window frames [16].

Plant fibers from nature absorb harmful oil dioxide and release oxygen during the cycle. Importantly, used textiles can be recycled by extracting good fibers to make other products, and the remains are disposed of in landfills to decompose in nature. Natural products, such as tea tree oil, eucalyptus, aloe vera can be used for finishing textiles that are antimicrobial, while synthetic agents can be effective but affect water pollution. The demand for antimicrobial textiles based on environmentally friendly means reduces the harmful effects that are correlated with the increase of microbes on the textile material [17].

It is a warning that cotton is planted on 3% of arable land in the world, and for its cultivation, about 10% of agricultural chemicals and 25% of pesticides are used [18]. Production of synthetic products from polymers release harmful nitrogen oxide during the production process. Bioprocessing also offers the potential for new industrial processes that require less energy and are based on renewable raw materials [19].

3. REDUCTION OF ENERGY CONSUMPTION IN THE TEXTILE INDUSTRY

The textile industry represents one of the sectors with a high resource intensity, as a result of which it has a very high potential for the transition towards innovative, sustainable and circular production, consumption and business models. As a result, EU member states have adopted several documents to support and encourage economic entities to implement the green and digital transition more quickly, which is necessary for improving competitiveness and for technological development [20].

In the field of textile production, energy consumption is a supporting input that influences thinking about changing the energy strategy in which to switch to a sustainable energy source, with less impact on the environment. In order to satisfy its need for energy, the sector resorts to two different types of energy sources: indirect sources (electricity) and direct sources of supply (natural gas, cogeneration - a procedure for the simultaneous generation of electricity and heat. This way of use means that from the same amount fuel receives, in addition to electrical energy, additional thermal energy, which allows for an increase in the degree of utilization of the chemical energy of the fuel and diesel fuel). Reducing greenhouse gas emissions related to energy consumption can be achieved in different ways, the main ones being energy efficiency, rational use of energy and cogeneration.

Table 3 shows the benefits of applying cleaner production processes on the example of First Textile, a company based in Turkey that produces knitted textiles, yarns, dyed and printed textiles [21].

Table 3: Benefits from the application of cleaner production processes on First Textile Co.

Benefits for environment	Cocts (Invest and Operations)	Annual savings	Time retourn of money
Reduction of water, energy and chemical consumption	0 USD	32.370-58.340 USD	Very Fast
Reduction of water and salt consumption	20.000 USD	57.680 USD	3 mounths
Reduction of steam and energy consumption, Air pollution control	28.820 USD	513.000 USD	1 year

Source: [22]

The linear economy allows us to move from resources, processing, the technological process of production to sale, while in the circular model, harmful inputs of chemicals are reduced, waste is recycled and renewable energy sources are used. The goal of the circular economy is to create a society in which the generation of waste is reduced to a minimum with a high level of resource reuse.

4. ENERGY TRANSITION METHODOLOGY

Methodology for the transition from existing energy sources to sustainable ones, i.e. renewable energy sources (RES) in the textile industry should create a system that will identify at the beginning the hybrid technology that will be prioritized. The final decision is based on transitional possibilities that are important such as technical parameters, financial-economic feasibility and sustainability. Identifying variables that can be renewable and integrated in the industry, with solar panels as a solution. The method can be presented through steps (Figure 2), in which three points are important:

1) for the development of a sustainable energy transition, a mix of available information on the amount of energy consumed and available raw materials is used, along with research (attitudes of stakeholders, as decision makers) on the application of the proposed resources;

2) in a changing environment, the textile sector deals with technological changes, so a model of annual energy consumption is created with changed sources, technologies and processes, which follow investments, but also tests of quantitative and qualitative benefits;

3) the acceptance of the transition model of technological innovation in energy depends on investors, local communities, educational institutions and research centers, who from a distance notice the progress and reduction of investment, pollution, invested energy, water consumption, and the increase of product quality and profit.

The total costs of textile production include raw materials, energy, machines, and water, while after production, the textile industry faces the costs of storage, disposal, and recycling. There is an estimate that energy costs range from 5 to 17% of total production costs. In the process of processing and later finishing, 80 to 85% of heat energy is consumed, while the remaining percentages go to electricity.

The process of spinning and weaving requires a higher consumption of electricity, so there is a need to use energy sources that are sustainable, clean and renewable in the long term, such as solar energy, wind energy, geothermal or some other type that will not have harmful gas emissions in thermal power plants.

4.1 Selection of transition energy and technology in the textile industry

In textile operations, solar energy can be used for electrical purposes and machine start-up needs, while thermal properties are manifested in textile dry-

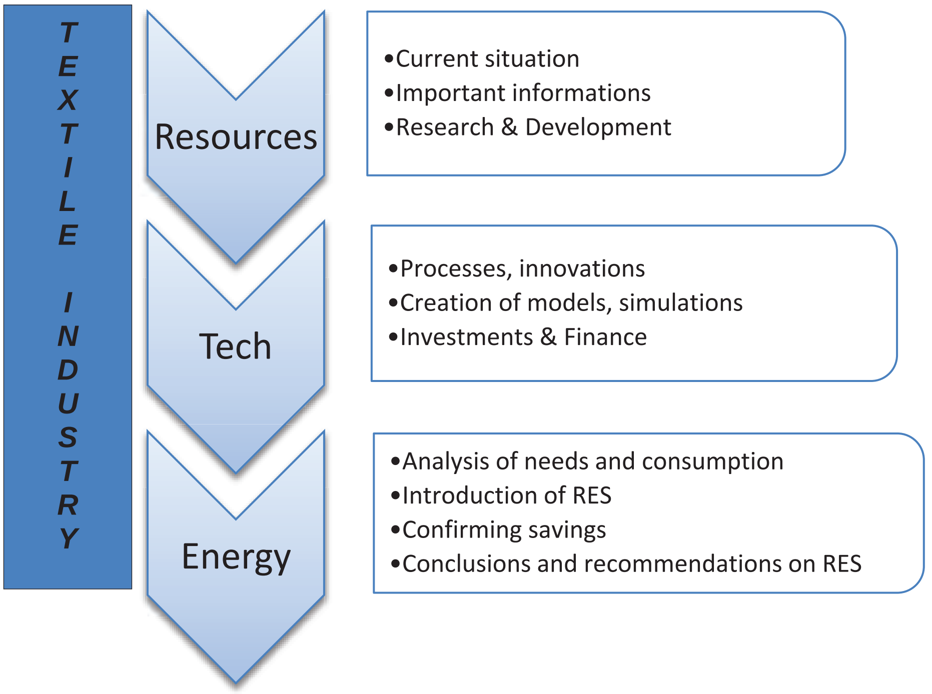

Figure 2: Energy transition in the textile industry

ing, bleaching, gathering and finishing. Solar energy as a renewable source does not pollute the environment and is simply converted into thermal or electrical form, and it is useful because it is easily integrated with other sources, thus reducing costs. The installation of textile processing machines that use solar cells as an energy source are technologically advanced in the textile industry that require a minimum power of 5-6 kW for processing, but also in halls for lighting, cooling or space heating. Direct solar energy can be used as heat to dry the fibers that are wet after dyeing, and drying depends on the geographical position and sun exposure of the factory roof. It is interesting that there is a need for low-temperature water in wet textile processing, which is partially obtained from solar and geothermal energy.

Geothermal waters with constant and favorable chemical-physical properties would benefit textile processing, but with an expert assessment of system integration due to pipelines, investments, space as well as the effects after treatment of these waters on the ecosystem. Technological solutions using biosolid waste for boilers are possible, and the textile processing industry can easily adapt to non-conventional machines, which for example can use textile waste that is burned and gets energy.

The choice of fuel in closed combustion systems is important for higher performance, but must be balanced against the intention to reduce the negative effects of pollution. In some areas of the textile industry, emphasis is placed on the moderate calorific value of the fuel, which does not burn quickly. For example, boilers installed in textile factories are being changed from flue to more efficient tube type.

The transition process can be laborious, with higher initial costs, but after a few cycles, production costs are reduced. In Germany, the USA or China, textile industries are moving towards a total transition to RES for general technological operations, while in areas with favorable geothermal properties such as Iceland and the Philippines, the drilling of deep wells, where the liquid is heated to produce steam and she started the turbines for the production of electricity.

5. CONCLUSION

Many resources are limited, and renewal depends on the responsible use of forests, water, air, land. Humans cannot destroy the sun and wind, and they are considered fundamental renewable energy sources, while geothermal energy, biomass, biogas can be disrupted and thus question the status of renewable energy.

The process of gradual transition to engagement of energy sources that are renewable, increasing energy efficiency in the supply chain, investing in innovation, encouraging initiatives for transition and transformation, as well as reducing the use of natural leather, should become a priority of the new development strategy of the textile industry.

The materials used in the textile branch of the industry depend on raw materials for the production of textiles, clothing, footwear and introduce nanomaterials, synthetics, artificial materials that must be produced, processed, joined and disposed of in a sustainable manner. In the textile industry, there are by-products, waste and dye impurities that are discharged into river courses and thus threaten the ecosystem.

The model of reducing the use of electricity from the electrical system by 50% of industrial needs individually for each textile factory would enable an increase in the energy transition from fossil fuels, electricity from thermal power plants, and heating plants to RES technology. The textile industry would reduce the total energy use per unit of product in plants where they use solar, hydroelectric, geothermal energy or landfill gas.

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