Contribution of the textile industry to the carbon footprint*

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Abstract

The production and use of raw materials and fabrics for textile products and the use of products themselves contribute significantly to the formation of greenhouse gases throughout their total life cycle. The article discusses the origin and extent of these greenhouse gases and the carbon footprint of these products.

Definition of concepts

Carbon footprint is a measure of the impact of human activity on the environment. It helps to measure the extent to which human activity contributes to global warming.

There are three general definitions of the carbon footprint in scientific world [6]:

1. carbon footprint is the carbon dioxide (CO_2) emissions from the combustion of fossil fuels by human activity;

2. carbon footprint is defined as the CO_2 and other greenhouse gases emitted by products, through the entire life-cycle of raw material sourcing, production, distribution, use and recovery;

3. at the heart of the concept of carbon footprint is the measurement of the impacts of human activities, based on the direct and indirect CO_2 transformation of the climate change impact of these activities.

Carbon footprint belongs to the family of different footprint indicators and accounts for a significant part of the ecological footprint. The carbon footprint shows how much greenhouse gas is emitted directly and indirectly into the air as a result of a company's activities, a person's lifestyle or the life cycle of a product. Each greenhouse gas emission is converted into metric tonnes of carbon dioxide equivalent (t CO_2e), which is also the unit of measurement of the carbon footprint. Carbon footprint of products can be calculated on the basis of life cycle analysis [9]. The larger the carbon footprint, the larger the measured climate change impact. The life cycle of a product is the stage from the extraction/production/growing and preparation of the raw material needed, through the manufacture of the product, to its use and the recovery or treatment of the waste generated after use. In the case of a process or service, the environmental impacts of the use of materials and energy, and of the process itself, are assessed.[1, 8]

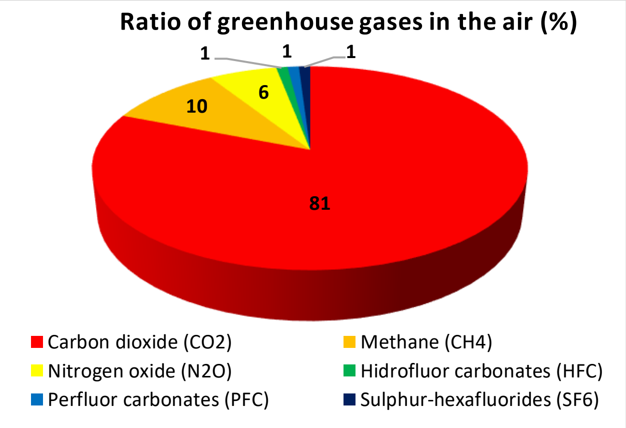

Fig. 1

Global warming and climate change on Earth is the result of the so-called greenhouse effect. The greenhouse effect affects the heat balance of planets whose atmosphere transmits light from its star (inwards) but not part of its own thermal radiation (outwards). As a result, some of the heat from the planet's surface does not return directly to space, but is involved in various physical and meteorological processes. (A similar but not identical process keeps greenhouses, from which the phenomenon gets its name.) The gases that absorb the planet's thermal radiation are called greenhouse gases. Natural greenhouse gases in the Earth's atmosphere and their contribution to the greenhouse effect are [2]:

water vapour	36–70%
carbon dioxide	9–26%
methane	4–9%
ozone	3–7%

The combined greenhouse gas emissions of Australia, Europe, the UK and the USA in 2012 were as shown in Figure 1 [5].

Carbon footprint of the textile industry

It can be seen that carbon dioxide is the most abundant pollutant in both data sets, so it is worth looking at its origin from the perspective of the textile and clothing industry. (It should be noted, however, that the carbon footprint of the „textile industry" and „clothing industry" is understood to cover the entire value chain, from the cultivation/manufacture of fibre materials, through the entire processing and transformation chain, including fabric production, cutting and sewing, to distribution, end-use and even waste disposal.)

The carbon footprint is the aggregate greenhouse gas emissions of a product. In the textile industry, CO_2 emissions are measured per 1 kg of textile product and expressed in grams (or kilograms). Over the entire life cycle of a textile product, around 50% of CO_2 emissions are caused along the value chain (fibre production, product manufacture, trade, transport) and 50% by everyday use (there are, however, large regional differences due to the way the product is produced, but these are mainly due to the availability and choice of energy source).[5]

The production of one metric ton of textile products produces around 15–35 metric tonnes of CO_2 equivalent greenhouse gas emissions. In 2017, the production and

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handling of clothing, footwear and household textiles consumed in the 28-member European Union resulted in 654 kg of CO_2 equivalent emissions per capita.[3]

The global textile industry releases 1.22 to 2.93 billion tons of carbon dioxide into the atmosphere every year. This means that the life cycle of textile products (including washing) is estimated to be responsible for 6.7% of total global greenhouse gas emissions.[4]

The problem is set to get worse as both textile production and consumption of textile products grow strongly. Since 1975, global production of textile fibres has almost tripled, with 107 million tonnes produced in 2018 and this figure is expected to reach 145 million tonnes by 2030.[4]

Another factor contributing to the rapid growth in clothing consumption – and hence in greenhouse gas emissions – is the fact that fast fashion has led to a significant proportion of the consumer population changing their wardrobe very frequently, with some brands now releasing up to 24 collections in 12 months, often at very low prices. This creates huge consumption. Unused items, often bought very cheaply, are simply thrown away and, unless recycled, end up in landfills or dumps, contributing to environmental pollution and increasing the carbon footprint.[4]

The textile industry (which here includes the clothing industry as well) – *with emphasis on the entire life cycle of textiles, from fibre production/cultivation to the final disposal of waste!* – is considered one of the world's largest greenhouse gas producers. The textile and aluminium industries are calculated to be the largest greenhouse gas emitters per unit of material. According to the US Energy Information Administration, the textile industry is the fifth largest emitter of CO_2 after primary metal processing, non-metallic mineral processing, gasoline production and chemicals.[5, 7]

It cannot be ignored, however, that the carbon footprint of textiles can vary greatly from region to region, and even from country to country, depending on the energy sources and the proportions used in the different stages of fibre production/manufacturing and textile production. To give just one example, the main energy sources in Europe are oil and gas, in China coal. The CO_2 emissions from oil heating are only about 50% of those from burning coal. In China, about 80% of the electricity produced is produced in coal-fired thermal power plants, so the carbon footprint of textiles made in China is 40% higher than in Europe. Figure 2 shows the carbon footprint ratios for different regions [5].

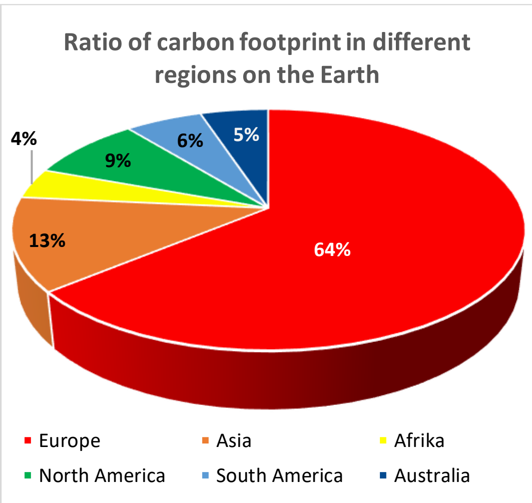

Fig. 2

Carbon footprint of the production of textile products

The cultivation of natural fibres, with all its associated operations, contributes significantly to the carbon footprint [5]. For example, in conventional cotton production, the largest contributor is the impact of synthetic pesticides: the production and use of 1 tonne of nitrogen-based pesticides contributes 7 tonnes of CO_2 equivalent to the carbon footprint. Of this, carbon dioxide itself accounts for 53%, with nitrogen dioxide contributing 45% and methane 2%. Organic cotton, due to the lower energy intensity of its cultivation, has a much better result, accounting for only 43% of the carbon footprint of conventional cultivation.

During the life cycle of cotton textiles, around 50% of CO_2 emissions are generated during fibre production, product manufacture, trade and transport, with the remaining 50% caused by daily use.

Dyeing and finishing are important processes in cotton textiles, resulting significant carbon dioxide emissions. CO_2 emissions are caused directly by energy consumers and indirectly by consumables such as lubricants and chemicals. The distribution of CO_2 emissions in the fully continuous textile production process of cotton textiles shows that about 40% of CO_2 emissions come from washing and steaming, 50% from drying and 10% from the use of chemicals. In the knitwear finishing process, the heating of water accounts for the largest share of emissions, i.e. 60%.

It has been calculated that for a long-sleeved white cotton shirt, the different processes over its lifetime represent the carbon footprint values and ratios shown in Figure 3 [5]. Noteworthy are the significant proportions of product production and consumer use (28 and 32%, respectively).

In the case of wool textiles, the production of 1 kg of fibre from sheep rearing to carded sliver generates 2.2 kg of CO_2, half of which is produced on the farm [5].

In the case of jute, methane formation is a major contributor to the digestion process which is one of the components of the carbon footprint.

The most important factor related to the carbon footprint of synthetic fibres is that they are produced from fossil fuels. Extracting oil from the ground and producing synthetic polymers require large amounts of energy and therefore emit much more CO_2 than natural fibres.

The production of acrylic fibres requires 30% more energy than polyester, and even more for polyamide. For synthetic fibres, it is not only the amount of greenhouse gas emissions that is important, but also the type of

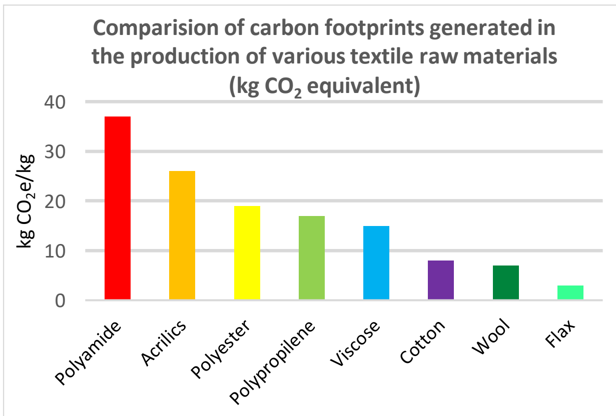

Fig. 3

greenhouse gases produced. Polyamide, for example, emits N_2O, which is 300 times more harmful than CO_2, and because of its long lifetime can reach and deplete the stratospheric ozone layer. Synthetic fibres also do not degrade and release heavy metals and other additives into soil and groundwater in landfills. Recycling requires expensive sorting, and the process produces pollutants. A comparison of the carbon footprint (kg CO_2 equivalent) of different fibre materials in production is shown in Figure 3 [5].

Carbon footprint of various textile production processes

Electricity is the main source of energy for textile production. According to 2008 data, the global textile industry used around 1 074 billion kWh of electricity (equivalent to 132 million tonnes of coal) and 9 trillion litres of water. However, only 15 to 20% of the electricity used was for the production of textiles (including clothing manufacture), the rest was used for textile cleaning. [5]

The distribution of electricity used in the textile industry by production process is shown in Figure 4. The relatively high electricity consumption of spinning is noteworthy, but note that within spinning, ring spinning represents 37% and turbine spinning 20%. [5].

The energy sources and carbon emissions of the textile dyeing and finishing processes for cotton and cotton-type fabrics are summarised in Table I [5].

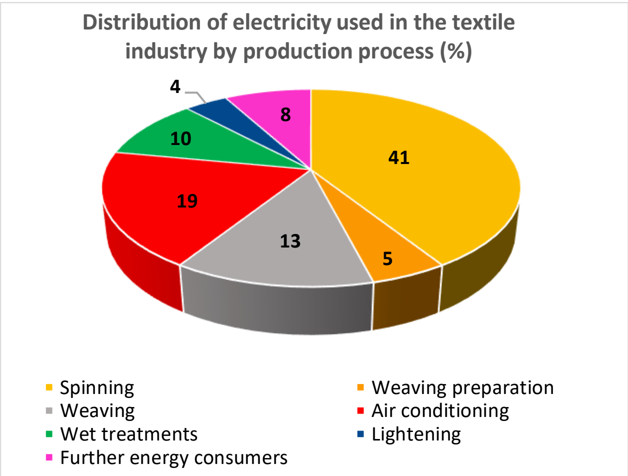

Fig. 4

Table I.

Process	Energy used	CO_2 emission
Singeing	Gas	Low
Washing/Heating	Gas	Very high
Steaming	Steam	Moderate
Drying	Gas/coal, steam	Very high
Fabric transport	Electricity	Low
Air conditioning	Electricity	Low
Chemicals		Low

The carbon footprint values generated in the production of a cotton T-shirt per production phase are illustrated in Figure 5 [5].

What can we do?

Reducing the carbon footprint, and thus the acceleration of global warming, is of paramount importance for preserving the Earth's liveability. As the textile industry is one of the economic processes that contributes significantly to the increase in the carbon footprint, professionals in this industry must do their utmost to reduce it as far as possible, knowing and taking into account that the demand for textiles is constantly increasing, both for clothing and for technical and surgical/hygienic textiles.

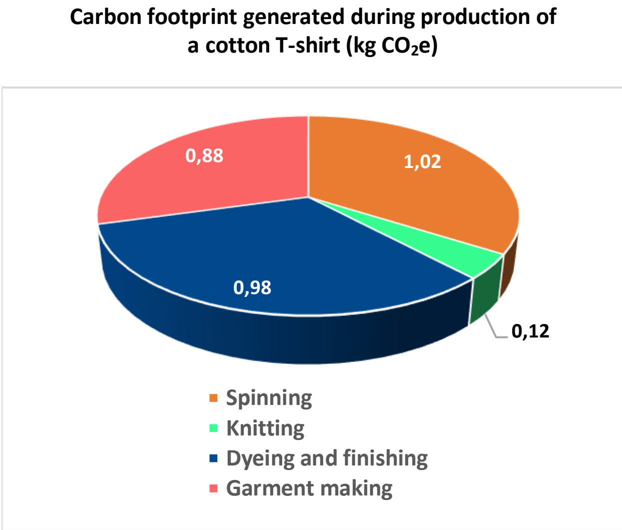

Fig. 5

Per capita consumption of clothing increases exponentially as people's living standards and fashion awareness improve. The complex supply chain of the textile industry creates a significant carbon footprint during production, distribution and use. Textile products create a carbon footprint at each stage of their life cycle. From harvesting to packaging, transport, use and disposal, every processing step increases the carbon footprint of textile products. With its huge production volume, the textile industry is a major source of greenhouse gas emissions worldwide.

Energy-efficient processes are increasingly being used to reduce carbon emissions from textile processing.

According to calculations, the production of synthetic fibres is highly energy intensive, so to reduce the carbon footprint, preference should be given to natural fibres, which have a lower carbon footprint than synthetic fibres. In addition, natural fibres have other advantages, such as biodegradability and the sequestration of carbon dioxide from the atmosphere by the plant. Producers of man-made fibres are constantly striving to develop new variants, production and processing methods that reduce the carbon footprint of these products, which are, despite all of their disadvantages, are indispensable.

Energy- and water-intensive textile processing is a major contributor to carbon footprints, so the main aim of all machinery and technology development is to reduce these as much as possible. A number of environmentally and carbon-efficient machinery and technology solutions are now known that contribute to resource savings, reducing processing time, energy and water consumption. Consumption of non-renewable energy can be reduced by preheating water with solar energy or with a heat exchanger in the sewer. It is desirable to include solar panels in the energy supply of as many plants as possible. A number of technologies allow wastewater recovery and recycling, thus also reducing the carbon footprint of processing. Continuous processes reduce the number of textile processing steps and thus water and energy consumption. Digital control of processes at all stages of production can contribute to efficient use of energy and water and thus reduce the carbon footprint.

There are significant efforts to reuse and recycle textiles. This also has environmental benefits. Recycling is only effective if the resulting carbon footprint is smaller than the one of disposal. The energy consumption and associated greenhouse gas emissions of the collection, recycling and use of a product should be taken into account and compared with the energy demand and CO_2 emissions of the production of new products.

We are witnessing a strong effort to spread the so-called *slow fashion* approach – the opposite of *fast fashion* – which aims to reduce the amount of time spent on clothing textiles by ensuring that consumers change their wardrobe as rarely as possible, do not throw out their tired or „out-of-fashion" clothes after one or two uses, but wear them for longer periods of time by varying the garments, perhaps even slightly altering them. In effect, this means extending the life cycle of the garments, thereby helping to reduce their carbon footprint and waste.

We have mentioned that the largest carbon footprint over the life cycle of a garment is the result of its use, mainly washing and cleaning. Garments that require washing, drying and possibly ironing require the most energy and energy use in the use phase. Cleaning operations account for 40–80% of the total life-cycle greenhouse gas emissions of such garments. It is worth reviewing how this can be reduced [7]:

- Machine drying is generally the largest energy consumer and greenhouse gas emitter.
- Garments that require hand-washing are likely to use much less energy in the use phase.
- Dry what you can in the open air, not in a tumble dryer.
- Dry-cleaned garments may emit fewer greenhouse gases than wet-cleaned garments.
- In many cases, garments are washed more often than is strictly necessary (e.g. after each use), which significantly increases overall greenhouse gas emissions.
- If not absolutely necessary, do not iron clothing or household textiles.

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