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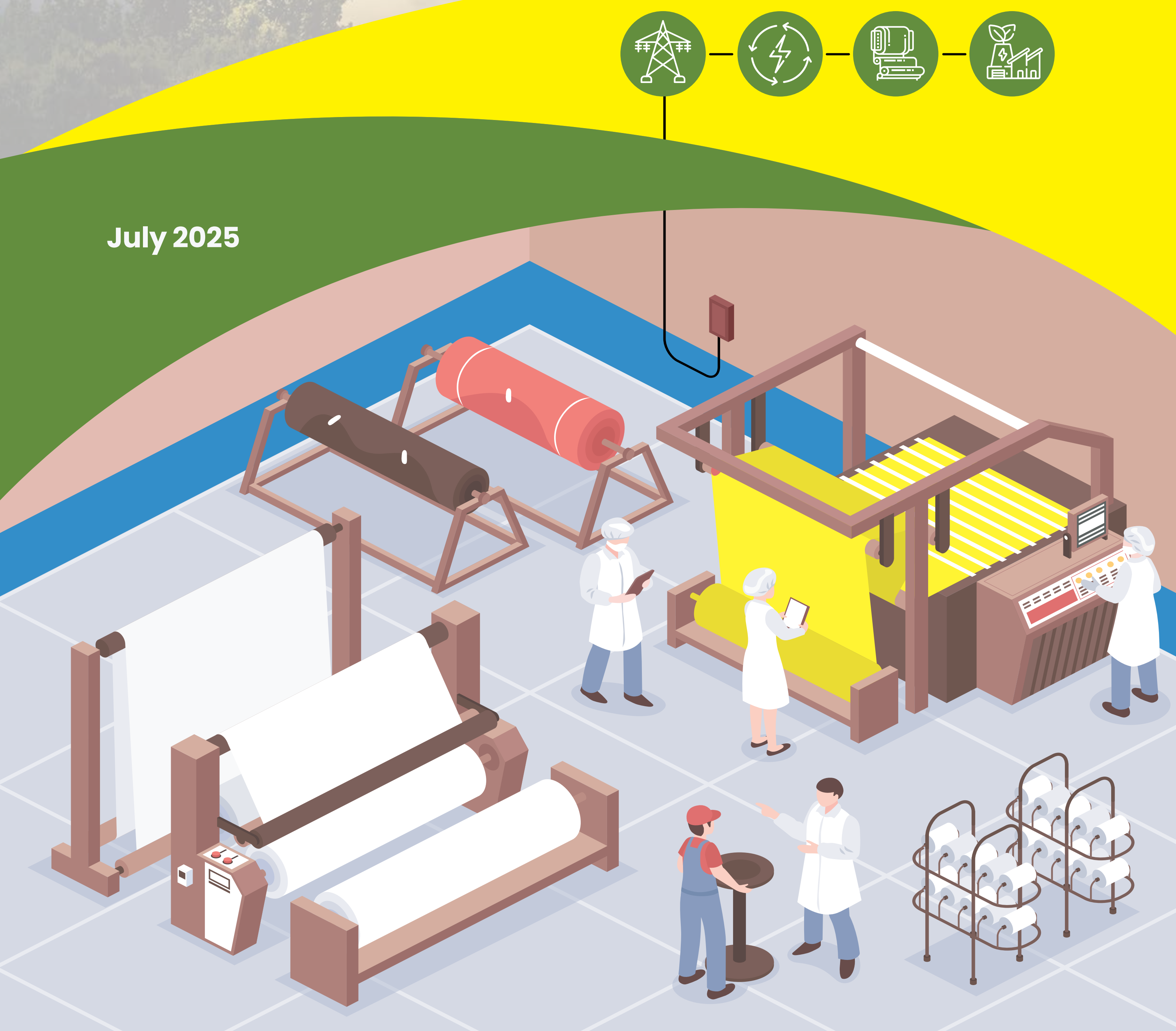
ELECTRIFYING THE TEXTILE INDUSTRY

Mapping Industrial Profile and Energy landscape



July 2025

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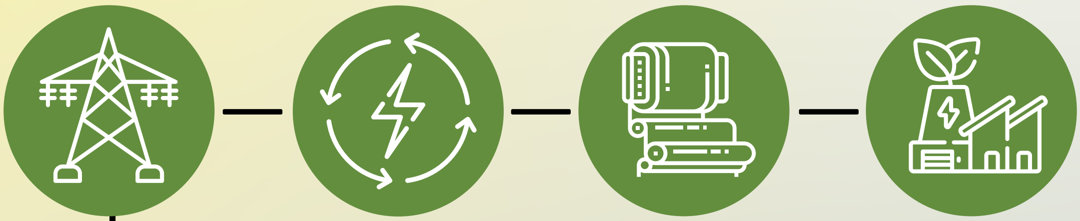

ELECTRIFYING THE TEXTILE INDUSTRY

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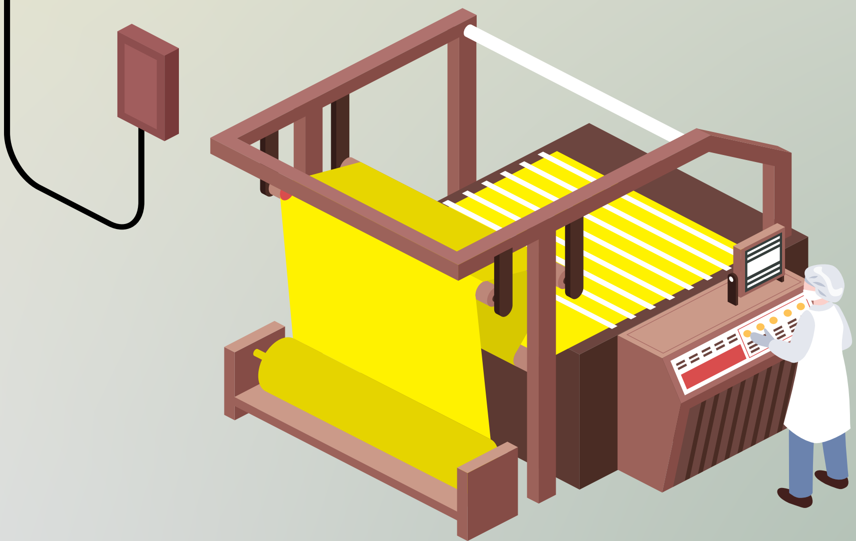

July 2025

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Executive Summary

India has set ambitious targets to revolutionise its textile industry, aiming for US$600 billion in exports and a domestic market worth US$1.8 trillion by 2047. This is expected to go up from US$44 billion and US$110 billion, respectively in financial year (FY) 22. Given the immense scale of the sector, the Indian textile and apparel sector undoubtedly emerges as a potent force towards the realisation of India's 2047 vision by boosting its textile exports share and in providing large-scale livelihood opportunities. The surge, driven by fast fashion and the e-commerce sector, necessitates an increased focus on low-carbon technologies to ensure efficiency and meet the incremental demand in sustainable ways. With the 500 GW of non-fossil capacity target by 2030, electrification offers huge opportunity to transition the textile industry from carbon intensive processes to clean sources of electricity. Accordingly, India's textile sector possesses significant decarbonisation potential, particularly through electrification.

Based on our analysis of Annual Survey of Industries (ASI) data for 2022-23, electricity makes up 37% of final energy use for textile operations in India, but only 10% in fuel-intensive processes like finishing, where additional electrification could significantly reduce emissions. The sector showcases a heavy reliance on fossil fuels—primarily coal and petroleum products—accounting for nearly 46 percent of energy use. The textile sector is heavily reliant on thermal energy, especially in wet processes such as finishing, dyeing, drying, and stentering. These processes alone contribute 43 percent of the textile industry's total energy consumption. Electrification in these areas could yield 25-30 percent in efficiency gains and environmental benefits, presenting a transformative opportunity for the sector-both nationally and globally[1].

The Indian textile industry is unique due to its dual structure, comprising both large industries and Micro, Small, and Medium Enterprises (MSMEs). The latter plays a pivotal role, contributing to a huge share of the textile output, particularly in geographical clusters. Given this fragmented structure, cluster-specific interventions are necessary to decarbonise effectively. As per our analysis, between FY 2009-10 and FY 2022-23, the overall energy consumption in the textile sector increased by 25 percent and the coal consumption increased by 86 percent highlighting its enduring importance in decarbonising the textile industry. The landscape analysis further reveals that Gujarat consumes almost 68 percent of the coal consumption in the textile sector, followed by Maharashtra and Rajasthan.

1 However this number could be much higher with other advance electrification technologies such as heat pumps which are not analysed as part of this study.

Notably, due to varied data reporting and accounting structures, the emissions from the textile sector reported under the national Greenhouse gas (GHG) emissions inventory are far lower than the actual emissions. This is because a significant portion is included under the 'non-specified industries'. Based on the emission estimation from ASI data, the actual emissions from the sector are much higher than currently reported, emphasising the need for more accurate data assessments and reporting.

However, the textile sector has emerged as a front-runner in installing captive solar and wind power projects. There have been credible shifts from coal-based captives to RE-based captives with coal-based captive capacities plummeting from 2,122 MW in 2018-19 to 559 MW in 2022-23, marking a remarkable 74 percent reduction. Further, the sector underscores the highest wind power installed capacity amongst all industries, with 1,477 MW.

Looking ahead to 2050, the textile industry's energy demand is projected to triple due to demographic growth, economic expansion, and increasing consumer markets. This surge underscores the urgent need for energy-efficient practices and a transition to clean energy to sustainably meet rising demand. Additionally, if the textile sector needs to work towards a Viksit Bharat Trajectory, it will require a near-doubling of efforts compared to current levels. High electricity costs present a dominant challenge to making investments in electrification, energy efficiency for most MSMEs. Solar-powered electrification solutions, however, present a promising alternative and are cost-effective in the long run.

Summary of the report includes:

- A Landscape assessment of the textile sector in India to understand the key textile energy consumption trends, processes and geographies.
- Wet processes, particularly dyeing, drying, and stentering, are key hotspots for energy consumption and present a prime opportunity for electrification.
- Projections for 2050 show three times increase in energy demand for the sector, driven by demographic and economic growth, requiring energy-efficient practices and renewable energy adoption.
- Electricity cost escalation could hinder electrification for textile industries, necessitating supportive policies and incentives to promote clean energy solutions.
- Notable discrepancies in textile emissions in the national GHG inventory highlights the need for building sectoral emissions data.
- This report emphasises the need for tailored, cluster-specific decarbonisation strategies and highlights the critical role of electrification and renewable energy adoption in driving sustainable growth in India's textile industry.

01

Introduction

As the need to address climate change becomes more urgent, there is a tectonic shift in efforts for industrial decarbonisation where every industry is becoming a part of this equation. Towards this, there is a global call for the alarming impact of the textile and apparel sector due to its substantial emissions and ecological footprint in not just energy-related emissions but water, chemicals, land and waste generation. The textile and the garment sector contribute to roughly 6-8 percent of the global carbon emissions[2]. However, the rise in these emissions is not aligned with the net zero pathway, and if the fashion sector continues on its current trajectory, by 2050, it could use more than 26 percent of the carbon budget associated with a 2 °C global warming limit.[3]

Today, apparel is one of the most common products and has become a fundamental part of a consumer's life, which they buy frequently, without being aware of the impacts it has on the environment. The fashion industry typically operates in a linear production, distribution and consumption method with a limited focus on recyclability or circularity.

Each stage is resource-intensive, right from the raw material stage where fertilisers are required to grow cotton (raw material), to using fossil fuels during the processing stages, and finally using chemicals for dyeing and producing the finished fabric (final product). The dyeing process requires constant washing, which consumes enormous amounts of water, while the chemical processes consume bleaches and dyes which are environmentally degrading. These processes are performed in different factories in different parts of the world, which involve transportation at each stage and have significant environmental footprints owing to the amount of fuel used for the traction of shipping containers. Moreover, the decrease in price of apparel, increased competition and faster trend cycles coupled with rising wasteful practices have created an urgent need to decarbonise this sector.

2 https://www.ilo.org/static/english/intserv/working-papers/wp053/index.html

3 https://www.ellenmacarthurfoundation.org/fashion-and-the-circular-economy-deep-dive

Need for Textile Decarbonisation

The global emphasis on sustainability reporting has intensified, and emerging regulations such as the EU Ecodesign for Sustainable Products Regulation (ESPR) and Corporate Sustainability Due Diligence Directive (CSDDD) are set to accelerate decarbonisation efforts across industries, including textiles. The ESPR aims to improve the environmental sustainability of textile products by enforcing stricter design and performance standards, mandating energy efficiency, recycled content, and extended product life cycles. Additionally, it introduces a Digital Product Passport (DPP), which will require detailed lifecycle data on carbon footprint and material sources. Meanwhile, the CSDDD holds corporations legally responsible for the environmental impact of their supply chains, requiring textile exporters to comply with lower-carbon manufacturing processes.

Further, several Extended Producer Responsibility (EPR) policies in European nations like France, Germany, and Sweden now hold brands accountable for the entire lifecycle of their products, including waste management and recycling. Given that 47 percent of India's textile exports are directed to the US and EU markets, compliance with these regulations is critical. Failing to do so could result in restricted market access, carbon tariffs, and loss of competitiveness.

For Indian manufacturers, these regulations necessitate a shift towards low-carbon textile production, energy-efficient processes, and renewable energy adoption. Electrifying wet processing operations such as dyeing, drying, and stentering could improve efficiency and reduce emissions by 25-30 percent, aligning with global sustainability requirements. Global fashion brands such as H&M have already begun enforcing green mandates on their suppliers, requiring them to adopt renewable energy, circular materials, and energy-efficient production. H&M, for example, has pledged to cut its carbon emissions by 56 percent by 2030 and has introduced preferential sourcing from suppliers that meet these standards.

With such regulations rapidly reshaping the global textile value chain, Indian textile manufacturers must accelerate their decarbonisation efforts to remain competitive. Proactive investments in electrification, renewable energy, and circular production models will not only ensure compliance with evolving EU and UK policies but also provide long-term cost benefits and market access advantages.

Indian Textile Industry: Sectoral Relevance

India has a rich history of textiles, dating back thousands of years. It is one of the few countries to have all the components of the textile manufacturing chain, ranging from yarn, fibre, fabric and apparel. The textiles and apparel industry contributes almost 2.3 percent to the country's GDP, 13 percent to industrial production and 8.2 percent to exports. India is the sixth largest exporter of textiles and apparel in the world with a 3.91 percent share in global trade.

The 5-F (Farm to fibre; fibre to factory; factory to fashion; fashion to foreign) and 4S (Style, Scale, Skill and Sustainability) vision laid down by the Government of India is the foundation for making India a global hub for textile manufacturing and exports. The Indian Textile and Apparel market is expected to grow at a 10 percent Compound Annual Growth Rate (CAGR) from the current $165 billion in 2022 to reach $350 billion (including exports) by 2030.[4]The sector is an employment powerhouse, providing jobs to approximately 45 million people directly and another 60 million through allied sectors, making it one of the largest sources of employment (over 100 million) in the country[5].

The textile sector is expected to play a significant role, with a target of US$100 billion in exports by FY30 and further achieving US$600 billion in exports by 2047, a significant increase from the US$34 billion recorded in the financial year 2024[6]. Given the immense scale of the sector, the Indian Textile and Apparel sector will undoubtedly emerge as a potent force towards the realisation of India's 2047 vision of a 30-35 trillion-dollar economy by boosting its textile export share and in providing livelihood opportunities.

Accordingly, the Indian textile industry, a historical powerhouse, is poised for significant growth. However, its reliance on fossil fuels for energy-intensive processes poses a significant environmental challenge. The textile industry faces numerous drivers and challenges to transform its energy and GHG footprint, reduce carbon dependence (decarbonisation), and grow while meeting demand. The variation of energy sources, multiple uses (energy and feedstock), diverse materials and process mix, and reliance on carbon for products is part of the challenge. To achieve the deep decarbonisation goal for the textile industry, four decarbonisation pillars (Figure 1 and Annexure 1) will need to be vigorously pursued in parallel in coming decades. However, this study focusses on '**Electrification**[7]' as a key vector to decarbonise the textile sector.

4 https://www.investindia.gov.in/sector/textiles-apparel

5 https://cdnbbsr.s3waas.gov.in/s33937230de3c8041e4da6ac3246a888e8/uploads/2023/11/2023110331747562.pdf

6 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2059503

7 Electrification – a process of replacing any non-electric energy source using fossil fuels with technologies that use electricity as a fuel source by either direct or indirect methods emerges as a key strategy to reduce textile industry emissions and thus mitigate climate change.

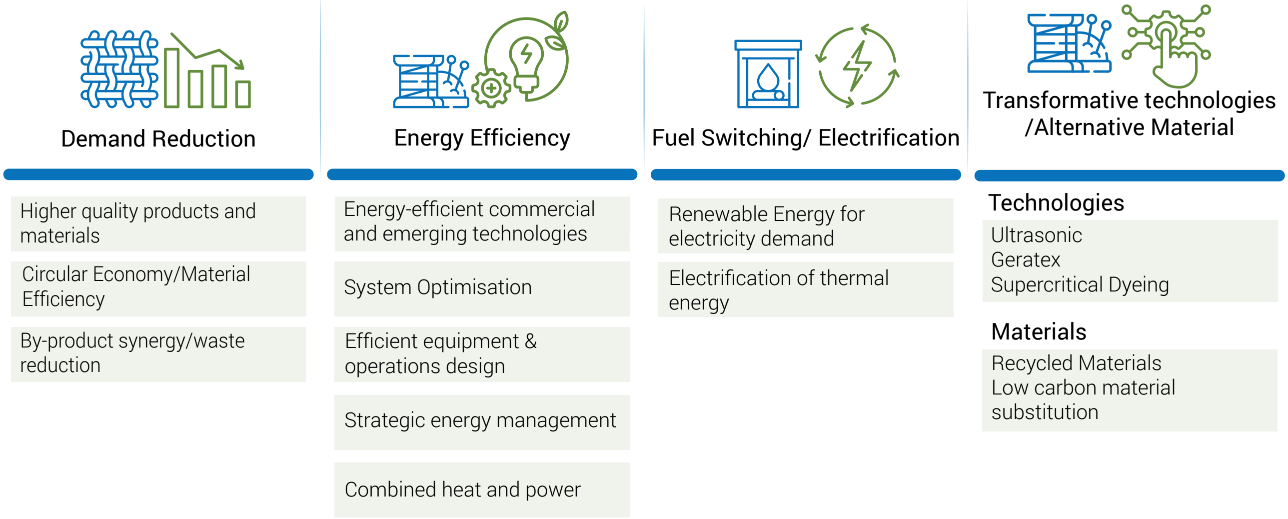


Figure 1: Decarbonisation strategies for the textile industry

Aim and Scope of the Study

This study explores the potential of deep electrification in the textile sector, focusing on the specific challenges and opportunities faced by India's textile industry. The report deep dives into energy consumption patterns, identifies opportunities for electrification, and explores India's textile industry landscape to uncover potential states and clusters.

The objectives of the study are to achieve the following goals:

- Create a landscape of the textile industry in India, including energy consumption patterns, geographies, technology, etc.
- Map the value chain and identify potential opportunities for impact reduction with a key focus on electrification.
- Conduct feasibility analysis, including the economic and environmental impact of the technology switch.

02

Understanding the Textile Value Chain-Literature Review

The lifecycle of a textile product involves several stages, starting from raw material production, material processing, finishing, product assembly, usage, and ultimately disposal. The primary emissions during textile production occur during raw material processing and finishing (refer to Figure 2, percentages reflect GHG contribution of processes for apparel production). Therefore, this study focuses solely on the industrial value chain of the textile sector. Chapter 2 provides a detailed discussion of the lifecycle stages of textile products.

The textile value chain represents the series of steps involved in producing a finished textile product. This section introduces the concept of the value chain and its importance in understanding the production process and environmental impacts. The textile manufacturing processes in the global textile industry are producing fibre, yarn, fabric, and finished products, including apparels.

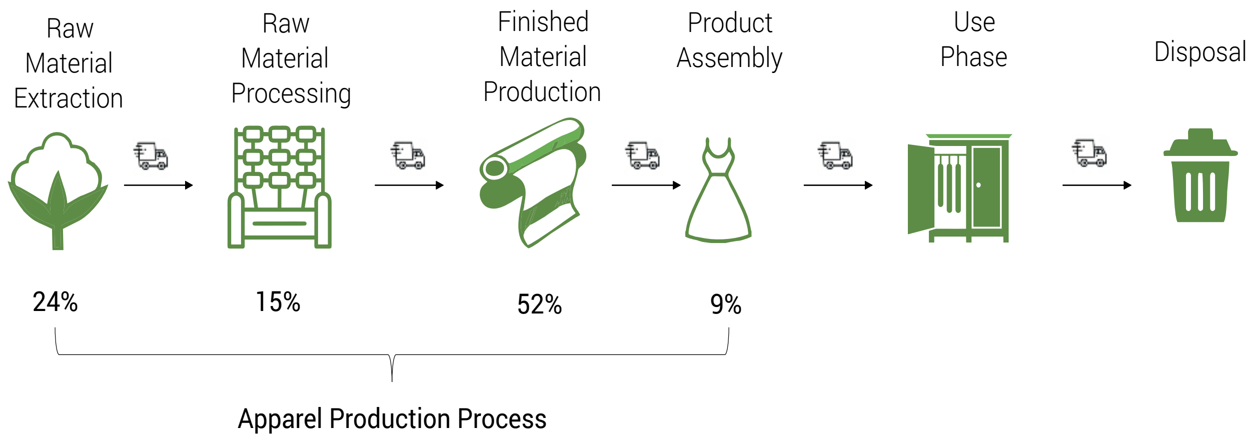


Figure 2: GHG emissions of textile production (Source: WRI, 2021)

The Global Textile Industry - A brief

The textile manufacturing processes are largely required by the fashion segment in the global textile market with a share of more than 65 percent of textile market products, followed by technical textiles and household products. The global fibre industry is expected to reach 149 million[8] by 2030, growing at CAGR of 3 percent for the last 20 years. The textile industry is dominated by man-made fibres, with China leading the market with an export share of 34.5 percent. The United States follows with 5.73 percent, Indonesia with 5.66 percent, and India with 5.06 percent in man-made fibre exports. The man-made fibre is followed by cotton fibre (natural), which is primarily grown in China, the U.S., India and Brazil. India's biggest export market resides with the U.S., and European Union with around 47 percent share in total textile and apparel exports.

Globally, polyester and cotton are the two most commonly used raw materials to manufacture fashion products, and their production has a considerable ecological impact. Cotton requires large amounts of water, while polyester have high GHG impacts and energy demand. The water requirements for cotton can be associated with the cultivation process of cotton and the reactive dyeing process. In contrast, the energy and GHG impacts of polyester are attributed to two processes: melt spinning and disperse dyeing, both of which have high energy requirements, usually thermal energy that is fuelled by fossil fuels.

Other Sustainable Alternatives

In recent years, brands have been adopting sustainable and alternative materials, such as organic cotton and recycled polyester, respectively, as a substitute for conventional materials, thereby offering a reduction potential for each of the impacts discussed previously. While the rest of the processes have more or less similar impacts for both conventional and sustainable materials, as for the raw material stage, the savings potential is listed below. The alternative processes can also be applied to the dyeing process, which is the key hotpot throughout the value chain. The dope dyeing method for polyester is identified as an alternative dyeing method that requires relatively less energy and water.

8 https://texmin.nic.in/sites/default/files/Indian%20Manmade%20fibre%20textile%20industry.pdf

The Textile Process Value Chain

The textile industry is considered to be one of the most complex industrial chains in manufacturing since the raw materials used have to undergo numerous processes based on the designs and requirements. Moreover, the number of technologies to perform these processes also varies depending on the origin of the materials (characterised in Table 1 below).

Table 1: Source of raw materials

Natural Fiber	**Vegetable**	Cotton, Jute, Linen, Ramie, etc.
	Animal	Wool, Silk, Mohair, etc.
	Mineral	Asbestos
Man-made	**Regenerated man-made**	Viscose, acetate, lyocell
	Synthetic	Polyester, Polyamide (Nylon), Polyvinyl, Acrylic,
	Mineral based	Metallic, glass, and carbon-based

The textile manufacturing value chain for apparel production can be broadly categorised into five broad stages that every material must undergo (Figure 3).

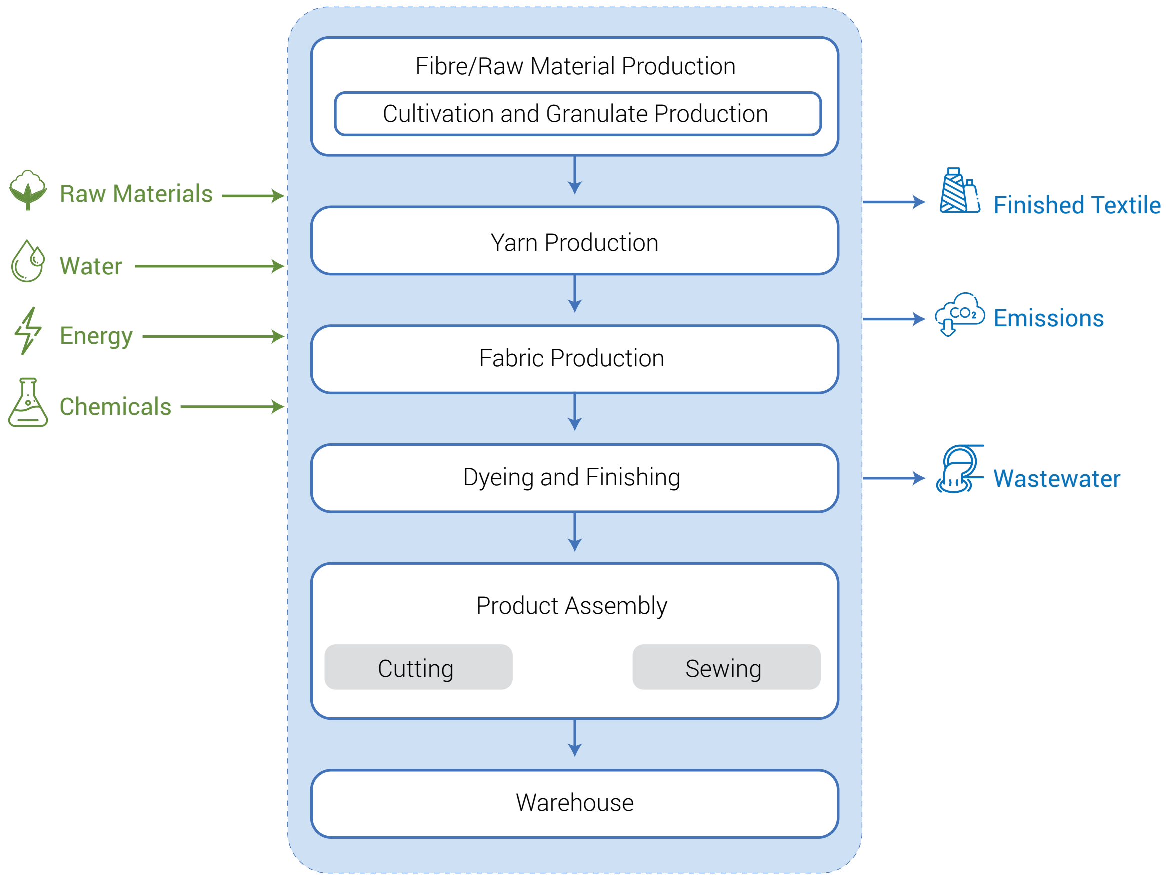
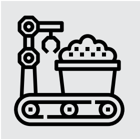
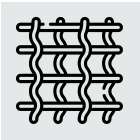


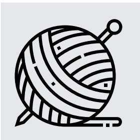
Figure 3: Textile manufacturing value chain



Raw Material Production: This first stage of the value chain covers the cultivation of natural fibres like cotton, wool, silk, and hemp, as well as the creation of synthetic fibres like polyester and nylon. For natural/cellulosic fibres, it includes all sub-processes such as the cultivation of crops, ginning and others depending on the type of natural fibre used. For synthetic fibres this stage includes the extraction of resources and granulate production process.

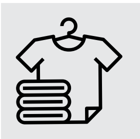


Spinning and Yarn Formation: This stage includes the spinning of yarn from either staple fibres or filament. It includes different subprocesses such as carding, combing, roving, and spinning for natural/cellulosic fibres, and spinning (partially oriented yarn and draw textured yarn) processes for synthetic filament.

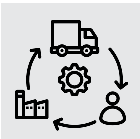


Weaving and Knitting: Yarn is then transformed into fabric through weaving or knitting. This stage includes all sub-processes like sizing and warping, sanforising, and compacting.

Dyeing, Printing, and Finishing: After weaving or knitting, fabrics are often dyed or printed and undergo various finishing processes to enhance their appearance, performance, or feel. This stage includes scouring, bleaching, dyeing, printing, and other finishing processes.



Garment Manufacturing and Assembly: This segment discusses the final stage of the value chain: turning fabrics into finished garments. It covers the process of cutting and sewing.



Extended Value Chain of Textiles (Use Phase and Disposal): The after-sales activities include the use phase and the disposal of garments, which largely depend on consumer behaviour. During the use phase, chemicals (such as detergents), energy and water are consumed for washing clothes, followed by ironing, for which the local vendors in India still rely on charcoal that has significant environmental impacts. In addition, with limited awareness of the ecological impacts, the laundry cycles in Indian households are quite frequent. Disposal practices in India, although informal, are already sustainable in some ways due to the inbuilt Indian culture of donating, repurposing or giving away garments instead of discarding them. The scope of this study excludes raw material production, use phase, and disposal phase of the textile value chain, and focuses just on the industrial value chain, which accounts for the maximum share of emissions and is intended to be discussed for decarbonisation. However, it is important to deep dive into the use phase and disposal of the textiles, which brings the consumer into the picture and should be assessed from the behavioural lens.

There are many materials used for textile products, but cotton and polyester dominate the market. While new materials are emerging, they make up only a small share of production. This report will not cover energy consumption differences at the process level due to material variability, as the main differences occur in raw material production, which is beyond the scope of study.

Energy by End-use Application

Energy usage within textile plants or across the value chain varies across different end-uses and serves diverse purposes. Figure 4 illustrates the breakdown of energy usage by end-use within the U.S. textile industry (U.S. Department of Energy in 2021). The similar breakdown data for the textile industries in

India was unavailable. While it may differ a bit between countries, it indicates the final energy use by end-use application in the textile industry.

The machine drive systems (including pumps, fans, motors, material handling and processing) and non-process energy use (lighting, HVAC, etc.) are electricity-run systems and account for 51 percent of the energy use in the U.S.[9] If total energy is to be compared in India, around a similar share of 37 percent is attributed to electricity-based energy consumption (Figure 11). Boilers and process heating, which utilise direct fire systems or thermal oil boilers, account for the maximum share of process energy consumption. The fuels used have high emissions of global and local pollutants, which can be addressed through electrification.

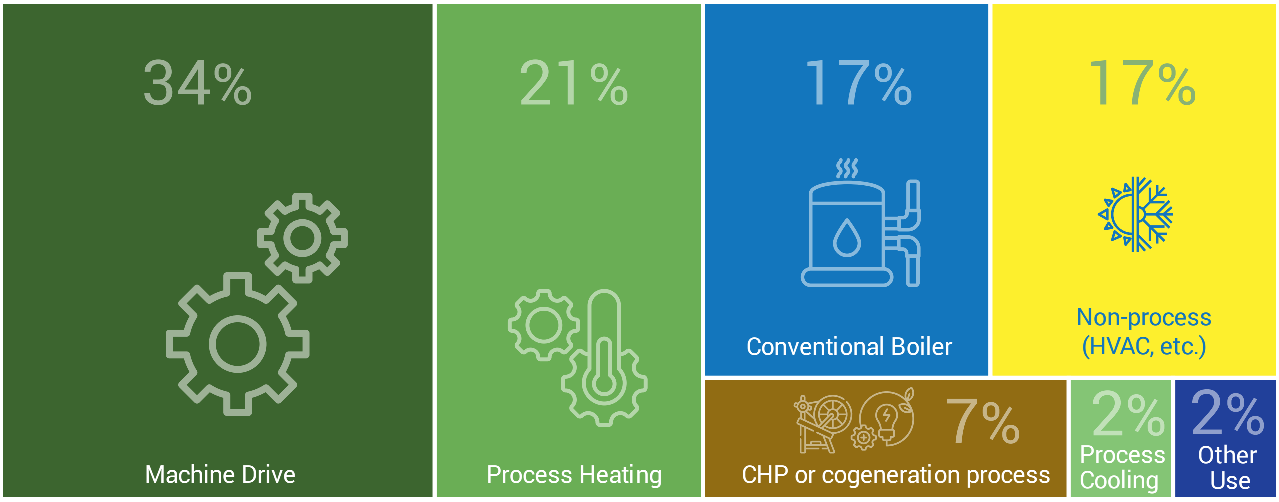


Figure 4: Distribution of energy use in the textile industry[9]

Process Deep Dive

In this section, we take a closer look at the processes that drive the textile industrial value chain. The industrial value chain of the textile sector starts with the **spinning** process, which is a thread-to-yarn process, and consumes mainly oil, lubricants, water, and electrical energy. Next in the chain comes **fabric production** (weaving or knitting), which consumes oil, energy, water, and hot sizing liquor. The penultimate process happens in the wet processing industry, which involves the **dyeing and finishing** of fabric, which includes processes like singeing, scouring, bleaching, mercerisation, drying, dyeing, stentering, etc., that utilises chemicals, dyes, auxiliaries, water, steam and heat. As part of these processes, bleaches and dyes are consumed, which are chemically laden and environmentally degrading. On the other hand, the dyeing process used for colouring the clothes requires constant washing, which consumes significant amounts of energy and water.

Figure 5 below presents the type of processes or sub-processes of different stages of the industrial value chain. The processes highlighted in blue colour have thermal energy requirement during the processing which is mainly supplied through fossil-based energy sources in India.

9 Textile and apparel industry's energy use by end-users in the U.S. in 2018 (US DOE, 2021).

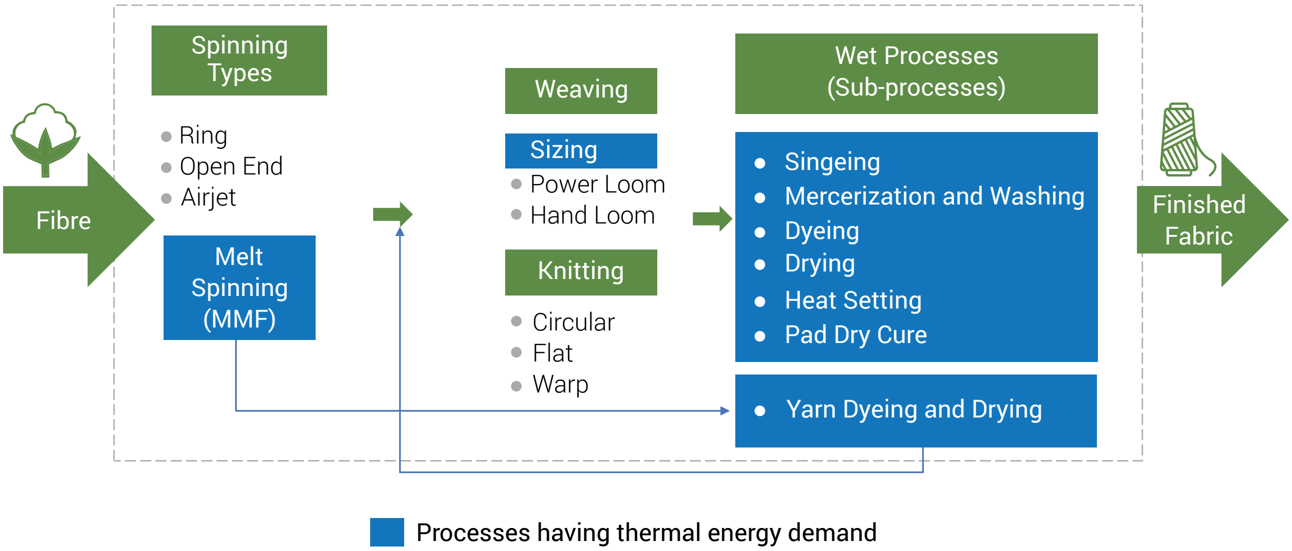


Figure 5: Type of processes within the textile industry value chain

Specific Energy Consumption of Textile Processes

The average Specific Energy Consumption (SEC) of the key processes of the textile industry is given as below. The processes up to fabric production is mechanical in nature and depends on electrical energy. The wet processing, i.e., dyeing and finishing, consumes the major chunk of energy in the form of thermal energy.

Table 2: Energy Consumption per kg for textile processes in India[10]

Process	Electric (kWh/kg)	Thermal (MJ/ kg)
Spinning	3 - 3.5	-
Weaving	2.9 - 3.1	-
Knitting	0.09 - 0.2	-
Dyeing and Finishing	0.04 - 0.15	10 - 23

10 https://shaktifoundation.in/wp-content/uploads/2014/02/textile.pdf

03

Landscape Assessment of the Indian Textile Industry

The textile industry in India stands as one of the oldest and most significant sectors, contributing substantially to the country's economy. The textile sector encompasses a diverse range of activities, from traditional handloom weaving to modern and technologically advanced manufacturing units.

Material Production

India has a robust production base of cotton, man-made fibres and blended yarns. The Indian textile industry is the second largest producer of cotton, silk and man-made fibres. India is also the leading producer of cotton among various textile materials, including silk, jute, wool, and synthetic fibres. In the fiscal year 2023-24, India's textile production included 5.53 million tonnes of cotton and 1.6 million tonnes of jute. The states of Gujarat and Maharashtra emerged as key contributors to cotton production, while West Bengal played a significant role in jute cultivation. Over the years , the cotton production growth have remained sluggish;rather declining at 2% every year. Cotton production in India is projected to reach 7.2 million tonnes (~43 million bales of 170 kg each) by 2030, driven by increasing demand from consumers.

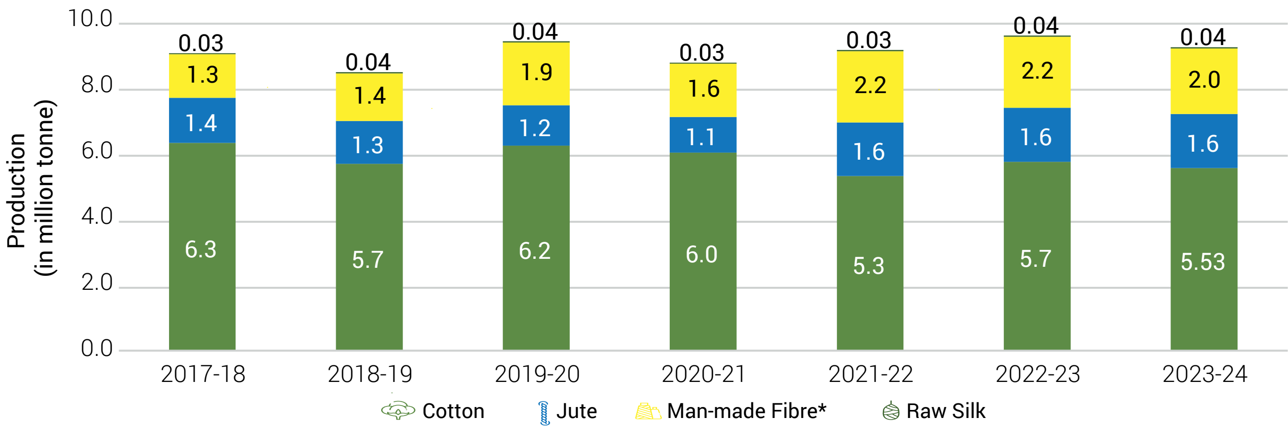


Figure 6: Material production (in million tonnes)[11] *Estimated

11 https://texmin.nic.in/textile-data

Textile Sector Import/Export

India is the 6th largest exporter of textiles and apparel in the world. Major export destinations for Indian textiles include the U.S. and the European Union, contributing to around 47 percent of the country's total exports in this sector[12]. Indian textiles are known for their quality, variety, and competitive pricing, which has helped the country maintain its position in the global textile market.

While India is a significant exporter of textiles, it also imports certain textile products to meet domestic demand. Some of the textile products India imports include high-quality raw materials like superior cotton, specialised machinery, dyes, and chemicals. Figure 7 represents India's export and import in USD million over the years.

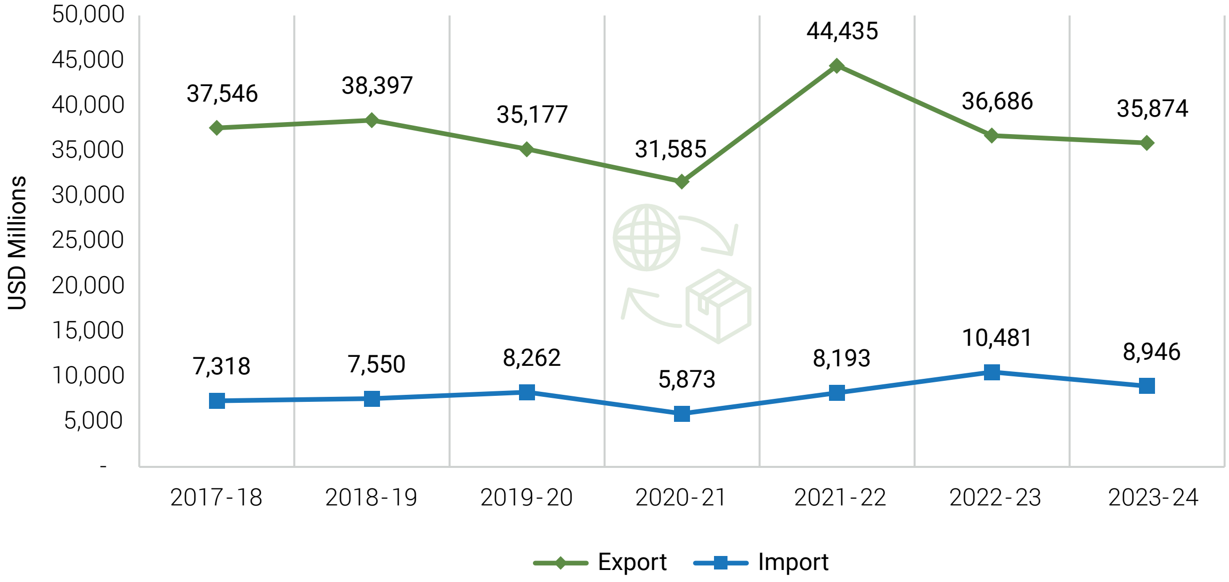


Figure 7: India's textile import and export (in USD million)[13]

Number of Units by Processes

In terms of manufacturing infrastructure, India has a robust network of textile value chain. To gain a deeper understanding of this value chain, data from the Annual Survey of Industries (ASI) has been utilised. According to the ASI survey, a total of 29,570 textile factories across the country were surveyed, out of which 22,135 are in operation in 2019-20. Out of these, the foundational process of spinning, converting raw fibres into yarn, takes place in 3,979 factories. Knitting and weaving, essential for the creation of various textile fabrics, are carried out in 6,320 factories. Meanwhile, the finishing stage, which includes critical treatments like dyeing and printing, is undertaken in 3,505 factories. Additionally, a significant number of 8,331 factories are engaged in the broader category of manufacturing other textiles. Figure 8 illustrates the year-on-year number of factories.

12 https://texmin.nic.in/sites/default/files/MOT%20Annual%20Report%20English%20%2807.11.2024%29.pdf
13 Ministry of Textiles, Annual reports

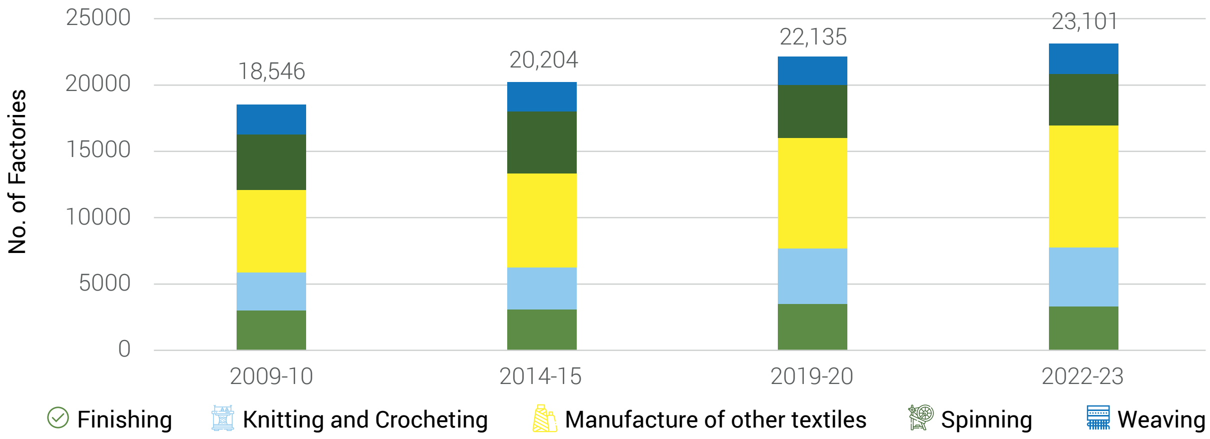


Figure 8: Operational number of textile factories[14]

Data Source: Coal consumption data for the textile sector was sourced from the (ASI) conducted by the Ministry of Statistics and Programme Implementation (MoSPI). While the Coal Directory of India, published by the Ministry of Coal, also provides sector-specific coal consumption figures, the ASI data was chosen for several reasons. Firstly, the ASI data offers a more comprehensive picture by encompassing a wider range of industries within the textile sector. Secondly, the significant discrepancy between the two datasets suggests potential limitations in the Coal Directory's coverage.

Additionally, ASI provides data on other fuel consumption across various textile processes. Hence, to gain a deeper insight into overall energy consumption trends within the textile sector, the ASI data was considered.

We underline three possible reasons for the gap between the two datasets:

- **Incompleteness in Coal Directory Data:** The Coal Directory might underrepresent textile sector coal consumption by including a significant portion in the 'others' category, possibly due to discrepancies in data reporting practice.
- **Exclusion of Imported Coal Consumption:** The Ministry of Coal reports only domestic coal consumption in the specific sector, excluding imported coal. Conversely, ASI data may capture both domestic and imported coal used by the textile industry.
- **Captive power plant consumption:** ASI data might include coal used in captive power consumption for textile industries, while the Ministry of Coal's data provides consumption figures separately for captive power plants.

To put the 8-9 MTPA figure into perspective, this volume of coal consumption is comparable in scale to that of India's cement sector annually.

Coal Consumption (in Million tonne)				
Data Source:	2009-10	2014-15	2019-20	2022-23
Annual Survey of Industries, MoSPI	5.2	8.1	8.8	9.6
Coal Directory of India, MoC	1.1	3.3	0.3	1.9

In this report, data up to 2022-23 is used, excluding 2020-21 and 2021-22 due to the impact of the COVID-19 pandemic. Including 2020-21 and 2021-22 could have introduced anomalies, potentially skewing the trend analysis. Therefore, data prior to the pandemic was used to ensure a more reliable and representative assessment of the trends.

14 https://mospi.gov.in/51-annual-survey-industries

Energy and Fuel Consumption

The textile industry heavily relies on fossil fuels for its energy consumption, with coal being the primary source for powering boilers and facilitating essential processes such as dyeing and printing, while diesel is predominantly used for generator operations. According to the ASI sample data, from 2009-10 to 2022-23, the overall energy consumption has increased from 280.4 Petajoules (PJ) to 350 PJ. During this period, coal usage grew from 28 percent to 42 percent, highlighting its enduring importance in powering the textile industry. However, the utilisation of other fuels such as diesel and biomass has exhibited a declining trend over the years. In overall fuel consumption, the share of electricity stood at 37 percent in 2022-23, while the share of fossil fuels accounted for the remaining 63 percent. The higher fossil fuel share highlights the potential for transition towards the use of other cleaner fuels within the textile industry. This further presents a promising opportunity to shift towards electrification and enable a more sustainable sector.

Figure 9 below illustrates the energy consumption trends in the textile sector:

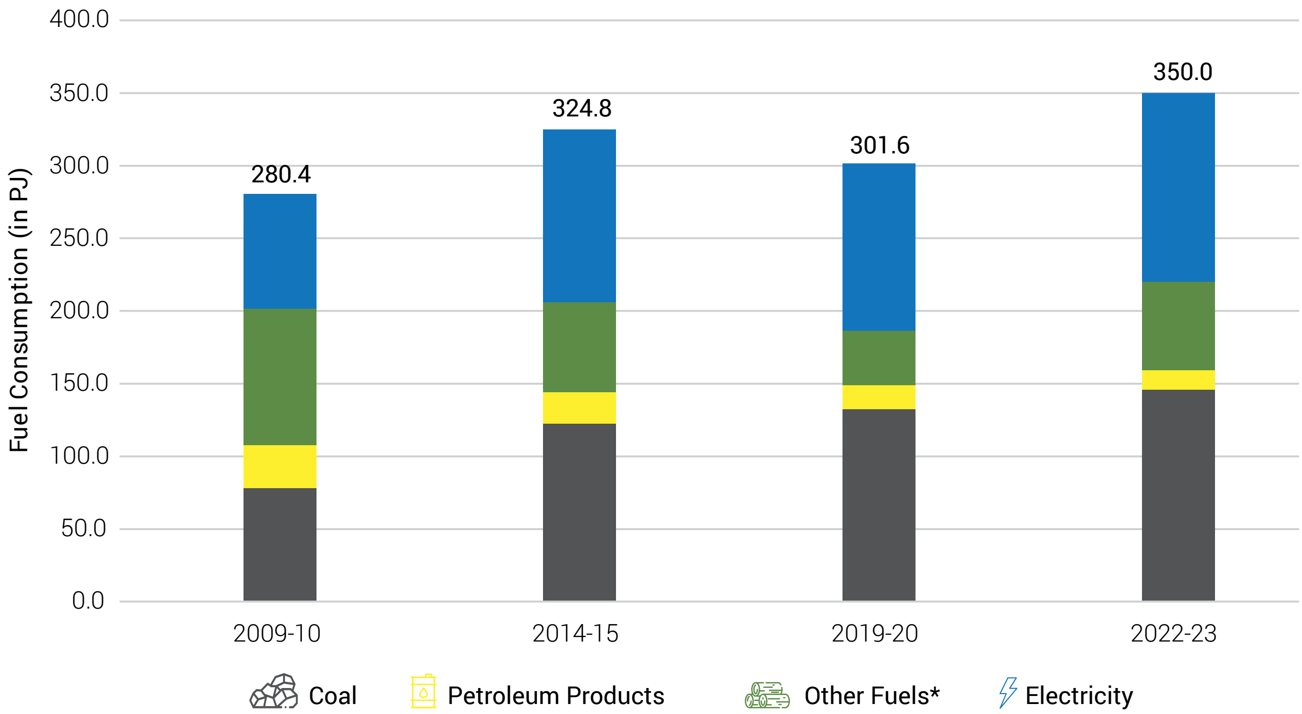


Figure 9: Energy consumption in textile sector[15]

In 2022-23, India's textile industry conservatively consumed around 350 Petajoules of energy. Around 37 percent of the total energy used in the Indian textile industry is electricity (Figure 10), the remaining portion consists of different types of fuels (predominantly coal, diesel and biomass) that are used in thermal processes to deliver heat mainly in textile wet processes, i.e., dyeing and finishing.

* Based on the stakeholder consultations, we have assumed that the other fuels are primarily biomass.

15 https://mospi.gov.in/51-annual-survey-industries, Author's Analysis

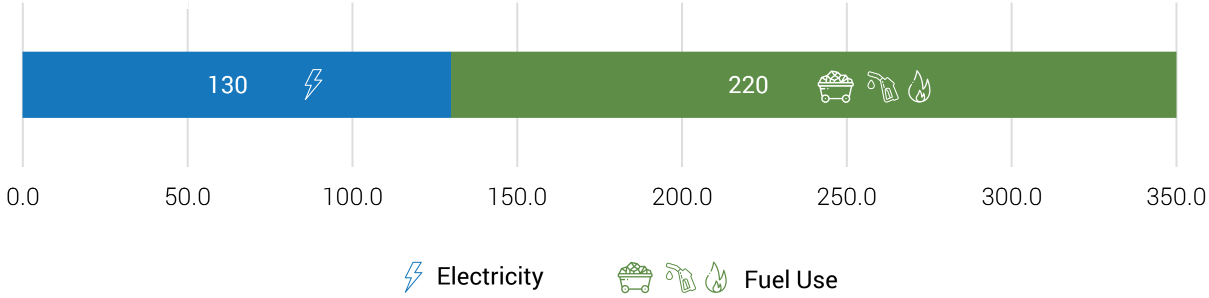


Figure 10: Share of energy consumed in 2022-23 (in PJ)[16]

The thermal energy needs of the textile industry are mainly fulfilled by coal (66 percent of fuel use), followed by other fuels, which mainly include biomass-based sources or heat purchased from nearby CHP plants. Petroleum products constitute 6 percent share of thermal energy supply.

Notably, significant share of coal is also used to generate electricity in captive industry which translate to higher share of electricity at end use consumption. As per a BEE report, electricity accounts for 47% of overall energy consumption in the textile sector. The susbsequent analysis in the report considers 47% of electricity share in energy consumption or 53% of non-electrified energy share for which the potential of electrification is assessed[17].

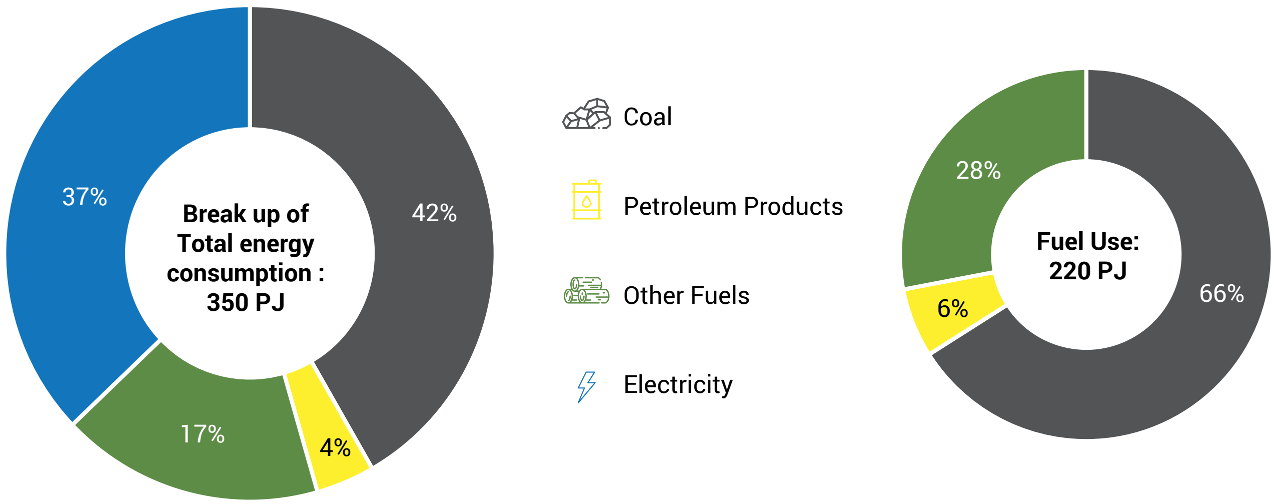


Figure 11: Fuel consumption share in 2022-23[16]

Process-wise Energy Consumption

In the textile industry's total energy consumption, the finishing process is the most energy-intensive where only 10% is electricity and the rest is fuel consumption. Electricity consumption is primarily for auxiliary consumption which includes motors, compressors and other equipments. During the FY 2022-23, 43 percent of the total energy consumption was attributed to the finishing process, with spinning and weaving accounting for 24 percent and 15 percent, respectively. In terms of fuel usage,

16 https://mospi.gov.in/asi-summary-results/849

17 https://sameeeksha.org/newsletter/newsletter_sep21.pdf

the finishing process predominantly relies on coal, whereas other processes primarily utilise electricity.

Within the finishing process, coal constitutes 73 percent of the total fuel consumption, with electricity accounting for a mere 10 percent and other fuels representing 17 percent. Conversely, in the spinning process, electricity comprises 72 percent of fuel consumption, with coal making up only 15 percent and other fuels contributing 13 percent. For weaving and knitting processes, electricity constitutes 47 percent and 52 percent of the energy mix, respectively. Figure 12 illustrates the breakdown of fuel consumption by different processes.

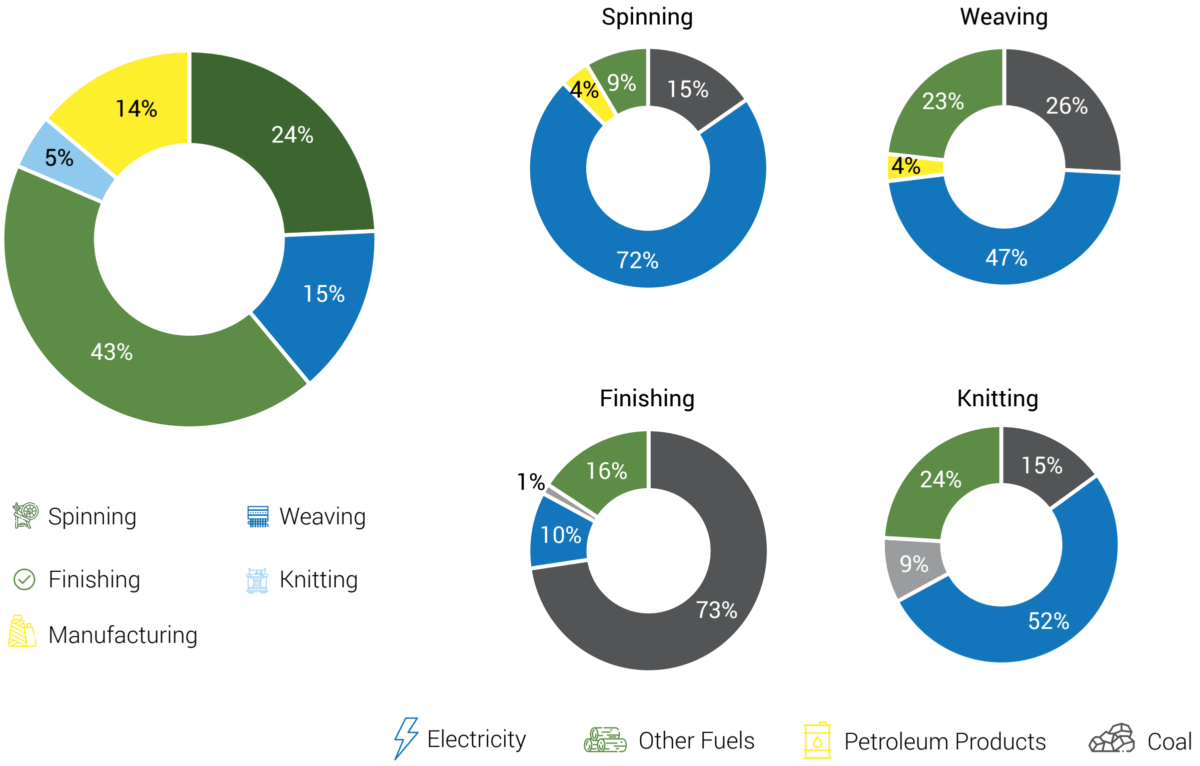


Figure 12: Share of total energy consumption in different processes in 2022-23[18]

CO_2 Emissions Profile

The textile industry heavily relies on coal and oil, contributing to a substantial carbon footprint. The global textile and garment industry is responsible for 6-8 percent of all carbon emissions, equivalent to 1.7 billion tonnes of CO_2 emissions annually. The industry's dyeing and treatment processes contribute significantly to industrial water pollution, and the extensive use of synthetic chemicals in textile production from raw materials poses an additional environmental risk.

In India, the manufacturing industries and construction activities account for 17 percent of emissions within the energy sector. Within the broader context of the manufacturing and construction sector, the textile industry contributes approximately 0.3 percent. According to the BUR-4 report, the greenhouse gas emissions from the textile sector stands at 0.64 million tonnes of CO2e (MTCO2e) in 2020[19].

18 https://mospi.gov.in/51-annual-survey-industries

19 https://moef.gov.in/wp-content/uploads/2024/01/INDIA_BUR-3.pdf; https://unfccc.int/sites/default/files/resource/India%20BUR-4.pdf

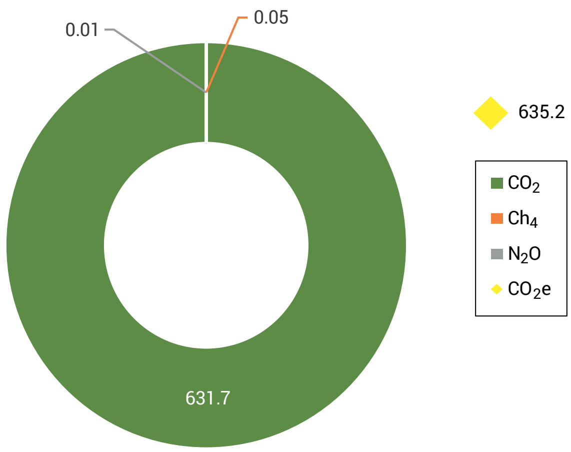


Figure 13: Textile sector GHG emissions in 2020 (in gigagrams)[21]

However, there exists a notable disparity in reported emissions within the textile sector under India's emission inventory in accordance with India's Fourth Biennial Update Report (BUR 4). This discrepancy stems from the structural classification of industries, which includes MSME industries as non-specified industries. Consequently, the MSME sector contributes roughly 80 percent of the total textile industry, and the overall MSME sector accounts for 36 percent of the total manufacturing output[20]. It is important to acknowledge that a significant share of textile sector emissions gets enshrouded under non-specified industrial emissions. The non-specified industrial emissions holds a large 43 percent share of industrial emissions.

As illustrated in Figure 14, emissions from the textile and leather sectors are reported as merely 0.16 percent of the total industrial emissions, equating to 0.64 $MTCO_2e$ out of a total of 391 $MTCO_2e$ from the industrial sector. This discrepancy significantly understates the energy consumption and emissions of the textile industry, as the estimated emissions are nearly 77 times higher than the reported figures. (Figure 15). This assessment further unpacks the Non-specified industry emissions majority of which are linked to the MSME sector.

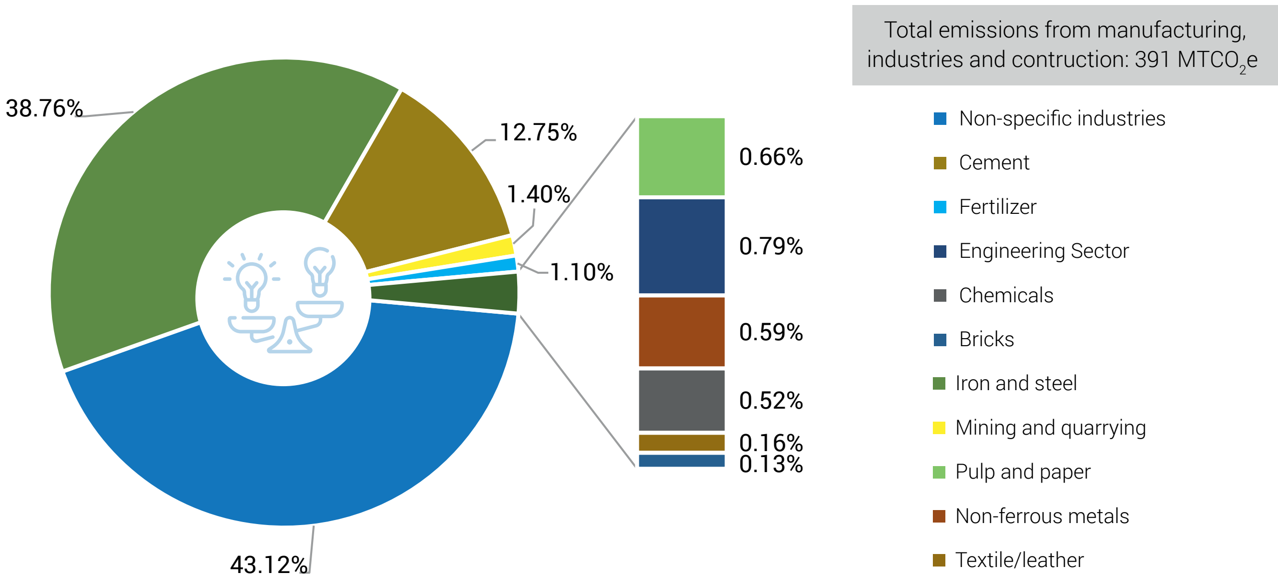


Figure 14: GHG emissions from the manufacturing industries & construction sector in 2020[21]

20 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2003870

21 BUR-4 Report, MoEFCC

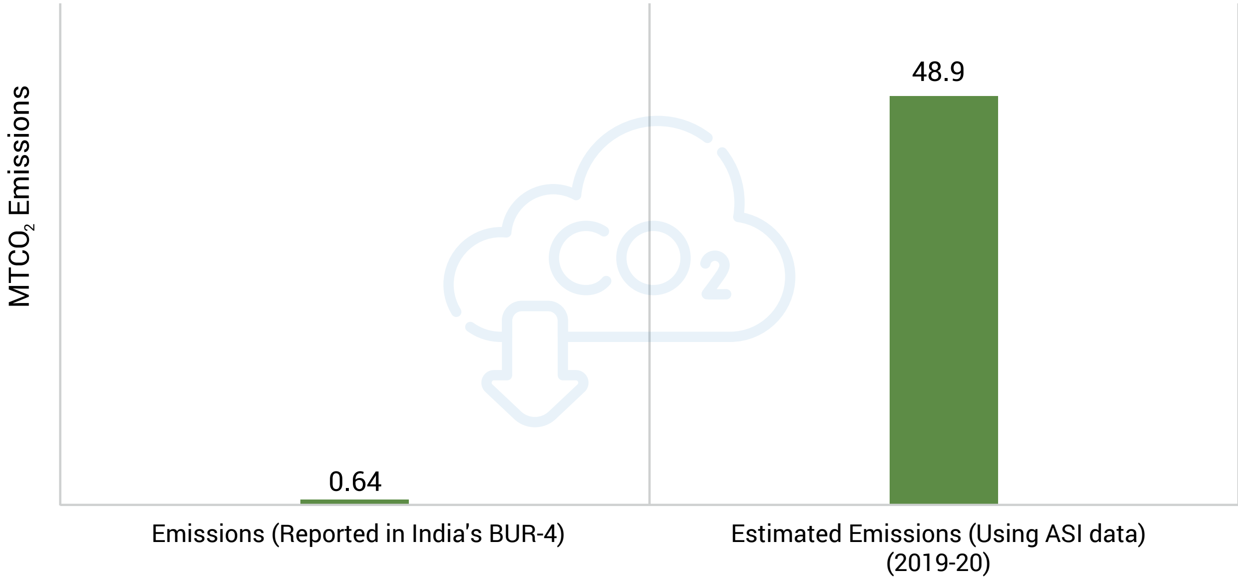


Figure 15: Emission reported in BUR-4 Vs Estimated Emissions

The textile sector has substantial energy demand and associated carbon emissions. Given the sector's significant reliance on fossil fuels, i.e., 46 percent (coal and other fuels) of total energy demand, there's a compelling case for electrification and a shift toward renewable energy is needed to facilitate meeting of India's decarbonisation goals.

Electricity consumption contributed most to the emissions due to the presence of large yarn manufacturing capacity[22], followed by coal consumption for heating requirements (Figure 16). It is noteworthy that the majority of emissions are attributed to electricity, which in 2023 was predominantly generated from coal (73 percent, CEA). These emissions are expected to decrease as the power grid and captive installation undergoes decarbonisation.

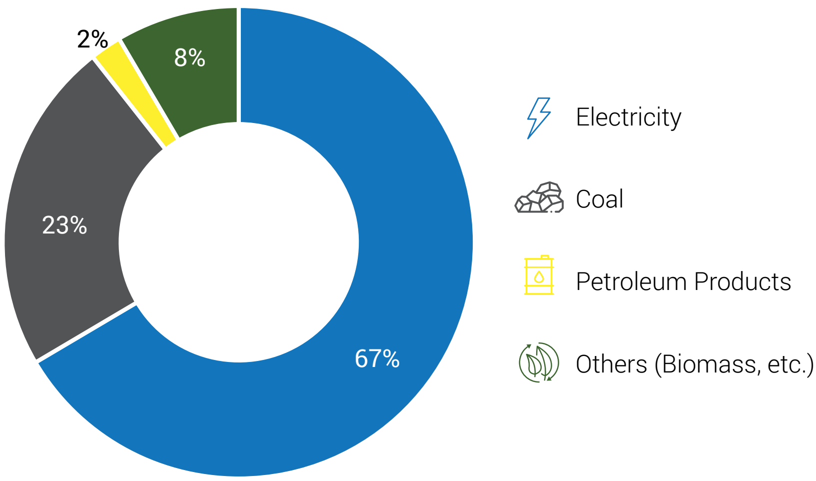


Figure 16: CO_2 emissions from the textile industry (Estimated)

22 Indian Textile Industry accounts for 22 per cent of the world's installed capacity of spindles (https://samvad.sibmpune.edu.in/index.php/samvad/article/download/98340/71477)

Key Textile Clusters

The textile industry holds significant importance in the economic landscape of India, with its presence spanning across various states. Tamil Nadu, with its well-established textile clusters in cities like Coimbatore, Tirupur, and Erode, has a robust textile industry fuelled by spinning mills, garment manufacturing, and dyeing units. Gujarat stands as another prominent player, with Ahmedabad and Surat leading in cotton production and finishing units. Maharashtra, particularly Mumbai and its surrounding areas, house a substantial portion of the textile sector, contributing significantly to India's textile exports. Other states like Uttar Pradesh, Punjab and Rajasthan also have their share in the textile sector, each with its unique strengths and contributions to India's rich textile heritage. Below, the map of India showcases the country's diverse textile clusters, highlighting the specific materials produced in each cluster.

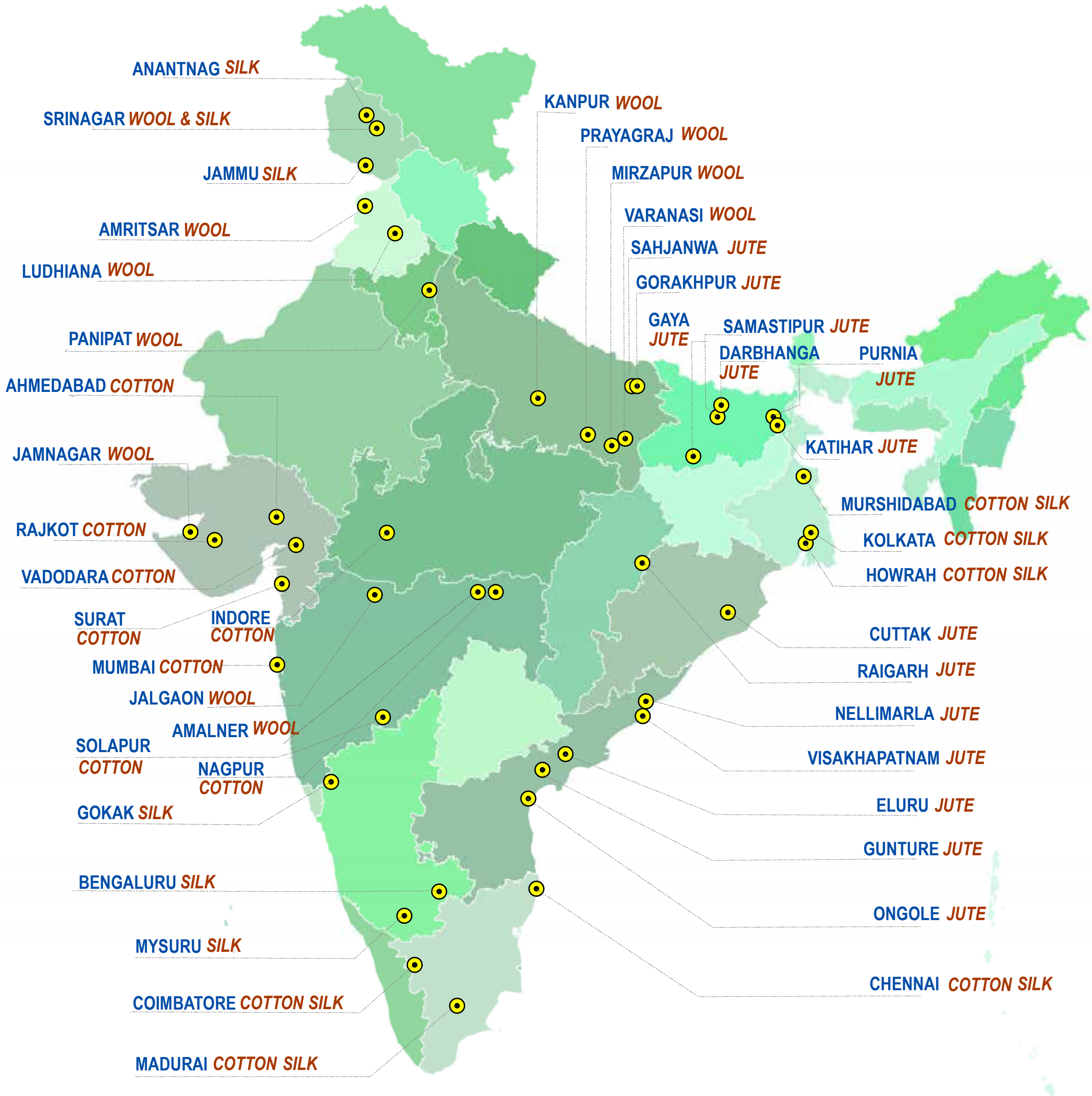


Figure 17: Textile cluster map of India[23]

23 https://www.mapsofindia.com/maps/india/textile-industry-map.html

Tamil Nadu emerges as the leader with the highest number of textile factories in the country, followed by Gujarat, Maharashtra, and Uttar Pradesh. Speaking of spinning, weaving, and finishing facilities, Tamil Nadu again takes the lead, followed by Gujarat and Maharashtra. The top 10 states shown in figure 18 account for around 93 percent of the textile industry in the country.

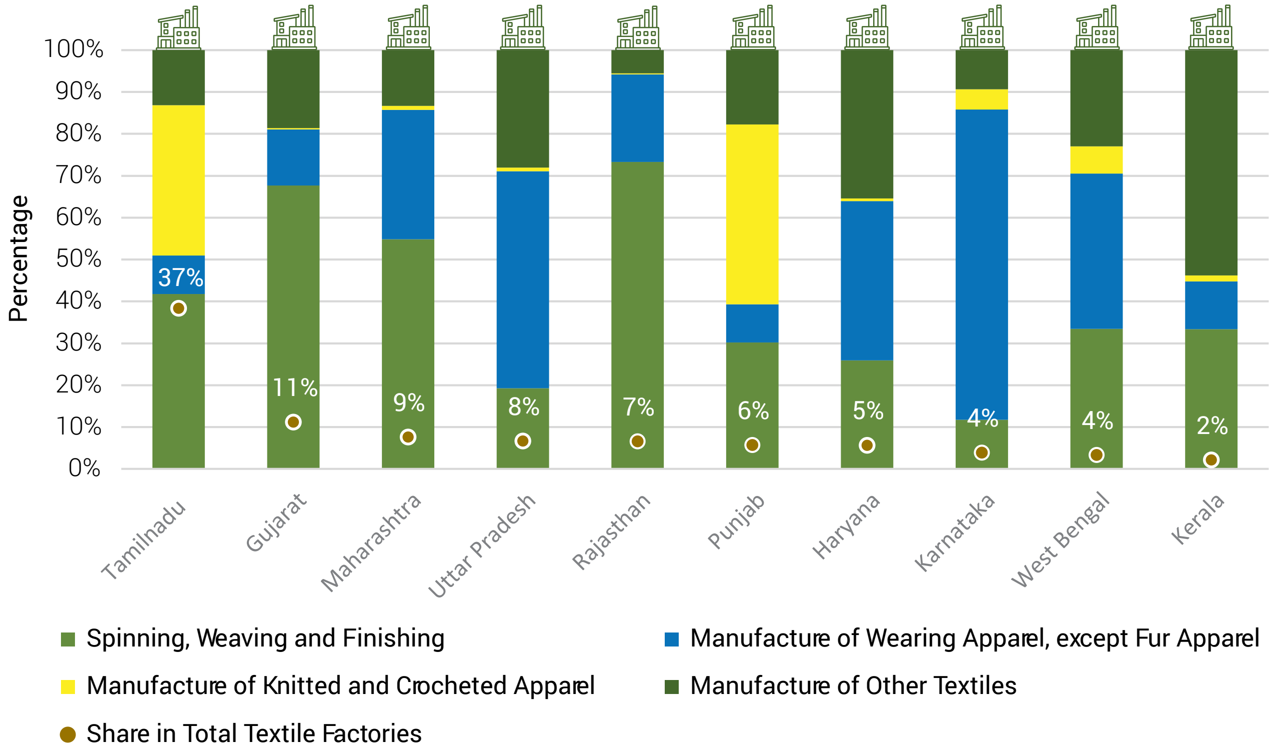


Figure 18: State and process-wise number of factories[24]

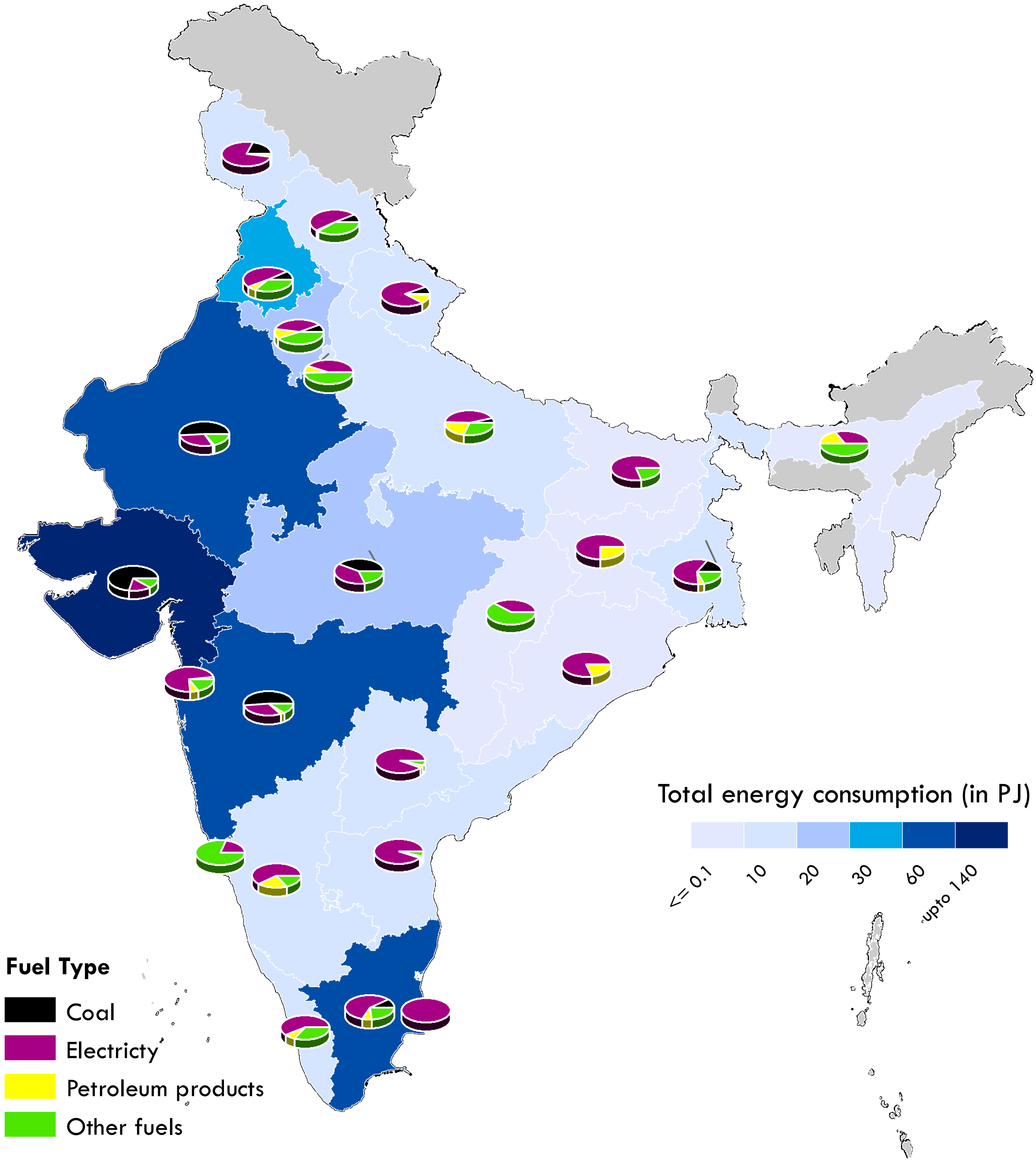
Notably, spinning, weaving, and finishing processes exhibit a higher coal consumption compared to others. Despite Tamil Nadu having the most spinning, weaving, and finishing factories, Gujarat consumes the largest amount of coal, approximately 68 percent of the total coal consumed in the Indian textile sector and 40 percent of the total textile energy consumption in India.

In the textile industry, electricity consumption is primarily attributed to spinning, weaving, and finishing processes. These accounts for approximately 77 percent of the total electricity consumed in the sector during 2022-23. Tamil Nadu emerges as the state with the highest electricity consumption during this period, consuming 9026 MU (25 percent), followed by Gujarat with 7087 MU (20 percent) and Maharashtra with 2835 MU (8 percent). The higher electricity consumption in Tamil Nadu indicates that the majority of processes within the state are electrified.

In the fiscal year 2022-23, the top 5 states accounted for 79 percent of the total energy consumption in the textile sector. Gujarat was the largest consumer, accounting for 40 percent of the total energy, followed by Tamil Nadu at 16 percent, Rajasthan and Maharashtra at 9 percent each, and Punjab at 6 percent. In terms of coal usage, these five states collectively represent 94 percent of the total coal consumption within the textile industry. Gujarat dominates with the highest consumption at 68%, followed by Maharashtra and Rajasthan, each accounting for 11%, while Tamil Nadu and Punjab contribute 3 percent and 1 percent, respectively.

24 https://mospi.gov.in/asi-summary-results/849

State-wise Fuel consumption in textile sector (in 2022-23)



The graph below provides a breakdown of fuel consumption from various sources across these five states in 2022-23.

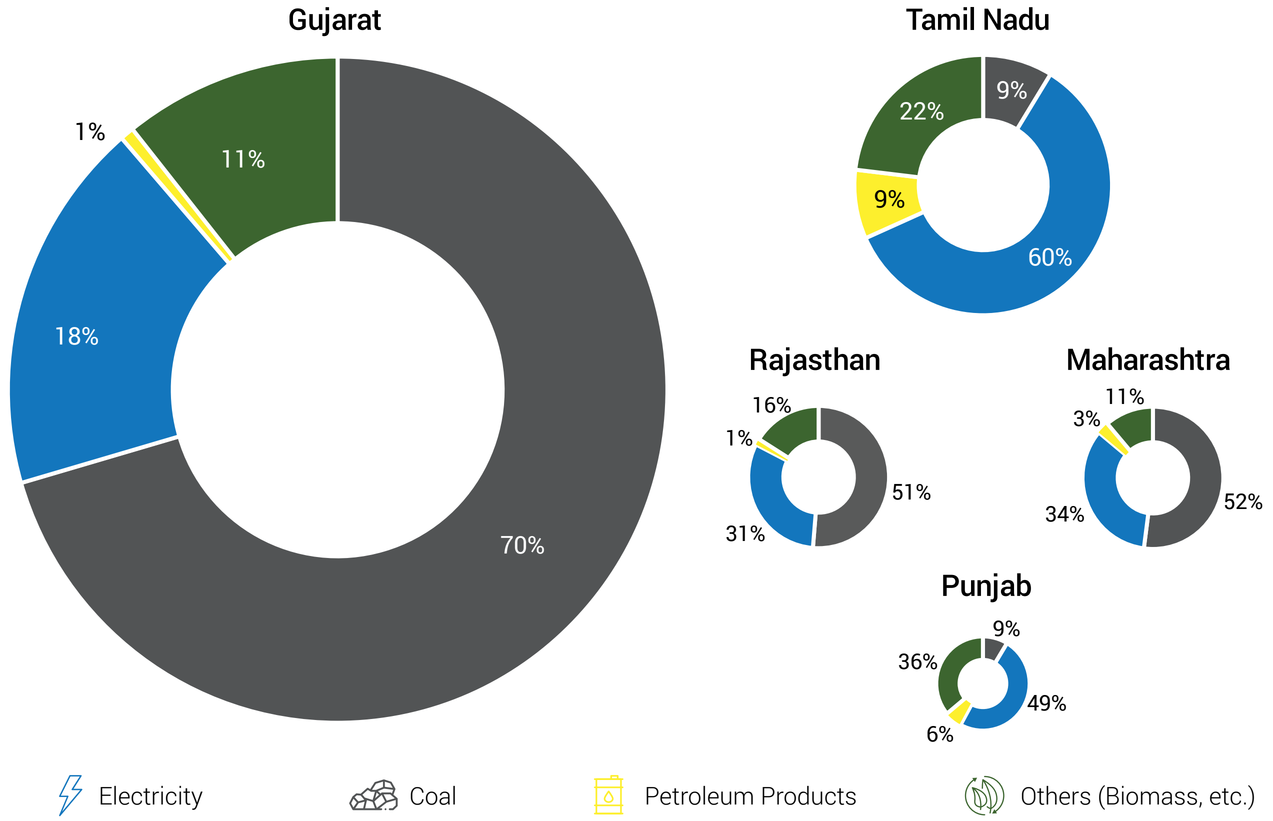


Figure 19: Understanding the Energy Mix in leading Textile States (2022-23)[25]

The fuel consumption patterns in India's textile industry vary significantly at the cluster level, with different sources of energy being utilised across key textile hubs. Major fuels used in India's major textile clusters include Electricity, Biomass, PNG, Coal, Lignite, and petcoke. Among the key clusters, Bhiwandi stands out as the only cluster that relies entirely on electricity, while other clusters use less than 25 percent of electricity in their overall fuel mix.

A recent study by the Bureau of Energy Efficiency (BEE) and the ICF consulting provides data on fuel break-up for key textile clusters in India by taking a few sampled units. The consumption of agro-residue is particularly high for textile clusters in Panipat in Haryana (85 percent), Pali in Rajasthan (62 percent) and Ludhiana in Punjab (59 percent). Firewood is the dominant fuel in Erode (91 percent), Tirupur (88 percent) in Tamil Nadu, and Solapur (81 percent) in Maharashtra. The Surat Cluster in Gujarat demonstrates a high dependence on lignite and imported coal, making up 76 percent of the fuel consumed. Lignite and imported coal are also predominantly used in the Surat (76 percent), Ahmedabad (54 percent) and Jetpur (46 percent) textile clusters in Gujarat. This high consumption of coal is particularly traced to the dominance of finishing and dyeing processes in these clusters. Additionally, petcoke is mainly consumed in Ludhiana (22 percent) and Pali (23 percent). These figures highlight the varying fuel consumption patterns across clusters, driven by factors such as local resource availability, infrastructure, and energy needs.

25 https://mospi.gov.in/as-summary-results/849, Author's Analysis

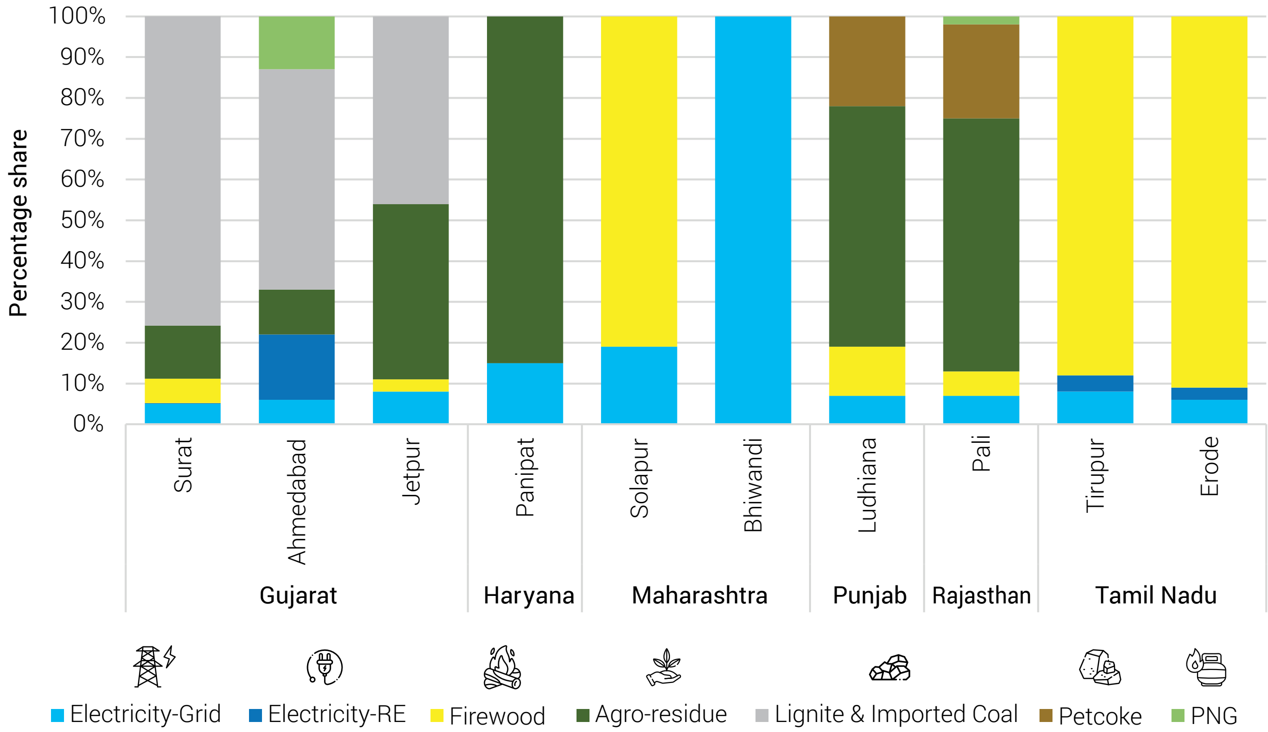


Figure 20: Cluster wise fuel consumption share[26]

Captive Power Installed Capacity

Captive power capacity plays a pivotal role in meeting the electricity needs of the textile manufacturing processes. The textile industry's shift towards cleaner energy sources is prominently reflected in its strides within the realm of captive power generation. Leveraging the momentum of reducing reliance on fossil fuels and embracing renewable energy alternatives, the textile sector has emerged as a front-runner in installing captive solar and wind power projects. The textile sector has the highest wind power installed capacity amongst all industries, with 1,477 MW. Additionally, it ranks second in captive solar power capacity projects, with a capacity of 517 MW, following the cement industry.

Figure 21 illustrates the distribution of installed captive power capacity in the textile industry based on energy sources. Coal-based captives witnessed a significant decline, decreasing from 2,122 MW in 2018-19 to 559 MW in 2022-23, marking a remarkable 74 percent reduction. Conversely, solar capacity experienced a compound annual growth rate of 63 percent from 2018-19 to 2022-23, while the installed capacity for wind power nearly doubled during the same period.

26 BEE and ICF Report on Energy & Resource Mapping of MSME Clusters in India – Textile Sector

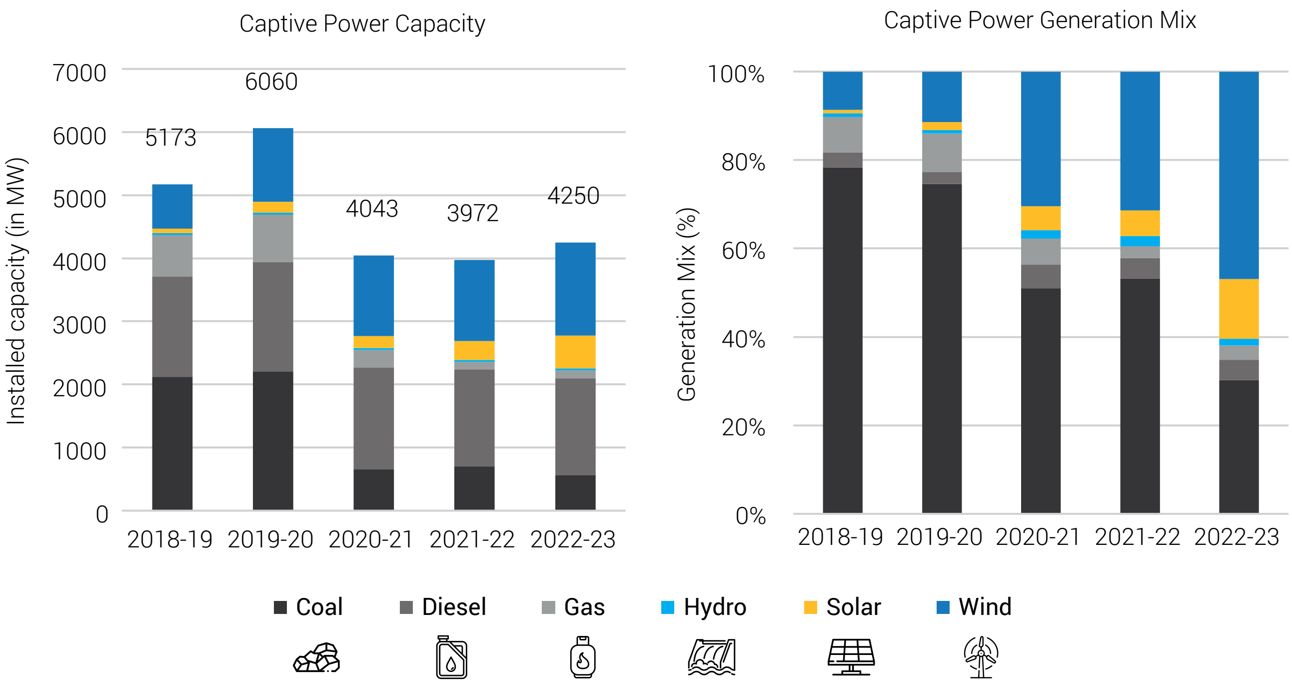


Figure 21: Captive power capacity and generation in textile industry[27]

Policy Landscape for the Indian Textile Sector

The Ministry of Textiles has consistently introduced and endorsed various programmes and schemes to revamp and modernise the Indian textile industry. It's essential to understand their pivotal role in shaping the sector's trajectory. These strategic interventions are not just announcements but active efforts by the government to drive sustainable growth, foster technological advancements, and mitigate environmental impact within the textile industry. The PM Mega Integrated Textile Region and Apparel (PM-MITRA) parks is a huge opportunity to boost the textile industry. The initiative provides ample scope improving the resource and energy efficiency by introducing common heating & effluent treatment technologies, energy efficiency and procurement of clean energy in such large greenfield/brown field projects. The Production linked Incentive Scheme focussing on MMF fabric , apparel and textiles is yet another effort to boost large scale infrastructure Other initiatives like the Technology Upgradation Fund Scheme (TUFS) and its subsequent iteration incentivises technological modernisation, National Technical Textile Mission (NTTM) and the Sustainable and Accelerated Adoption of efficient Textile technologies to Help Small Industries (SAATHI) promote research and development of sustainable alternatives and application-based textiles. The details of the progress made in these programmes/ initiatives are mentioned in Annexure 2.

Electricity tariff is a critical pre-investment consideration for the MSME players in the textile sector. as they work towards electrifying themselves. While the Government of India aims to foster industry growth through favourable regulations and incentives, high power costs will continue to act as a barrier towards adoption of such new and efficient technologies.

27 https://cea.nic.in/general-review-report/?lang=en

- As electricity prices escalate, the need for electrification as an alternative to conventional fossil fuel-based heating systems diminishes significantly.
- The current industrial tariffs, including taxes, surcharges and additional surcharges land up to ~ ₹8.5-10 per kWh, which is not sustainable to remain competitive in the market.
- There is a need to promote support for renewable energy options under different implementation modes (on-site/offsite modes) for textile clusters to lower down costs and reduce coal dependency of the sector. In June 2023, Maharashtra introduced its Integrated and Sustainable Textile Policy for 2023-2028, which includes a capital subsidy for the installation of solar power plants which is available to both new and existing textile units, along with the continuation of electricity tariff subsidies. Further, there is no 1 MW cap for net metering for solar projects installed by textile units in Maharashtra, hence allowing the large textile industries to maximise their solar energy generation potential and take advantage of the net-metering arrangement.

Table 3: Average Industrial Electricity Tariff comparison

State	Power Tariff 2017-18 (₹./kWh)	Power Tariff 2023-24 (₹./kWh)	Power Tariff Subsidy - as per textile policy (₹/kWh)	Policy
Gujarat	5.58	6.03	1 Rs/kWh	The Gujarat Textile Policy 2024, valid from October 1, 2024, to September 30, 2029, offers a power tariff subsidy of ₹1 per unit for five years to eligible textile units. Eligibility includes new units and existing units undergoing expansion, diversification, or modernisation
Tamil Nadu	7.06	9.92	Free electricity to power loom weavers at 750 units bi-monthly and concessional power tariff to power loom sector	Tamil Nadu New Integrated Textile Policy 2019
Maharashtra	7.78	9.39	₹2.50 per kWh	The Integrated and Sustainable Textile Policy 2023-2028

04

Approach and Methodology for Sectoral Projections

This section briefly outlines the methodology employed to investigate the electrification potential and emission reduction strategies (discussed in subsequent chapters) within the textile industry in India. By adopting a systematic approach, this study aims to identify opportunities for improvement and propose actionable strategies to electrify and decarbonise the textile sector in India. The scenario analysis in the study aimed to understand the textile sector outlook in 2050, and the energy demand and emissions implications of adopting electrification technology compared to the baseline case with no interventions.

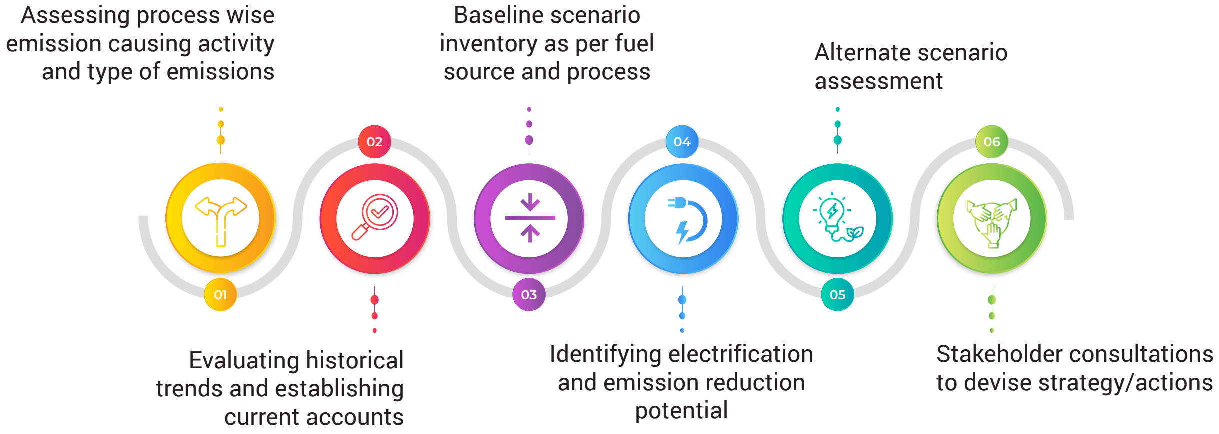


Figure 22: Flowchart of methodology

Base Year: The year 2020 is selected as the base year for projection in the study. Firstly, it represents the most comprehensive, granular, and latest data available for the textile industry in India. By selecting 2020 as the base year, the study ensures that the analysis can provide the study objectives with reliable and up-to-date information, allowing for accurate assessment and projection of trends. Furthermore, 2020 serves as an appropriate baseline for comparison, as it provides a snapshot of the industry's performance and dynamics before the onset of the pandemic. This enables the study to capture the pre-pandemic landscape, facilitating a more robust evaluation of the industry's trajectory and potential future scenarios.

Time Frame for Future Projections: The year 2050 has been selected as the target year for this study to provide a long-term perspective on the textile industry's trajectory and potential future outcomes. The year 2050 represents a significant milestone as the target year aligns with global sustainability aspirations, such as the United Nations' Sustainable Development Goals (SDGs) and the Paris Agreement on climate change. Furthermore, India has set the target to attain the 'developed nation' status by 2047. This study will assist in assessing the sector's impact and identifying the necessary focus needed to align with India's developmental and climate change objectives.

05

Assessment of Electrification Potential

In the textile sector, process heating and steam generation are the most energy-intensive processes in textile processing (Figure 3). In 2022-23, a total of 350 PJ of energy was used, and process heating comprises 63 percent of total energy consumption (Figure 10). The fuel consumption for process heating accounted for 33 percent of GHG emissions from the textile sector (Figure 15). The magnitude of process heat energy use and its carbon footprint makes process heat a major opportunity in the textile sector for low-carbon solutions.

Considering the temperature requirements for process heating within the textile sector is crucial, as it offers valuable insights into the suitability of various technologies. Typically, process heat or steam is needed at temperatures equal to or below 200°C in the textile industry (Table 4). This makes low-temperature process heating ideal for electrification or the adoption of other low- or no-carbon heat sources. Electric technologies such as heat pumps, microwave systems, and infrared technologies, along with alternative sources like solar, solar thermal and nuclear energy, can be explored within this temperature range. Currently, conventional boilers and thermopacks are installed that use coal as an energy source for process heat and steam requirements.

Table 4: Process-wise temperature requirements[28]

Process	Steam Temperature (^{0}C)
Sizing	95
Drying	130
Desizing	90

28 https://apparelimpact.org/wp-content/uploads/2024/08/Low-Carbon-Thermal-Energy-8.27.24.pdf

Process	Steam Temperature (⁰C)
Scouring	90
Mercerising & Washing	90
Bleaching & Washing	90
Drying	135
Dyeing & Washing	135
Printing	130
Finishing	190-210

The technology assessment is undertaken at two levels, i.e., one that replaces the existing conventional central system that supplies heat or steam to different processes. And the second one follows the technology upgradation approach which may be independent of the central source of energy supply in a textile (wet processing) unit. Figure 23 further describes multiple routes of electrification that can be explored.

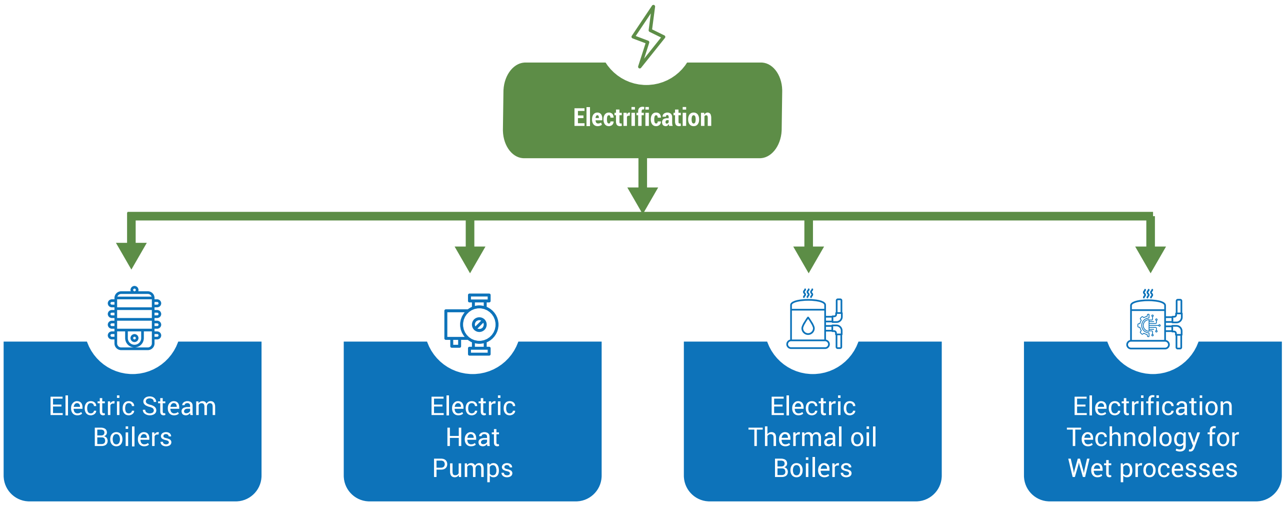


Figure 23: Electrification technologies

Electrification through Steam Boilers

Traditionally, steam boilers have been associated with heavy reliance on fossil fuels such as coal, oil, and natural gas. However, the advent of electric steam boilers is gearing up to revolutionise this landscape. By utilising electricity as their primary energy source, these boilers eliminate the need for combustion, thereby significantly reducing greenhouse gas emissions and air pollutants. Moreover, electric steam boilers offer unparalleled flexibility and scalability, making them suitable for a wide range of industrial processes and heating applications. Furthermore, electric steam boilers boast high energy efficiency, with modern designs incorporating advanced technologies such as microprocessor-based control systems and variable speed drives. Typically, a conventional steam boiler has an efficiency of

70–80 percent, while an electric boiler has an efficiency of about 99 percent. These features optimise energy consumption. In addition to their environmental benefits, electric steam boilers offer reliability, safety, and ease of maintenance. With fewer moving parts compared to conventional boilers, electric systems require minimal servicing and pose lower risks of mechanical failure or accidents.

Electric steam boiler possesses significant environmental benefits when powered with renewable energy source - either solar or wind. However, the widespread adoption of electric steam boilers faces a few challenges – The primary concern being the cost of electricity as highlighted by the industry stakeholders. The analysis will present the potential application of electric steam boilers replacing a typical capacity conventional boiler.

Electrification through Heat Humps

Electric heat pumps are increasingly recognised as a high-efficiency solution for low- to medium-temperature industrial heating applications, typically upto 120-150 degree celcius, with developments underway to push these limits further. Unlike conventional systems that rely on combustion, heat pumps operate on a vapour compression cycle, transferring heat from a lower-temperature source such as ambient air, wastewater, or process waste heat to a higher-temperature process stream. This cycle involves four key components: an evaporator (where heat is absorbed), a compressor (where vapour is pressurised), a condenser (where heat is released), and an expansion valve (to lower the pressure and restart the cycle).

While conventional heating systems typically operate at efficiencies ranging from 60–85 percent, consultations with technology provider revealed that heat pumps can achieve a coefficient of performance (COP) of 2.5–4.5, translating to 250 percent or more efficiency under optimal conditions. Advanced industrial units also integrate multi-stage compression and intelligent controls to maximise energy efficiency. Technology maturity varies by temperature range i.e., low-temperature (<90°C) systems are commercially available and widely deployed, while medium-temperature (90–150°C) systems are at early commercialisation stages (Technology Readiness Level 8 out of 9). High-temperature (>150°C) units are still at the R&D or pilot scale.

Heat pumps offer high energy efficiency, lower operational costs, modularity, and the potential to integrate waste heat recovery. When powered by renewable electricity, they can significantly bring down the costs for per kg of steam generation. However, barriers include low market penetration, high capital costs, and retrofitting challenges in legacy systems.

Electrification through Thermal Oil

In the textile and dyeing industry, stenters are machines used to set, dry and finish fabrics. Stenters are associated with a thermal effect - the mechanical action of cross-stretching or heat setting of the fabric. Earlier, this heat was provided indirectly by steam. Later, the option to provide this heat with thermal fluid became very common. In this, thermal fluid from a boiler passes through a heat exchanger and heated air gets sucked by a fan through a filter. After the heat from the thermal fluid has been transferred to the air, it is returned to the general network of the boiler. Traditionally, fossil fuels like coal or natural gas are used for heating the fluid. Replacing them with an electric source will offer significant advantages as discussed above, as the stenters account for around 30-40 percent of the thermal energy needed.

Electrification of Wet Processes

The following technologies represent alternative options for the electrification of sub-processes in the wet processing units including singeing, mercerising and washing, dyeing, drying, heat setting, finishing, and drying. The savings obtained from the electrification of processes are the reduction in energy demand to deliver the same performance from the equipment.

Table 5: Alternative electrification technologies for wet processing units[29]

Processes	Existing common technologies	Electrification technology	Benefits	Energy Savings
Singeing	Gas burners	Electric heating elements (e.g., silicon carbide rods)	Higher singeing grade, no wastage through exhaust gas, longer life, corrosion resistance	**30%**
Mercerizing and Washing	Steam Coils-Coal-fired steam boilers	Electric boilers/ Electric resistance ultrasonic washing machines	Reduction in the number of baths, water and chemicals	**30%**
Dyeing	Steam boilers	Electric boilers/ Electric resistance heating	No steam generation and distribution losses	**30%**
Drying	Steam supplied cylinder dryers	Electric boilers/ Infrared heating	Direct heating instead of convection heating through a medium (air, water, metal, etc.)	**25%**
Heat Setting (Stentering)	Gas-fired systems, thermal oil systems	Electric heating technology	No steam generation and distribution losses	**25%**
Finishing	Cylinder dryer/ Hot air dryer	Electric boiler/ Electrical Resistance heating elements/ infrared heating elements	No steam generation and distribution losses	**30%**
Yarn Drying	Convection drying (hot air stream)	Electric boilers/ Radiofrequency dryers	No steam generation and distribution losses	**30%**

Economic Analysis: The following section will discuss the cost implications of switching to electrification technology. The annualised cost methodology has been adopted for the analysis that refers to the cost-per-year of owning and operating the equipment. The method is often used as an effective way to compare the cost-effectiveness of different technologies.

29 Hasanbeigi, A., Zuberi, J. 2022. Electrification of Heating in the Textile Industry. Global Efficiency Intelligence. Florida, United States.

The cost heads include:

- Capital Costs: The initial investment required for acquiring and installing the equipment or infrastructure that is necessary for the operation. The capital costs are annualised based on the life of the equipment.
- Fuel Costs: These are the expenses associated with acquiring and utilising the fuel needed to power the operations. It encompasses the purchase price of the fuel itself, as well as any transportation or delivery costs incurred. The fuel demand is first estimated based on the efficiency of the equipment, and further the costs.
- Carbon Costs: This refers to the economic costs associated with the negative impacts of carbon emissions on society. It quantifies the long-term damages caused by each ton of carbon dioxide emitted into the atmosphere, including effects on public health, agriculture, infrastructure, and the environment. Incorporating the social cost of carbon into decision-making processes helps account for the true cost of carbon emissions and guides efforts to mitigate climate change. The cost of carbon is taken as USD 80 per ton (Richie et al, 2018) projected to reach USD 250 per ton in 2050.

The other cost heads include water cost, maintenance cost, labour cost, fuel handling costs, etc. which insignificantly contribute to annual costs and are thus not considered in the analysis.

Based on the analysis, the capital costs don't contribute much to the annual cash flow as the fuel costs hold the majority share in the cash flow. The fuel costs are dependent on efficiency improvement and the cost of fuel over the years. Hence, the comparative analysis of the electrification equipment in the textile sector is not segregated as per the technology type, but only the fuel source, as it will drive the cost economics when annualised.

A typical capacity boiler is assumed to arrive at the capital costs. The average costs were taken in consultation with technology providers. Further, the overall energy demand is estimated based on average operations in a year. The considered efficiency is used to estimate the fuel demand.

Table 6: Technical parameters for various energy sources[30]

Parameter	Unit	LDO	Natural Gas	Coal	Unit	Electricity
Thermal Energy Required	kcal/hour*	1220000	1220000	1220000	kcal/hour	1220000
Capital Cost	Million INR	3	3	2.5	Million INR	4.5
Life	Years	25	25	25	Years	15
Calorific Value	kcal/kg	10000	12500	4000	kcal/kWh	860
Fuel Required for Rated Capacity	kg/hr	122	98	305	kWh/hr	1419
Efficiency	%	88%	90%	75%	%	99%

30 Inputs from technology provider, Hi Therm Boilers. For this report , only electric boilers have been considered for cost benefit calculations and not any other electrifying technology options.

Parameter	Unit	LDO	Natural Gas	Coal	Unit	Electricity
Actual Fuel Required	kg/hr	139	109	407	kWh/hr	1433
Specific Costs	INR/ kg	70	75	7	INR/kWh	7
Daily Costs	Million INR per day	0.23	0.20	0.07	Million INR per day	0.24
Annual Fuel Required (300 days)	Kilo Tonne	1	1	3	GWh	10
Annual Costs	Million INR	70	59	20	Million INR	72

*Steam Capacity- 2 Tonnes per Hour at pressure 16.5 kg/cm^2 and temperature 180-200 degree celcious

Fuel Costs: Understanding fuel cost dynamics is crucial for evaluating the economics of electric systems in the textile industry. Presently, fuel costs significantly impact operational expenses, while future trends until 2050 remain uncertain due to various factors like geopolitical shifts and technological advancements. Electric boilers offer advantages like lower emissions and stable electricity prices, enhancing competitiveness over traditional heating systems. By analysing both current and future fuel costs, stakeholders can assess the cost-effectiveness of electrification initiatives and make informed decisions aligned with economic and sustainability objectives. The cost analysis in the chapter is built on the costs discussed below.

Table 7: Fuel cost and calorific value for various energy sources

Source	Fuel Cost		Calorific Value	Assumptions/ Source
	2024	2050		
Grid-based Electricity	7 INR/kWh	6 INR/kWh	3.6 MJ/kWh	The system cost will decrease in 2050 owing to the higher share of RE generation. (TERI, 2023)
Solar	2.5 INR/kWh	1.8 INR/kWh	-	As the penetration of solar and wind energy expands, economies of scale will drive down their prices even further.
Wind	4 INR/kWh	3.5 INR/kWh	-	
Coal (to Industry)	7 INR/kg	19.4 INR/kg	15 MJ/kg	The cost of coal, diesel, and natural gas has increased at a CAGR of 4%.
Diesel	70 INR/kg	194.1 INR/kg	45.5 MJ/kg	
Natural Gas	80 INR/kg	207.9 INR/kg	45 MJ/kg	

The delivered costs per unit of energy by different fuels at the point of consumption is a factor of calorific value and efficiency of fuel conversion. Figure 24 below presents the change in price till 2050.

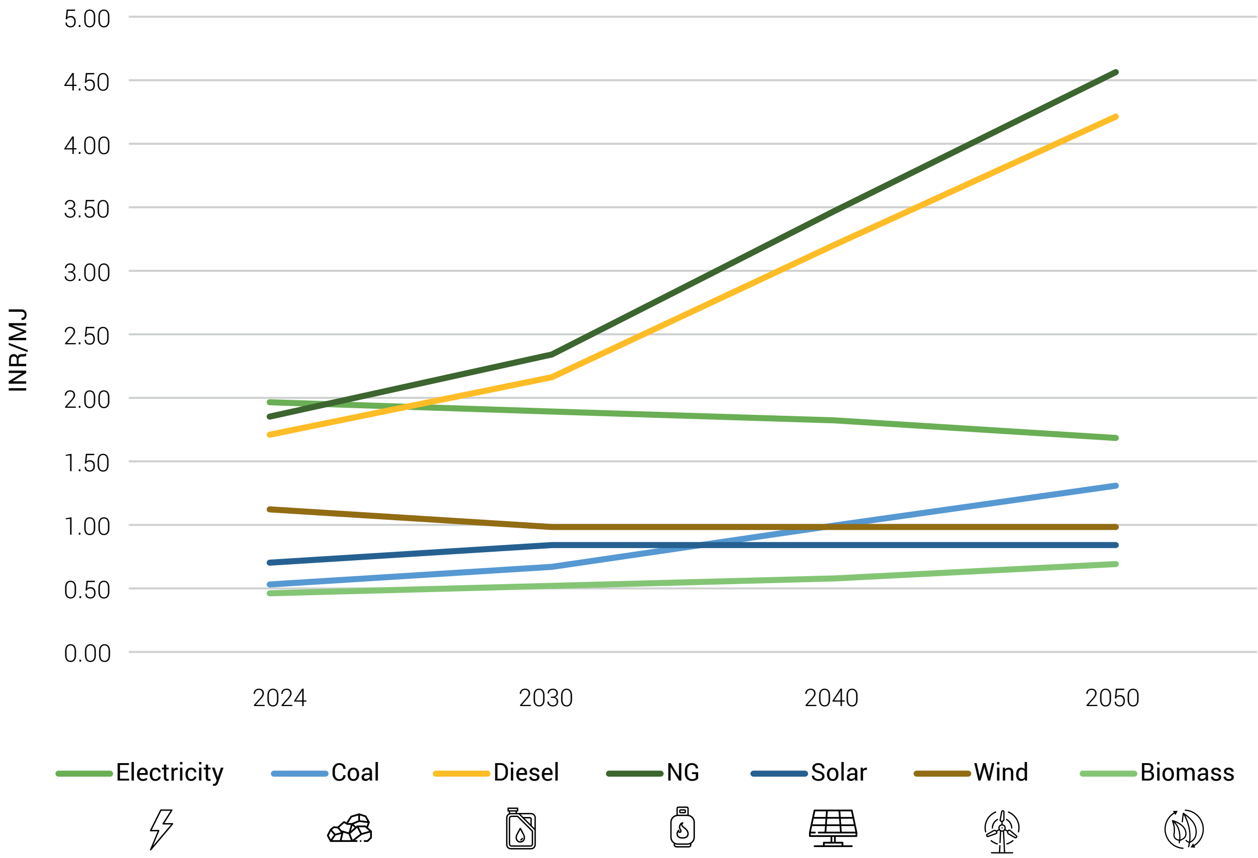


Figure 24: Change in fuel cost till 2050

Results

Figure 25 presents the annual costs of operations using different fuels. The following key findings can be derived from the economic analysis:

- Solar and Wind have the lowest and most stable total costs across all years. No fuel and CO_2 costs make them the most economically viable options.
- Coal becomes increasingly expensive due to rising CO_2 costs, making it less competitive by 2050.
- Grid Electricity is moderately costly but shows declining CO_2 costs, improving its viability over time.
- LDO and Natural Gas show high and rising costs, especially from 2040 onwards, driven by fuel price escalation and CO_2 penalties these become least favorable.
- Annualized investment costs are insignificant across all technologies, especially when compared to the dominant fuel and carbon costs, highlighting that capital costs becomes insignificant for the life cycle of the technology.

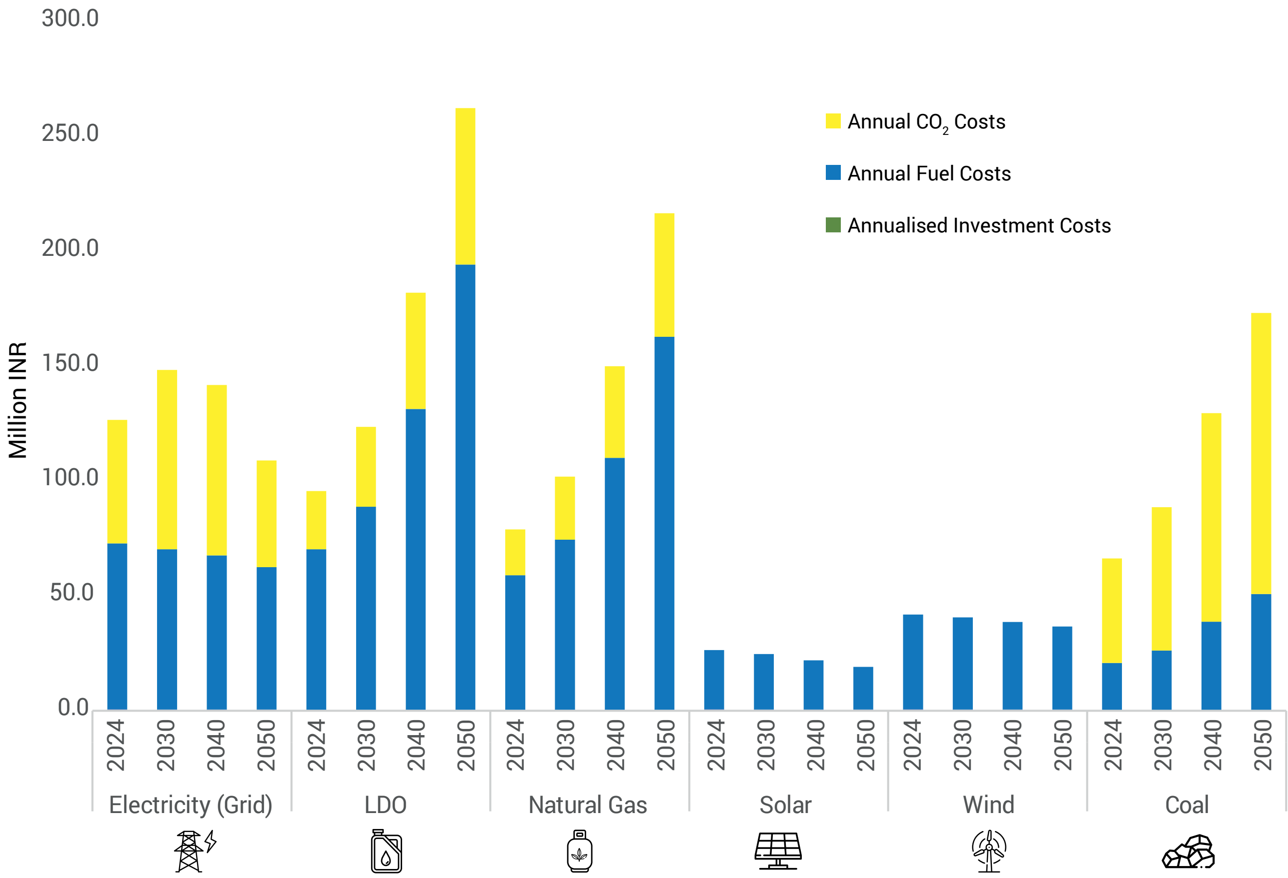


Figure 25: Annual costs of operations using different fuel

06

Analysis- Projecting Future Energy Demand and Emissions

Material Demand

Anticipating the material demand of the textile sector, by 2050 requires a nuanced understanding of the industry's evolving landscape, influenced by a multitude of economic, social, and technological factors. Several factors will shape material demand within the textile sector including population growth, urbanisation, income levels, and demographic shifts. Multiple approaches have been explored to project future material demand:

- **Projecting material demand w.r.t GDP or GDP per capita:** Data spanning the last three decades has been analysed to examine the relationship between GDP and fibre production. The analysis underscores a notably strong positive correlation of 0.90 between these two variables. However, upon delving deeper into the relationship, we found the elasticity of fibre production in response to GDP to be 0.65, indicating a relatively inelastic connection. Consequently, considering this insight, we have opted against pursuing regression analysis to model fibre production relative to GDP.
- **Historical Growth rate :** The fibre production has been employed to examine the historical growth rates over the past 10, 20, and 30 years, revealing Compound Annual Growth Rates (CAGR) of 0.5 percent, 4.6 percent, and 3.6 percent, respectively. The industry has experienced sluggish growth over the past decade, attributed to subdued demand in both domestic and export markets. Additionally, the onset of the COVID-19 pandemic further exacerbated the situation, leading to dampened orders amidst substantial existing inventories. Consequently, we utilised the 30-year CAGR of 3.6 percent to project future fibre production in India which is also the forward-looking time frame till 2050. **Based on these trends, it indicates that total production is could rise from approximately 8 million tons in 2020 to 24 million tons by 2050.**

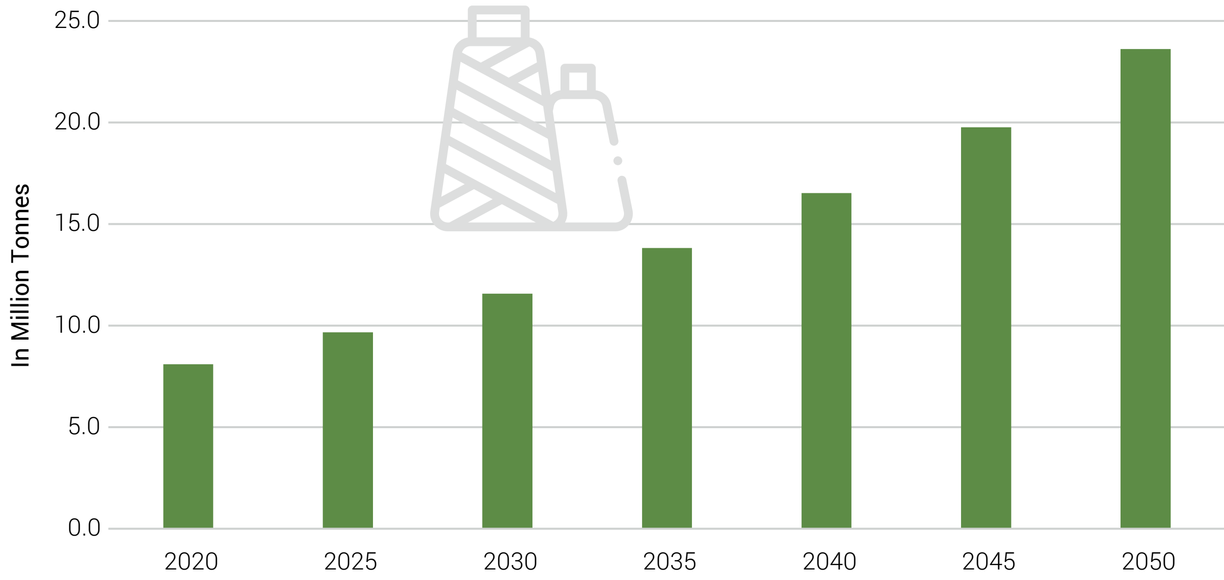


Figure 26: Fiber production in baseline trajectory (in million tonnes)

Given the present production levels, India's contribution to global fibre production stands at approximately 8 percent. To gauge India's projected share in 2050, global fibre production has been forecasted based on per capita fibre production trends. In 2020, global average per capita fibre production was recorded at 14 kg per capita, and has been growing at a CAGR of 1.2 percent. Using this growth rate, per capita fibre production is projected at 25 kg per capita by 2050 and leveraging population estimates provided by the UN, global fibre production is anticipated to surge from 109 million tons in 2020 to 193 million tons in 2050. With above estimates of fibre production in India, it's share is expected to increase from 8 percent to 12 percent of global production by 2050.

Viksit Bharat Scenario: Viksit Bharat, or "Developed India," encapsulates a vision of India's journey towards comprehensive development and prosperity by 2047. Central to this vision is the acceleration of industrial production, exemplified by initiatives like 'Make in India', aimed at achieving global leadership. To realise this ambitious goal, each sector's contribution to GDP must significantly surpass the baseline level.

In the textile industry, for instance, China currently dominates with over 50 percent of the global production share in 2024. To attain global leadership, it is presumed that India should target a 30 percent share of global fibre production. This necessitates a substantial increase in efforts, approximately 2.4 times more than the baseline scenario. Such endeavours are crucial for India to establish itself as a frontrunner on the global stage and realise the aspirations set forth by Viksit Bharat.

The ambitious projected fibre demand of 24 million tons by 2050, up from 9.2 million tons in 2023, is well-supported by strong policy initiatives and the government's **Viksit Bharat** vision to transform India into a developed nation by 2047. Key schemes like **PM MITRA (₹4,445 crore)** and **PLI for textiles (₹19,798 crore)** aim to expand domestic production and scale exports to **US$50 billion in garments by 2030**. The long-term vision targets a US$1.2 trillion domestic textile and apparel market by 2047, with US$600 billion in exports. Other initiatives like National Technical Textile Mission (NTTM) are increasing fibre intensity across sectors, with vision of expanding the technical textile segment from US$7.1 billion in 2020 to US$11.6 billion, growing at 7.2% CAGR. The adopted CAGR of 3.6% for the 2050 projection is conservative compared to the higher near-term growth rates needed to meet 2030 targets.

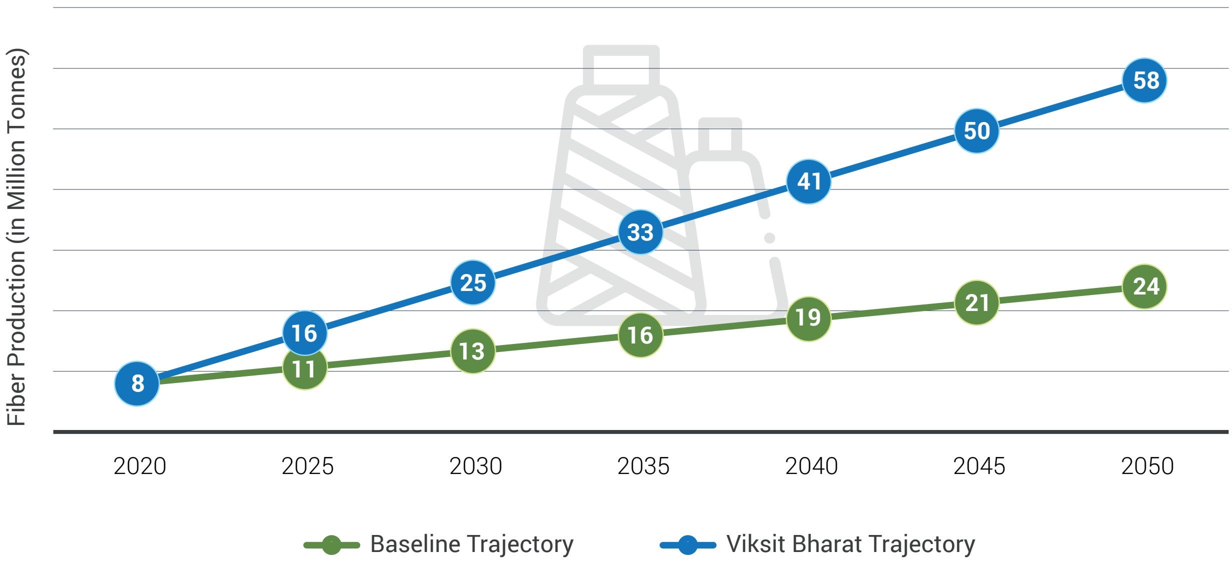


Figure 27: Fiber production in baseline vs Viksit Bharat trajectory

Share of Natural and Man-made Fibers

The textile industry has undergone significant transformations over the years, characterised by shifts in consumer preferences, technological advancements, and global economic dynamics. Historically, natural fibres such as cotton dominated the market, but the emergence of synthetic fibres like polyester and nylon has reshaped the material landscape.

Currently, man-made fibre (MMF) makes up 72 percent of global fibre production, but India's textile industry relies heavily on cotton. To meet the global demand and increase its share of total production, India needs to expand its capacity for producing other fibres. Currently, MMF accounts for only 27 percent of India's total fibre production. Given the historical growth in MMF production, India is expected to reach a 50 percent share by 2050.

This highlights the need for the Indian textile industry to diversify its fibre sources and focus on increasing MMF production to remain competitive in the global market.

Poor Cotton Yield

India contributes approximately 25 percent to the global cotton production. However, the yield per hectare of cotton in India is considerably low, at 448 kg/Ha, compared to China's 2027 kg/Ha.[1] This means India requires approximately 4.5 times more land to produce the same quantity of cotton as China.

With no anticipated increase in agricultural land allocated to cotton production in the future, for the estimated cotton production of 12 MT in India, the yield has to be doubled at around 900-1000 kg/Ha.

1, https://www.indexmundi.com/agriculture/?commodity=cotton&graph=yield

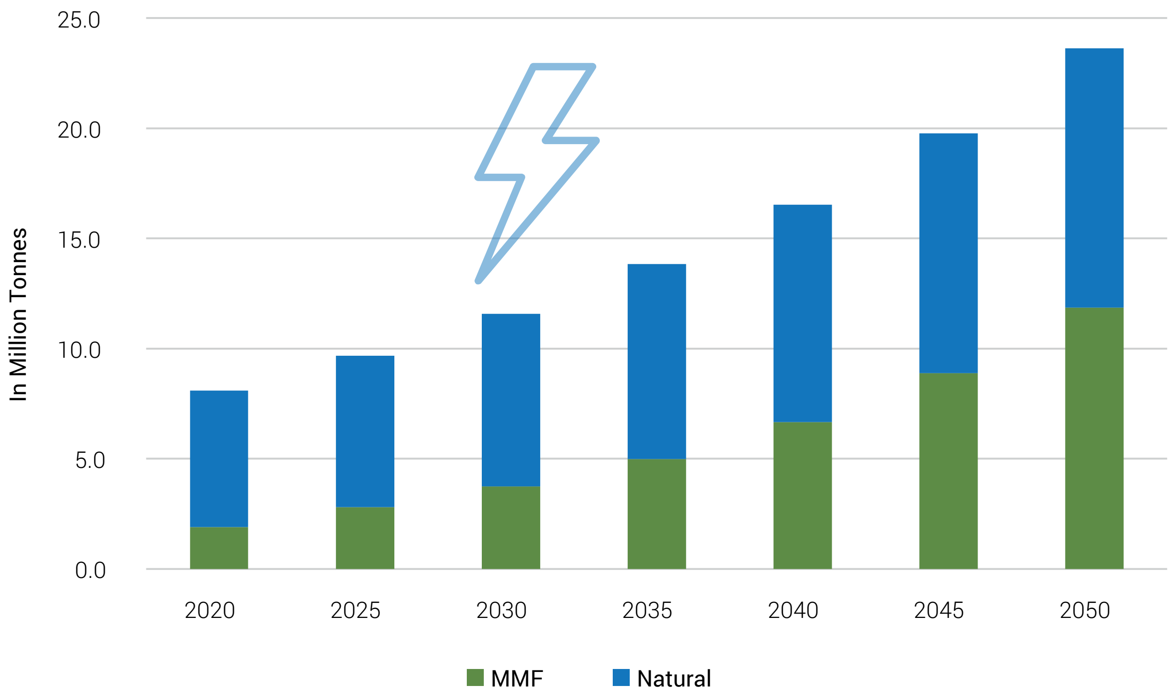


Figure 28: Share of MMF and natural fibres

Total Energy Demand

The overall energy demand will increase from 350 PJ in 2023 to 1040 PJ in 2050 (threefold) in the baseline case, while it can go up to 2552 PJ (around 7 times) in an aspirational growth of the sector aligned with the developed country trajectory. The primary energy demand projections haven't considered the change in energy demand based on the changed share of material supply or the change in the sources of energy or electrification that may affect the overall energy requirements.

› **Primary Energy Demand**

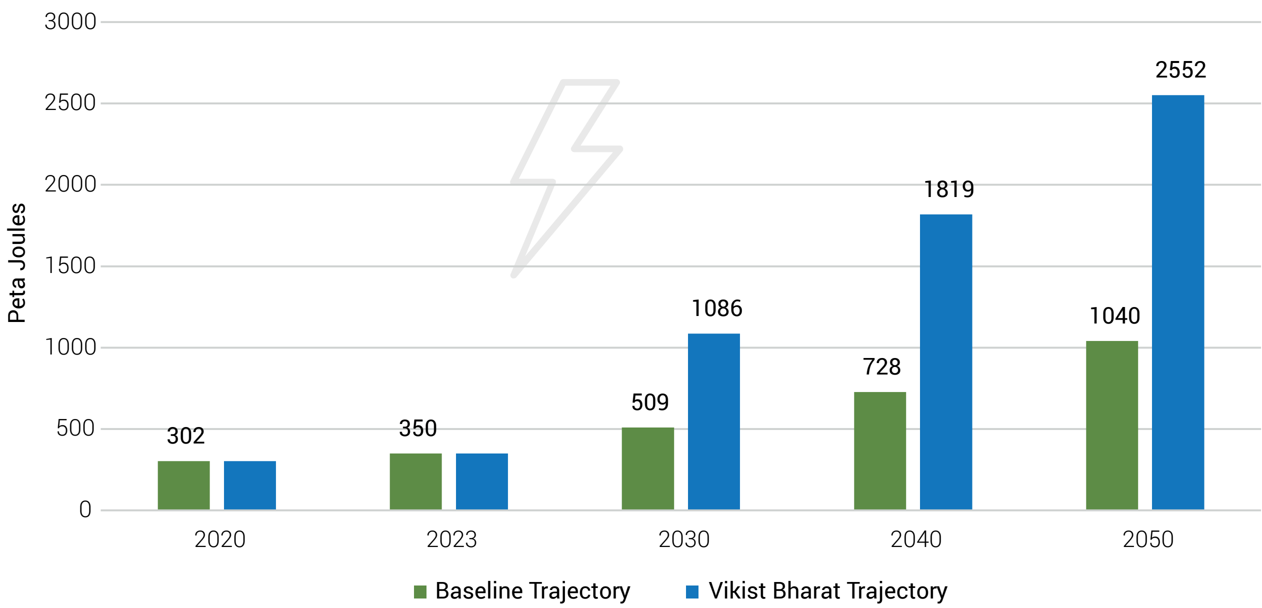


Figure 29: Total energy demand in baseline vs Viksit Bharat trajectory

- **Energy Efficiency Improvement:** Specific Energy Consumption- Based on the landscaping exercise of the textile industry in India, the specific energy consumption of finished fabric in India is 0.89 toe/ tonne in 2020 which was increased by 10 percent in 2023 to 0.98 toe/ tonne (ASI). There has been an improvement in process efficiency due to the implementation of efficient technology under schemes like PAT and TUFS. The baseline improvement is assumed at 0.5 percent annually in the baseline trajectory and accelerated improvement at 1.4 percent is explored in the Viksit Bharat trajectory.

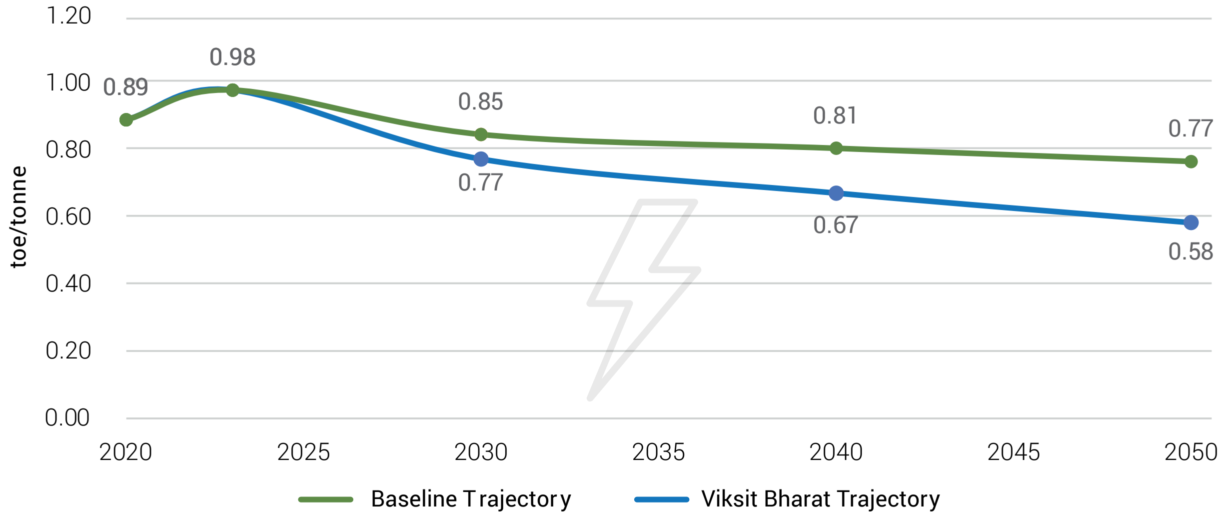


Figure 30: Specific energy consumption (SEC)

The efficiency improvement due to the upgradation of motors and other equipment's can result in SEC reduction by 14 percent in baseline case, while if the adoption happens at accelerated rate this can result in savings of around 35 percent (Figure 30).

The combined savings from efficiency improvement and electrification are represented in Figure 31 compared to the expected demand with no change in fuel mix and efficiency levels (Figure 29). This reflects that 100% electrification and SEC improvement will result in energy savings of 196 PJ and 688 PJ in baseline and Viksit Bharat trajectory respectively.[31]

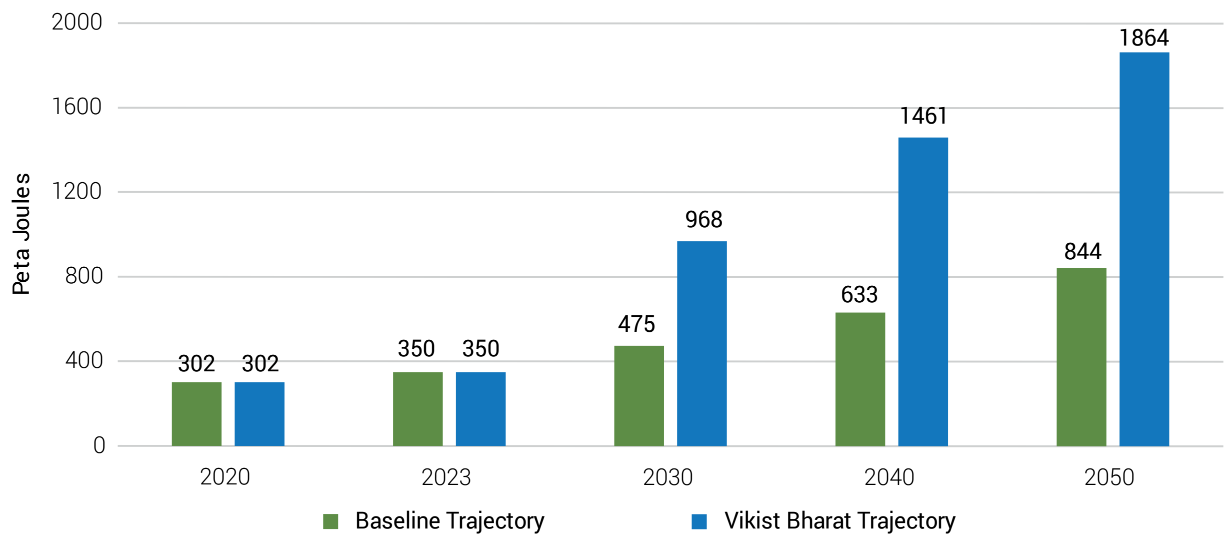


Figure 31: Estimated energy demand and corresponding savings in different scenarios

31 Electrification savings are calculated based on 53% of the non-electrified thermal energy demand, assuming a 25% improvement in efficiency (as shown in Table 6)

Emissions

The baseline emissions in the year 2020 and 2023 have been presented in Chapter-2 estimated at 48.9 and 56 $MTCO_2$ emissions respectively. The future emissions are projected using the equation below. The energy demand has been estimated using the activity data, i.e., industrial production, while the emission factors are converted to per unit of energy demand (Table 8).

Emissions = Energy Demand x Emission Factors

Emissions have been estimated for both the discussed trajectories under three scenarios:

- Baseline case (no change in energy mix, and grid mix)
- 100 percent electrification through grid
- 100 percent electrification through 50 percent Grid and 50 percent RE

Emission factors

Table 8: Emission factor considered for emissions calculation

Energy source	Unit	Emission Factor	Emission Factor ($MTCO_2$/ Peta Joules)
Grid Electricity (2020)	*$kgCO_2$/kWh*	**0.80**	**0.22**
Grid Electricity (2050)	*$kgCO_2$/ kWh*	**0.18**[32]	**0.05**
Coal	*$kgCO_2$/ kg*	**1.67**	**0.11**
Petroleum products	*$kgCO_2$/ kg*	**2.73**	**0.06**
Other (Biomass, etc.)	*$kgCO_2$/ kg*	**1.10**	**0.11**

32 IESS Version 3.0

Emissions with No Change in Energy Mix

Figure 32 illustrates the projected emissions if the fuel mix for energy demand in the textile sector remains the same as in 2023. The CO_2 emissions will rise from 56 $MTCO_2$ in 2023 to 166 $MTCO_2$ in 2050 under the baseline trajectory, while they can go up to 409 $MTCO_2$ under the Viksit Bharat trajectory of the textile sector.

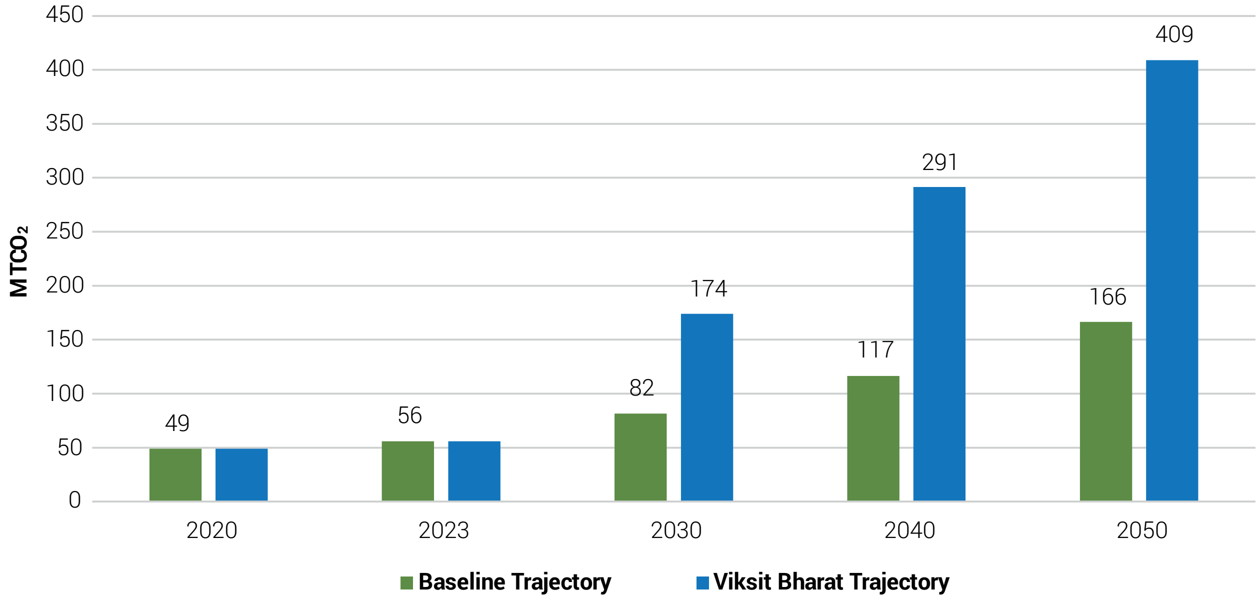


Figure 32: Emissions with no change in energy mix

Emissions Reduction Due to Electrification

This section presents the reduction in emissions due to the electrification of thermal processes. The electrification trajectory follows 25 percent, 50 percent and 100 percent in years 2030, 2040, and 2050 respectively for both scenarios. The grid emission factor will improve to 0.18 $kgCO_2$/kWh by 2050 and will follow a linear trajectory for intermediate years.

In the baseline trajectory, the increase in emissions will be very limited in the case of electrification and even further benefits can be accrued with RE-based electrification. Savings of 69 percent and 85 percent could be achieved with a 100 percent grid electrification and a 50 percent RE-based electrification, respectively, when compared to no-effort trajectory (Figure 33). With grid electrification, the increase in emissions can be brought down even when the activity is increased three times, while the emissions can be halved with RE-based electrification.

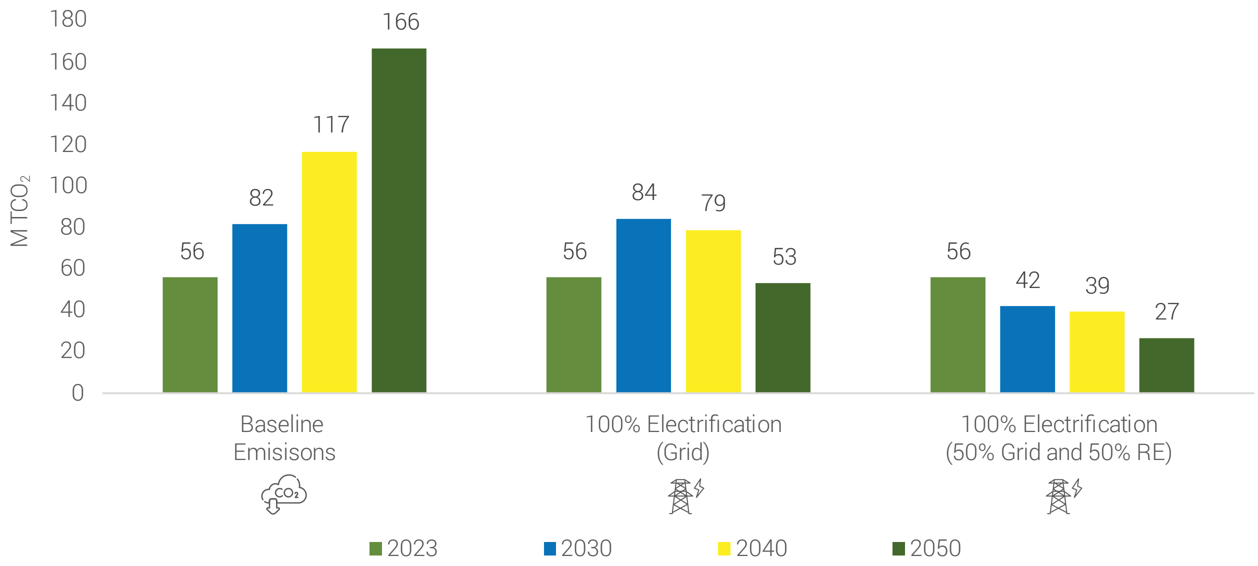


Figure 33: Estimated emissions in baseline trajectory

As we look into 100 percent electrification under the Viksit Bharat trajectory, it is observed that while the energy consumption increases by 5.3 times, the associated emissions are expected to increase only by a factor of 2.2 in grid electrification and 1.1 in RE based electrification scenario. Thus, building significant potential for textile sector decarbonisation with electrification as a key vector. The analysis suggests that solar energy-based electrification of thermal energy in the textile industry is the best alternative in terms of cost and environmental benefits.

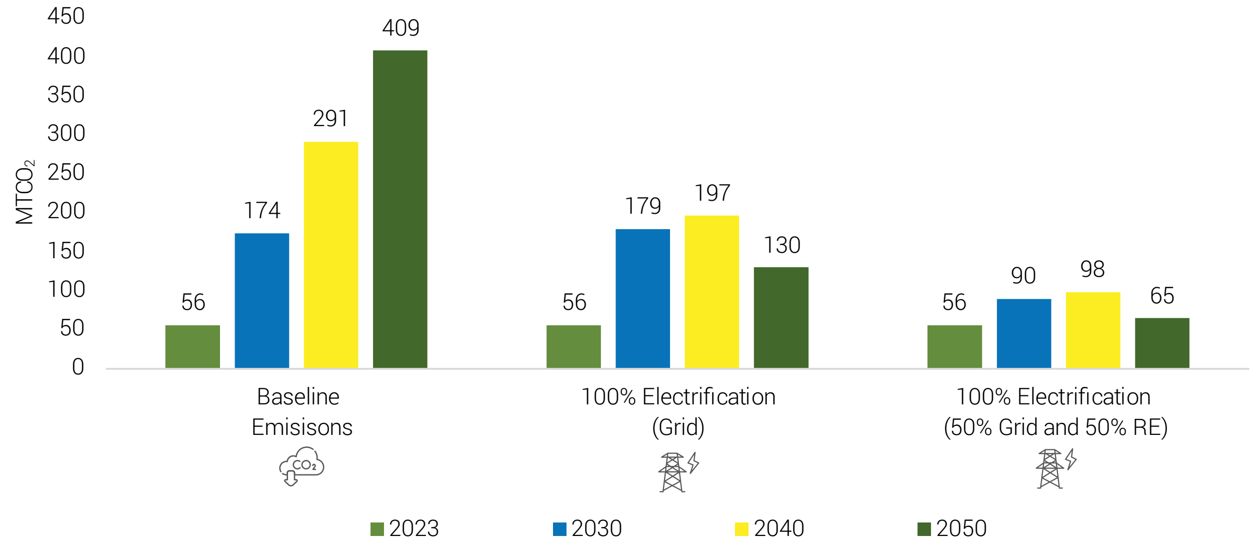


Figure 34: Estimated emissions in Viksit Bharat Trajectory

07

Key Findings

1. **Industry Growth trends:** The fibre production has been employed to examine the historical growth rates over the past 10, 20, and 30 years, revealing Compound Annual Growth Rates (CAGR) of 0.5 percent, 4.6 percent, and 3.6 percent, respectively. The industry has experienced sluggish growth over the past decade, attributed to subdued demand in both domestic and export markets.
2. **Process Hotspots:** Wet processes, specifically dyeing, drying and stentering, emerge as critical focal points, constituting a substantial portion of thermal energy consumption within the textile industry. Our analysis reveals that finishing processes account for 42 percent of the sector's overall energy usage.
3. **Geographical Hotspots:** Our Landscape assessment reveals that Gujarat consumes almost 59 percent of the coal consumption in the textile sector, followed by Rajasthan (13%) and Maharashtra (13%). The coal consumption in Gujarat can be traced to a higher share of wet processing industries to meet its energy demand. Three major textile clusters in Gujarat- Surat, Ahmedabad and Jetpur contribute to high lignite and imported coal consumption. Further, the electricity consumption in Tamil Nadu can be traced to a higher share of spinning and weaving units in the state.
4. **Emissions Disparity:** There exists a notable disparity between the reported emissions of the textile sector in India's Third National Communication (TNC) and the sector's actual energy consumption and emissions. The latter is estimated to be almost 40 times higher than reported. This discrepancy is primarily attributed to the structural classification of industries within India's emission inventory. The categorisation of the large number of textiles MSMEs as 'non-specified industries' leads to a considerable portion of the sector's emissions being concealed within this broader, less defined category.
5. **High Potential for Electrification**: The textile sector has substantial energy demand and associated carbon emissions. Given the sector's significant reliance on fossil fuels, i.e., 46 percent of total energy demand, there's a compelling case for electrification and a shift toward renewable energy is needed to facilitate meeting of India's decarbonisation goals.
6. **Future Sectoral Outlook 2050**
   - **Increase in energy demand:** Projections for the textile industry in 2050 indicate a significant surge in energy demand. Driven by factors such as demographic expansion, economic growth, and expanding consumer markets, our forecasts project a 3x increase in energy consumption compared to current levels. This underscores the urgent need for implementing energy-efficient practices and transitioning towards renewable energy sources to sustainably meet the escalating demand.

- To attain global leadership, India needs to set a target of a 30 percent share of global fibre production. This will require significant increase in efforts, approximately 2.4 times more than the baseline scenario. Such endeavours are crucial for India to establish itself as a frontrunner on the global stage and realise the aspirations set forth by Viksit Bharat.
- Emissions: Despite technological advancements and efficiency optimisations, the textile sector continues to contribute significantly to carbon emissions. By 2050, the emissions in the baseline scenario could be brought down by 69 percent through grid electrification, and 85 percent through a combination of electrification and captive RE.

7. **Powering Textiles with Solar**: As electricity prices escalate, electrification solutions as alternatives to conventional fossil fuel-based heating systems diminishes significantly. The current industrial tariff of ₹8-10/ kWh is not sustainable to remain competitive in the market. These high electricity costs may restrict companies from seeking electrified energy solutions or revert to traditional fossil fuel-based systems, despite their environmental drawbacks. The analysis suggests that electrification technology powered by solar energy emerged as the best cost-effective solution, while grid-connected electrified technology will not be cost-effective without any support mechanism compared to coal-based boilers.
8. **Proven Technologies for Deep Electrification of Textile Sector:** the textile sector in India is heavily reliant on fossil fuels for steam generation, process heating, and drying. The technologies discussed are proven electrification routes also offering significant decarbonisation potential. Electric steam boilers provide near-total efficiency (~99%) and are suitable for replacing conventional boilers in dyeing, finishing, and washing operations. Electric thermic fluid heaters serve as viable substitutes for fossil-fuel-based thermopacks used in stenter machines and other indirect heating processes. Heat pumps, with a COP of 2.5–4.5, can effectively supply low- to medium-temperature heat (up to 200°C), while also recovering waste heat from exhaust streams or effluents—particularly relevant for drying and pre-heating applications. When powered by renewable electricity, these technologies can drastically reduce emissions from thermal energy use in textile operations. Although capital costs and steam cost economics with respect to other fuels like coal, biomass; and electricity pricing remain key concerns, these technologies offer very high operational efficiency, modular scalability, and long-term alignment with net-zero goals. As deployment scales and technology matures, costs are expected to decline, improving their economic attractiveness across industry.

08

Conclusion

Achieving deep decarbonisation in India's textile sector is a complex but essential undertaking, requiring a multifaceted approach across four key pillars: demand reduction and material efficiency, energy efficiency, fuel switching and electrification, and transformative technologies. While the industry faces significant challenges—diverse processes, carbon-intensive materials, and substantial investment—the potential benefits are huge, contributing to national climate goals, enhancing global competitiveness, and fostering sustainable development.

Electrification, particularly for low to medium heat processes like dyeing and drying, presents a significant opportunity for emissions reduction. The dominant energy consumption in wet processes (43%), coupled with their currently low electrification rate (10%), signals a prime area for intervention. This gap is a direct opportunity for targeted electrification initiatives that promise substantial efficiency gains and emissions reductions. However, addressing the current cost disadvantage compared to fossil fuels and other low-carbon fuels through supportive policies and incentives is critical for its widespread adoption.

A successful transition necessitates concerted efforts from all stakeholders. Governments, technology providers and financiers play a crucial role in developing forward- looking policies, providing financial incentives, facilitating technology readiness and information sharing to overcome barriers like high initial costs and technical expertise gaps. Industry clusters and associations must work with grid operators and electric utilities for necessary grid upgrades and economic readiness to promote RE backed electrification technologies.

However, a well-defined and vigorously pursued decarbonisation would also need to align with global sustainability changes and should explore alternative materials, embrace innovative processes like ultrasonic treatment and supercritical dyeing and further promote circular economy principles to minimise material consumption and waste generation. Such a roadmap should be supported by robust policy frameworks, technological innovation, and collaborative efforts across the value chain to transform the Indian textile industry into a deeply decarbonised, resource-efficient, and sustainable sector that meets the needs of a growing nation while minimising its environmental footprint.

09

Annexures

Annexure 1

Deep Decarbonisation Pillars for the Textile Sector

Demand Reduction and Material Efficiency: There's considerable potential to decrease the carbon footprint across industries and product lifecycles. This can be achieved by optimising material consumption during product design, usage, and end-of-life stages. Strategies like light-weighting, minimising over-design, extending product lifespans, enhancing product quality, reducing waste in manufacturing, and promoting re-manufacturing, repurposing, re-use, and recycling can effectively contribute to this objective. There potential in replacing energy-intensive materials such as silk, taffeta, blended fabrics and with alternative materials such as rPET, bamboo-based viscose, Tencel, etc., considering resource availability to lower the carbon footprint of final products.

Energy Efficiency: Implementing energy efficiency measures and technologies reduces fuel and electricity consumption, along with their associated CO_2 emissions, in the industry. The technologies and measures are often well-known and cost-effective, providing immediate actions that can be taken in near-term to reduce overall demand for energy from industry. Substantial CO_2 emissions reduction can be achieved through the application of commercialised energy efficiency technologies and measures in the textile industry.

Fuel Switching and Electrification: Switching to lower carbon-intensive fuels can help to significantly reduce CO_2 emissions associated with fuel use in the industry. The extent to which the industry uses fossil fuels and the potential for switching to lower-carbon fuels (biomass, renewable natural gas (RNG), green hydrogen) for heat should be investigated. Such an investigation could build the case for such fuel switches and look into the potential fuel availability and technological aspects of using fossil fuels versus low-carbon fuels in the textile sector.

Electrification of Industry: Textile processing involves a range of heating operations, including singeing, drying, washing, dyeing, stentering, curing, and more. These operations utilise various process heating technologies, which can be broadly categorised into four groups based on of fuel they use: steam-based, oil-based, electric-based, and hybrid systems. During process heating, materials are heated through heat transfer from a heat source, such as a flame, steam, hot oil, or an electrical heating element. This heat transfer occurs through conduction, convection, radiation, or a combination of these mechanisms. Typically, lower temperature processes rely on conduction or convection, while higher temperature processes predominantly utilise radiative heat transfer. The textile sector heat demand is required at temperatures below 200°C. It is easier to electrify low-temperature processes, hence there is significant potential for low to medium heating applications.

Transformative Technology

- **Ultrasonic Technology:** The technology is used in the wet processing unit for treatment. This technology involves the application of high-frequency sound waves (ultrasonic waves) to the fabric surface, which induces better absorption on the fabric surface, reducing the chemical, water, and energy consumption. Ultrasonic technology is known for its ability to provide precise and uniform treatment to fabrics. Other benefits[33] of this technology includes:
  - 30 percent less chemicals and water consumption
  - Up to 50 percent energy savings
  - Reduction of process temperature from 95°C to 60°C
  - Shorter washing cycles
  - High process reliability for quality improvement
- **Cool Padding:** The cool padding method involves the application of dyes at lower temperatures compared to traditional dyeing techniques, which typically require high heat. By using cool padding, energy usage can be cut by up to 60 percent, and water consumption can be reduced by approximately 50 percent. Additionally, this technology minimises the release of harmful chemicals. While cool padding technology in dyeing offers numerous benefits, there are challenges to scaling up the operations along with the high initial investment.
- **Super Critical Dyeing:** The supercritical dyeing technique utilises supercritical carbon dioxide as a dyeing medium to conserve thermal energy, conducting dyeing in high-pressure autoclaves where carbon dioxide exists as a supercritical fluid at approximately 31°C and pressures exceeding 72 bars (Gaikwad, 2020). This anhydrous process eliminates the need for processing water and reduces energy consumption for heating the dyeing liquor. While limited to dyeing polyester (PET), this method has gained traction in recent years and is poised for scalability. However, challenges persist in the textile industry, particularly in India, where fragmented sub-sectors lack the scale required for global competitiveness.
- **Energy Efficiency Technologies:** Some of the commercially available best practices and technology upgrades implemented in the Indian textiles industry under the PAT scheme include:
  - Super Batch Cooking
  - Two-Stage Oxygen Delignification – OxyTrac
  - BCTMP Process (bleached chemi-thermomechanical pulp)
  - Ultra-Low Intensity Refining
  - Opti Batch Process
  - Biogas firing in rotary lime kiln (Replacement of Furnace Oil)
  - Boiler Conversion: Fluidised bubbling to Spouted bed

33 https://www.weber-ultrasonics.com/en/reference-geratex/

» Solar Energy Utilisation for Process Heating at Low and Intermediate temperature (Replacement of LP Steam) i.e., 50°C to 250°C

» Oxyfuel burning in lime kiln and black liquor boilers

» Installation of Extended Delignification System for cooking of wood (to reduce steam consumption)

Alternative Materials: The textile industry is increasingly turning to recycled and regenerative materials as part of efforts to decarbonise and promote sustainability. These materials offer significant environmental benefits by reducing reliance on virgin resources, minimising waste, and mitigating the industry's carbon footprint.

- **Recycled Materials:** Recycled fibres, such as polyester, cotton, and nylon, are derived from post-consumer or post-industrial waste streams. By repurposing materials that would otherwise end up in landfills, recycled fibres helps conserve natural resources and reduces energy consumption and emissions associated with virgin fibre production.
- **Regenerative Materials:** Organic fibres, such as organic cotton and hemp, are grown using regenerative agricultural practices that promote soil health, biodiversity, and carbon sequestration. By avoiding synthetic fertilisers and pesticides, organic farming reduces greenhouse gas emissions and minimises environmental impacts.

Annexure 2

List of Central Government's schemes/initiatives in the textile sector

Scheme/ Initiatives	Implementation Period	Main objectives/features
Technology Upgradation Fund Scheme (TUFS)[34]	01.04.1999 to 31.03.2007	› Capitalise on technology upgrades in the textile industry. › Funds for new and existing units. › From the fiscal year 1999-2000 to 2012-13, a cumulative subsidy of ₹15,909 crore was disbursed under the TUFS scheme.
Modified TUFS (MTUFS)	01.04.2007 to 31.03.2012	› Expanded scope for technology investment.
Revised TUFS (RTUFS)	28.04.2011 to 31.03.2013	› Continued support for technology upgradation.
Revised Restructured TUFS (RRTUFS)	01.04.2013 to 11.07.2016	› Enhanced focus on technical textiles.
Amended TUFS (ATUFS)[35]	13.01.2016 to 31.03.2022	› Launched with an outlay of ₹17,822 crore, aims to upgrade textile industry technology. › From FY 21 to FY 23, ₹1,855.93 crore subsidy disbursed. › Total subsidy released: ₹8,714.45 crore since 2015-16. › Incentivised 1,117 energy-saving machines in five years.
National Technical Textile Mission (NTTM)[36]	2020-21 to 2024-25	› Aims to elevate India's position in the global technical textile market. › Approved budget of ₹1,480 crores.
PM-MITRA (Mega Integrated Textile Region and Apparel)[37]	2021-22 to 2027-28	› Establish 7 PM MITRA parks with a ₹4,445 crore budget from 2021-22 to 2027-28. › Each park is expected to generate 100,000 direct jobs and attract ₹10,000 crore investment

34 Technology Upgradation Fund Scheme (TUFS) for Textile sector, Loksabha Secretariat Report

35 Rajya Sabha Unstarred Question No-953

36 Rajya Sabha Unstarred Question No-151

37 https://www.texmin.nic.in/sites/default/files/mitra_0.pdf

Scheme/ Initiatives	Implementation Period	Main objectives/features
Production-Linked Incentive (PLI) Scheme[38]	FY 2025-26 to FY 2029-30	› ₹10,683 crore allocated over 5 years for the textile industry. › Promotes high-value MMF Fabric, Garments, and Technical Textiles. › Aims to create over 7.5 lakh jobs, attract ₹19,000 crore investments, and increase turnover by ₹3 lakh crore in 5 years.
Textile Cluster Development Scheme (TCDS)	2021-22 to 2025-26	› Enhance competitiveness and integration in textile clusters. › The total outlay of the scheme is ₹853 crore. › The Scheme for Integrated Textile Park (SITP) is now part of TCDS, with ₹1516.04 crore released for 56 parks; 30 completed, 24 in progress.
Sustainable and Accelerated Adoption of efficient Textile technologies to Help Small Industries (SAATHI)[39]	Launched in 2018	› Promote energy-efficient technologies in power-loom sector. › EESL will replace outdated electric motors with energy-efficient IE3 motors, saving 10-15% in energy and costs, benefiting unit owners without upfront expenses.
SAMARTH - Scheme for Capacity Building in Textile Sector (SCBTS)[40]	2017-18 to 2019-20 Extended 2021 to 2024	› To address skilled workforce needs. › This scheme aimed to train 417,888 individuals, with 155,981 trained as of Dec-22.
Integrated Processing Development Scheme (IPDS)	01.04.2017 to 31.03.2020 Continued from 2021-22 to 2025-26	› Enhance India's textile industry competitiveness with eco-friendly technology, support CETPs, and foster R&D for cleaner technologies. › ₹173.23 crores released, 4 CETP projects approved for Zero Liquid Discharge.
Perform, Achieve, Trade and (PAT) Scheme[41]	Launched in June 2008 and ongoing	› Enhance energy efficiency in textile industries. › 168 Designated Consumers notified. › Achieved energy savings of 0.33 Mtoe and reduced CO_2 emissions by 1.604 million metric tonnes annually from PAT Cycle I to V.

38 https://pib.gov.in/PressReleasePage.aspx?PRID=1753118
39 https://pib.gov.in/newsite/PrintRelease.aspx?relid=181389
40 https://samarth-textiles.gov.in/public_dashboard/
41 https://beeindia.gov.in/sites/default/files/publications/files/Impact%20Assessment%202022-23_%20FINAL%20Report.pdf

Scheme/ Initiatives	Implementation Period	Main objectives/features
BEE-GEF-UNIDO Programme[42]	Ongoing	› Promote energy-efficient technologies in MSME clusters. › Implemented 599 small energy-efficient projects by March 2023. › Energy and Resource Mapping in 15 SME clusters covering Textile, Food Processing, and Leather sectors. › So far, 33 EE/RE projects have saved 213 Toe of energy and reduced CO2 emissions by 1390 tonnes and achieved INR 8.73 crores co-financing from MSMEs.

42 https://beeindia.gov.in/sites/default/files/publications/files/Impact%20Assessment%202022-23_%20FINAL%20Report.pdf

About Vasudha Foundation

Vasudha Foundation is a non-profit organisation set up in 2010. We believe in the conservation of Vasudha, which in Sanskrit means the Earth, the giver of wealth, with the objective of promoting sustainable consumption of its bounties. Our mission is to promote environment-friendly, socially just and sustainable models of energy by focusing on renewable energy and energy-efficient technologies as well as sustainable lifestyle solutions. Through an innovative approach and data- driven analysis, creation of data repositories with cross-sectoral analysis, along with outreach to ensure resource conservation, we aim to help create a sustainable and inclusive future for India and Mother Earth.

VASUDHA FOUNDATION
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