Bureau of Energy Efficiency
Ministry of Power, Government of India

Sectoral Report

Energy & Resource Mapping of MSME Clusters in India – Textile Sector

ICF

Prepared by
ICF Consulting India Pvt. Ltd.

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ICF Team

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List of Abbreviations

BEE	Bureau of Energy Efficiency
CAGR	Compound annual growth rate
DIC	District Industries Centre
EEM	Energy Efficiency Measures
ECM	Energy Conservation Measures
EPC Company	Engineering Procurement and Construction Company
GHG	Greenhouse Gas Emissions
GDP	Gross Domestic Product
GEDA	Gujarat Energy Development Agency
HAREDA	Haryana Renewable Energy Development Agency
HSD	High Speed Diesel
KPI	Key Performance Indicator
LPG	Liquified Petroleum Gas
MEDA	Maharashtra Energy Development Agency
MSME	Micro, Small and Medium Enterprises
PNG	Piped Natural Gas
PPA	Power Purchase Agreement
PLC	Programmable Logic Controller
PEDA	Punjab Energy Development Agency
RMG	Ready Made Garments
SEC	Specific Energy Consumption
SGTPA	South Gujarat Textile Processors Association
SIDBI	Small Industries Development Bank of India
TEDA	Tamil Nadu Energy Development Agency
TCV	Temperature Control Valve
TFH	Thermic Fluid Heater
TOE	Tonnes of oil equivalent
USD	United States Dollar
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

1. About the project

1.1 Project Overview

The Micro, Small, and Medium Enterprises (MSME) sector has emerged as a dynamic sector of the Indian economy over the last five decades. It contributes significantly to the economic and social development of the country by fostering entrepreneurship and generating the largest employment opportunities at comparatively lower capital costs, next to the agriculture sector in India.

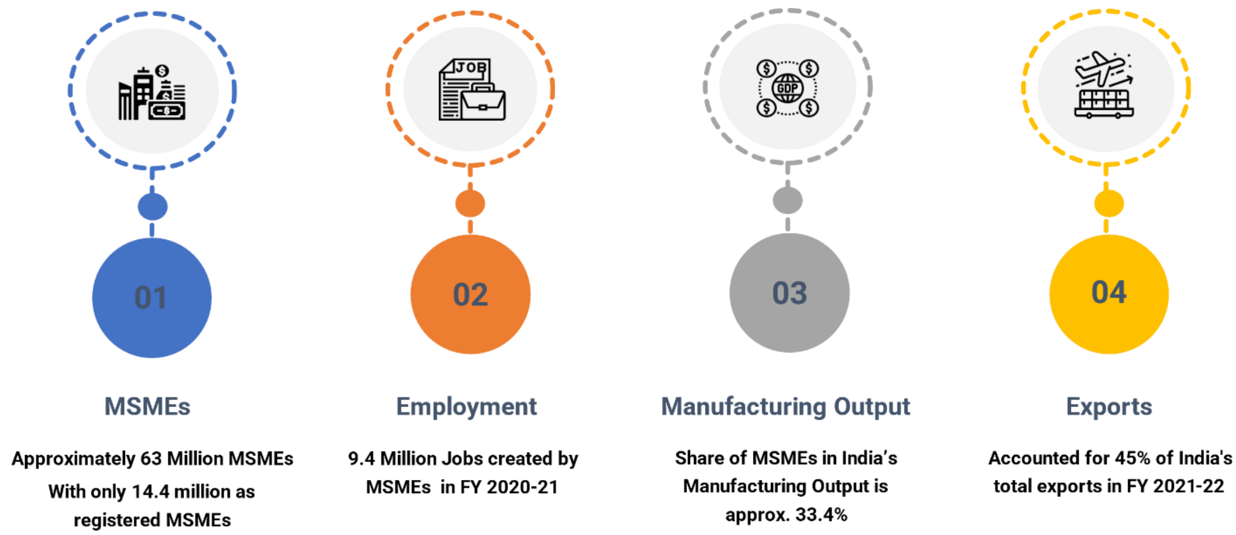


Figure 1: Highlights of MSME sector in India*

Source: IBEF & PIB

MSMEs are complementary to large industries and this sector contributes significantly to the inclusive industrial development of the country. A diverse range of products and services are produced by MSMEs to meet the demands of domestic as well as global markets.

Amongst all the MSME sectors, the textile industry is a vital sector of the Indian economy as India is the 3^{rd} largest exporter of Textiles & Apparel in the world, accounting for 4.6 per cent share in the global trade. India's total merchandise exports stood at a significant 10.5[1] per cent in FY 2021-22 (Ministry of Textiles, 2023). The sector holds importance from the employment point of view as well. It provides direct and indirect employment and source of livelihood for millions of people including a large number of women and rural population.

[1] https://texmin.nic.in/sites/default/files/English%20Final%20MOT%20Annual%20Report%202022-23%20%28English%29_0.pdf

The government has prepared a draft National Textiles Policy to revitalize the textile and apparel industry in India and aims to achieve USD 300 billion exports by FY 2024-25 and creation of additional 35 million jobs by attracting investments. [2]

With increased output to support exports, the textile sector is also one of the most energy-consuming industries, with low energy efficiency practices. Manufacturing activities in the textile and clothing sectors in India are very resource-intensive; they utilize fossil fuels for the production and dyeing of polyester while pesticides, and a lot of water to grow cotton, and they produce a lot of solid waste and wastewater.

The textile industry is a big energy and water consumer, with 34% of the energy consumed in spinning, 23% in weaving, 38% in chemical processing, and the remaining 5% used for miscellaneous areas[3], of an entire manufacturing process. It has also been discovered that the amount of fuel consumed in textile mills corresponds to the amount of water consumed. As a result, reducing water consumption will also save energy. Understanding of the traditional operating practices is thus a key goal of fundamental research to optimize energy consumption across different process sections.

To make the sector energy and resource-efficient, BEE has initiated the project **"Energy and Resource Mapping of MSME Clusters in India - Textile Sector"** and entrusted ICF Consulting India Pvt. Ltd. with the objective of energy mapping of different energy-intensive MSME clusters of the Textile sector. The study primarily focuses on the estimation of the energy consumption, production, and technology aspects together with conducting detailed techno-economic assessments for the selected clusters. Benchmarking various processes of the textile sector and preparing policy recommendations along with the development of an implementation roadmap to make the sector energy & resource-efficient and environment-friendly are also part of this study.

1.2 Project Objectives

The overall objective of the project is to map clusters for the textile sector throughout the country and estimate energy consumption, technology, and production scenario in each cluster, and further, prepare a future road map and implementation plan for the sector. The specific objectives of the project are as follows:

I. To analyze energy consumption scenario (covering all types of fuel - electrical, solid, liquid, and gaseous)
II. To conduct technological assessment of existing processes, energy efficiency improvement potential, energy-efficient technologies, best operating practices, and readiness of the cluster for the adoption of identified technologies.
III. To conduct a benchmark study for the sector
IV. To develop an implementation roadmap including policy recommendation.
V. To conduct outreach and dissemination of Knowledge

[2] https://economictimes.indiatimes.com/industry/cons-products/garments-/-textiles/new-national-textiles-policy-will-be-unveiled-after-union-budget/articleshow/46043054.cms

[3] https://www.fiber2fashion.com/industry-article/3377/energy-conservation-in-textile-industries-savings#:~:text=The%20textile%20industry%20retains%20a,another%205%25%20for%20miscellaneous%20purposes.

1.3 Major components of the project

The major components of the project are Cluster Selection, Detailed Energy Assessment, Benchmark Study, Analysis & Policy Recommendation as well as Dissemination of Knowledge.

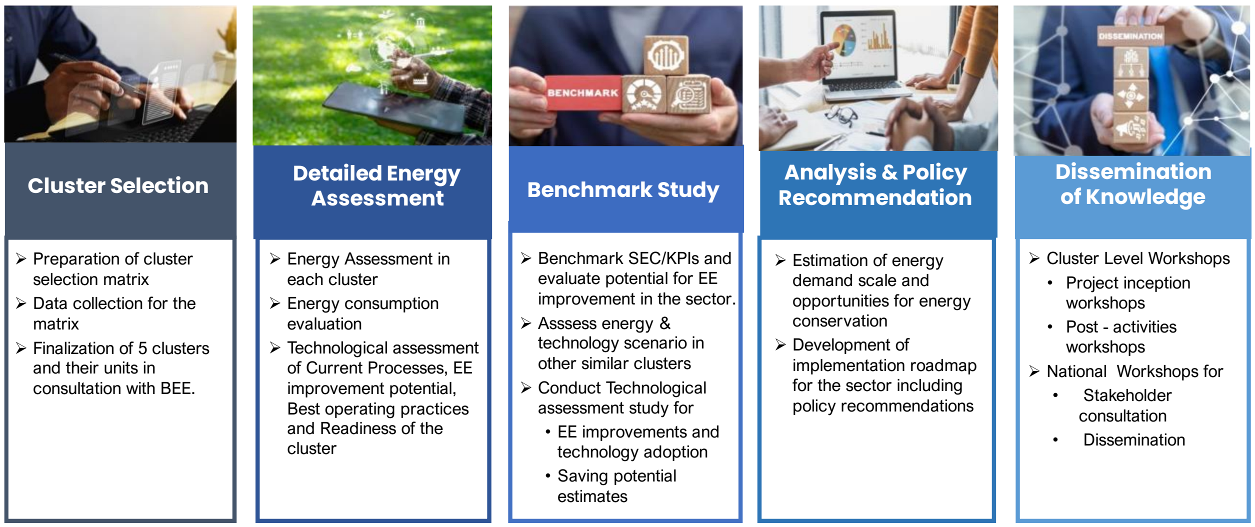


Figure 2: Major Components of Energy and Resource Mapping Project

Cluster Selection: This is the first steppingstone to commence the project. It includes the preparation of the cluster selection matrix and data collection for the matrix. Based on the data evaluation, scoring is provided to each of the clusters. The first five high scorers are selected as the major textile cluster for the detailed assessment, whereas the next five clusters on the scoring list are the additional cluster for this project.

Inception Meeting: The project team conducted the inception meeting with the key stakeholders of all the selected clusters to inform them about the project objectives and planned activities. Thereafter, the Expression of Interest (EOI) letters were collected from the unit owners who were willing to be a part of this project and energy audits.

Detailed Energy Assessment: This encompasses the energy assessment across all the five major clusters of textile industry in India through the energy audits. It starts with the process overview along with the energy profile establishment. Further, this incorporates the evaluation of energy baseline and feasibility and technology readiness of energy efficient technology solutions for current processes, impact assessment of Energy Conservation Measures (ECMs)/ Energy Efficiency Measures (EEMs).

Benchmarking Study: Based on the energy audit reports across all the clusters, the benchmarking study includes Specific Energy Consumption (SECs), as Key Performance Indicators (KPIs) and evaluate potential for energy efficiency improvements.

Analysis and Policy Recommendations: This includes estimation of energy consumption and opportunities for energy conservation. For the recommendations, the project includes the development of a roadmap encompassing policy recommendations and an implementation plan.

Dissemination of knowledge: At the end of the project to disseminate the knowledge, the post activity technical dissemination workshop for each cluster along with the national-level stakeholder consultation workshop and national-level stakeholder dissemination workshop.

1.4 Selected Textile Cluster

The textile sector is one of the most important sectors in India, contributing to the country's economy, employment, and exports. The sector is mainly composed of micro, small and medium enterprises (MSMEs) that produce a variety of products such as yarn, fabric, garments, home textiles, technical textiles, etc. The textile MSMEs are clustered in different regions of the country, based on the availability of raw materials, skilled labour, market access, and historical factors.

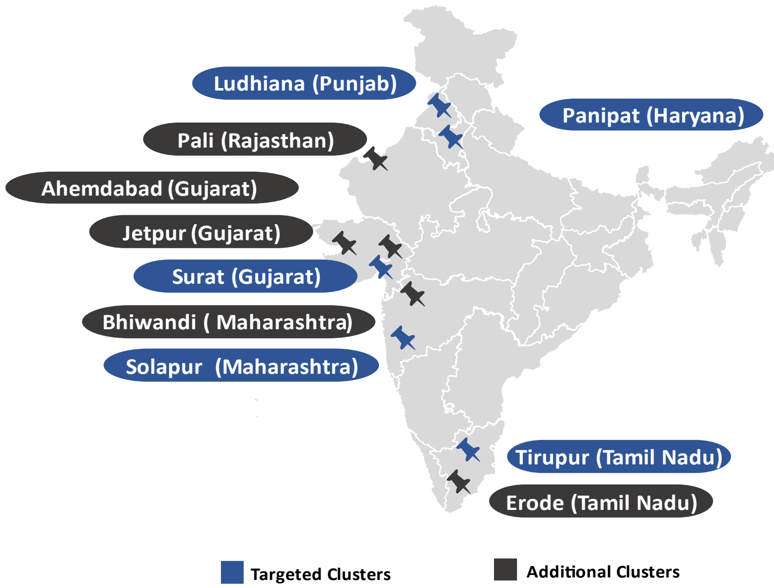


Figure 3: Targeted and Additional textile clusters of the project

The project aims to enhance the competitiveness and sustainability of the textile MSME clusters in India by providing them with technical assistance, capacity building, market linkages, and policy support. The project covers five targeted clusters and five additional clusters that have been selected based on their potential for growth and development. The following figure summarizes some

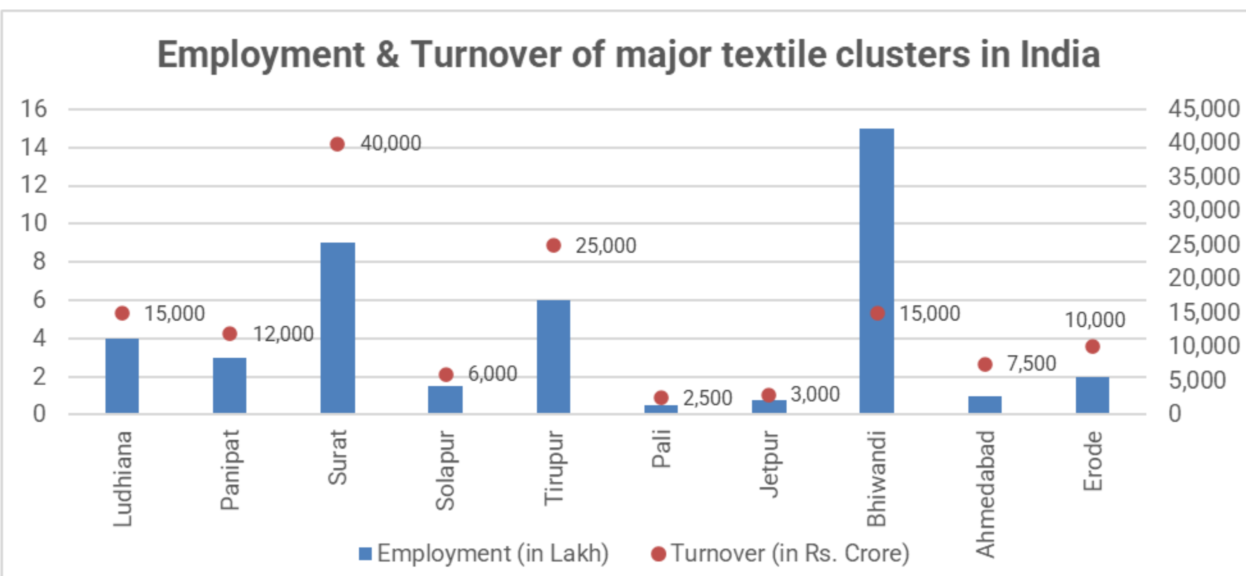


Figure 4: Employment and Turnover of major textile clusters in India

key facts and figures [4]about these clusters.

2. Textile Industries in the MSME Sector

The textile and apparel (T & A) market in India is highly diversified with varied segments of products like traditional handloom, handicrafts, wool, and silk goods etc. The domestic apparel & textile industry in India contributes approximately 2 per cent to the country's GDP, 7 per cent of industry output in value terms, and 12 per cent of the country's export earnings[5]. India is the 3rd largest exporter of textiles and apparel in the world and holds a 4.6 per cent share of the global trade in textiles and apparel (Ministry of Textiles, 2023).

The United States, the European Union, and the United Kingdom account for nearly 50 per cents of India's textile and clothing exports (Ministry of Textiles, 2023). In addition, India is the major producer of cotton and jute in the globe. It is also the world's second largest producer of silk, accounting for 95 percent of all hand-woven fabric (Invest India, 2022). The export of India's overall merchandise has increased from 313 billion USD in FY 2019-20 to 422 billion USD in FY 2021-22 (DGCI&S , 2022).

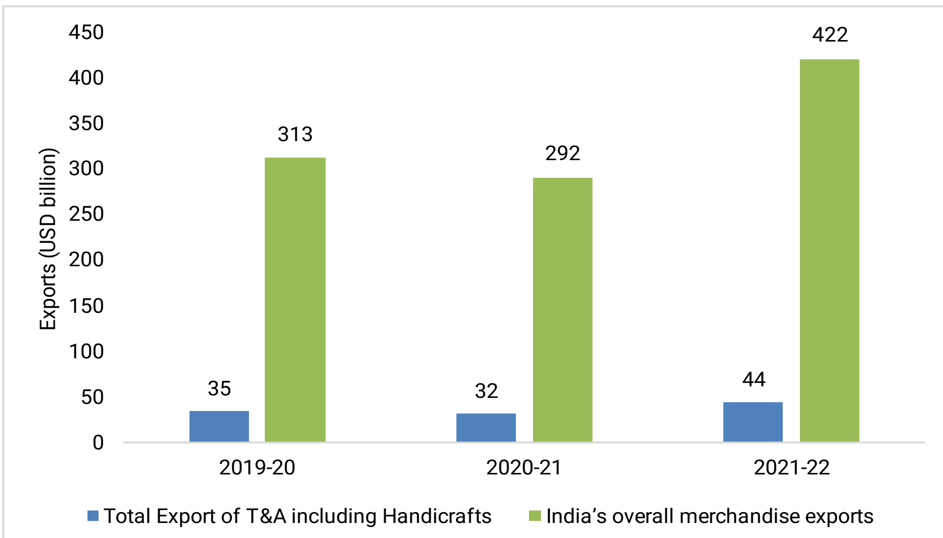


Figure 5: India's Exports of Textile & Apparels and overall merchandise exports (Data Source: DGCI&S, 2022)

Growth estimated in the Indian textile and apparel industry is 10 per cent CAGR from FY 2019-20 to reach USD 190 billion by 2025-26[6], whereas apparel market stood at USD 40 billion in 2020 and is expected to reach USD 135 billion by 2025[7].

This sector is experiencing growth due to rising demands in exports, due to changing tastes and preferences, and a growing population driving demand for textiles. The sector has also received policy support as the government is setting up mega textile parks as part of the **Pradhan Mantri Mega Integrated Textile Region and Apparel Parks (PM-MITRA)** Scheme. Additionally, the launch of the Production Linked

[4] https://sfurti.msme.gov.in/SFURTI/Reports/DPR_Functional_Upto.aspx

[5] https://commerce.gov.in/about-us/divisions/export-products-division/ep-textile/
[6] https://apparelresources.com/business-news/trade/indian-apparel-market-predicted-reach-us-135-billion-2025-say-iff-2023-speakers/
[7] https://www.ibef.org/download/1673938053_Textiles-and-Apparel-Nov2022.pdf

Incentive aims to strengthen the textiles value chain, especially the technical textiles and man-made fibers segment.[8]

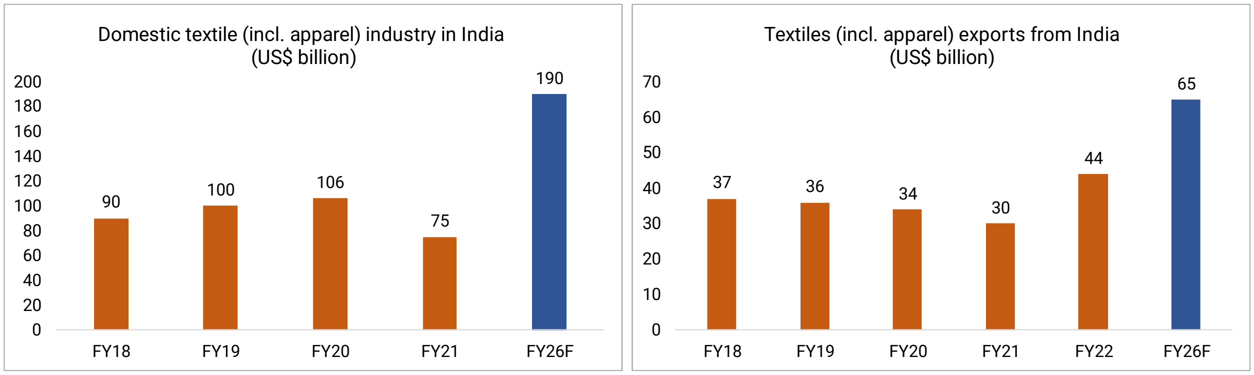


Figure 6: Domestic value and export value of textile and apparel industry

2.1 Sectoral Background of Textile industries

The textile industry in India is characterized by both organized and decentralized unorganized sectors. Within the organized sector, the industry comprises spinning and composite mills that engage in large-scale, mechanized textile production. This segment plays a significant role in the industrial landscape. Conversely, the decentralized unorganized sector is highly diverse and primarily encompasses power loom, handloom, and hosiery units, which predominantly specialize in weaving activities. This unorganized sector further encompasses various smaller units involved in knitting, yarn production, and fabric processing. These smaller units collectively contribute to the richness and complexity of the Indian textile landscape. The structural composition of the Indian textile industry is graphically depicted in the figure below, offering a visual representation of the interplay between these organized and unorganized sectors. This complex structure underscores the varied and intricate nature of the industry's operations.

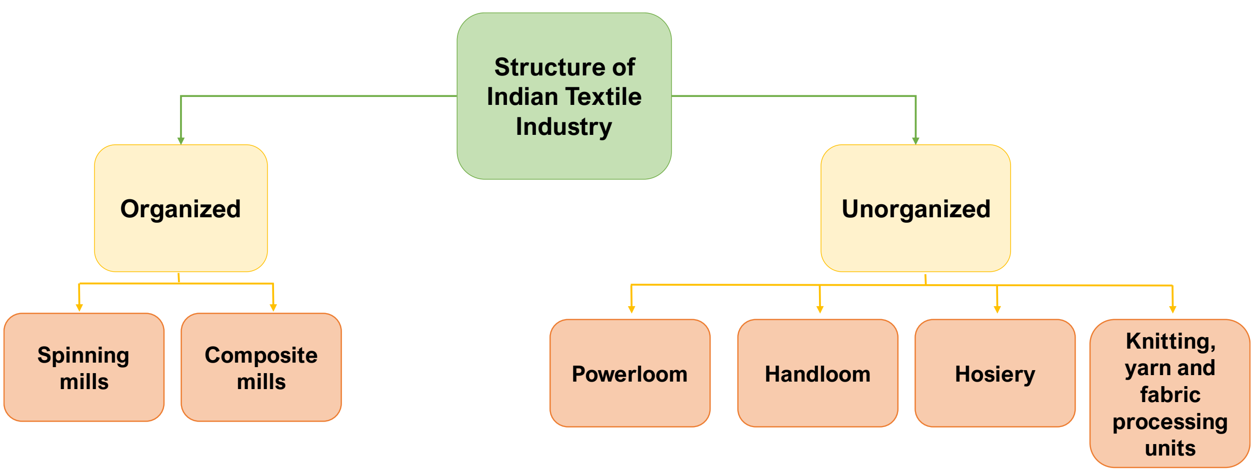


Figure 7: Structure of Indian Textile Industry, *Source: (Jha, 2020)*

[8] https://www.ey.com/en_in/tax/how-pli-will-help-the-man-made-fibres-and-technical-textiles-sector

The Indian textile industries exist as both large industries as well as MSMEs. While large industries are usually integrated plants, the MSME units are often diversified with each unit focusing on a particular segment of the overall process i.e. – spinning, weaving, knitting, dyeing, readymade garments etc. India has numerous MSMEs operating across the value chain, particularly in the production of fabrics, dyeing, printing, stitching of Readymade Garments (RMG), as well as in retail (via small stores). The textile industries in MSMEs are generally located as clusters. Some of the major MSME textile clusters in India are situated in Surat (Gujarat), Tirupur (Tamil Nadu), Panipat (Haryana), Pali (Rajasthan), Jetpur (Gujarat), Solapur (Maharashtra) among others.

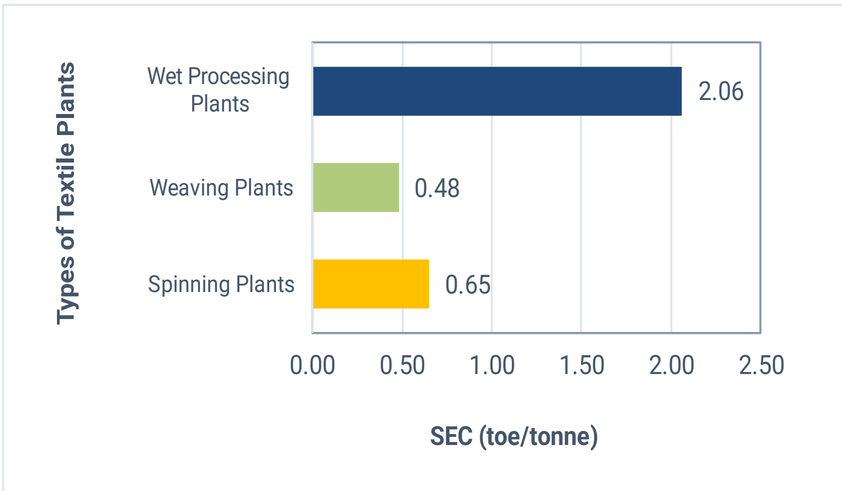


Figure 8: Variation of SEC across different textile manufacturing plants*

as derived from https://www.aceee.org/files/proceedings/2011/data/papers/0085-000041.pdf

Amongst the various segments of the textile MSMEs, the wet-processing units turns out to be the most energy intensive textile industries with almost four times the Specific Energy Consumption (SEC) as against that of spinning, knitting and RMG segments. This is owing to the fact that wet-processing units are thoroughly dependent on fuel for its thermal energy requirements in addition to the electricity consumption across its various processes whereas the other segments like spinning, knitting and RMG are mostly electricity driven. Fig 8 shows the gap in the SEC amongst the different textile processing segments.

The five targeted textile MSME clusters covered under the project are Ludhiana, Panipat, Surat, Solapur, and Tirupur. Further, the project includes five additional MSME clusters in Pali, Jetpur, Bhiwandi, Ahmedabad and Erode.

2.2 Products and Production

In the realm of textile production, India claims the second position worldwide, contributing a substantial 6.9% to the global output. Notably, it leads the globe in cotton production and is the primary contender to China in the domains of silk and man-made fiber production, as reported by the Ministry of Textiles in 2023.

India's textile industry boasts an impressive valuation of 223 billion U.S. dollars, contributing significantly to the country's GDP with a share of approximately 2.3%.[9]

India's textile clusters serve as key contributors to three major applications: household, technical, and fashion & clothing. Household products encompass a wide array, including bedding, floor furnishings, kitchen textiles, upholstery materials, towels, and more. The technical textile sector fulfills demands in diverse industries such as construction, transportation, medical applications, and protective wear. Lastly, the fashion & clothing segment spans the gamut from apparel, dress materials, and ready-made garments to ties, clothing accessories, handbags, and related items.

Table 1: Major textile products and production in the selected MSME clusters*

Cluster	Major Textile Products	Production (Tonnes/year)
Ludhiana, Punjab	• Woolen and Knitwear • Hosiery	6,52,788
Surat	• Sarees • Dress materials	15,14,157
Solapur	• Towels (Terry and Cotton) • Napkins • Solapur Chaddar • Home Furnishings (Bed sheets, bedspreads and carpets)	1,78,902
Tirupur	• Dyed yarns & fabrics • Semi-finished garments • Knitted garments	10,02,476
Panipat	• Home furnishing textile (bedsheet, mattress cover, cushion covers, curtain) • Blankets	15,97,827

as derived from information collected during the actual site visit

In the context of the energy assessment study, the analysis encompassed various textile clusters. These clusters specialize in distinct textile product categories, with Panipat primarily engaged in the manufacturing of home furnishing textiles and towels, while Surat focuses on the production of sarees and dress materials.

Remarkably, these two clusters stand out as the most prolific in terms of production output within the broader textile industry. Their significance is highlighted not only by the sheer volume of products they generate but also by the complex manufacturing processes involved in their respective operations. These intricate processes having a substantial impact on the industry's overall energy consumption and resource utilization, making it imperative to conduct a thorough analysis of these clusters to formulate effective energy conservation and sustainability strategies for the textile sector. Figure 9 shows the detailed

[9] https://www.ibef.org/industry/indian-textiles-and-apparel-industry-analysis-presentation

breakdown of the products and their production profiles within each cluster, thus providing a comprehensive overview of cluster-wise production data.

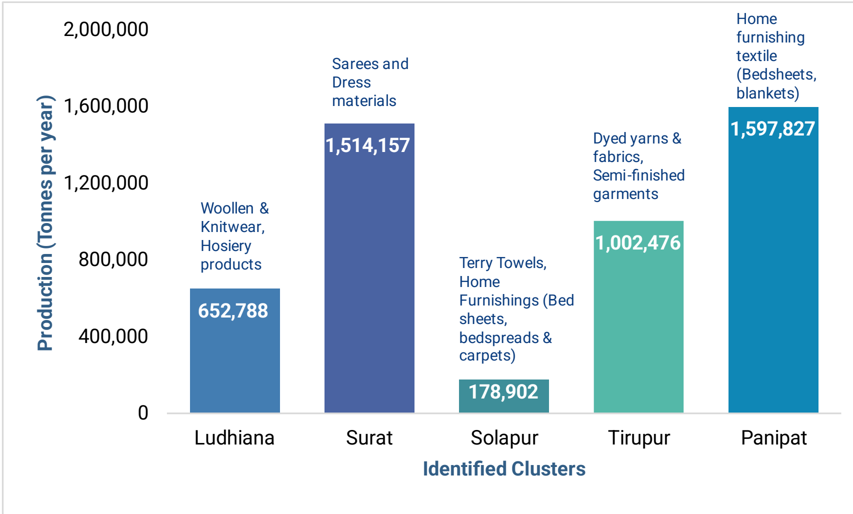


Figure 9: Cluster wise major products and production profile for Textile sector

2.3 Manufacturing Process and Technology Status

Textile manufacturing in India is a multifaceted industry that encompasses a diverse range of processes, with each stage tailored to the specific products being produced. These processes typically include fiber production, yarn manufacturing, fabric production, pre-treatment, dyeing and printing, and finishing treatments. The intricacies of the manufacturing process, as well as the technologies and equipment employed within the textile units, are of particular importance, especially within the Micro, Small, and Medium Enterprises (MSME) sector. In this context, it's crucial to delve into the details of the manufacturing methods, machinery, and technologies utilized in these units to gain a comprehensive understanding of the textile industry's dynamics in India. To provide a more in-depth insight into this, this section presents a comprehensive overview of the manufacturing processes and equipment in the MSME textile sector.

2.3.1 Knitwear and Hosiery Products

Indian knitwear has a substantial economic and employment impact on the nation. The key knitwear clusters include Ludhiana in Punjab, Tirupur in Tamil Nadu, Delhi, Bangalore, and Mumbai. Knitting is the second largest fabric production technique used in the world after woven fabric.

2.3.1.1 Manufacturing Process

The manufacturing process of knitwear involves yarn testing and feeding, yarn dyeing, knitting, inspection and dispatch.

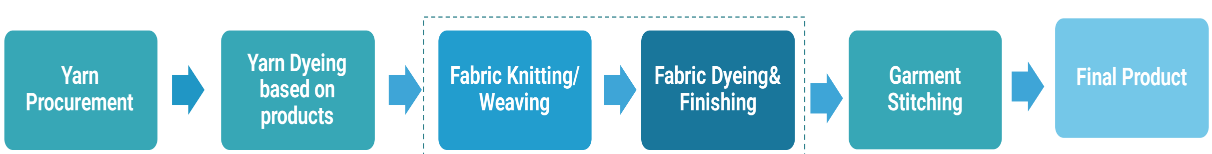


Figure 10: Manufacturing Process

Yarn Testing and Feeding: The yarn purchased from the manufacturers is first tested to see if it is as per the desired properties. It is then placed in the machine and then into the creel of the machine. After this, the yarn is fed into the yarn feeder through an inching motion.

Yarn Dyeing: Pre-treatment of the yarn includes scouring and bleaching processes where yarn hanks are hung on rotating cylinders and treated with chemical agents to remove natural fats, waxes, and unwanted impurities. Later, for dyeing, salt is added to the dyeing bath and temperature of 60°C with a pH of 6 is maintained for 20 minutes. Further, dye is added at a temperature of 60°C, kept for 20 minutes, and then dyeing is done at 60°C for 1 hour. Batch time for dyeing is approximately 4-5 hours. Then yarn hanks are washed with soaping agent and freshwater to remove the unfixed dye color from the yarn and then treated with mild acetic acid and fixing agent. Yarn hanks are unloaded from the dyeing machine and placed in hydroextractor to remove the excess water. When the machine rotates, the maximum amount of water is eliminated from yarn due to centrifugal forces developed in the machine.

Yarn Drying and Winding: The yarn hanks are placed in the hot air chamber of the tumble dryer machine for about 40 minutes where the heating temperature is kept around 105 – 110°C. The yarn hanks after getting dried are inspected and then converted into cones through cone winding machine for ease of use in the fabric manufacturing units. The cones are then dispatched for weaving or knitting units for fabric production.

Knitting: Then as per the order requirement, fabric design and stitch length are checked. Once found satisfactory, the knitting machine is set up as per the design and GSM and knitting starts.

Inspection & Dispatch: After the knitting step completion, the fabric roll is withdrawn and weighed. Further, the quality department inspects the fabric and numbers the roll of the fabric as per grading. Finally, the fabric is dispatched for dyeing and finishing.

2.3.1.2 Technology and Equipment Used

The main process equipment in the knitwear and hosiery units are soft flow machine, and stenter machine. The other utility equipment includes steam boilers and auxiliaries, TFH, air compressors, pumps, electric motors and lighting equipment.

Soft Flow Machine: The textile industry units use soft flow dyeing machines to process the grey fabric. It is suitable for dyeing a wide range of knitted and woven fabric in rope form, including dyeing of lightweight woven fabrics and pile fabrics. In the dyeing machine, water is used for keeping the fabric in circulation. The soft flow dyeing machines provide significant savings in processing time and result in 50% savings in water. The maximum working temperature of these machines is around 140-150ºC. The machine uses steam of about 2 to 6 kg/cm^2 pressure and compressed air of 5 to 7 kg/cm^2 pressure.

Figure 11: Soft Flow Machine

Stenter machine: The Stenter machine represents a vital component in the textile finishing process, primarily employed for the application of heat or stretching of fabrics. It comprises two endless chains, meticulously auto lubricated, which typically span a considerable length ranging from 20 to 60 meters. These chains are equipped with pins or clips designed to secure the edges of the fabric as it progresses through a series of hot-air chambers, typically numbering between 3 to 8, each with an approximate length of 3 meters. These chambers play a pivotal role in the heat treatment process, featuring precise temperature control mechanisms at the chamber level, which encompass both heating and cooling functions. This controlled heat application serves various finishing purposes, enhancing the fabric's characteristics and quality. Typically, the heating element elevates the fabric's temperature from approximately 130°C to 180°C, a transformation achieved through methods like heat exchange facilitated by hot oil circulation or direct fuel combustion. This meticulous control over temperature and the uniformity of the process ensures that the textile materials undergo the desired finishing treatment, meeting the required quality standards in the textile industry.

Figure 12: Stenter

Steam Boilers: Steam boilers are extensively used in major stages of processing in textile manufacturing ranging from pre-processing of textiles, dyeing, and printing to finishing of textiles as they require steam and hot water generated from the boilers in one way or another. The selection of a steam boiler is based on the heating load (for obtaining the capacity of the boiler), boiler heating parameters, and its efficiency calculations. The units generally employ solid fuel-fired boilers using agro-residue or petcoke as fuel with a capacity ranging from 5 to 8 TPH (tonnes per hour).

Figure 13: Steam Boiler

2.3.2 Saree and Dress material

Sarees and dress materials are predominantly manufactured within specialized clusters located in regions such as Surat, Bhagalpur, Santipur, and Bargarh. Among these, Surat stands out as the largest textile hub in India, boasting a staggering production output of over 40 million meters of fabric per day. Bhagalpur, on the other hand, has gained renown for its exquisite silk sarees and dress materials, particularly the coveted tussar silk variety. In Santipur, a traditional handloom cluster situated in West Bengal, artisans craft cotton and silk sarees and dress materials distinguished by their employment of fine count yarns and intricate designs. Meanwhile, Bargarh, a prominent weaving cluster in Odisha, specializes in the creation of Sambalpuri sarees and dress materials, employing techniques such as tie-dye or ikat to produce these distinctive and highly sought-after textiles.

2.3.2.1 Manufacturing Process

The production of sarees and synthetic dress materials involves dyeing and printing of the grey fabric obtained from different sources.

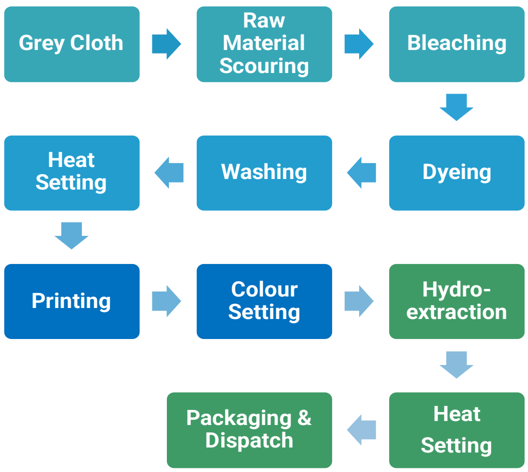


Figure 14: Manufacturing Process

Scouring: Scouring is used to remove natural or acquired impurities like oil, dirt, wax, and grease from fabric making it cleaner and more absorbent. It is usually done by adding mild soaping agent or detergent.

Bleaching: Cloth material undergoes bleaching, a process of fabric whitening to remove natural color such as tan of linen and thus facilitating the dyeing process. Initially, the jet dyeing machines are filled with the required quantity of water and after attaining the required temperature the fabric is loaded. Thereafter, the required chemicals for bleaching like hydrogen peroxide and brightening agent are added. The water is completely drained after the process is completed.

Shrinking: Fabric after getting bleached is passed through drum washer machine where it is shrunk to reduce the bulkiness to stabilize dimension of fabric that is attaining the required size and thickness of the fabric. The process is carried out in high temperature and pressure closed vessels that contain the bleaching agent.

Dyeing: Jet dyeing is basically employed. The temperature of the solution is raised to 50°C and concentrated dyestuff solution (prepared separately) is added to the liquor. After the addition of dyeing agent, the temperature is raised to 130°C and maintained for about 1 hour.

Washing: After the fabric is dyed, washing is done in the drum washer machines. The fabric is given hot and cold-water baths in the machine in batches with each batch duration of approximately 8-10 minutes. After this, heat setting of the fabric is done using stenter at temperature of about 120-130°C to make it suitable for printing.

Printing: Printing is carried out by mechanized screen-printing process which is flat bed printing and rotary printing. Also, hand printing though it is an old method but is used in some units for carrying out printing process.

Colour Setting: Fabric is inspected and passed through loop machines which is maintained at 130°C – 170°C for better colour setting. The fabric is then washed in series of normal water and hot water baths in presence of chemicals for colour setting.

Hydro-extraction & Heat Setting: Fabric is passed through hydro-extractors for removing excess water. Then after this, heat setting of fabric is done to restore the fabric's width using stenters at temperature of 150-180°C. After this, fabric is finally packaged for transportation to go into stitching process.

2.3.2.2 Technology and Equipment Used

The main process equipment in the saree and dress material manufacturing units are Jet dyeing machine, Stenter machine and drum washer. The other utility equipment includes steam boilers and auxiliaries, TFH, air compressors, pumps, electric motors and lighting equipment.

Figure 15: Jet Dyeing machine

Jet dyeing machine: Jet dyeing machine is used mainly for polyester fabric dyeing with disperse dyes. The fabric movement in the machine occurs only due to water or liquor force. A jet of dye liquor is pumped out from the annular ring through which a rope of fabric passes in a tube called venturi. The venturi tube has a constriction, so the force of the dye liquor passing through it pulls the fabric with it from the front to the back of the machine. Thereafter the fabric rope moves slowly in folds round the machine and then passes through the jet again. The units usually use jet dyeing machine for dyeing with 130°C to 140°C operating temperature and 2.5 to 3.5 kg/cm^2 operating steam pressure and 3 to 4 kg/cm^2 operating air pressure.

Long Jet Dyeing Machine:

Drum washers: Drum washing machines are used for pre-shrinking of fabric done in pre-treatment process and in washing process after the dyeing. The parameters of the machine include 130°C to 140°C operating temperature and 2.5 kg/cm^2 operating pressure and batch time of 8-10 minutes.

2.3.3 Semi-finished textile products

Semi-finished textile includes the production process of different textile product types including dyed yarns, dyed fabrics, and printed fabrics.

2.3.3.1 Manufacturing Process

The production of semi-finished textile products involves steps of scouring, washing, bleaching, dyeing, hot & cold washing, unloading, centrifuge, heat setting, packaging and dispatch as discussed below.

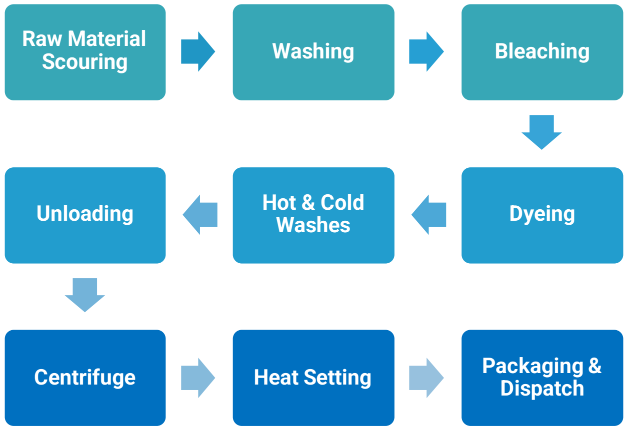


Figure 16: Manufacturing Process

Scouring: Scouring is used to remove natural or acquired impurities like oil, dirt, wax, and grease from fabric making it cleaner and more absorbent. It is usually done by adding mild soaping agent or detergent.

Bleaching: Cloth material undergoes bleaching, a process of fabric whitening to remove natural color such as tan of linen and thus facilitating the dyeing process. Initially, the jet dyeing machines are filled with the required quantity of water and after attaining the required temperature the fabric is loaded. Thereafter, the required chemicals for bleaching like hydrogen peroxide and brightening agent are added. The water is completely drained after the process is completed.

Dyeing: The temperature of the solution in the soft flow machine is raised to 50°C and concentrated dyestuff solution (prepared separately) is added to the liquor. After the addition of the dye, the temperature is raised to 90°C and is maintained at that temperature for about 60 minutes.

Hot and Cold wash: Four rounds of cold washes and four hot water washes are carried out for each batch. **Centrifuge and heat-setting:** After completion of the process, the fabric is unloaded and loaded in the centrifuges for removal of water and is taken to the folding and rolling machines for improving the width of cloth which gets shrunk during the washing and dyeing process. Then fabric is taken for heat setting. **Compacting Process:** Compacting is the process of mechanically compressing fabrics in the lengthwise direction in order to reduce the fabric's propensity to shrink during consumer usage. Additionally, the process of compacting causes an increase in the thickness and areal density of the fabric as well as a decrease in the overall yardage of the fabric.

2.3.3.2 Technology and Equipment Used

The main process equipment is soft flow dyeing machine and stenter machine. The other utility equipment includes steam boilers and auxiliaries, TFH, air compressors, pumps, electric motors and lighting equipment.

Soft Flow Machine: The textile industry units use soft flow dyeing machines to process the grey fabric. It is suitable for dyeing a wide range of knitted and woven fabric in rope form, including dyeing of lightweight woven fabrics and pile fabrics. In the dyeing machine, water is used for keeping the fabric in circulation. The soft flow dyeing machines provide significant savings in processing time and result in 50% savings in water. The maximum working temperature of these machines is around 140-150ºC. The machine uses steam of about 2 to 6 kg/cm^2 pressure and compressed air of 5 to 7 kg/cm^2 pressure.

Figure 17: Soft Flow Machine

Stenter machine: A Stenter machine is used for heat application or stretching the fabrics. It consists of two endless auto-lubricated driven chains, typically 20 to 60 m in length carrying pins or clips to hold the fabric edges while passing through a number of hot-air chambers (3–8, each of about 3 m). The heat treatment units associated with each chamber with chamber-level temperature control mechanisms including heating and cooling operate for finishing purposes. Usually, the heater heats the fabric from 130°C to 180°C (using heat exchange with hot oil circulation or direct fuel combustion).

Figure 18: Stenter

Steam Boilers: Steam boilers are extensively used in major stages of processing in textile manufacturing ranging from pre-processing of textiles, dyeing, and printing to finishing of textiles as they require steam and hot water generated from the boilers in one way or another. The selection of a steam boiler is based on the heating load (for obtaining the capacity of the boiler), boiler heating parameters, and its efficiency calculations. The cluster units employ solid fuel-fired boilers using firewood as fuel with a capacity ranging from 2 to 8 TPH (tonnes per hour).

Figure 19: Steam Boiler

2.3.4 Terry-towel and Home Furnishing

Home-furnishing including bed sheets and bedspreads along with the terry towels are produced in clusters such as Panipat, Solapur and Erode.

2.3.4.1 Manufacturing Process

The main process operations for production of towels and bed sheets in Solapur cluster are as follows:

Doubling: In the Doubling process thin single yarn is converted to double yarn for strengthening the yarn by using doubling machine. Prior to twisting, the doubler winding machine's primary function is to wound two or more ends on a package. Additionally, the doubler winding machine needs to have a tensioning mechanism that makes sure the ends are uniformly taut before being wound into a cheese or cone.

Yarn dyeing: To eliminate dirt and other foreign contaminants, the yarn is first steeped in soap water for 24 hours before being taken to be bleached. The yarn is bleached by soaking it in bleaching agent-mixed tanks. The bleaching process is finished, and then the yarn is washed in regular water.

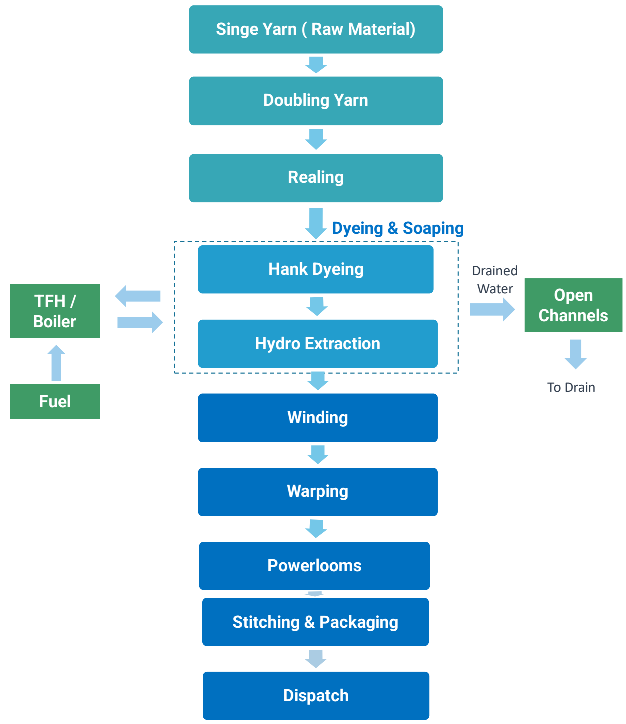


Figure 20: Manufacturing Process

The necessary amount of water, chemicals, and colouring ingredients are poured into the tanks of the hank dyeing machine. Either oil circulation or direct steam infusion raises the water's temperature. Fuel for a fire is wood. The yarn is coloured as needed, and each batch of dyeing takes between 90 and 120 minutes. The necessary dyeing temperature varies the colours, and the following information provides specifics on the temperatures needed for different kinds of colours.

After dyeing, the yarn is washed with normal water, and the yarn is taken for soaping for color fixation in hot water for about 20 minutes in hank dyeing machines. The water is drained to the waste drainage lines. The wet yarn is taken to hydro extractors for removing water in the yarn and taken for drying in the natural sunlight.

Winding & Warping: The yarn after drying is taken for winding in which the yarn is wounded to bobbins and cones. The winded yarn is taken for further process which is warping. Warping is the process of winding yarn to beams in accordance with a predetermined pattern (custom designs). The beams are then removed for weaving.

Weaving: The yarn-wound beams are taken and set into power looms with the predetermined design pattern. The yarn is transformed into the finished product (a towel or cheddar) on power looms through weaving. The finished weaving is then taken for packing and sewing.

2.3.4.2 Technology and Equipment Used

The main process equipment is soft flow dyeing machine and Stenter machine. The other utility equipment includes steam boilers and auxiliaries, TFH, air compressors, pumps, electric motors and lighting equipment.

Soft Flow Machine: The textile industry units use soft flow dyeing machines to process the grey fabric. It is suitable for dyeing a wide range of knitted and woven fabric in rope form, including dyeing of lightweight woven fabrics and pile fabrics. In the dyeing machine, water is used for keeping the fabric in circulation. The soft flow dyeing machines provide significant savings in processing time and result in 50% savings in water. The maximum working temperature of these machines is around 140-150ºC. The machine uses steam of about 2 to 6 kg/cm^2 pressure and compressed air of 5 to 7 kg/cm^2 pressure.

Figure 21: Soft Flow Machine

Stenter machine: A Stenter machine is used for heat application or stretching the fabrics. It consists of two endless auto-lubricated driven chains, typically 20 to 60 m in length carrying pins or clips to hold the fabric edges while passing through a number of hot-air chambers (3–8, each of about 3 m). The heat treatment units associated with each chamber with chamber-level temperature control mechanisms including heating and cooling operate for finishing purposes. Usually, the heater heats the fabric from 130°C to 180°C (using heat exchange with hot oil circulation or direct fuel combustion).

Figure 22: Stenter

Steam Boilers: Steam boilers are extensively used in major stages of processing in textile manufacturing ranging from pre-processing of textiles, dyeing, and printing to finishing of textiles as they require steam and hot water generated from the boilers in one way or another. The selection of a steam boiler is based on the heating load (for obtaining the capacity of the boiler), boiler heating parameters, and its efficiency calculations. The Solapur cluster units employ solid fuel-fired boilers using firewood as fuel with a capacity ranging from 2 to 5 TPH (tonnes per hour).

Figure 23: Steam Boiler

3. Cluster Level Energy Consumption

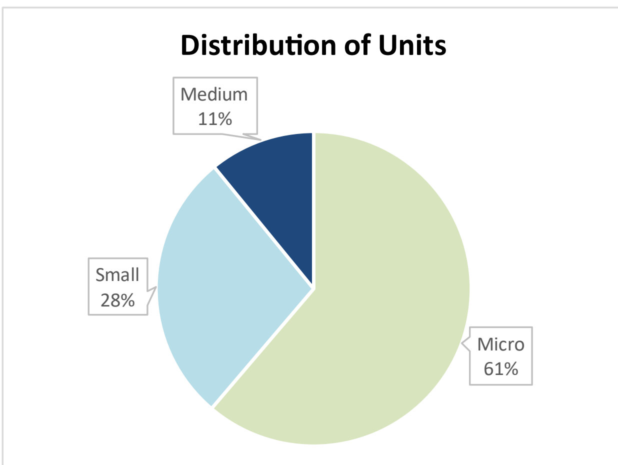
Each textile cluster is characterized by its products & production processes, technologies, energy forms, etc. This section provides details of cluster level production, cumulative energy consumption, energy share, key performance indicators (mainly specific energy consumption), and greenhouse gas (GHG) emissions for all the clusters covered under the project.

3.1 Identified MSME clusters

The five targeted textile MSME clusters covered under the project are Ludhiana, Panipat, Surat, Solapur, and Tirupur. Further, the project includes five additional MSME clusters based on cluster visits, secondary data, and interactions held with key stakeholders.

3.1.1 Ludhiana Textile Cluster

Ludhiana is a knitwear and hosiery producing cluster located in the state of Punjab. There are about 294 textile units in the cluster. The annual estimated production of the cluster is about 0.65 million tonnes per year. The products and production profile of the cluster during the assessment year is given below.



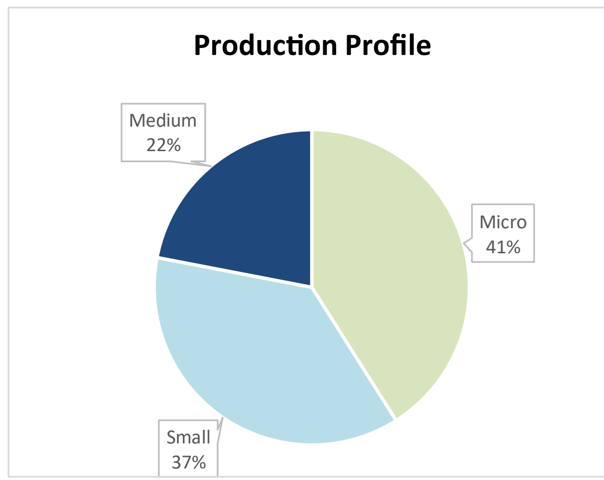


Figure 24: Distribution of MSME Units and their production wise share

Annual production estimated from the Ludhiana textile cluster is 6,52,788 tonnes and is dominated by the micro segment (180 units) with 2,67,780 tonnes of production per annum. This is followed by the small enterprises segment (82 units) with annual production of 2,41,552 tonnes and the rest is catered by medium segment having 32 units and 1,43,456 tonnes of annual production.

Cluster uses thermal energy majorly (93%) and electrical energy accounts for only 7%. In terms of thermal energy, cluster uses wood, pet coke, and agro-residue in steam boilers and thermic fluid heaters as a fuel and HSD for backup power generation. The thermal energy consumption corresponds to 3,15,717 toe per annum. Cluster consumes around 22,931 toe of electrical energy which is sourced from grid and is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

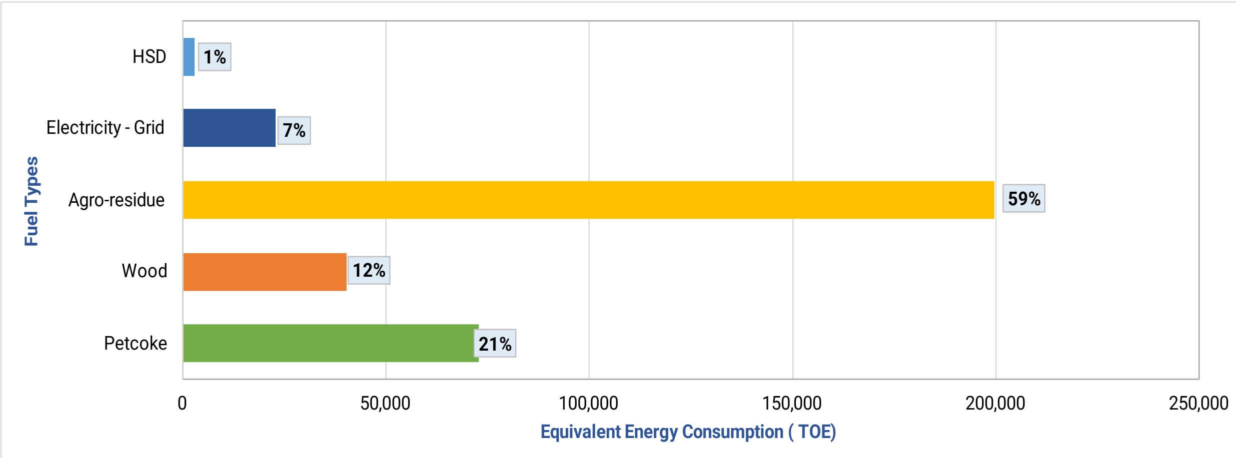


Figure 25: Fuel wise energy share

The cumulative annual energy consumption of about 294 dyeing units of the Ludhiana textile cluster in the year 2022 is estimated to be 3,38,647 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 5,19,861 tonnes of CO_2 equivalent. Table 3 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.

Table 2: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Petcoke	tonne/year	87,260	72,775	2,95,463
Wood	tonne/year	1,08,199	40,315	Carbon neutral fuel
Agro-Residue	tonne/year	5,57,419	1,99,723	
HSD	kl/year	3,322	2,903	8,424
Electricity - Grid	Million kWh/year	267	22,931	2,15,974
Total			**3,38,647**	**5,19,861**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 3: Key Performance Indicators

Specific Energy Consumption			
Type of unit	Electrical Energy (toe/tonne)	Thermal Energy (toe/tonne)	Overall SEC (toe/tonne)
Micro	0.03	0.53	0.56
Small	0.04	0.46	0.50
Medium	0.04	0.43	0.47
Cumulative SEC	**0.04**	**0.48**	**0.52**

The specific energy consumption levels of the Ludhiana cluster are in the range of 0.56, 0.50 and 0.47 for Micro, Small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 0.30, 0.95 and 1.46 for Micro, Small and Medium Enterprises respectively.

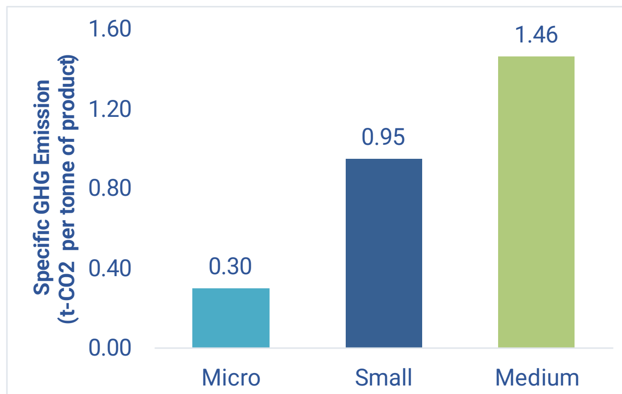
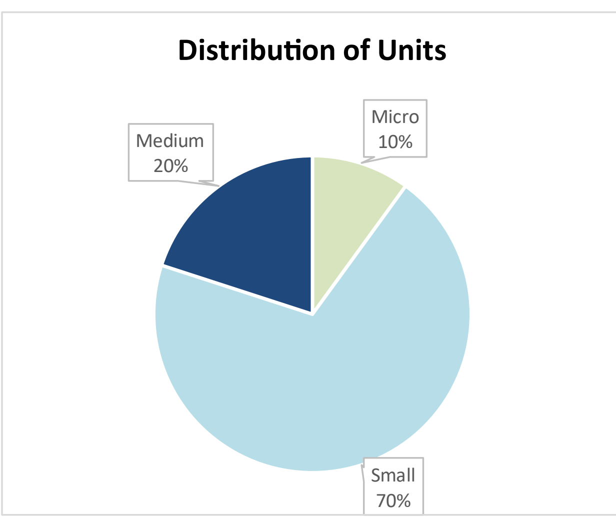


Figure 26: Specific GHG Emission

3.1.2 Tirupur Textile Cluster

The town of Tirupur is situated near Coimbatore, in Tamil Nadu is an important textile cluster in India. The Tirupur cluster consists of the wet-processing units of both the Tirupur and the Perundurai SIPCOT areas.



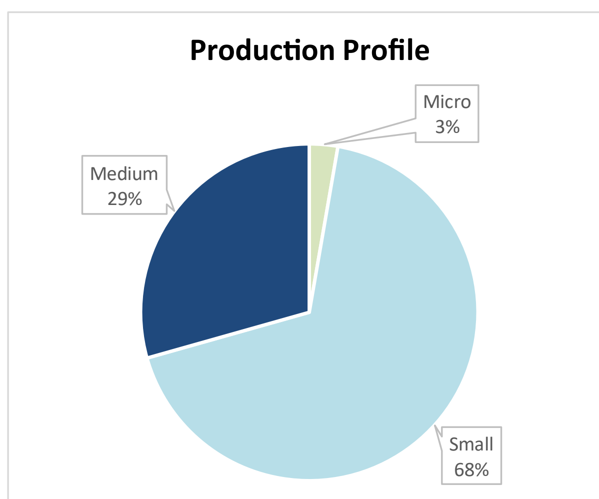


Figure 27: Distribution of MSME Units and their production wise share

There are about 360 and 50 textile wet-processing units operational in Tirupur and Perundurai respectively. The products and production profile of the cluster during the assessment year is given in Figure 27.

Annual production estimated from the Tirupur textile cluster is 10,02,476 tonnes and is dominated by the small segment (287 units) with 6,80,579 tonnes of production per annum. This is followed by the medium enterprises segment (82 units) with annual production of 2,94,547 tonnes and the remaining is constituted by the micro segment having 41 units and 27,350 tonnes of annual production.

Cluster uses thermal energy majorly (88%) and electrical energy accounts for only 12%. In terms of thermal energy, cluster uses wood, HSD, and LPG, as a fuel and it corresponds to 11,42,598 toe per annum. Cluster consumes around 1,55,322 toe of electrical energy is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

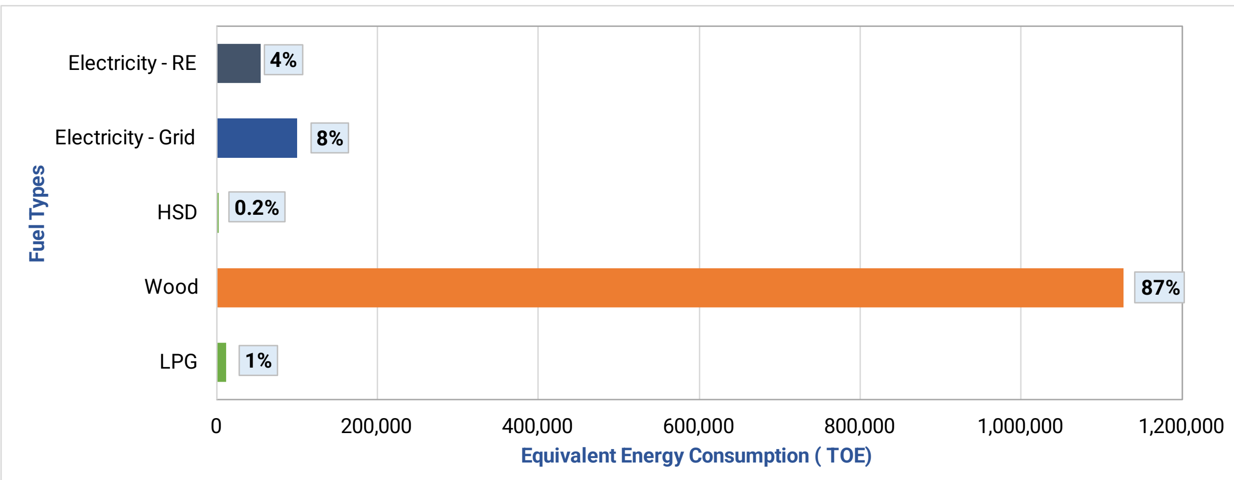


Figure 28: Fuel wise energy share

The cumulative annual energy consumption of about 410 units of the Tirupur textile cluster is estimated to be 12,97,919 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 9,83,970 tonnes of CO_2 equivalent. Table 5 represents the total annual energy consumption and GHG emissions caused by different types of energy sources utilized by the wet processing units of the cluster.

Table 4: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Wood	tonne/year	30,24,833	11,27,053	Carbon neutral fuel
HSD	kl/year	3,652	3,191	9,261
LPG	tonne/year	10,935	12,353	32,641
Electricity – Grid	Million kWh/year	1,163	1,00,022	9,42,068

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Electricity – RE	Million kWh/year	643	55,300	NA
Total			12,97,919	9,83,970

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 5: Key Performance Indicators

Specific Energy Consumption			
Type of unit	Electrical Energy (toe/tonne)	Thermal Energy (toe/tonne)	Overall SEC (toe/tonne)
Micro	0.03	0.52	0.55
Small	0.19	1.25	1.44
Medium	0.09	0.93	1.02
Cumulative SEC	**0.15**	**1.14**	**1.29**

The specific energy consumption levels of the Tirupur cluster are in the range of 0.55, 1.44 and 1.02 for Micro, Small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 0.26, 1.17 and 0.61 for Micro, Small and Medium Enterprises respectively.

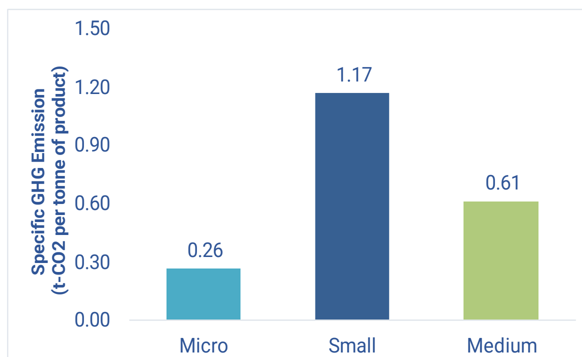


Figure 29: Specific GHG Emission

3.1.3 Surat Textile Cluster

Surat is a saree and dress material producing cluster located in the state of Gujarat. There are about 400 textile units. The total estimated production of the cluster is about 1.5 million tonnes per year from January to December 2022. The products and production profile of the cluster during the assessment year is given below.

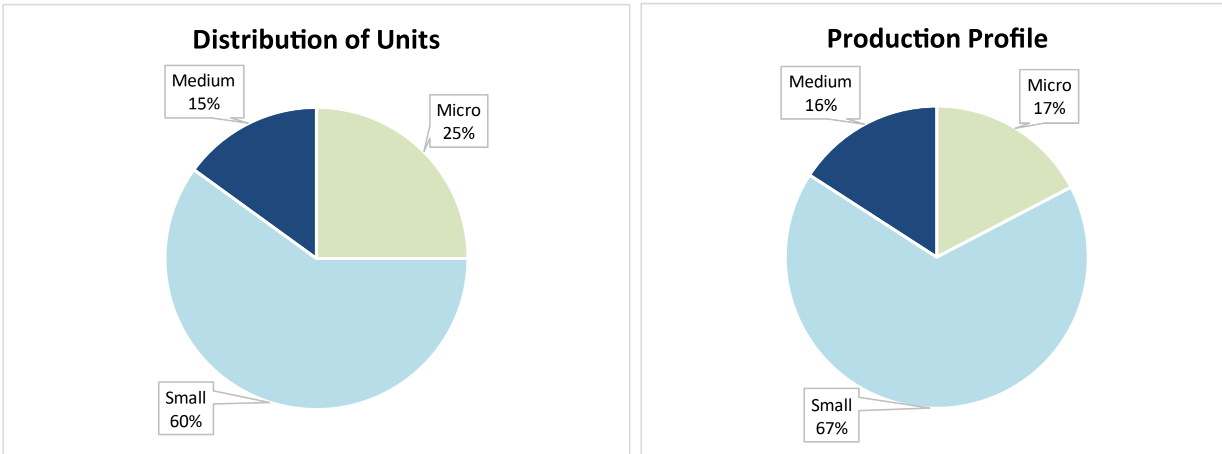


Figure 30: Distribution of MSME Units and their production wise share

The Surat textile cluster's estimated annual production is a substantial 1,514,157 tonnes. Within this cluster, the small-scale sector, represented by 240 units, takes the lead by contributing a noteworthy 10,16,187 tonnes to the annual production figures. Following closely behind is the micro-enterprise segment, consisting of 100 units, which collectively produces 2,56,734 tonnes per year. The remaining share of production is fulfilled by the medium-scale enterprises, comprising 60 units and contributing 2,41,237 tonnes to the annual production output.

Cluster uses thermal energy majorly (95%) and electrical energy accounts for only 5%. In terms of thermal energy, cluster uses wood, agro-residue, imported coal, lignite as fuel, HSD, and PNG, and it corresponds to 27,95,183 toe per annum. Cluster consumes around 151,107 toe of electrical energy (Grid and RE based) and is being used for running jet dyeing machine, stenter, air compressors, motors, water circulation and process pumps.

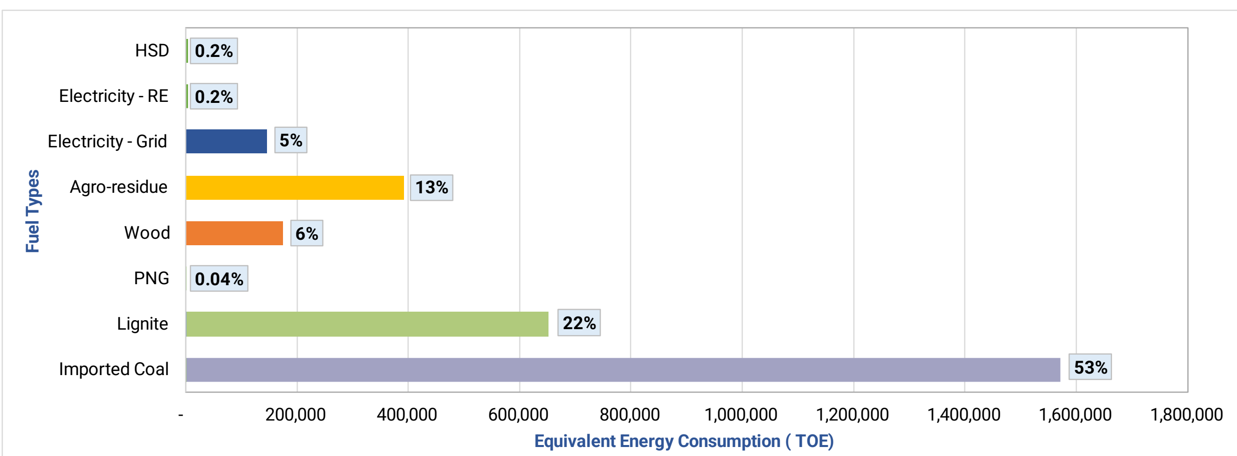


Figure 31: Fuel wise Energy share

In the year 2022, the collective annual energy consumption of approximately 400 units within the Surat textile cluster is projected to reach a substantial figure of 29,46,290 toe. Alongside this energy consumption, the corresponding GHG emissions generated by these cluster units are estimated to be a considerable 1,11,47,947 tonnes of CO_2 equivalent. Detailed data concerning the total annual energy consumption and GHG emissions attributed to the varied energy sources employed by the wet processing units within the cluster can be found in Table 7, providing a comprehensive breakdown of this critical environmental and energy-related information.

Table 6: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Imported Coal	tonne/year	39,26,685	15,70,674	71,30,859
Lignite	tonne/year	14,43,184	6,51,453	26,20,823
PNG	Million SCM /year	1.12	1,160	2,286
Agro-residue	tonne/year	10,94,120	3,92,023	Carbon Neutral Fuel
HSD	kl/year	5,349	4,675	13,564
Wood	tonne/year	4,70,203	1,75,198	Carbon Neutral Fuel
Electricity – Grid	Million kWh/year	1,704	1,46,563	13,80,414
Electricity – RE	Million kWh/year	53	4,544	Carbon Neutral
Total			**29,46,290**	**1,11,47,947**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 7: Key Performance Indicators

Specific Energy Consumption			
Type of unit	**Electrical Energy (toe/tonne)**	**Thermal Energy (toe/tonne)**	**Overall SEC (toe/tonne)**
Micro	0.10	1.77	1.87
Small	0.10	1.78	1.88
Medium	0.09	2.20	2.29
Cumulative SEC	**0.10**	**1.85**	**1.95**

The Surat cluster exhibits specific energy consumption levels that fall within a distinct range. For Micro, Small, and Medium Enterprises, these values stand at 1.87, 1.88, and 2.29, respectively. Additionally, the GHG emission indicators are articulated in the form of specific GHG emissions, quantified as tonnes of CO_2 emitted per tonne of product. Within this context, the values differ among the different enterprise scales, with respective figures of 8.83, 7.52, and 5.13 for Micro, Small, and Medium Enterprises.

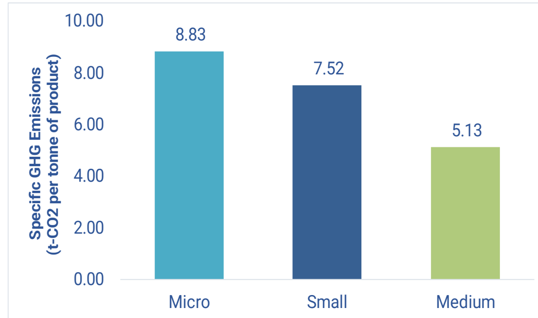


Figure 32: Specific GHG Emission

3.1.4 Solapur Textile Cluster

Solapur City in Maharashtra hosts a textile industry cluster that is well known for its cotton bed sheets (chaddars) and towels. There are about 700 textile units in the cluster. The total estimated production of the cluster is about 0.18 million tonnes per year from January to December 2022. The products and production profile of the cluster during the assessment year is given below.

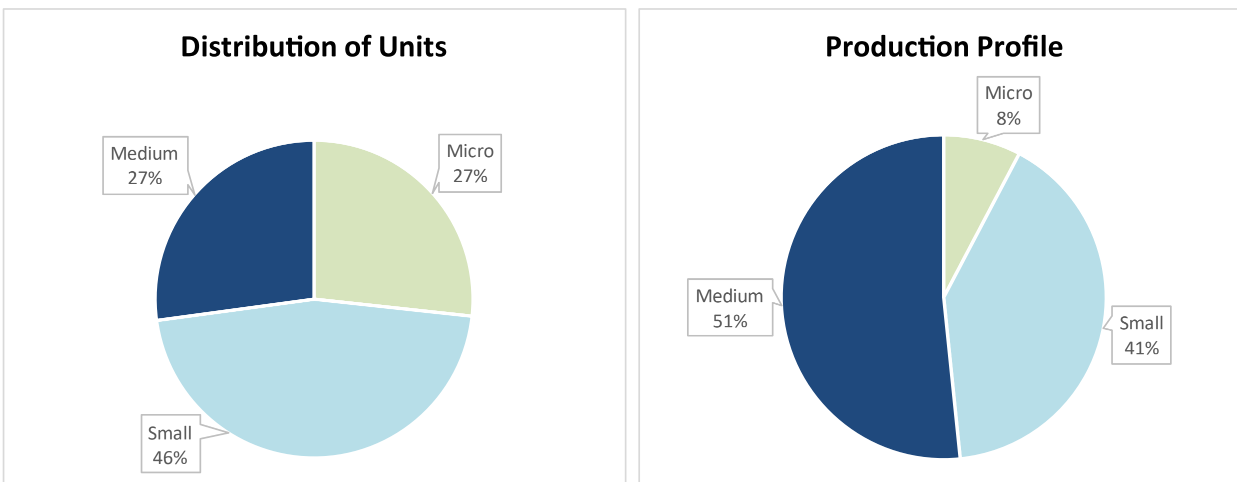


Figure 33: Distribution of MSME Units and their production wise share

Annual production estimated from the Solapur textile cluster is 178,902 tonnes and is dominated by the medium enterprises segment (190 units) with annual production of 92,356 tonnes. This is followed by the small segment (323 units) with 72,753 tonnes of production per annum and rest is catered by micro segment having 187 units with 13,793 tonnes of annual production.

Cluster uses thermal energy majorly (81%) and electrical energy accounts for only 19%. In terms of thermal energy, cluster uses wood in steam boilers and thermic fluid heaters as a fuel and it corresponds to 48,748 toe per annum. Cluster consumes around 11,795 toe of electrical energy and is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

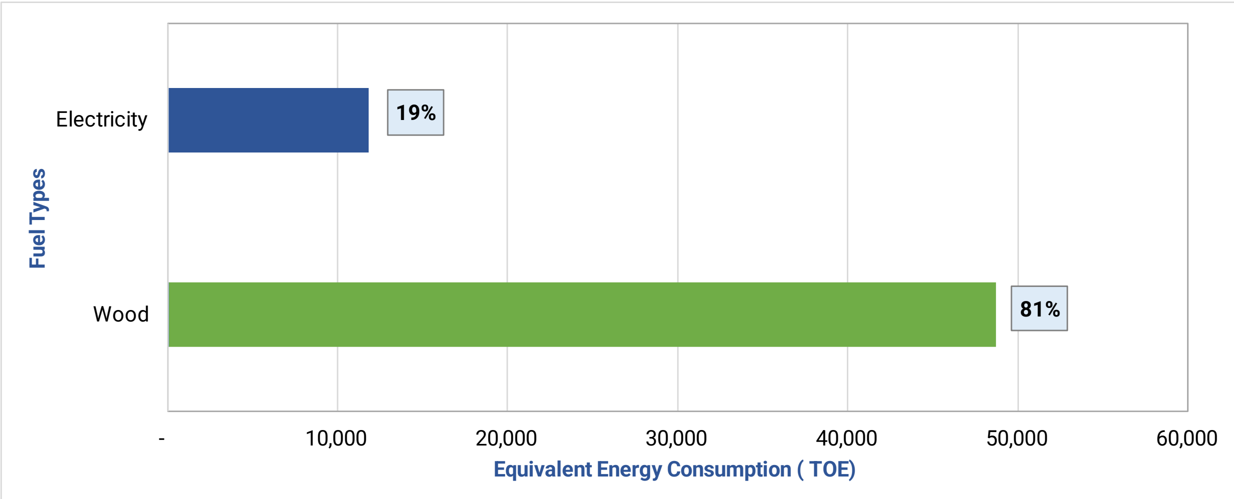


Figure 34: Fuel wise Energy share

The cumulative annual energy consumption of about 700 dyeing units of the Solapur textile cluster in the year 2022 is estimated to be 60,542 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 1,11,088 tonnes of CO_2 equivalent. Table 9 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.

Table 8: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Wood	tonne/year	1,30,831	48,748	Carbon neutral fuel
Electricity	Million kWh/year	137	11,795	1,11,088
Total			**60,542**	**1,11,088**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 9: Key Performance Indicators

Specific Energy Consumption			
Type of unit	Electrical Energy (toe/tonne)	Thermal Energy (toe/tonne)	Overall SEC (toe/tonne)
Micro	0.04	-	0.04
Small	0.05	0.12	0.17

Medium	0.08	0.43	0.52
Cumulative SEC	**0.07**	**0.27**	**0.34**

The specific energy consumption levels of the Solapur cluster are in the range of 0.04, 0.17 and 0.52 for Micro, small and Medium Enterprises respectively.

Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 0.42, 0.47 and 0.77 for Micro, Small and Medium Enterprises respectively.

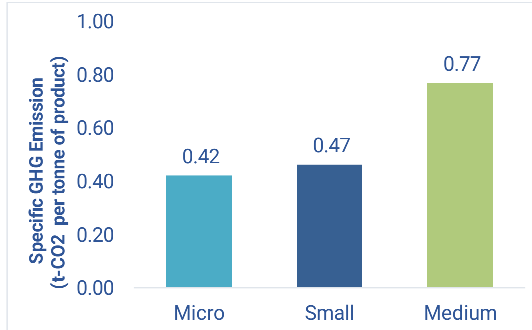
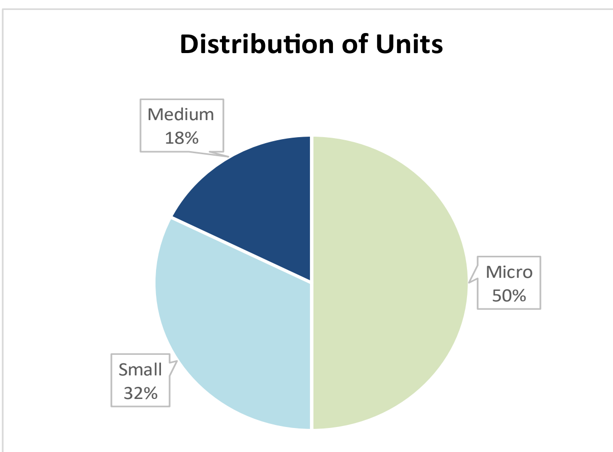


Figure 35: Specific GHG Emission

3.1.5 Panipat Textile Cluster

Panipat is an important industrial location of Haryana and is known to be the city of handlooms and an international home furnishing textile hub in India. There are about 850 textile units in the cluster. The total estimated production of the cluster is about 1.6 million tonnes per year from January to December 2022. The products and production profile of the cluster during the assessment year is given below.



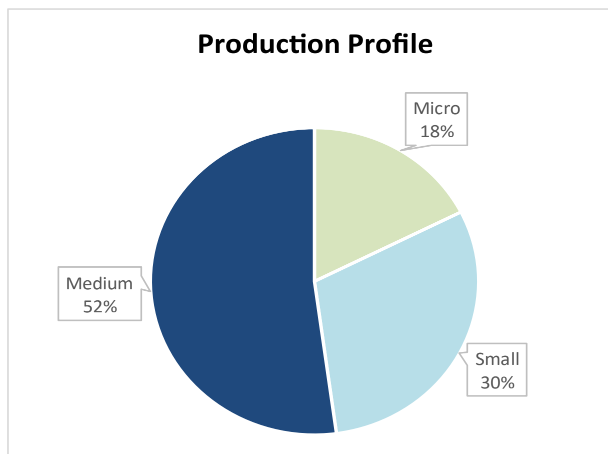


Figure 36: Distribution of MSME Units and their production wise share

Annual production estimated from the Panipat textile cluster is 15,97,827 tonnes and is dominated by the medium segment (150 units) with 8,33,061tonnes production per year. This is followed by the small enterprises segment (275 units) with annual production of 4,84,413 tonnes and rest is catered by micro enterprises segment (425 units) with 2,80,353 tonnes of annual production.

Cluster uses thermal energy majorly (85%) and electrical energy accounts for only 15%. In terms of thermal energy, cluster uses agro-residue in steam boilers and thermic fluid heaters as a fuel and it corresponds to 9,15,796 toe per annum. Cluster consumes around 1,60,816 toe of electrical energy and is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps

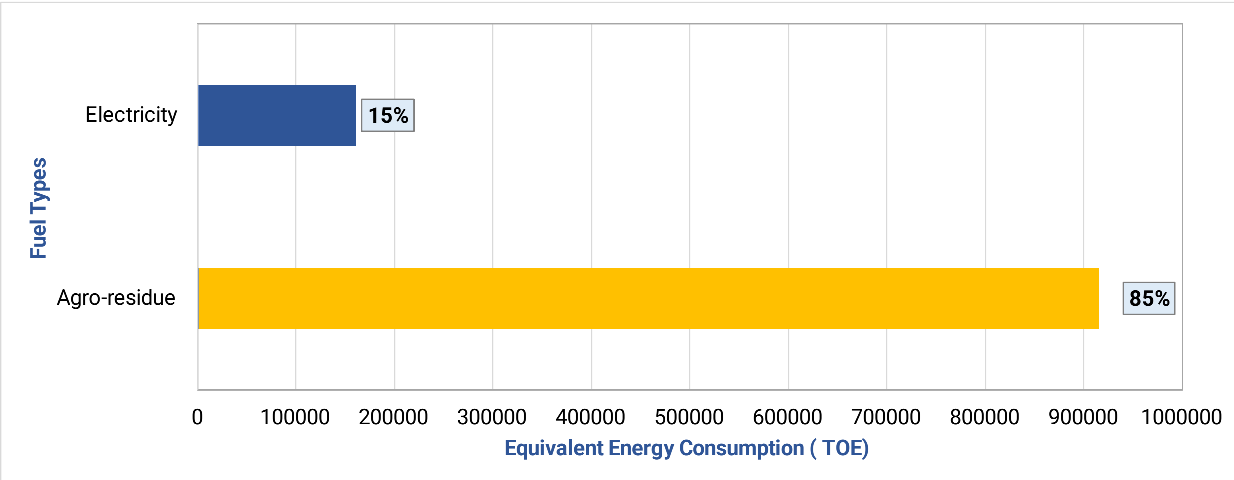


Figure 37: Fuel wise energy share

The cumulative annual energy consumption of about 850 dyeing units of the Panipat textile cluster in the year 2022 is estimated to be 10,76,612 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 15,14,666 tonnes of CO_2 equivalent. Table 11 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.

Table 10: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Agro-residue	tonne/year	25,55,947	9,15,796	Carbon neutral fuel
Electricity	Million kWh/year	1,870	1,60,816	15,14,666
Total			**10,76,612**	**15,14,666**

Key Performance Indicators: The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 11: Key Performance Indicators

Specific Energy Consumption			
Type of unit	**Electrical Energy (toe/tonne)**	**Thermal Energy (toe/tonne)**	**Overall SEC (toe/tonne)**
Micro	0.28	2.37	2.65
Small	0.03	0.38	0.41
Medium	0.08	0.08	0.16
Total	**0.10**	**0.57**	**0.67**

The specific energy consumption levels of the Panipat cluster are in the range of 2.65, 0.41 and 0.16 for Micro, small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 2.62, 0.25 and 0.79 for Micro, Small and Medium Enterprises respectively.

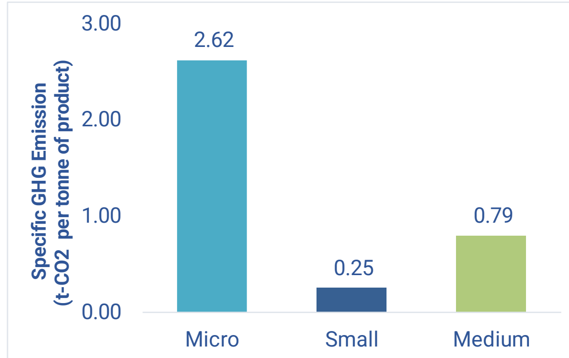


Figure 38: Specific GHG emission

3.2 Additional Cluster Information

Beyond the primary focus on the five initially identified textile MSME clusters, the project extends its reach to encompass five more clusters. These selections are made through a rigorous assessment process that takes into account multiple factors, including the availability of secondary data, on-site visits, and extensive interactions with key stakeholders in the textile industry.

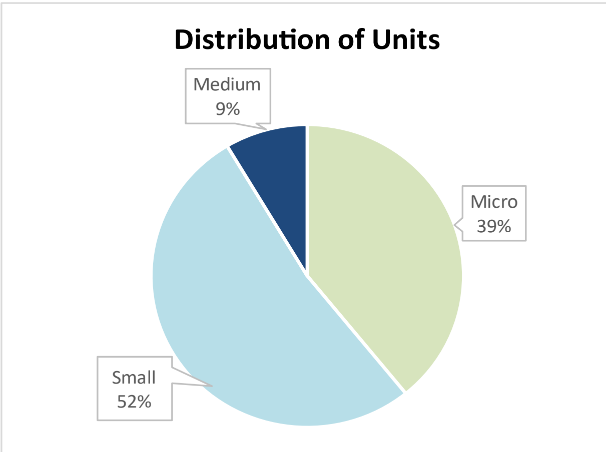
The additional clusters, namely Pali, Jetpur, Bhiwandi, Ahmedabad, and Erode, are characterized by their unique contributions to the textile sector. Each of these clusters has its own distinct strengths, specialties, and areas of expertise. For example, Pali is renowned for its particular textile products, Jetpur has its own set of unique capabilities, Bhiwandi plays a key role in the textile landscape, Ahmedabad contributes significantly to the sector's dynamics, and Erode brings its specific strengths to the textile value chain.

By incorporating these additional clusters into the project's scope, the aim is to provide a more comprehensive understanding of the textile industry in India. This expansion ensures that a diverse range of textile production and manufacturing practices, regional variations, and sector-specific nuances are considered, ultimately contributing to a more holistic assessment and insights into the textile sector's operations and dynamics.

3.2.1 Pali Textile Cluster

Pali is an important textile processing cluster located in Rajasthan which is known for its textile, dyeing and printing works. There are about 350 textile units in the cluster. The total estimated production of the cluster is about 0.34 million tonnes per year. The products and production profile of the cluster during the assessment year is given in Figure 39.

The Pali textile cluster boasts an estimated annual production of 3,44,700 tonnes, with the small-scale segment taking the lead in this output. Comprising 183 units, this segment contributes a significant 2,19,600 tonnes per annum. Following closely is the micro-enterprise segment, consisting of 137 units, which collectively generates an annual production of 41,100 tonnes. The remaining share of production is contributed by the medium-scale segment, which comprises 30 units and yields 84,000 tonnes of production annually.



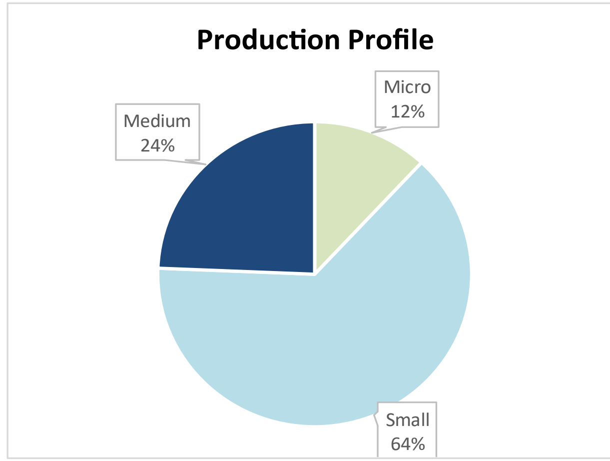


Figure 39: Distribution of MSME Units and their production wise share

Within this textile cluster, the energy consumption is predominantly thermal, accounting for 92% of the total energy utilized. The cluster's energy sources include agro-residue, petcoke, and wood, utilized in steam boilers and thermic fluid heaters as fuel, with High-Speed Diesel (HSD) acting as a backup for power generation. This amounts to a total of 5,12,052 tonnes of oil equivalent (toe) annually. Furthermore, electrical energy is employed for various operations, such as running soft flow machines, stenters, air compressors, motors, water circulation systems, and process pumps, accounting for an annual consumption of approximately 40,829 toe.

This data provides a detailed insight into the energy and production dynamics within the Pali textile cluster, highlighting the significance of both small-scale and medium-scale enterprises and the diverse sources of energy driving the cluster's operations.

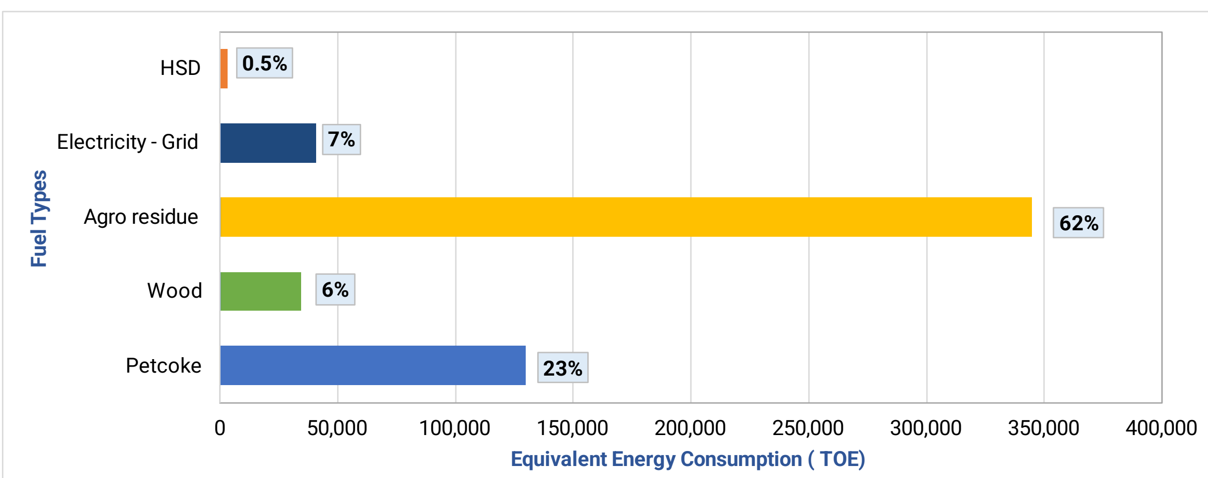


Figure 40: Fuel wise Energy Share

The cumulative annual energy consumption of about 350 textile manufacturing units of the Pali textile cluster in the year 2022 is estimated to be 5,52,881 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 9,21,239 tonnes of CO_2 equivalent. Table 13 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.[10]

Table 12: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Wood	tonne/year	92,512	34,470	Carbon neutral fuel
Petcoke	tonne/year	1,55,776	1,29,917	5,28,081
Agro-residue	tonne/year	9,62,043	3,44,700	Carbon neutral fuel
Electricity-Grid	Million kWh/year	475	40,829	3,84,556
High Speed Diesel (HSD)	kL/year	3,392	2,964	8,602
Total			**5,52,881**	**9,21,239**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 13: Key Performance Indicators

Specific Energy Consumption			
Type of unit	Electrical Energy (toe/tonne)	Thermal Energy (toe/tonne)	Overall SEC (toe/tonne)
Micro	0.84	1.51	2.35
Small	0.57	1.51	2.08
Medium	0.69	1.51	2.20
Cumulative SEC	**0.63**	**1.51**	**2.14**

[10] *as derived from information collected from secondary research, Sameeeksha and interaction with local stakeholders.*

The specific energy consumption levels of the Pali cluster are in the range of 2.35, 2.08 and 2.20 toe/tonne for Micro, small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 9.59, 1.69 and 1.85 for Micro, Small and Medium Enterprises respectively.

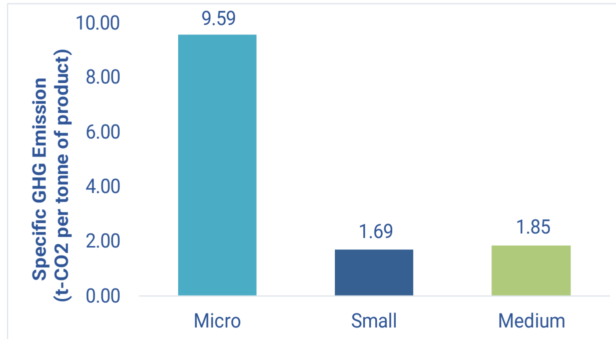


Figure 41: Specific GHG Emission

3.2.2 Jetpur Textile Cluster

Jetpur cluster is one of the largest and most well-known cluster for textile printing and dyeing workshops in the country. It is known for production of cotton sarees as well as export of ‘Khanga and Kitanga (used by native Africans)’. There are about 1,120 textile units in the cluster. The total estimated production of the cluster is about 0.7 million tonnes per year. The products and production profile of the cluster during the assessment year is given in the figure below.

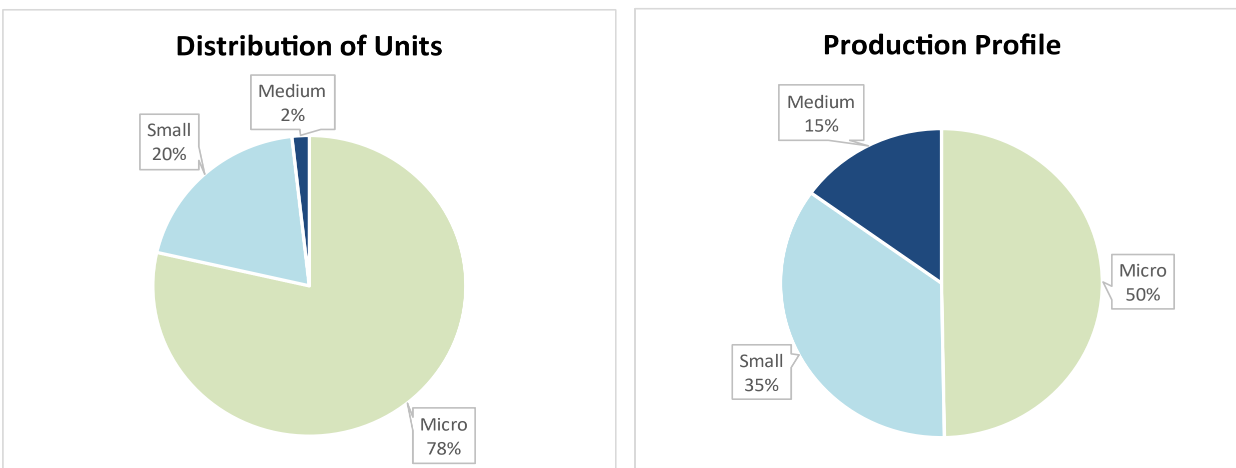


Figure 42: Distribution of MSME Units and their production wise share

Annual production estimated from the Jetpur textile cluster is 7,31,290 tonnes and is dominated by the micro segment (880 units) with 4,05,313 tonnes of production per annum. This is followed by the small enterprises segment (220 units) with annual production of 2,87,097 tonnes and rest is catered by medium segment (20 units) with 38,880 tonnes of annual production.

Cluster uses thermal energy majorly (92%) and electrical energy accounts for only 8%. In terms of thermal energy, cluster uses lignite, agro-residue and wood in steam boilers and thermic fluid heaters as a fuel and it corresponds to 72,447 toe per annum. Cluster consumes around 6,525 toe of electrical energy and is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

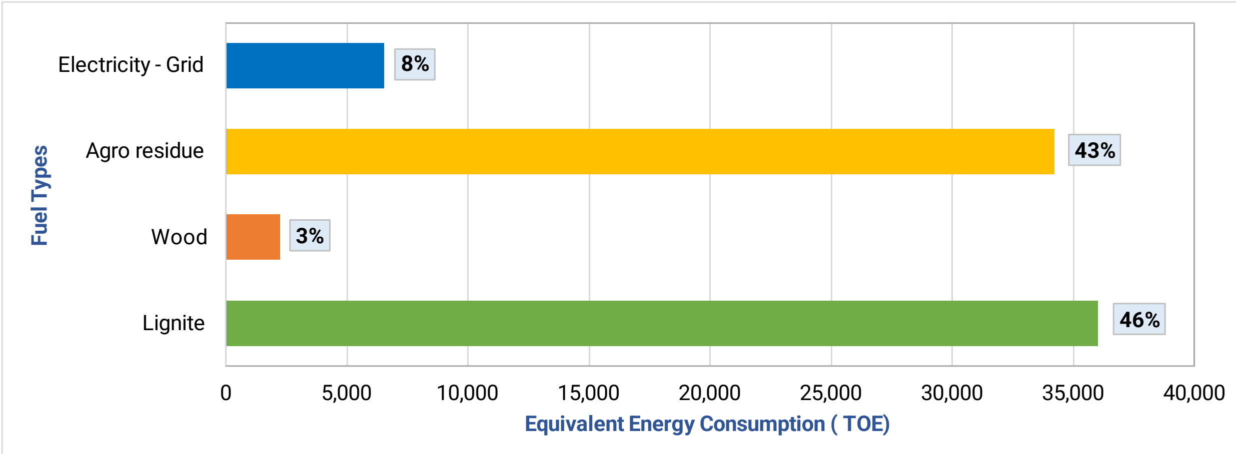


Figure 43: Fuel wise energy share

The cumulative annual energy consumption of about 1,120 dyeing units of the Jetpur textile cluster is estimated to be 78,972 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 2,06,601 tonnes of CO_2 equivalent. Table 15 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.[11]

Table 14: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Wood	tonne/year	6,420	2,247	Carbon neutral fuel
Agro-residue	tonne/year	1,40,880	34,200	Carbon neutral fuel
Lignite	tonne/year	90,000	36,000	1,45,148
Electricity - Grid	Million kWh/year	~ 76	6,525	61,453
Total			**78,972**	**2,06,601**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 15: Key Performance Indicators

Specific Energy Consumption			
Type of unit	**Electrical Energy**	**Thermal Energy**	**Overall SEC**

[11] *as derived from information collected from secondary research, Sameeeksha and interaction with local stakeholders.*

	(toe/tonne)	(toe/tonne)	(toe/tonne)
Micro	0.00	0.00	0.00
Small	0.00	0.01	0.01
Medium	0.13	1.81	1.93
Cumulative SEC	**0.01**	**0.10**	**0.11**

The specific energy consumption levels of the Jetpur cluster are in the range of 0.003, 0.01, 1.93 toe/tonne for Micro, small and Medium Enterprises respectively.

Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 0.03, 0.02, and 4.92 for Micro, Small and Medium Enterprises respectively.

Figure 44: Specific GHG emission

3.2.3 Bhiwandi Textile Cluster

The Bhiwandi cluster located in the state of Maharashtra is one of the biggest clusters of powerloom fabric manufacturing activities. There are about 6,000 textile units in the cluster. The total estimated production of the cluster is about 3.6 billion tonnes per year. The products and production profile of the cluster during the assessment year is given below.

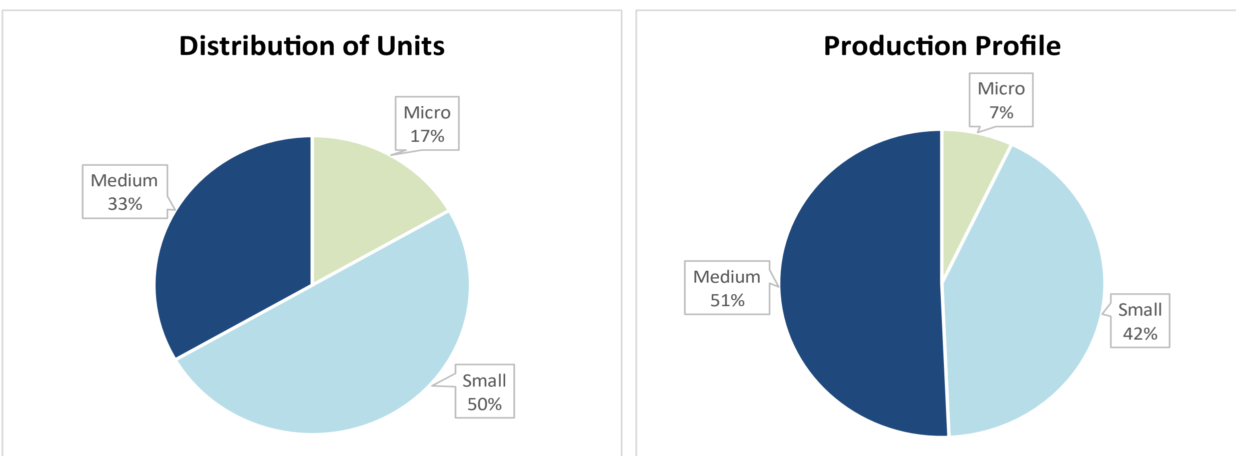


Figure 45: Distribution of MSME Units and their production wise share

The Bhiwandi textile cluster demonstrates significant annual production, estimated at 35,78,400 tonnes. The landscape of production is characterized by distinct enterprise segments, with the medium-scale segment taking the lead. Comprising 2,000 units, this segment contributes substantially to the annual production, accounting for 18,14,400 tonnes. Following closely is the small enterprise segment, encompassing 3,000 units, with a collective annual production of 15,12,000 tonnes. The remaining share of production is catered to by the micro-enterprise segment, represented by 1,000 units, which contributes 2,52,000 tonnes to the annual output.

Energy consumption within the cluster is predominantly reliant on grid electricity, constituting 100% of the total energy utilized. This electricity is deployed in various operational aspects, such as the warping machine, spinning machine, power looms, and for lighting and ventilation purposes, including the operation of fans.

The substantial production output, along with the variation in enterprise scales, highlights the diversity and significance of the Bhiwandi textile cluster within the textile industry. Additionally, the cluster's dependence on grid electricity for its energy requirements underscores the critical role of electricity in powering the cluster's operations, which encompass various stages of the textile production process.

The Bhiwandi textile cluster comprises a substantial number of dyeing units, approximately 6,000 in total. These units collectively exhibit a significant annual energy consumption estimated at 4,02,287 tonnes of oil equivalent (toe). In parallel, the associated greenhouse gas (GHG) emissions generated by these cluster units are calculated to be approximately 37,88,978 tonnes of carbon dioxide equivalent (CO2e).

For a detailed breakdown and analysis of these energy consumption and GHG emissions figures, Table 17 has been prepared. This table offers a comprehensive overview of the total annual energy consumption and GHG emissions associated with the different energy sources employed by the wet processing units within the cluster. This data serves as a crucial reference point for understanding the environmental and energy-related impact of the cluster's operations, offering valuable insights for sustainability and efficiency improvements within the textile industry.[12]

Table 16: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Electricity-Grid	Million kWh/year	~ 4,678	4,02,287	37,88,978
Total			**4,02,287**	**37,88,978**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 17: Key Performance Indicators

Specific Energy Consumption		
Type of unit	**Electrical Energy (toe/tonne)**	**Overall SEC (toe/tonne)**

[12] [12] *All the information is collected form associations, major representative units and Cluster Profile Report – Bhiwandi power loom (textile) industries (TERI, 2016)*

Micro	0.11	0.11
Small	0.11	0.11
Medium	0.12	0.12
Cumulative SEC	**0.11**	**0.11**

The specific energy consumption levels of the Bhiwandi cluster are in the range of 0.11, 0.11 and 1.12 for Micro, small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 1.00, 1.00 and 1.11 for Micro, Small and Medium Enterprises respectively.

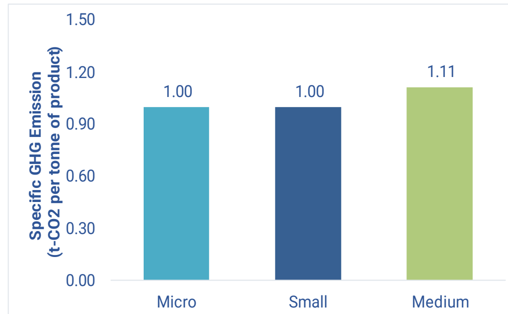


Figure 46: Specific GHG Emission

3.2.4 Ahmedabad Textile Cluster

The textile cluster of Ahmedabad located in the state of Gujarat is one of the prominent and oldest industrial clusters which is known for its cotton textile manufacturing. There are about 150 textile units. The total estimated production of the cluster is about 0.6 million tonnes per year. The products and production profile of the cluster during the assessment year is given below.

Annual production estimated from the Ahmedabad textile cluster is 6,33,695 tonnes and is dominated by the micro segment (105 units) with 3,00,737 tonnes of production per annum. This is followed by the medium enterprises segment (26 units) with annual production of 2,25,553 tonnes and the rest is catered by medium segment having 19 units and 1,07,406 tonnes of annual production.

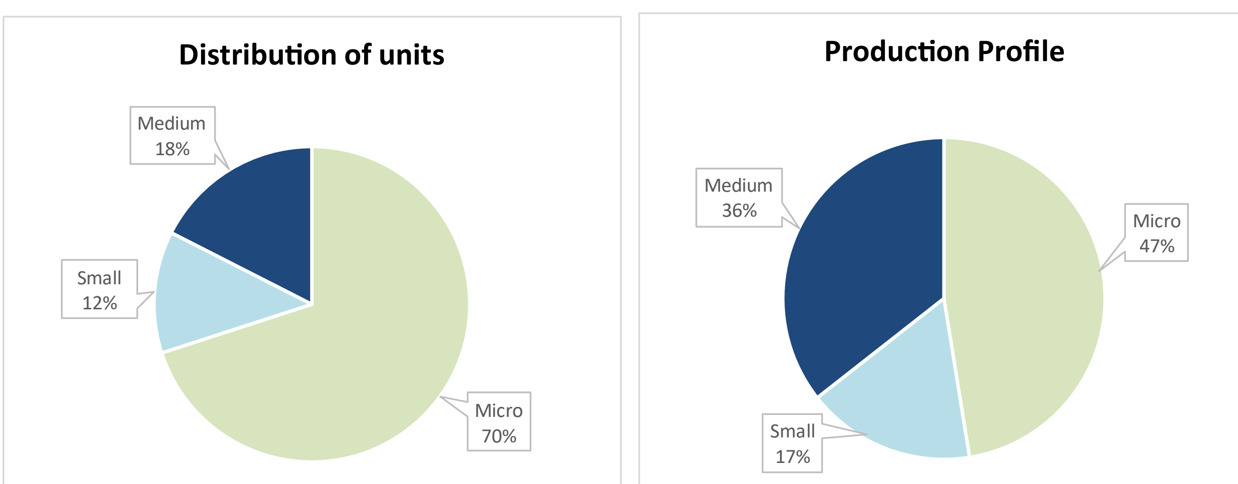


Figure 47: Distribution of MSME Units and their production wise share

Cluster uses thermal energy majorly (79%) and electrical energy accounts for the rest 21%. In terms of thermal energy, cluster uses imported coal, lignite, agro-residue and PNG in steam boilers and thermic fluid heaters as a fuel and it corresponds to 13,92,675 toe per annum. Cluster consumes 3,62,558 toe of electrical energy and is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

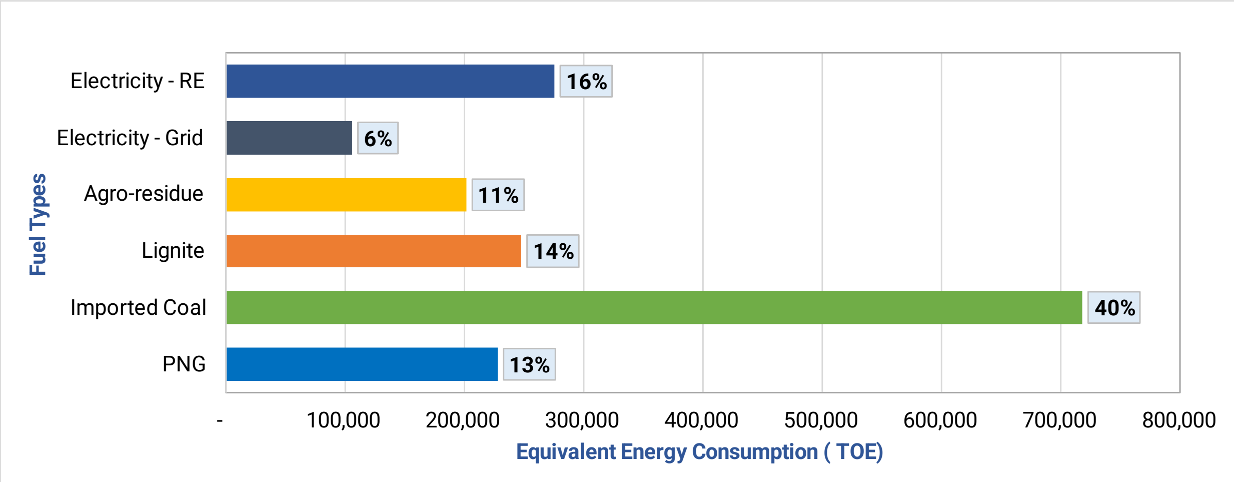


Figure 48: Fuel wise energy share

The cumulative annual energy consumption of about 150 dyeing units of the Ahmedabad textile cluster is estimated to be 17,55,233 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 55,52,452 tonnes of CO_2 equivalent. Table 19 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.

Table 18: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
PNG	Million SCM /year	208	2,16,348	559,497
Imported Coal	tonne/year	17,04,372	6,81,749	30,95,140
Lignite	tonne/year	5,21,625	2,35,462	9,47,272
Agro-Residue	tonne/year	5,34,239	1,91,418	Carbon Neutral Fuel
Electricity – Grid	Million kWh/year	1,174	1,00,922	9,50,543
Electricity – RE	Million kWh/year	3,042	2,61,636	Carbon Neutral Fuel
Total			**17,55,233**	**55,52,452**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 19: Key Performance Indicators*

Specific Energy Consumption			
Type of unit	Electrical Energy (toe/tonne)	Thermal Energy (toe/tonne)	Overall SEC (toe/tonne)
Micro	0.25	2.70	2.94
Small	0.16	2.28	2.44
Medium	1.20	1.50	2.70
Cumulative SEC	**0.57**	**2.20**	**2.77**

as derived from information collected from secondary research and interaction with industry association and local stakeholders

The specific energy consumption levels of the Ahmedabad cluster are in the range of 2.94, 2.44 and 2.94 for Micro, Small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 10.48, 9.00 and 6.36 for Micro, Small and Medium Enterprises respectively.

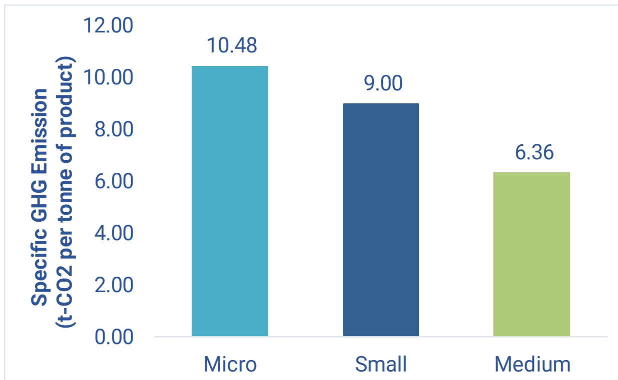
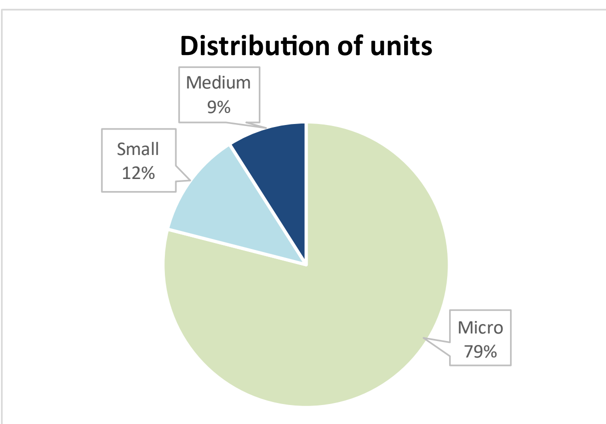


Figure 49: Specific GHG Emission

3.2.5 Erode Textile Cluster

The textile cluster of Erode located in the state of Tamil Nadu is one of the prominent and well-established textile manufacturing and processing cluster of India. The cluster is known for handloom weaving and



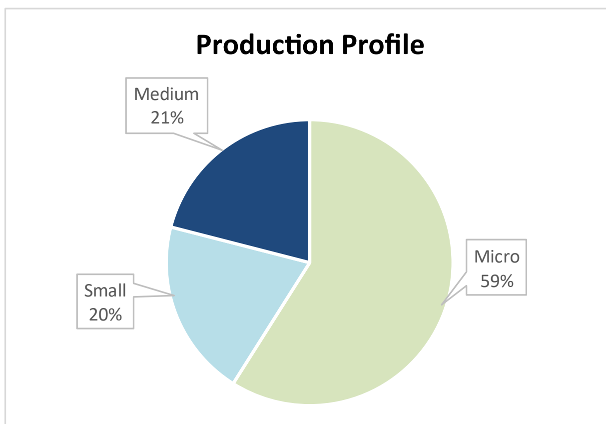


Figure 50: Distribution of MSME Units and their production wise share

carpet manufacturing. There are about 235 textile units involved in wet processing located in the industrial area of Erode and Namakkal. The total estimated production of the cluster is about 0.3 million tonnes per year. The products and production profile of the cluster during the assessment year is given below.

Annual production estimated from the Erode textile cluster is 3,18,732 tonnes and is dominated by the micro segment (186 units) with 1,87,921 tonnes of production per annum. This is followed by the small enterprises segment (21 units) with annual production of 66,890 tonnes and rest is catered by medium segment having 28 units and 63,921 tonnes of annual production.

Cluster uses thermal energy majorly (91%) and electrical energy accounts for the rest 9%. In terms of thermal energy, cluster uses firewood in steam boilers and thermic fluid heaters as a fuel and it corresponds to 2,32,467 toe per annum. Cluster consumes 22,948 toe of electrical energy sourced from grid and as well as RE suppliers. Electricity is being used for running soft flow machine, stenter, air compressors, motors, water circulation and process pumps.

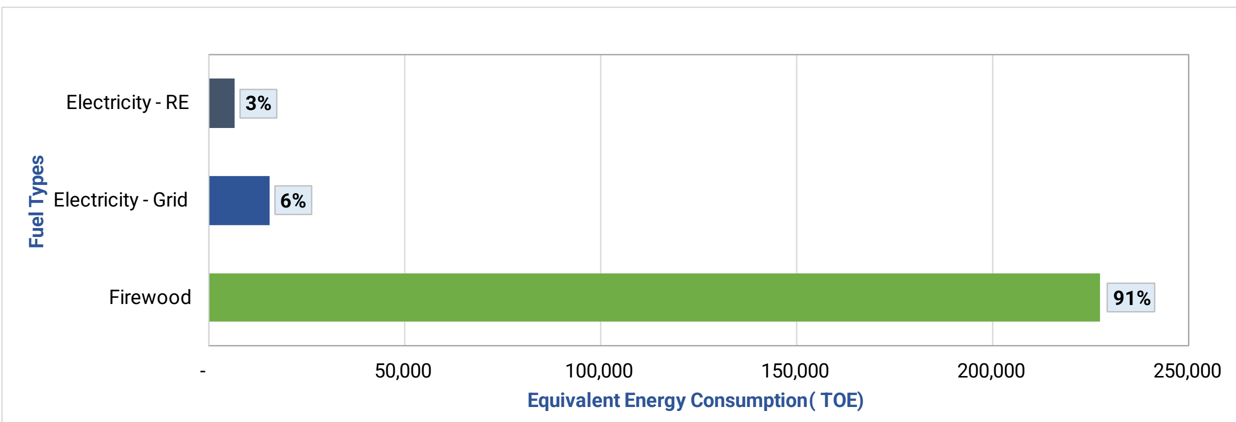


Figure 51: Fuel wise energy share

The cumulative annual energy consumption of about 235 wet processing units of the Erode textile cluster is estimated to be 2,55,416 toe. The equivalent GHG emissions generated by the cluster units are estimated to be 12,06,014 tonnes of CO_2 equivalent. Table 21 represents the total annual energy consumption and GHG emissions caused by the different types of energy sources utilized by the wet processing units of the cluster.

Table 20: Cluster level energy consumption

Energy Source	Annual energy consumption		Equivalent energy consumption (toe/year)	GHG emissions (t – CO_2 eq.)
	Unit	Value		
Firewood	tonne/year	5,81,168	2,32,467	Carbon Neutral Fuel
Electricity – Grid	Million kWh/year	186	15,991	1,50,612

Electricity – RE	Million kWh/year	81	6,958	Carbon Neutral Fuel
Total			**2,55,416**	**12,06,014**

Key Performance Indicators

The key performance indicators (KPIs) and the corresponding variables for different products in the cluster are shown in table below.

Table 21: Key Performance Indicators*

Specific Energy Consumption			
Type of unit	**Electrical Energy (toe/tonne)**	**Thermal Energy (toe/tonne)**	**Overall SEC (toe/tonne)**
Micro	0.02	0.37	0.39
Small	0.20	1.39	1.59
Medium	0.10	1.11	1.22
Cumulative SEC	**0.07**	**0.73**	**0.80**

as derived from information collected from secondary research and interaction with industry association and local stakeholders

The specific energy consumption levels of the Erode cluster are in the range of 0.39, 1.59 and 1.22 for Micro, Small and Medium Enterprises respectively. Similarly, the GHG emission indicator is expressed in the form of specific GHG emission provided as tonnes of CO_2 per tonne of product. Its value is 1.84, 7.51 and 5.68 for Micro, Small and Medium Enterprises respectively.

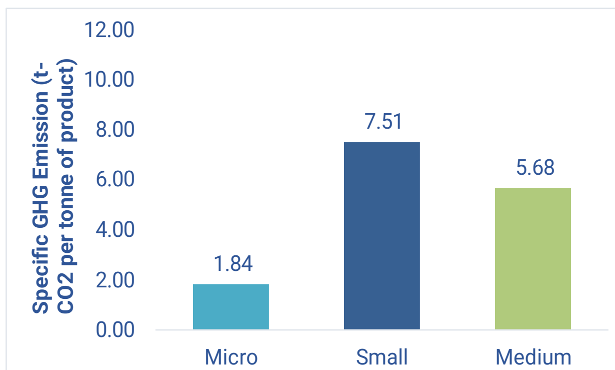


Figure 52: Specific GHG Emission

4. Sector Level Energy Consumption

In the comprehensive study of textile MSME sector conducted, after selection of five major and five additional textile clusters of India, data collection was done through walkthrough audits in the identified clusters and through research in the additional clusters. These clusters are carefully selected to provide a comprehensive representation of the diverse range of textile products within the Indian textile products of textile sector of India. Ludhiana, Panipat, Surat, Tirupur, Solapur, Pali, Jetpur, Bhiwandi, Ahmedabad and Erode are the major MSME clusters involved in this textile sector study. The energy consumption profile of the sector and SEC at cluster as well as sectoral level together with comparison with global level performance is discussed in this section.

4.1 Energy Consumption Profile

The major clusters covered under the study produce a wide range of products ranging from fabric materials, sarees, towels to hosiery and knitwear. The total annual production of textile units of these clusters is approximately 10.6 million tonnes. The energy share of textile clusters and fuels used in different clusters is explained below.

Cluster-wise Energy Share

Table 23 shows the cumulative energy consumption and GHG emissions of the major textile clusters included in the study. The cumulative energy consumption of the major textile clusters is 87,64,799 toe and GHG Emissions generated are 2,59,52,815 tonnes of CO_2 equivalent.

Table 22: Cumulative energy consumption and GHG emissions of major textile clusters

Type of Energy	Energy Consumption (toe)	GHG Emissions(t-CO_2)
Thermal Energy (Firewood, Agro-residue, Lignite, Imported Coal, Petcoke, PNG)	74,27,682	1,64,52,463
Electricity (Grid based and RE based)	13,37,117	95,00,352
Total	87,64,799	2,59,52,815

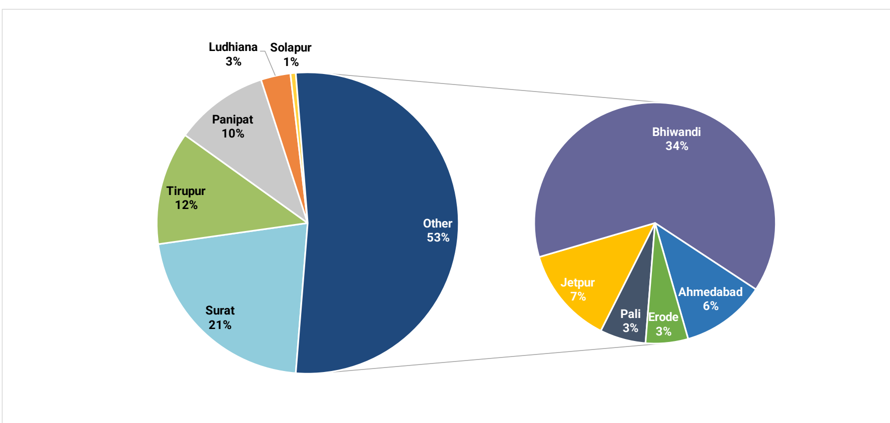


Figure 53: Cluster-wise share in energy consumption

Figure 53 shows the percentage share of the major textile MSME clusters of the study in the energy consumption profile. The highest energy consumption is of Bhiwandi (34%) followed by Surat (21%) and Tirupur (12%). These clusters collectively hold a substantial portion of the total energy consumption, underscoring their importance in the regional industrial landscape. Panipat with a 10% share, Jetpur with a 7% share and Ahmedabad with 6% share maintain substantial share in energy consumption. Pali (3%), Ludhiana (3%), Erode (3%) and Solapur (1%) have relatively limited share in the energy consumption as compared to other clusters but play a significant role in the industrial energy profile.

Figure 54 shows the share of thermal energy and electricity in total energy consumption of the major clusters. The highest share of thermal energy and lowest share in electricity is in Surat (95% thermal energy, 5% electricity) whereas the lowest share of thermal energy and highest share in electricity is in Bhiwandi (100% Electricity) followed by Ahmedabad (21% electricity, 79% thermal energy). On an average, approximately 80% of the total energy consumed is through thermal sources of energy while the remaining 20% share is attributed to electricity usage.

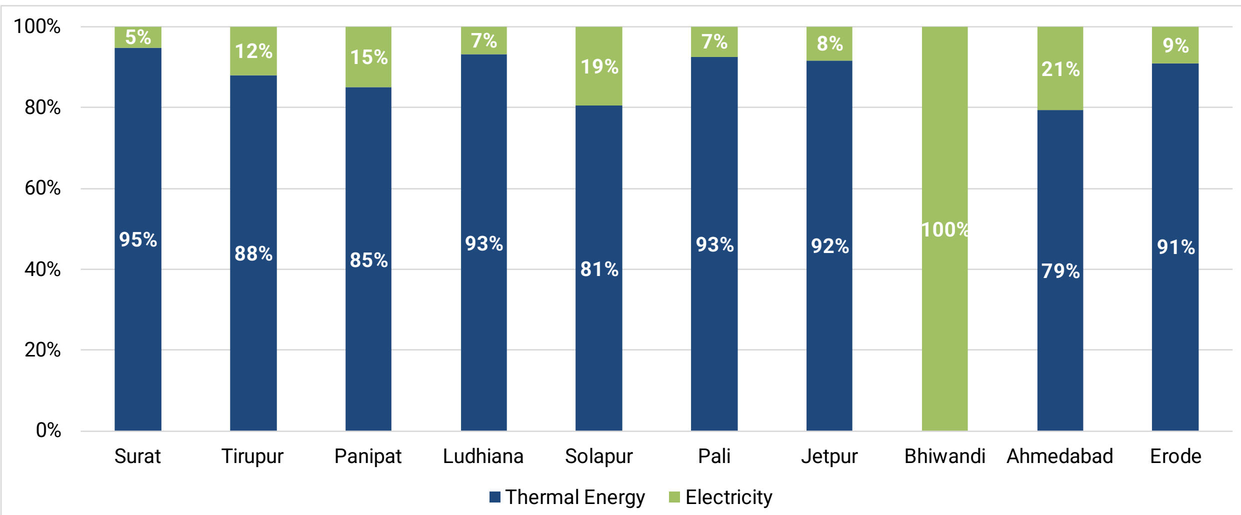


Figure 54: Share of Thermal Energy and Electricity in major clusters

Fuel wise energy share

The main fuels used in the major clusters are Electricity (Grid and RE based), Firewood, Agro-residue, Piped Natural Gas (PNG), Lignite & Imported coal and petcoke. In addition to these, HSD (High Speed Diesel), and LPG (Liquified Petroleum gas) are also used in some of the clusters but in negligible proportions. Figure 55 shows the energy profile of industrial clusters in terms of primary fuels energy consumption patterns. The consumption of agro-residue is predominant in Panipat (85%) while firewood consumption is majorly in Erode (91%), Tirupur (88%) and Solapur (81%). Lignite and imported coal are consumed in Surat, Ahmedabad and Jetpur predominantly. Petcoke is utilized only in Ludhiana (22%) and Pali (23%) alongwith agro-residue and firewood as energy sources.

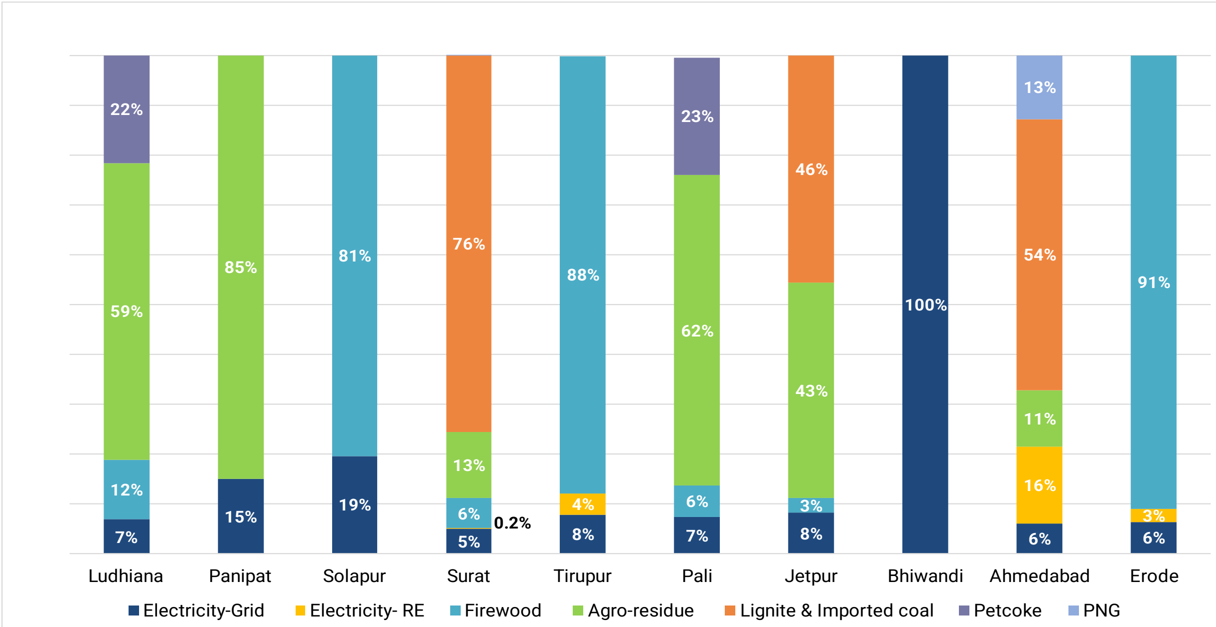


Figure 55: Fuel wise energy share in major clusters

Figure 56 shows the sectoral level energy share which is calculated based on the clusters included in the study. Typically, at sectoral level, lignite and imported coal has largest share (37%) in fuel consumption followed by agro-residue with 24% share and firewood having 19% of consumption. Petcoke and PNG have only 2% share each while rest 16% share is of electricity (Grid and RE based). The fuel wise energy profile of the industrial clusters reflects the high reliance on lignite and imported coal which are associated with higher GHG emissions and showcases the need of transitioning from these sources to cleaner energy sources.

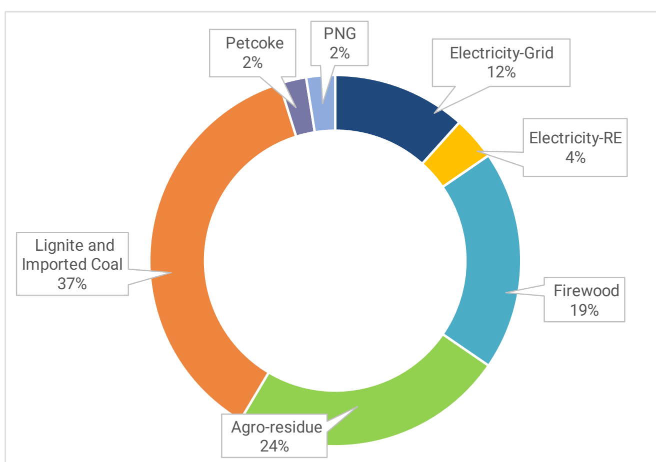


Figure 56: Sectoral level energy share

4.2 SEC at the sector level

The study of specific energy consumption patterns is essential for energy efficiency assessment and resource optimization. It is done to understand the details of energy consumption in the textile sector which is essential to provide valuable insights for achieving energy efficiency and resource efficiency in the sector.

Cluster wise SEC

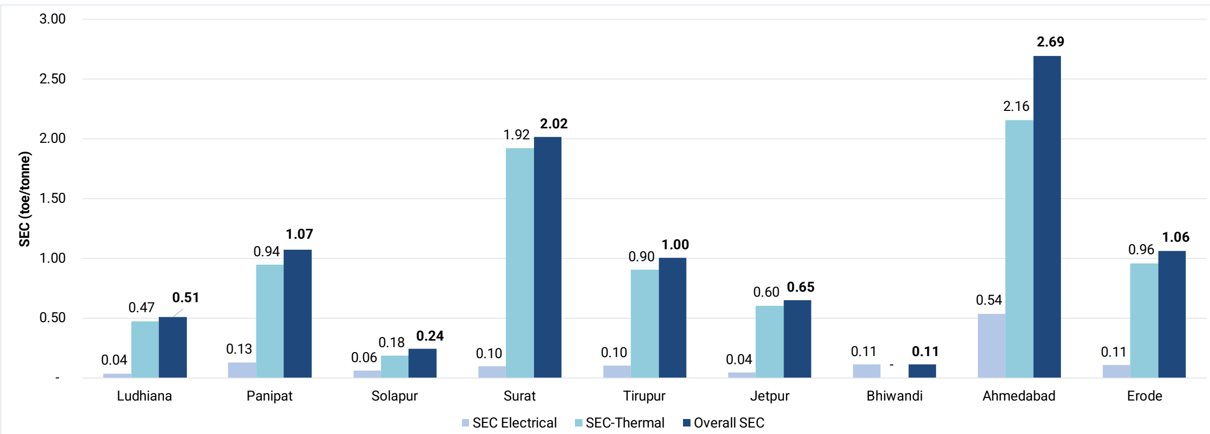


Figure 57: SEC for major clusters in textile sector

The study of Specific energy consumption (SEC patterns of the major clusters is done to obtain sectoral level SEC. Figure 57 shows the comparative of SEC Electrical, SEC Thermal and SEC Overall for major clusters of the textile sector involved in the study. The overall SEC is highest for Ahmedabad followed by Surat while it is lowest for Bhiwandi. Panipat, Tirupur and Erode have a comparable range of SEC value while Ludhiana, Solapur and Jetpur have slightly lower SEC values.

MSME Category Unit-wise SEC

Figure 58 shows the comparative of SEC Electrical, SEC Thermal and SEC Overall for different types of units namely micro, small and medium unit. Micro and medium category units have a higher value of the energy consumed per tonne of product (SEC) while small units have comparatively lower SEC values. For each category of unit, SEC Electrical is approximately 10 to 15% of overall SEC while Thermal SEC is around 85 to 90% of the overall SEC.

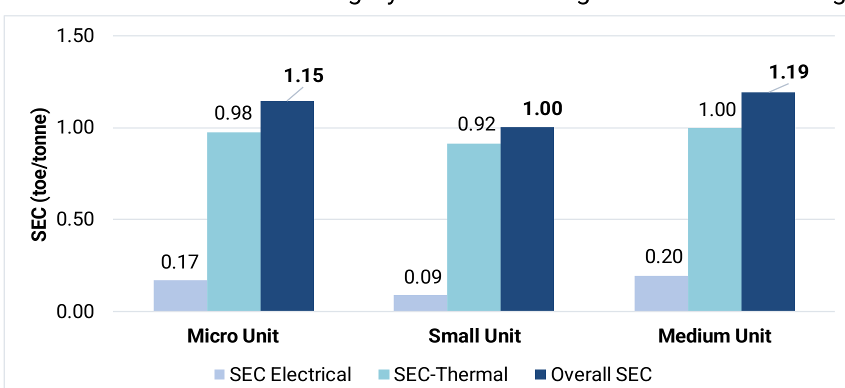


Figure 58: SEC based on category of unit

Sector level SEC

Figure 59 shows the comparative of SEC Electrical, SEC Thermal and SEC Overall at sector level for the textile sector. It is calculated considering the major clusters involved in the study. The overall SEC for the textile sector encompassing the clusters of Ludhiana, Tirupur, Panipat, Surat, Solapur, Pali, Jetpur, Bhiwandi, Ahmedabad and Erode producing diverse range of products is 1.12 toe/tonne. The value of SEC-Electrical is 0.15 toe/tonne while SEC-Thermal is 0.96 toe/tonne.

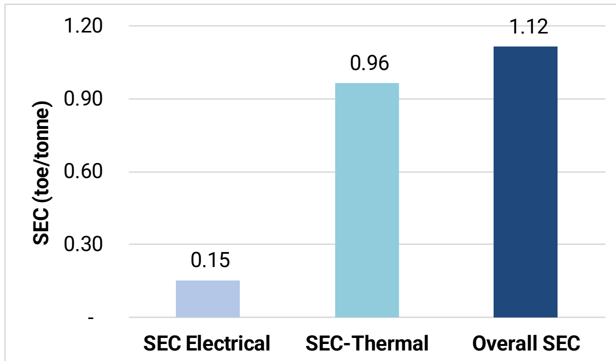


Figure 59: Sector level SEC

Product type wise SEC

Figure 60 shows the SEC values for various types of products produced by major textile clusters included in our study. The major product categories considered in our study are sarees and dress materials, semi-finished products, home furnishing textiles, hosiery and knitwear products and towels and bedsheets. Sarees and dress materials exhibit the highest SEC, standing at 2.02 toe/tonne, whereas towels and bedsheets show the lowest SEC at 0.24 toe/tonne. Semi-finished products and home furnishing textiles both have an SEC of around 1 toe/tonne, with the latter having a slightly higher value while SEC for hosiery and knitwear is around 0.51 toe/tonne.

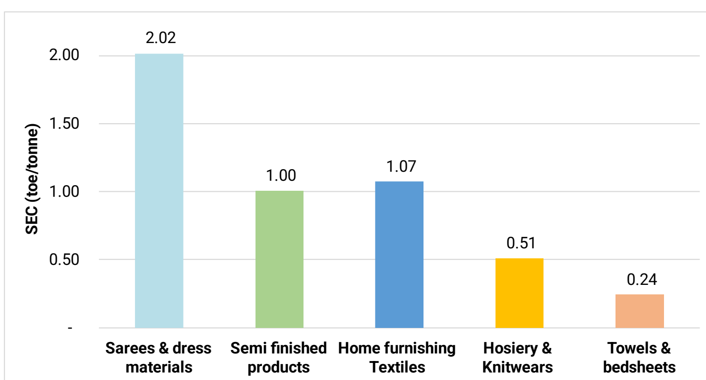


Figure 60: Product type wise SEC

4.3 Comparison with the global level performance

Major players across the world in wet processing of the textile industry besides India are China, Vietnam, Bangladesh, Turkey, Indonesia, Italy, Pakistan and Thailand.

Bangladesh: Bangladesh's wet processing industries heavily relies on energy and groundwater consumption during production; mainly, textile dyeing mills contribute to the carbon footprint and water footprint impact to the environment.

The average energy consumption KPI for textile dyeing mills was found to be 0.221 toe/tonne, whereas the average carbon emission KPI was 1.64 t-CO_2/tonne, where the maximum and minimum KPI was 3.90 t-CO_2/tonne and 0.88 t-CO_2/tonne, respectively[13].

Vietnam: Vietnam's textile and garment industry accounts for 16% of the country's GDP and employs around 12% of the workforce. The total energy consumption from the Vietnam textile sector accounts for 4.23 million TOE with 1,978 million tons of CO_2 emissions in the year 2020. The Vietnam Textile and Apparel Association (VITAS) has set a target of helping the country's textile and garment industry turn more environment friendly by 2030, by which the industry plans to reduce energy consumption by 15% and water consumption by a fifth. In recent years, textile, garment and footwear firms have paid special attention to green growth.[14]

Indonesia: The energy aspects of the green industry requirements covered threshold of electrical energy consumption, thermal energy consumption and GHG emission, per ton of textile product, at 1,100 kWh/tonne, 3,500 kWh/tonne and 2,03 tonne CO_2/tonne respectively.[15]

. It has been identified by JICA that there is 30% energy saving potential in Indonesia by 2023 within textile industry.

China: China is a dominant player in the global textile industry, including wet processing. The country has a vast textile manufacturing base and is a major producer of dyed and finished textiles. The energy consumed by the textile industry is approximately 4.3% of China's total energy consumption in the manufacturing industries.[16]

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[13] https://www.mdpi.com/2673-7248/2/4/29

[14] Rapport (ens.dk)

[15] https://www.researchgate.net/publication/337805361_Energy_Efficiency_Monitoring_in_Textile_Industries_to_Achieve_GHG_Emissions_Reduction_Target_in_Indonesia#pf5

[16] https://www.mdpi.com/1996-1073/13/7/1683

5. Energy And Resource Efficiency

The textile sector showcases a wide range of Specific Energy Consumption (SEC) owing to the diversity of the products across different clusters. This section highlights some of the widely available energy efficiency and decarbonization options for the MSME industries.

5.1 Energy Efficiency Options

The energy efficiency options in the industries of textile sector in various processes and utilities together with the renewable energy options that will help them achieve substantial energy saving are discussed below.

5.1.1 Processes

5.1.1.1 Fabric Moisture Control in Stenters

Background

In the MSME textile processing units, the moisture content of the fabric at the inlet and outlet of the stenter is often found not being monitored or recorded correctly and/ or is being left to the expertise of the stenter operator to regulate the speed and heat supply. Consequently, this manual approach often leads to over-drying of fabrics in stenters which in turn consumes more heat from the supplied thermic fluid. This over-drying not only impacts product quality but also results in excessive fuel consumption at the TFH, affecting overall operational efficiency.

Fabric Residual Moisture Controller:

To address this challenge, the proposed solution involves the integration of a Fabric Residual Moisture Control system. This system employs a contact measurement approach for running fabrics, utilizing roller sensors strategically positioned at various locations at the stenter's exit to perform online residual moisture content measurements. The system includes a dedicated monitor for displaying and controlling residual moisture levels. Operators can input the desired moisture percentage into the programmable monitor, which, in turn, adjusts the fabric's speed based on real-time moisture data to achieve the specified moisture content. Variable Frequency Drives (VFDs) can be employed to enhance control precision, ultimately leading to

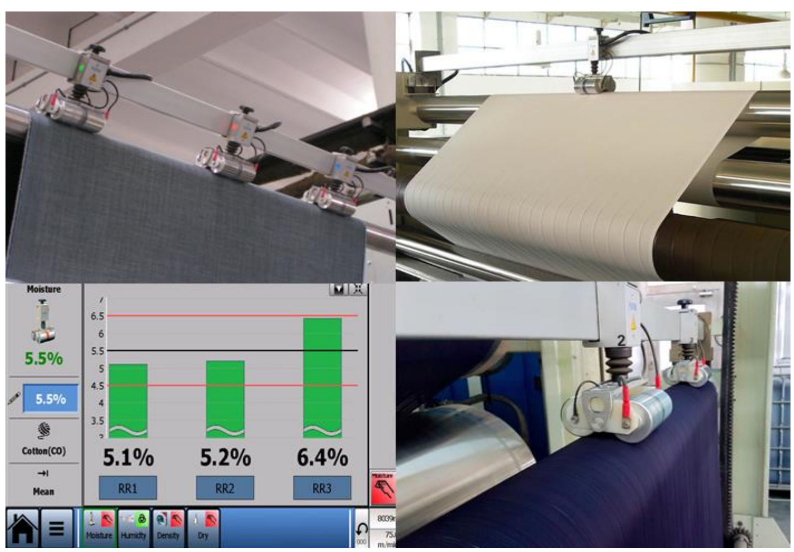

Figure 61: Sensor for Fabric Moisture Controller

improved productivity and higher product quality. Notably, the proposed system features no moving parts, ensuring a prolonged operational lifespan of a minimum of 10 years when proper power quality is maintained.

Recommendation

The installation of the Fabric Residual Moisture Control system offers a viable solution to address the moisture control issues in stenter machines. This system operates independently from the existing setup and requires minimal integration effort, primarily involving electrical connections. Fine-tuning the system and conducting performance monitoring can be completed within a maximum timeframe of one day. This implementation will lead to more accurate control over fabric moisture levels, ultimately enhancing both product quality and operational efficiency.

Energy & GHG reduction potential

The assessment studies and literature surveys provided information and operational data that showed the potential of a Fabric Residual Moisture Control system to reduce GHG emissions significantly. The following table presents a cost-benefit analysis of the proposed system.

Table 23: Cost-benefit analysis for installation Fabric Residual Moisture Controller

Parameters	Values
No. of stenters (nos.)	1
Energy saving (%)	3-4
Investment (lakh INR)	1-1.5
Simple payback period (Yr)	1-2
GHG reduction potential (tCO_2/year)	40-50

Installation of a Fabric Moisture Controller may lead to a reduction of approximately 3-4% energy annually for a single stenter machine. The implementation cost of the Fabric Moisture Controller system is estimated to be around 1-1.5 lakhs including commissioning cost, service tax, civil work, and other misc. cost. The simple payback period works out to be 1-2 years.

Sustainable impact

- **Save energy and CO_2**: By continuously measuring and controlling the residual moisture, the energy used in various processes (such as drying, humidification, etc.) can be significantly reduced. This consequently makes it possible to reduce CO_2 emissions.
- **First-Time-Right-Principle**: Rejected or second choice goods can be avoided, thanks to process monitoring and the associated reproducibility. This saves both the use of materials and the costs involved.

5.1.1.2 Blower Speed Optimization in Stenters

Background

Stenters generally have 5 to 6 heating chambers with each chamber having a pair of blowers attached to the pair of air ducts having perforations for producing air jets. Blowers are used to circulate the hot air across the fabric as they blow air onto the grid of heat exchanger tubes containing hot thermic fluid which is then guided onto the fabric through nozzles. The blower motors are generally two speed motors for controlling the speed of the blower. They often run at full capacity regardless of the actual production needs. This can result in excessive energy consumption, higher operational costs, and higher GHG emissions. In some units, VFD are installed with stenter fans, but they have been installed to just smoothen the starting current and hence work mainly as a soft starter.

Installation of VFD on stenter fans

VFD in Stenter Fans with a complete auto feedback modulation is simple in technology, implementation and maintenance as VFDs are quite common in industrial units. The system is available in modules off the shelf. However, implementation would require the careful establishment of benchmarks and integration of the system to achieve maximum energy savings. VFDs can be used to: -

- Modulate speed in the first section to heat the fabric very fast.
- Modulate fan speed in the subsequent chambers to maintain temperature above rated temperature.
- There are no moving parts in the proposed system hence it is likely to run for a long time (minimum 10 years) if the proper power quality is maintained.

Recommendation

Air Jet is mainly required in the evaporation process and to some extent in the fabric heating process. The holding process requires maintaining of temperature above specified temperature and hence, air jet velocity is not critical here. Even in the evaporation process, maximum evaporation takes place at an air jet velocity of 32 ft/sec. Thus, the installation of VFD on stenter fans to have a complete auto feedback modulation system stands to give huge benefits in terms of energy savings.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant energy savings and thereby GHG reduction as a result of indirect grid electricity savings can be achieved by the installation of VFD on Stenter Fans with a complete auto feedback modulation system. A comparative cost-benefit analysis of the auto modulation system against existing technologies is given below:

Table 24: Cost-benefit analysis for Blower Speed Optimization

Parameters	Values
No. of Blowers per stenter (nos.)	5

Energy saving (%)	30-40
Investment (lakh INR)	7-8
Simple payback period (Yr)	1-2
GHG reduction potential (tCO_2/year)	50-60

Installation of a VFD with auto feedback modulation for blower speed optimization may lead to a reduction of approximately 50 to 60 tCO_2 annually for a single stenter machine in addition to 30 to 40% energy savings. The implementation cost is estimated to be around 7 to 8 lakhs including commissioning cost, service tax, civil work, and other miscellaneous cost. The simple payback period works out to be 1 to 2 years.

Sustainable impact

- **Energy saving**: VFDs enable precise control of blower speed and airflow. By adjusting the output to match the actual demand of the stenter machine, energy consumption is significantly reduced.
- **Lower Environmental impact:** Reduced energy consumption due to VFDs leads to a lower carbon footprint, contributing to environmental sustainability.

5.1.1.3 Exhaust Humidity Control System

Background

In the majority of textile units, the humidity in exhaust which is one of the basic process parameters of stenter is neither measured nor controlled while its setting is done on the manual estimation basis which has possibilities of error. Optimization of exhausts can be achieved by controlling the exhaust humidity to between 0.1 and 0.15 kg water/ kg dry air. This is called the Wadsworth criterion. Reduction in fresh air consumption in stenter from 10kg/kg of fabric to 5 kg/kg of fabric transpires to a total of 57% of energy saving.

Exhaust Humidity Control System

Exhaust air moisture measuring systems are used to measure the moisture of exhaust air in the exhaust air duct (driers) and to adjust the exhaust air dampers and fans accordingly using servo motors. This helps to prevent heat losses due to the exhaust air being too dry. In the Exhaust Moisture Control System, a sensor senses moisture quantity in the exhaust and depending upon the settings of PLC, gives a signal to the VFD installed on the blower to ensure rated moisture percentage all the time. It provides a higher level of automation technology to control the moisture removal in the stenter along with diagnostic analysis and communication interface.

Recommendation

The Exhaust Humidity Control system has the potential to bring down energy consumption by adjusting the exhaust air dampers and fans according to the moisture level of the air and thereby prevent heat loss due to exhaust air being too dry. The constant conditions produced by the control increase the reproducibility of the production process and product quality. The key benefits of exhaust humidity control system are as follows:

- Improve the precision of control on the existing process and hence would yield better results on productivity as well as quality fronts.
- The control system can be retrofitted to the existing Stenters Machine with minimal modification to existing Machinery.
- Product quality is expected to improve significantly.

Figure 62: Exhaust monitoring system consisting of sensors`

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant amount of GHG reductions can be achieved by the installation of an Exhaust Humidity Controller System. A cost-benefit analysis of the Exhaust Humidity Controller System is given below:

Table 5: Cost-benefit analysis for Exhaust Humidity Controller System

Parameters	Values
No. of Blowers per stenter (nos.)	5
Energy saving (%)	5-10
Investment (lakh INR)	3-4
Simple payback period (Yr)	2 - 3
GHG reduction potential (tCO_2/year)	15 - 20

Installation of Exhaust humidity control system may lead to a reduction of approximately 15 to 20 tCO_2 annually for a single stenter unit with 5 to 10% of energy saving. The installation cost of the Exhaust Humidity Controller System is estimated to be around 3 to 4 lakhs including commissioning cost, service tax, civil work and other misc. cost. The simple payback period works out to be 2 to 3 years.

Key Benefits

- **Improved energy efficiency:** Monitoring and controlling the exhaust humidity ensures that only the necessary amount of heat is applied during drying processes, thus improving the energy efficiency.
- **Reduced Resource consumption:** Efficient humidity control can lead to reduced water consumption in textile processes.
- **Improved Product quality:** Maintaining optimal humidity levels can enhance the quality of textile products.

5.1.1.4 Waste Heat Recovery (WHR) system in Stenters

Background

In the textile industry, stenters play a crucial role in both fabric drying and finishing process, particularly heat setting. Steners account for around 30% of total thermal energy consumption in the wet processing stage out of which a substantial amount of energy is utilized to heat ambient air at room temperature to desired temperature of 180 to 200° C to heat set the fabric. Further, the hot air expelled from the stenter's exhaust is released into the atmosphere at a high temperature without any mechanism in place for heat recovery. This results in significant heat losses that could otherwise be harnessed and put to use.

Waste Heat Recovery (WHR) system

In order to efficiently utilize the heat carried by the exhaust air of stenter, implementing the heat recovery system is an effective solution. The WHR system consists of Heat exchangers fitted to the stenter which have bundles of glass tubes to recover heat from the hot stenter exhaust. The material is selected so as to take care of the impure hot air released by the stenter. Bruckner uses Aluminum Coated finned type heat exchanger. The tubes are fitted in a drawer-like arrangement to facilitate cleaning. The WHR system is a counterflow type and can be any of the:

Figure 63: Waste heat recovery system with integrated exhaust air filter system

- heat pumps,
- Plate exchangers,
- Circulation-linked ribbed pipe systems,
- Tubular exchangers

The preheated air can form make-up air and hence energy required to heat fresh air to the preheated temperature levels is saved. Also, the recovered heat can be used to preheat the water for other processes such as dyeing and washing hot water thus saving the energy to heat water.

Recommendation

The Waste Heat Recovery (WHR) system helps to pre-heat the fresh air at the stenter inlet. This results in reduced consumption of significant fuel in the case of the stenters using thermic fluid which is supplied by wood-fired Thermic Fluid Heaters and reduced gas consumption in case of gas fired stenters. This recovery system reduces the energy costs of production immensely in addition to a reduction in CO_2 levels. One more option is to use the waste heat recovery systems with integrated air filter system using electrostatic precipitators in order to purify the exhaust air thereby resulting in reduction in air pollutants and GHG emission levels along with significant energy savings.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant amount of GHG reductions can be achieved by the installation of a Waste Heat Recovery (WHR) system. A cost-benefit analysis of the proposed system is given below.

Table 25: Cost-benefit analysis for Waste Heat Recovery (WHR) system

Parameters	Values
No. of stenters (nos.)	1
Energy saving (%)	10-15
Investment (lakh INR)	10-12
Simple payback period (Yr)	2.5-3
GHG reduction potential (tCO_2/year)	100-120

Installation of a Waste Heat Recovery (WHR) system may lead to a reduction of approximately 10-15% energy annually for a single stenter machine. The implementation cost of the Waste Heat Recovery (WHR) system is estimated to be around 10-12 lakhs including commissioning cost, service tax, civil work, and other misc. cost. The simple payback period works out to be 2.5-3 years.

Sustainable Impact

- High-effective energy savings
- Reduction in the total amount of dissolved solids in the boiler feed water
- The hot condensate fed to the boiler minimizes the amount of dissolved oxygen and thus helps to prevent corrosion.
- Decreased demand for make-up water

5.1.1.5 Adoption of Gas fired Stenter

Background

Generally, in the textile industries, thermic fluid heaters (TFH) are used to provide heating requirements for stenters. In stenters, thermic fluid heated to desired temperature is circulated through heat exchanger coils. As the thermic fluid circulates through heat exchanger, it transfers heat to the fresh air which is now blown into the stenter chambers by the dedicated blowers and thus the chamber temperature is maintained as per the required heat setting and drying requirements. In this process, substantial amount of heat loss occurs owing to multiple heat exchanges i.e. from fuel to TFH and TFH to fresh air and other line losses during thermic fluid transfer.

Gas fired stenters

To address this challenge and reduce heat losses, the thermic fluid-based stenter can be replaced with a gas fired stenters. In these stenters, gas-based burners use natural gas to be burnt inside the heating coils and the heat is directly transferred to the incoming air from the blowers to be circulated inside the chambers and thereby ensure optimal temperature with controlled fuel consumption. Some of the gas is recirculated while most is evacuated.

Figure 64: Gas fired stenters

Recommendation

Gas-based stenters work out better in various areas as compared to thermic fluid system based stenters. They lead reduction of fuel consumption with reduced heat losses. They offer precise temperature control, uniform heat distribution, and the flexibility to accommodate various types of textiles. Surat is one of the clusters where gas based stenters are exclusively used. In case gas supply is unreliable or not constant, mixed direct/indirect heating with gas burners is also a good alternative.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of gas fired stenters. A cost-benefit analysis of the proposed system is given below:

Table 5: Cost-benefit analysis for Gas fired stenter

Parameters	Values
Energy saving (%)	30 - 40
Investment (lakh INR)	35 – 40
Simple payback period (Yr)	1 year

The installation cost of a single gas fired stenter is estimated to be around 35-40 lakhs per stenter with an energy saving potential of 30 to 40%. The simple payback period works out to be around 1 year.

Sustainable Impact

- **Reduced fuel consumption-** Gas-fired stenters with improved fuel efficiency contribute to a more sustainable and environmentally friendly manufacturing process.
- **Quick startup-** As there is no intermediate exchange fluid to be heated, reduces the startup time.
- **Reduced space-** Since no general installation of tubing is required, or space to install a boiler or auxiliary equipment.

5.1.1.5 PLC based automation and control system for dyeing machines

Background

Some of the textile cluster units still employ jigger machines for fabric dyeing. Conventional jiggers are one of the oldest dyeing machines and do not have a variable liquor ratio, which is why the quantities of water, pigments and chemicals cannot be adjusted properly to the varying quantities of fabric being processed. This often leads to usage of significant amounts of water and chemicals resulting in environmental concerns and increased operating costs. Also, the machines are operated manually and thus are more reliant on labor and lacks precision control. Similarly jet dyeing machines are mostly operated manually where the batch time and amount of water and chemicals used depends on the skills and performance of operator leading to same challenges as in jigger machines.

PLC based automation and control system

To address this challenge, PLC (Programmable logic controller) based automation and control system is a viable solution for both jigger and jet dyeing machines. PLC is a computerized control system often used for industrial processes which monitors the state of inputs and based on the custom program controls the state of outputs. In the dyeing machine, PLC based automation and control system will automate various processes such as dye dosing, dye dispensing and also ensure precise and consistent control of temperature and amount of water and chemical usage leading to higher quality and more uniform results. This system offers flexibility to operate, and reduce the operating time thus reducing the batch time of the machine resulting in the improvement of overall production capacity. It automatically selects the heating and cooling cycle as per the process requirement and also optimizes the temperature as per the system requirement.

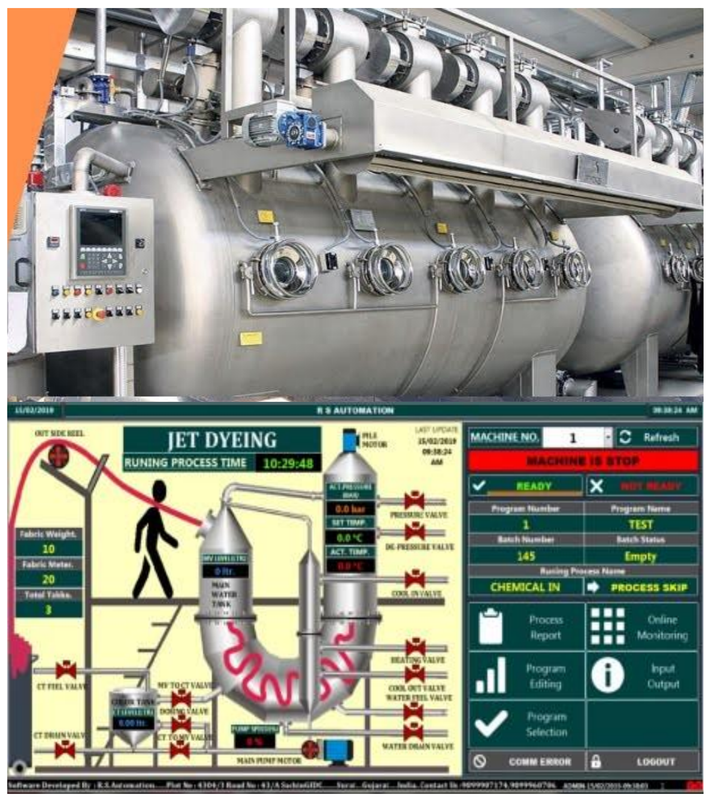

Figure 65: PLC based automation and control system

Recommendation

Selecting a PLC-based automation and control system for a dyeing machine is a crucial decision that can greatly impact the efficiency and performance of the dyeing process. It will result in a reduction in specific steam and water consumption. Additionally, it will bring uniformity in colour and optimize the process cycle including pressurization, de-pressurization and cooling cycles. It will lead to both time and energy savings during batch processing, ultimately reducing the reliance on human labor.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant energy savings can be achieved by the installation of PLC based automation and control system. A cost-benefit analysis of the proposed system is given below:

Table 26: Cost-benefit analysis for PLC based automation

Parameters	Values
Energy saving (%)	20 – 25
Investment (lakh INR)	8 – 10
Simple payback period (Yr)	2.5 – 3
GHG reduction potential (tCO_2/year)	35 – 40

Installation of PLC based automation and control system may lead to GHG emission reduction of approximately 35 to 40 tCO_2 annually in addition to 20 to 25% energy saving. The implementation cost of the recommended system is estimated to be around 8 - 10 lakhs including commissioning cost and other miscellaneous cost. The simple payback period works out to be 2.5 to 3 years.

Sustainable Impact

- Reduction in steam and water consumption
- Significant energy savings
- Enhance overall production capacity and colour uniformity.
- Automatically selects the heating and cooling cycle as per the process requirement
- Optimize the temperature as per the system requirement.

5.1.1.5 Energy efficient dyeing technologies

Background

There are many issues with current textile dyeing methods employed in the textile industries and many of them are related to excess water consumption and pollution. The current dyeing methods not only requires huge amount of water but also consumes large amount energy to heat up water and steam necessary for desired finish leading to high energy usage and high operational costs.

Waterless Dyeing Technology

Waterless dyeing technology addresses this challenge by eliminating or minimizing the water usage. It uses supercritical CO_2 as dyeing medium instead of water which dissolves and carries the dyes to the fabric thus, achieving fast and even dyeing. Basically, when CO_2 is heated and pressurized, it becomes supercritical (SC-CO_2), it has a very high solvent power, allowing the dye to dissolve easily. Owing to its high permeability upon heating, the dyes are transported easily and deeply into fibers, creating vibrant colours. The process does not use water or any process chemicals to dissolve the dyes or other purposes. The CO_2 produced is reclaimed. Fabric washing and drying processes are not required in this dyeing technology because at the end, depressurization results in the release of carbon dioxide in gaseous state leaving the fabric dry. Due to this, it reduces the CO_2 emissions and energy consumption as well as the operational costs as compared to the conventional dyeing technologies. At the end of dyeing process, excess dyes and residues are separated from CO_2, resulting in 95 % of CO_2 being recycled and sent to the storage tank for reuse.

Figure 66: Waterless Dyeing machine

The Dutch company DyeCoo Textile Systems produced the first industrial dyeing machines that use supercritical CO2. The polyester textile producer Tong Siang Co. Ltd in Thailand is the first textile mill to implement a commercial-scale supercritical fluid CO2 machine.

This technology is currently being used for dyeing of polyester (the most widely used textile fiber) and polypropylene fiber however, the application of this technique on wool, polyacrylate, and cotton is under research and development stage.

Sustainable impact

- **No water, no process chemicals, zero waste water**- It eliminates the need of water even for dyeing, washing and drying processes and since there is no waste water, therefore there is no need of waste water treatment.
- **High amount of energy saving-** Since there is no use of heated water or steam, it leads to large energy savings
- **Lower operational costs-** Short batch cycles, efficient dye use, no waste water treatment all contribute to significantly reduced operating costs.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of waterless dyeing technology. A cost-benefit analysis of the proposed system is given below;

Table 27: Cost-benefit analysis for Waterless dyeing Machine

Parameters	Values
Energy saving (%)	60 - 65
Investment (lakh INR)	2000 – 3000
Simple payback period (Yr)	1 – 2
GHG reduction potential (tCO_2/year)	55 - 60

Waterless dyeing machines may lead to a reduction of approximately 60 - 65% energy annually. The implementation cost of the recommended system is estimated to be around 20 to 30 crores including commissioning cost and other miscellaneous cost. The simple payback period works out to be 1- 2 years.

5.2.2 Utility

5.2.2.1 Replacement of PRS system with Micro Turbine

Background

Generally, the steam generated by boiler and distributed at a high pressure of about 9 to 10 bar to ensure reduced pipe diameter and reduced ration losses while the pressure requirement of the processes is of 3 to 4 bar only. To manage the steam pressure and ensure that pressure is reduced to a desired level as required in different processes such as dyeing or drying, pressure reducing systems are used in industries. But, during this pressure reduction process, a significant amount of useful heat is lost in this process resulting in wastage of thermal energy.

Microturbine

Replacement of pressure reducing system with microturbine is a solution to utilize the heat lost during pressure reduction for electricity generation to supplement the industrial units grid electricity supply. Microturbine utilizes high pressure steam generated by the boiler to generate electricity and also reduces the steam pressure in this process. Microturbines are tiny gas turbines that can generate both electricity and heat. They vary in electrical output from around 6 kW to 250 kW. These are designed to be used in large domestic or small commercial environments where they can provide both forms of energy. Microturbine has the potential of 10-15% electrical energy savings. Microturbines have shown good perspectives for the distributed generation of electricity in the low-generation range because they have high reliability and simple design. Microturbines help in the generation of electricity from otherwise energy wasted by the PRDS system.

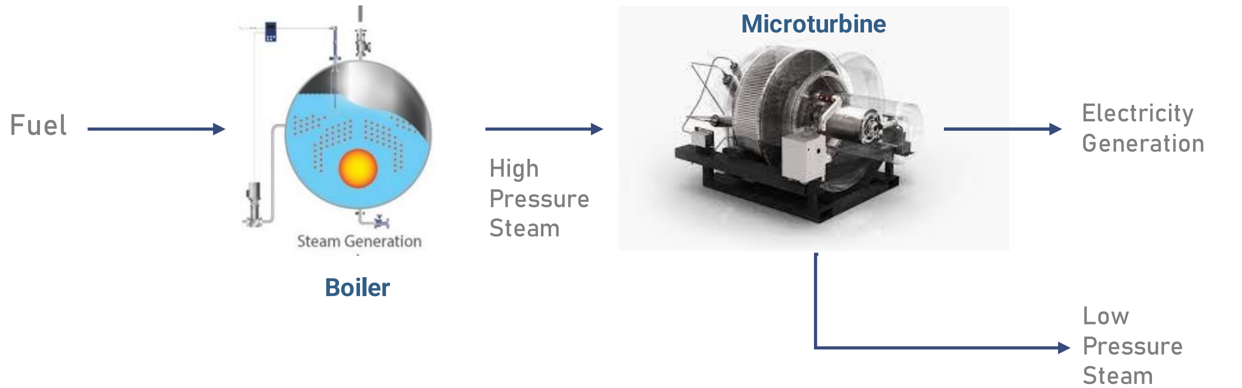

Figure 67: Working of Microturbine

Key benefits:

- **Reduced electricity bills and integrity of power supply:** Reduces the power utilized from the grid thereby resulting in reduced energy bills and dependence on the grid.
- **Reduced maintenance cost**
- **Reduced carbon footprint:** Overall reduction in GHG emissions
- **Plant optimization.** Fully utilize steam system capacity to maximize overall plant efficiency; Enables operators to use the energy released by the pressure reduction to supplement the existing electricity supply.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of microturbines. A cost-benefit analysis of the proposed system is given below depending on the rated capacity of microturbine.

Table 28: Cost-benefit analysis for Microturbine

Parameters	Case - 1	Case - 2	Case - 3
Rated capacity (kW)	6.5	65	200
Energy saving (%)	10-15	10-15	10-15
Investment (lakh INR)	2-5	25-30	55-60
Payback period (Yr)	1-1.5	1-1.5	1-2
GHG reduction potential (tCO_2/year)	20-30	370-380	440-450

Microturbines may result in an annual energy reduction of approximately 10 - 15% energy annually in addition to reduction in annual carbon dioxide emissions ranging from 200 to 400 tonnes of CO_2 for a single unit installation. The implementation cost of the recommended system is estimated to be around 15 to 60 lakhs depending upon the rated capacity of microturbine. The simple payback period works out to be 1- 2 years.

5.2.2.2 Replacement of standard efficiency motors with Energy Efficient motors

Background

Electric motors account for a very large share of electrical load and electricity consumption in the textile units. The textile industries use induction motors in utility applications which include their usage in air compressors, fans & blowers, pumps, etc. Generally, the industrial units use old and rewound motors which leads to increased losses and deteriorated motor efficiency.

Energy efficient motors

Energy efficient motors are a viable solution to address this issue. IEC Standard 60034-30-1 categorizes electric motors based on their energy efficiency, from IE1 (lowest efficiency) through IE2 (high efficiency) and IE3 (premium efficiency) to IE4 (super premium efficiency). The textile units can replace the inefficient/rewound motors with IE3 motors (premium efficiency motors) which are recommended for continuous process industries where high saving potential is essential. These motors result in reduced losses and improved energy efficiency. They have the added advantages of short payback period, enhanced motor life and require less maintenance.

Figure 68: Energy Efficient motors

Figure 68 shows that the efficiency of IE3 is more as compared to IE1 motors. It is evident that the difference in efficiency between the IE1 and the IE3 motors is more prominent in lower capacity motors as against the higher capacity ones. Hence the potential for energy savings is higher in lower capacity motors. Further, the lower capacity motors require less investment and results in quicker payback periods owing to higher energy savings. Figure 69 shows the variation of payback period and energy saving against motor rating. The higher the capacity of the motor, the lesser the energy savings and longer is the payback period.

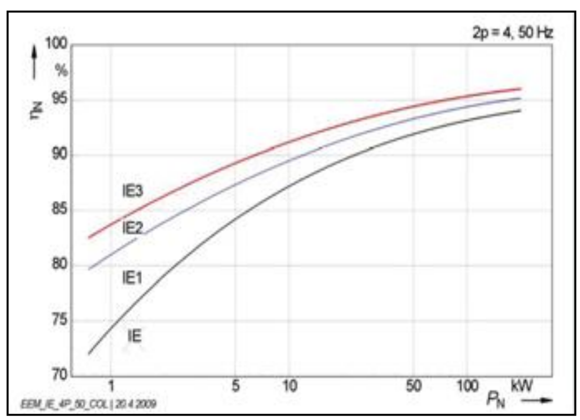

Figure 69: Comparison of efficiency of energy efficient motors

Moreover, it is observed that most of the MSME textile units have a larger number of low and medium capacity motors (5 to 15 HP) than those of higher capacities. Thus, it is advisable to consider to replace maximum number of low capacity and/or rewound old motors with EE IE3 ones of appropriate capacities.

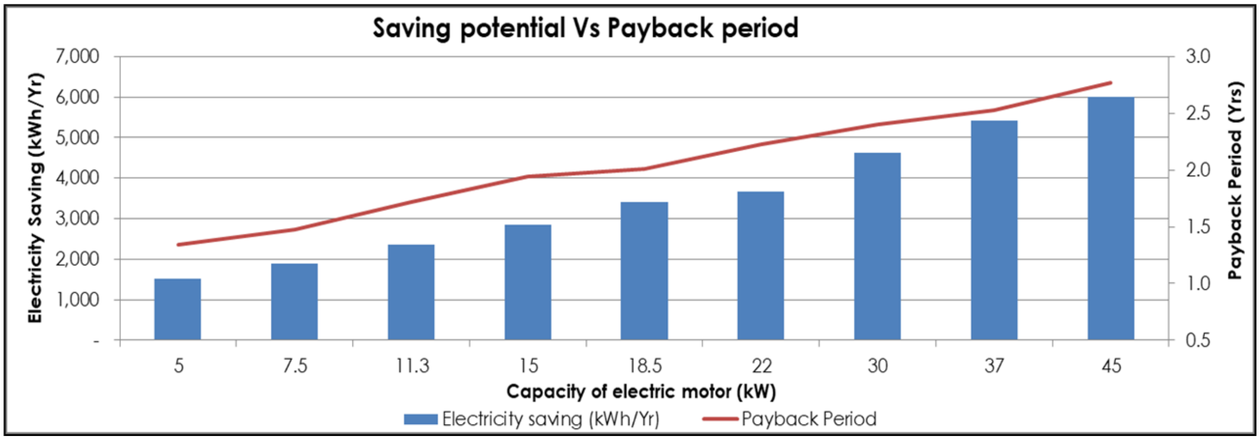

Figure 70: Saving potential vs Payback period for IE3 motors of capacity varying from 5kW to 45kW

Key benefits:

- **Reduce Energy Costs:** Enhanced design and construction lead to reduced energy consumption
- **Higher Productivity Gains:** Quicker response time and consistent performance results in high productivity gains
- **Lower Maintenance Costs:** They are typically built with high-quality materials and advanced engineering, resulting in a longer operational lifespan and lower maintenance requirements.
- **Improved Operation:** IE3 motors are often designed to operate at lower temperatures, reducing the risk of overheating and have advanced control features leading to improved operation

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of IE3 energy efficient motors. The cost-benefit analysis of the proposed system is given below.

Table 29: Cost-benefit analysis replacement of existing IE1 motors with IE3 energy efficient motors

Parameters	Case - 1	Case - 2	Case - 3
Rated capacity (kW)	3.7 kW (5 HP)	7.5 kW (10 HP)	11 kW (15 HP)
Energy saving (%)	6.5 to 7%	4.5 to 5%	4 to 4.5%
Investment (Lakhs)	0.15	0.30	0.45
Payback period (Yr)	1 to 1.5	1.5 to 2	2 to 2.5
GHG reduction potential (tCO_2/year)	1 to 1.5	1.5 to 2	2 to 2.5

Considering that low and medium-capacity motors constitute more than 90% of the total number in operation, it can be stated that the overall potential for energy saving across electrical motors is significantly high. Typical electricity saving potential for an IE3 motor with a rated capacity of 7.5 kW and 11 kW, falls in the range of 4-5%. GHG reduction range varies across the rated capacity, which is 1.5-2 tCO_2 per annum for a 7.5 kW IE3 motor and 2 to 2.5 tCO_2 per annum for a 11 kW IE3 motor. Investment for a 7.5 kW IE3 motor is 30,000 INR, whereas, with an increased capacity of 11 kW, the investment increases to 40,000 – 45,000 INR. The simple payback period falls in the range of 1.5 to 2.5 years.

5.2.2.3 Replacement of standard efficiency pumps with Energy Efficient (EE) Pumps

Background

Pumps play a very important role in the textile industry. Both in the process as well as auxiliary systems, the energy consumed by the pumping system is significant. It is observed that most of the pumps in the textile units are not running at full capacity and are often worn out.

Energy efficient pumps

To address this issue, it is recommended to use the energy-efficient pumps that come with more than 70% operating efficiency and therefore bring down the overall power consumption of the unit. They are compact in size with wide operating pressure ranges. The energy efficient pumps help in optimizing energy usage across the entire pumping system on the plant and thereby help in minimizing overall GHG emissions.

The pump is selected based on how well the pump curve and system head flow curve matches which gives the operating point. The operating point of the pump must be close to its best efficiency point (BEP), which is the point at which the pump operates at its highest efficiency and thus gives the best performance.

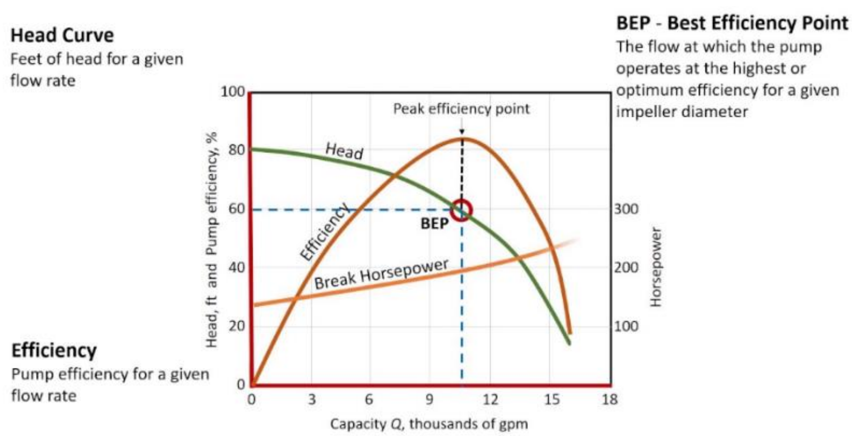

Figure 71: Pump characteristic curve

The most significant savings in the energy consumption of a pumping system can be achieved by selecting the most appropriate pump technology for an application with premium efficiency. Matching the most appropriate pump construction with the optimum impeller design will result in the most cost-effective solution, both in terms of initial capital investment and long-term operating costs. The correct sizing of the pump represents the next most significant economic opportunity to reduce energy consumption.

Enhanced energy efficiency and additional energy savings can be attained by utilizing a variable speed drive (VSD) in conjunction with a maximum diameter impeller to drive the pump. This allows the rotational speed of the pump to be adjusted to achieve the desired head and flow for the process application. The potential improvement in efficiency, when compared to a pump operating at a constant speed, can reach up to 10%. Installation of a VSD with existing pumps provides adaptability to changing system requirements and potential expansion plans, eliminating the need for pump replacements after installation.

Key benefits:

- **Reduced Energy Costs:** Enables to achieve significant cost savings over time thus provide improved energy efficiency, reduced the energy costs and production costs as well as support green credentials.
- **Lower Maintenance Costs and Reliable Pumping:** Improved the reliability of pumping systems, reducing the need for costly repairs and replacements. By increasing equipment lifespan, businesses can save money over time and reduce their environmental impact.
- **Improved Operation:** As compared to standard pumps, these provide comparatively improved pump performance and system operation.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of energy efficient pumps. The cost-benefit analysis of the proposed system is given below.

Table 30: Cost-benefit analysis for EE pumps

Parameters	Case - 1	Case - 2	Case - 3
Rated capacity (kW)	3.7 kW (5 HP)	7.5 kW (10 HP)	11 kW (15 HP)
Energy saving (%)	21 to 25%	15 to 20%	15 to 20%
Investment (lakh INR)	0.75	1.49	2.24
Simple payback period (Yr)	2 to 2.2	2.2 to 2.5	2.3 to 2.5
GHG reduction potential (tCO_2/year)	4 to 4.5	7.5 to 8	10.5 to 11

Energy efficient pumps may lead to a reduction of approximately 15 to 20% energy annually. The implementation cost of the recommended system is estimated to be around 0.75 to 2.24 lakhs including commissioning cost and other miscellaneous cost. The simple payback period works out to be 2 to 2.5 years.

5.2.2.4 Installation of PMSM Air Compressor or VFD Retrofit

Background

The textile units mostly use fixed speed screw type air compressors. These compressors run for an average of 15 to 16 hours only while for remaining time they are either running on light load conditions of no load. The unload cycle consumes nearly 30 to 35% of loaded power resulting in ample amount of wastage of energy.

PMSM Air compressor or Retrofit VFD

Figure 72: PMSM air compressor

To cater this issue, it is recommended to replace fixed-speed screw and/or reciprocating type air compressors with PMSM (Permanent Magnet Synchronous Motor) air compressor. PMSM air compressor can trace the loading power and change rpm while the system is running on a partial load and maintain the same high-efficiency level as when it is running on a full load, it offers flexible loading with high energy savings. It meets the efficiency standard for frequency conversion driving permanent magnet motors, outperforming IE4 by a wide margin.

One more recommendation is retrofitting the rotary screw air compressors with VFDs. The installation of a VFD allows the compressor speed to be reduced or increased based on the compressed air requirements of the plant. This eliminates the unloading condition and reduces the amount of unloading power consumed. VFD works best with rotary screw compressors, as their flow rate and their power consumption are virtually proportional to their speed. So, as the motor adapts to its speed, so do the screw elements and, as a result, the amount of compressed air delivered gets optimized.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant energy savings can be achieved by the use of PMSM Air compressors. The cost-benefit analysis of the proposed system is given below.

Table 31: Cost-benefit analysis for PMSM air compressors

Parameters	Case - 1		Case - 2		Case - 3	
	Reciprocating type	Rotary screw	Fixed speed rotary screw	PMSM air compressor with inverter	Rotary screw with inverter	PMSM air compressor with inverter
Rated capacity (kW)	7.5(<15hp)		22 (15 to 25hp)		37(>25hp)	
Energy saving (%)	10-15		25-30		10-15	

Investment (Lakhs)	1.50	5.50	12.50
Payback period (Yr)	2-2.5	2.5-3.0	3-3.5
GHG reduction potential (tCO_2/year)	8-10	30-35	35-40

PMSM air compressors may lead to a reduction of approximately 20 to 25% energy annually. A typical electricity saving potential of 25-30% can be achieved with a rated capacity of 22 kW up from fixed speed rotary screw compressor, whereas with a 37-kW rated capacity and moving up from a rotary screw with an inverter to PMSM air compressor, can lead to only 10-15% of electricity savings. To make a replacement, an investment of 5.5 lakh and 12.5 lakh INR need to be incurred for 22 kW and 37 kW rated capacity, respectively. These replacements have a simple payback period of 2.5 to 3.5 years.

Key benefits:

- **Significant energy savings:** It reduces the energy consumption by at least 25%
- **Low operating noise:** Compared with ordinary air compressors, PMSM air compressors have less vibration and low noise, and are suitable for use on more occasions.
- **Stable air pressure:** It can start smoothly through the PID regulator inside the frequency converter and can quickly adjust the response when the air consumption fluctuates greatly.

5.2.2.5 Optimization of Air to fuel ratio for Boiler and TFH

Background:

In majority of the textile industries, an elevated level of oxygen is commonly observed in the exhaust flue gas of the boiler signifying that the air concentration is higher than the optimal air concentration needed in the boiler during the combustion process. When air to fuel ratio is excessively high, it means there is abundance of air involved in the combustion, which absorbs extra heat resulting in fuel wastage and thus proves to have detrimental effect on the boiler efficiency.

Oxygen trim system:

To address this issue, Oxygen analyzers and oxygen trim systems can be used with boiler to optimize the air to fuel ratio through oxygen monitoring and automatic adjustment of air and fuel supply to the combustion process. Portable oxygen analyzers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 50-75% is feasible. The most common method is the continuous oxygen analyzer with a local readout-mounted draft gauge, by which the operator can adjust airflow. A further reduction of 30-50% can be achieved with the previous system. The oxygen "trim" system continuously

Figure 73: Oxygen trim system connected to boiler

monitors the flue gas and provides feedback to the burner controls to automatically minimize excess combustion air and optimize the air-to-fuel ratio. The system contains the Zirconium probe, PLC controller cum display and preset mechanism integrated with VFD to modulate speed of FD fan. The unit also consists of a self-calibration mechanism to ensure accuracy of less than 2%. There are two types of approaches for O_2 trim, namely:

- Single point (jackshaft) positioning with a trim actuator.
- Parallel positioning (metering), separate actuators for the fuel valve(s) and FD damper

Parallel positioning is a more commonly used approach as compared to single point positioning. Parallel positioning control helps a burner to optimize its fuel-to-air ratio by using dedicated motorized actuators for the fuel and air valves. These parallel positioning controls directly tie into the electronic firing rate control, enabling more efficient and consistent performance. Adding O_2 trim helps minimize excess air and keeps the burner from going excessively rich, which leads to inefficient combustion. It saves up to 3% in fuel costs and increases efficiency by up to 2%.

Key Benefits:

- O_2 monitoring and alarm due to low excess air or combustibles.
- Reduces GHG emissions by reducing electricity and fuel consumption.
- Combustion efficiency computation per fuel to alert the owner about service requirement for burner
- Flue gas temperature monitoring and alarms, alerts the owner when the boiler tubes are fouled and shut down due to high flue gas temperature.

Energy & GHG reduction potential

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use Air to fuel control system The cost-benefit analysis of the proposed system is given below.

Table 32: Cost-benefit analysis for Air to fuel control system

Parameters	Values
Energy saving (%)	15 to 30%
Investment (lakh INR)	18 to 19
Simple payback period (Yr)	1 to 2
GHG reduction potential (tCO_2/year)	300 – 500

Air to fuel control system may lead to a reduction of approximately 15 to 30% energy annually. The implementation cost of the recommended system is estimated to be around 18 to 19 lakhs including commissioning cost and other miscellaneous cost. The simple payback period works out to be 1 to 2 years. Due to the substantial investment required, it is frequently advisable to implement this in smaller or medium-sized facilities.

5.2.2.6 Optimization of Thermic Fluid flow rate with PID-based temperature controller & VFD

Background

The TF pump installed at the plant is used to circulate thermic fluid to the process and return the cooled liquid to the TFH. It is often seen that the temperature range of thermic fluid between the supply and return flow is quite low, varying from 10ºC to 15ºC. This indicates that the fluid is returning to the TFH without transferring the required heat to the process and frequent circulation results in higher power consumption by the TFH pump. This often leads to ineffective heat utilization at the user end; undue circulation of TF causing higher power consumption as well as higher surface heat loss.

PID based flow control system for TFH with Temperature control valves

To address this challenge, it is recommended to install PID-based temperature controller on the supply and return lines of the TFH and maintain the temperature difference at around 20ºC. A PID-based temperature controller connected to one two-way valve is used to control the process temperature by regulating the flow or pressure of thermal fluid. Also, one VFD should be installed in the TFH Pump interlocked with the PID-based temperature controller which will send a signal to the VFD to increase or decrease the pump flow as per the real-time delta T measurement across the supply and return lines. By employing this PID-based solution, precise control over the flow of thermic fluid can be achieved, optimizing the heating process.

Figure 74: 2 way valve

The PID regulates the flow rate by adjusting valves or other control mechanisms, ensuring that the thermic fluid is delivered at the desired rate for efficient heating. This automated system not only enhances accuracy but also allows for real-time adjustments based on temperature and other parameters, contributing to improved operational efficiency and energy savings in thermic fluid heating applications.

Key Benefits:

- **Reduces and regulates the thermic fluid flow by VFD control on circulation pumps:** The PID, in conjunction with VFD control on circulation pumps, allows for precise regulation of the thermic fluid flow.
- **Reduced power consumption and surface heat losses**. The use of VFDs ensure that pumps only provide the necessary amount of fluid flow required for the desired temperature control resulting in reduced power consumption and surface heat losses.
- **Reduces the GHG emission** by reducing electricity consumption.

Energy & GHG reduction potential:

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that large energy savings can be achieved by the use of temperature control valves. The cost-benefit analysis of the proposed system is given below.

Table 33: Cost-benefit analysis for PID-based temperature and flow control system

Parameters	Values
Energy saving (%)	50 - 60%
Investment (lakh INR)	8 - 11
Simple payback period (Yr)	2 – 3
GHG reduction potential (tCO_2/year)	25 – 30

PID-based temperature controller with VFDs may lead to a reduction of approximately 50 to 60% energy annually. The implementation cost of the recommended system is estimated to be around 8-11 lakh. The simple payback period works out to be 2 to 3 years.

5.2.2.7 Condensate recovery system

Background

In the dyeing section, low-pressure steam is being used in the dyeing machines. The purpose of the steam is to raise the temperature of the dyeing liquor using a heat-exchanger (indirect heating). The plant generally has installed a gravity-based condensate recovery system using a common steam trap in the main recovery line. It has been observed that condensate temperature at the output of the end-use application is higher than the condensate temperature earlier, which indicates significant heat loss from the condensate stream owing to a lack of adequate steam trap and pumping system. Inadequate condensate recovery impacts not only the dyeing machine's performance but also the overall efficiency of the boiler.

Condensate Recovery System:

Installation of condensate recovery system to reuse the water and useful heat contained in the discharged condensate is the most appropriate solution to address this issue. Use of dedicated steam traps at adequate points and condensate recovery pumps (PPPU) can improve the condensate recovery system. A Steam trap is an automatic drain valve which distinguishes between steam and condensate. It holds back steam & discharges condensate under varying pressures or loads. The steam traps should have good capacity to vent out air and other non-condensable gases quickly while holding back the live steam. This ensures that the steam remains dry at the desired temperature, thus maximizing the energy efficiency of the steam system.

Figure 75: Condensate Recovery System

Key Benefits:

- **Reduced fuel cost:** Condensate contains thermal energy. Condensate recovery therefore reduces fuel requirements, since the amount of energy to be added to boiler feedwater to produce steam is reduced.
- **Lower water related expenses:** With every drop of returned condensate reduces the amount of make-up water that has to be injected into the steam system and also condensate is an excellent source of feed water.
- **Reduced effluent:** Volume of effluent generated is reduced with increasing levels of condensate return.
- Improved process control and efficiency of steam system

Energy & GHG reduction potential:

The analysis of the information and operational data gathered from the assessment studies and literature surveys reveals that significant energy savings can be achieved by the use of condensate recovery system. The cost-benefit analysis of the proposed system is given below.

Table 34: Cost-benefit analysis for improved condensate recovery system

Parameters	Values
Energy saving (%)	25 to 30%
Investment (lakh INR)	7 – 8
Simple payback period (Yr)	2 – 3
GHG reduction potential (tCO_2/year)	25 – 30

Condensate recovery system may lead to a reduction of approximately 25 to 30% energy and GHG reductions of 25 to 30 tCO_2 annually. The implementation cost of the recommended system is estimated to be around INR 7 to 8 lakhs. The simple payback period works out to be 2 to 3 years.

5.2.3 Renewable

The use of renewable energy sources such as solar and wind in the textile industry is a positive step towards a more sustainable future. As more textile companies adopt these technologies, we can expect to see a reduction in carbon emissions and a more environmentally friendly industry.

5.2.3.1 Rooftop solar Photovoltaic (PV) system

Background

Figure 76: Rooftop solar PV system

Most of the textile units in the major Indian clusters have sufficient empty rooftop area which can be utilized for solar PV system installation. Rooftop solar photovoltaic system is one of the options for sourcing green and low-cost electricity in textile industries particularly in the textile products processing units. Rooftop solar panels utilize sunlight to generate electricity. Most of the textile clusters are situated at ideal geographical locations receiving ample tropical sunlight.

The installation of the rooftop solar panels will effectively utilize the existing shed/roof without requirement of any additional investment for land. The landed cost of electricity from solar PV system in comparison to industrial tariff rates is cheaper by 15 to 25 percent. The electricity utilization in textile manufacturing units is high mainly in the dyeing process and stenter machine sections which operate throughout the day, as per requirement, and therefore rooftop panels can provide a significant share of electricity to the units during the daytime. This would result in reduced grid electricity and backup power consumption, thereby resulting in significant saving on energy costs.

For installation of solar rooftop PV system in industrial units, CapEX (Capital Expenditure) model and RESCO(Renewable Energy Service Company) Solar model or OPEX (Operating Expenses) model are the two feasible and effective financial models employed. CApEX model is the most common business model used for solar deployment in India. This model offers ownership, control and long-term savings but with high upfront investment.

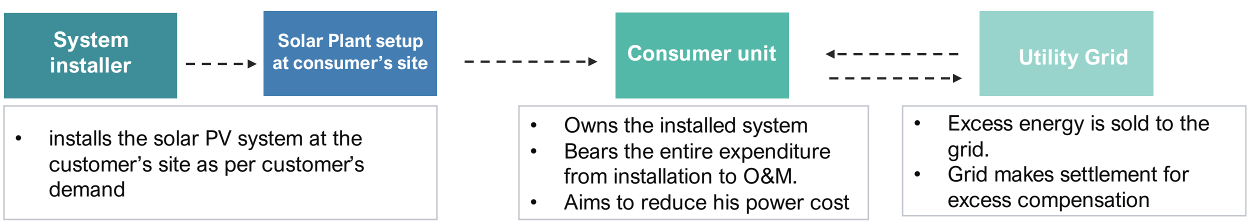

Figure 77: CapEX model

As shown in Figure 76, in this model, the industrial/consumer unit owns the installed system and invests upfront cost i.e., is responsible for entire expenditure from installation to operation and maintenance. Here, the solar EPC company is hired by the consumer unit to provide turnkey installation of the solar system along with annual operation and maintenance (O&M) services at a mutually agreed cost per annum. While the commercial benefits of investment and benefit of selling the surplus power generated is taken by consumer unit. In case of excess energy, the consumer unit sold it to utility grid as a result of settlement with the grid for excess compensation.

The other most adopted model in solar industry is RESCO or OPEX model. In this model, a Renewable Energy Service Company (RESCO) provides energy to the consumers from the plant based on the renewable energy sources usually, solar PV. The solar system is owned by the RESCO while the customer signs the power purchase agreement, and the consumer pays for the electricity consumed on monthly basis. The RESCO owner takes complete ownership and responsibility of the operations and maintenance of the system for the duration of its lifetime. RESCO may benefit by selling the surplus power generated to the DISCOM.

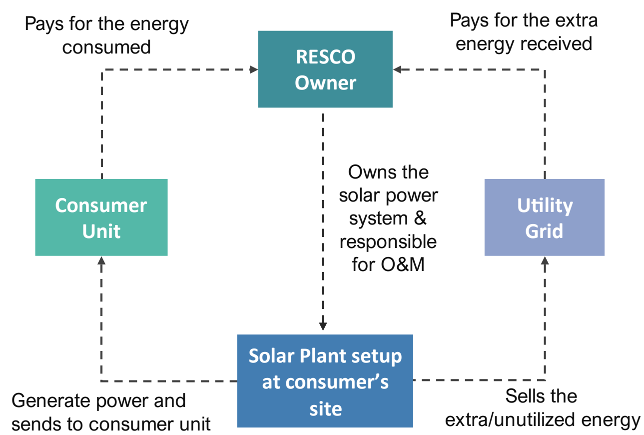

Figure 78: RESCO model

BOOT (Build, Own, Operate and Transfer) is a type of RESCO model where the RESCO constructs, owns, operates and transfers the ownership of the rooftop solar project to the customer (Rooftop Owner) after expiry of contract period or as per agreed terms. After the transfer of ownership, the customer is responsible for O&M. Customer may choose to retain the services of the original RESCO or he may make his own arrangements for O&M requirements.

5.2.3.2 Third party purchase (TPP) from solar and wind suppliers

Purchasing solar and wind power from third-party suppliers through power purchase agreements (PPAs) is indeed a viable and sustainable alternative for industrial units, especially when rooftop solar PV systems are not feasible. It will reduce their dependence on costlier gird electricity and also result in emission reductions in addition to energy savings. This can save upto 30 to 40% tariffs as solar power is cheaper than grid power.

Third party (Open access) model eliminates the constraint of on-site solar installation by offering a scalable option that is not limited by the availability of space at the consumer unit. The model enables large power consumers with connected load of more than 1 MW power to procure cheaper electricity from open market in India. The third party sets up the solar plant at a remote location with own expenditure. The party owns and operates the plant and is also responsible for plant O&M. The consumer unit can contract with a solar IPPs (independent power producers) through a power purchase agreement to buy power generated from their solar plant and pay for the electricity consumed by the unit. Similarly, this model can also be applied for wind power system.

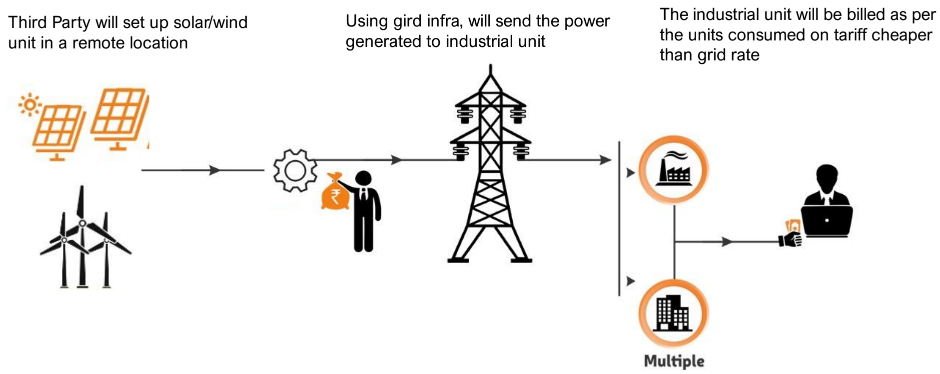

Figure 79: Third Party model

5.2 Resource Efficiency Options

Cleaner production methods boost the textile industry's competitiveness by reducing production and waste management, optimizing resource use, building brand value, and satisfying key international brand requirements. Resource efficiency in the textile industry varies across countries based on their economic development, policies, technologies, and cultural approaches to sustainability. Below we have summarized key resource efficiency options and provided the actions taken by different countries.

5.2.1 Material Efficiency

Material efficiency in the textile industry involves optimizing the use of raw materials and inputs throughout the entire product lifecycle to minimize waste, reduce resource consumption, and maximize the value and sustainability of the products. It encompasses efficient material selection, design, production, consumption, and end-of-life strategies.

- Optimized Material Selection: This includes the use of sustainable and recycled fibers to reduce the demand of virgin resources. Fabrics made from biodegradable materials such as organic cotton, hemp, bamboo, and Tencel (made from wood pulp) are gaining popularity, reducing dependence on petroleum-based synthetic fibers.
- Waste Reduction: This encompasses implementing efficient cutting techniques and pattern layouts to reduce fabric wastage during manufacturing. Collecting and repurposing textile waste such as scraps and offcuts to create new products or materials.

Patagonia's Material Efficiency Initiatives (United States)
Patagonia is moving towards 100% renewable and recycled raw materials. By using both synthetic and natural fibers made from pre-consumer and postconsumer waste, Patagonia is limiting dependence on raw materials and reducing carbon emissions. Also, Patagonia initiated the Common Threads Recycling Program, encouraging customers to return worn-out Patagonia clothing and gear for recycling. The recycled materials are used to create new products, minimizing waste, and maximizing material efficiency.

5.2.2 Water Efficiency

The textile industry is one of the most water-intensive sectors, from fiber production to dyeing and finishing processes. Implementing water-efficient practices helps reduce water consumption, minimize pollution, and contribute to environmental conservation.

- Water Recycling and Reuse: This includes implementing systems to treat and recycle wastewater generated during the production process. Treated water can often be reused for various non-critical processes, reducing the overall demand for fresh water.
- Closed-Loop Water Circuits: It encompasses the design and installation of closed-loop water systems to circulate water within the manufacturing process, minimizing water wastage and the need for continuous freshwater input.
- Process Optimization: Optimizing the dyeing and finishing processes to use the least amount of water required to achieve the desired color and finish. Proper process management can significantly reduce water wastage.
- Waterless Dyeing Technologies: Explore and adopt waterless dyeing technologies like air dyeing, foam dyeing, or digital printing, which require little to no water compared to traditional dyeing methods.
- Rainwater Harvesting and Greywater Use: Harvest rainwater for non-potable uses such as cleaning and irrigation. Additionally, consider using greywater (wastewater from sinks and showers) for non-critical processes within the facility.

DyeCoo: Waterless Dyeing with CO_2 (The Netherlands)

The DyeCoo system uses recycled carbon dioxide in a closed-loop process to dye textiles. This method involves the use of CO_2 as a solvent, enabling the dye to penetrate the fabric efficiently. By eliminating the need for water, DyeCoo's technology offers substantial water savings and reduces the environmental impact associated with traditional dyeing methods. The closed-loop system prevents dye and chemicals from entering the water stream, contributing to pollution reduction and a more sustainable textile industry.

5.2.3 Use of Renewable energy

Incorporating renewable energy sources such as solar or wind power to the manufacturing facilities are of utmost importance. Renewable sources help reduce reliance on non-renewable energy, decrease greenhouse gas emissions, and promote a greener and cleaner production process. Here are various ways renewable sources are utilized in the textile industry:

- Use of RE sources: This can be done through installing solar panels on rooftops and open spaces to harness solar energy, reducing reliance on conventional grid-based electricity. Solar thermal systems are used to provide hot water and steam needed in various textile processes like dyeing and finishing, thereby reducing the energy demand from conventional sources.

Solar Rooftop Installations: Arvind Limited (India)

Arvind Ltd. has installed solar panels on the rooftops of its manufacturing units and other available spaces to harness solar power. The solar power generated is utilized to meet a significant portion of the energy requirements for the textile manufacturing processes. By integrating solar energy into their operations, Arvind Limited has reduced their dependence on non-renewable energy sources and significantly lowered their carbon footprint.

5.3 Energy and Resource Savings Potential

The table below provides a comprehensive overview of the significant technological options, detailing their potential for energy and resource savings. This includes an assessment of their energy-saving capabilities, sector-specific investment requirements, emission reduction impact, and the respective payback periods.

Table 35: Assessment of energy saving measures (Investment, Saving and GHG emission reduction)

Measure	Saving potential (%)	Payback period (years)	Energy saving (toe/yr)	Sector level investment (INR lakh)	Emission reduction (tCO2)
Process Section					
Fabric Moisture Control in Stenters	3 – 4%	1 – 2	5,86,898	105,090	4,72,223
Blower Speed Optimization in Stenters	30 - 40%	1 – 2	325,359	394,088	3,064,424
Exhaust Humidity Control System	5 – 10%	2 – 3	226,303	191,789	1,117,355
Waste Heat Recovery System	10 – 15%	2.5 – 3	2,81,927	1,05,090	11,34,204
Utility Section					
Replacement of PRS system with microturbine	10 – 15%	1 – 2	33,187	15,764	3,12,571
Replacement of standard efficiency motors with Energy efficient motors	4 – 7%	2 – 2.5	80,563	1,26,739	7,58,792
Replacement of standard Efficiency pumps with EE pumps	15 – 25%	2 – 2.5	2,27,165	4,08,380	21,39,581
Installation of PMSM Air compressors	10 – 30%	2 – 3.5	41,646	99,836	3,92,246
Air to Fuel ratio Optimizer for Boiler and TFH	15 – 30%	1 – 2	1,114,784	199,671	4,484,821
PID based temperature and flow control system with 2-way valves for TFH	50 – 60%	2 – 3	33,428	1,15,599	3,14,844
Condensate recovery system	25 – 30%	3 – 4	1,66,032	84,072	6,67,952

6. Institutional Framework in Textile sector

The MSME (Micro, Small, and Medium Enterprises) sector is intricately connected with a diverse array of stakeholders, each playing a crucial role in fostering its growth and development. These stakeholders form a dynamic ecosystem that encompasses industry associations and apex bodies, cluster level industry associations, apex bodies, research and development (R&D) institutes, and governmental agencies and departments. The brief details of the stakeholders as shown in figure below and their functions in the MSME sector are provided in this section.

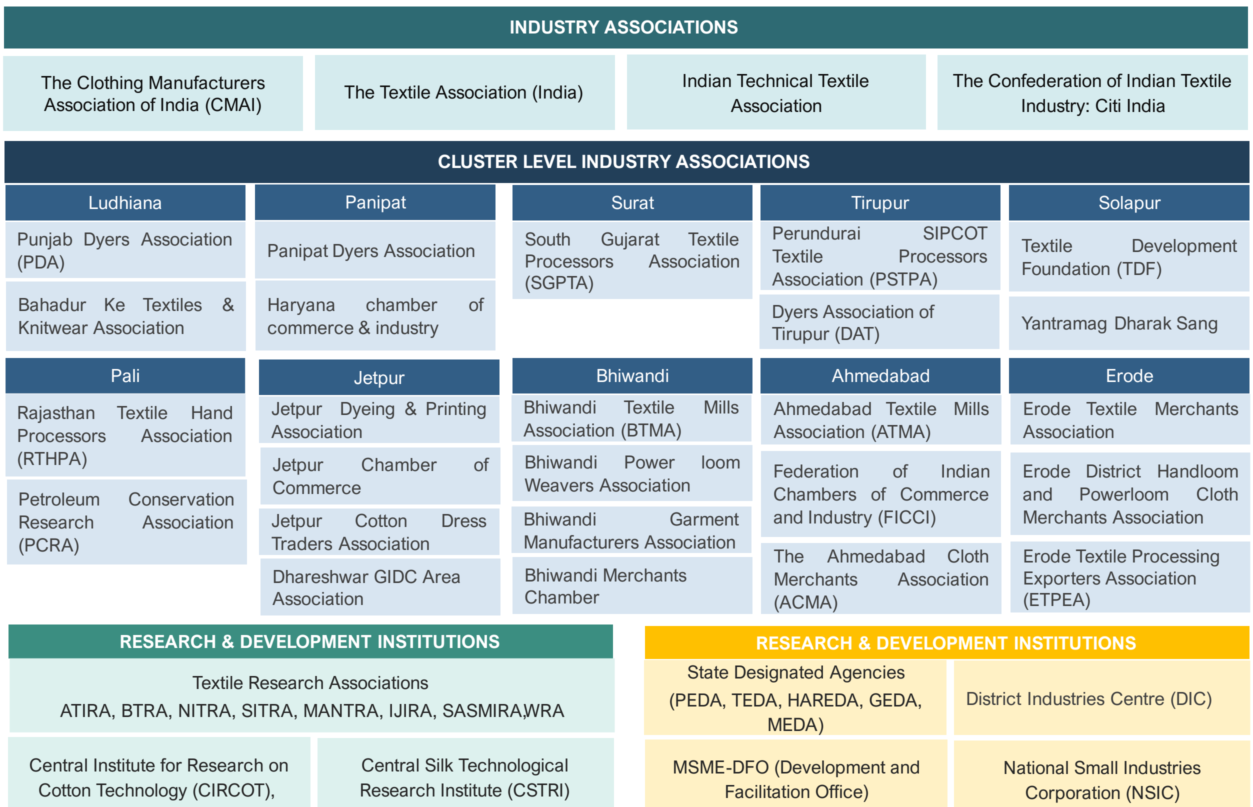

Figure 80: Key stakeholders

6.1 Industry Associations and apex bodies

The industry associations and apex bodies in the textile sector are available at the national level and/or cluster level. They play a pivotal role in transforming the textile sector of India into a more energy and resource-efficient industry. These associations act as catalysts for change by fostering collaboration, disseminating best practices, supporting policy advocacy, facilitating technology adoption, and advocating for sustainable initiatives.

6.1.1 The Clothing Manufacturers Association of India (CMAI)

The Clothing Manufacturers Association of India (CMAI) is the pioneer and most representative Association of the Indian apparel industry for over four decades. It has a membership base of over 20,000 companies, including Readymade Garment Manufacturers, Exporters, Retailers and Ancillary Industry. With its headquarter in Mumbai, CMAI also has branches in New Delhi, Bangalore and Pune.[17]CMAI plays a vital role as a catalyst for industry transformation, actively engaging with the government on policy matters that profoundly affect the future of the apparel sector. One of CMAI's significant accomplishments for the industry is its pivotal role in the establishment of the Apparel Export Promotion Council (AEPC) back in 1978. Today, AEPC regulates the promotion of the entire spectrum of garment exports from India.

6.1.2 The Textile Association (India)

The Textile Association (India) established in the year 1939 and headquartered in Mumbai is the largest national professional body of India having more than 26,000 memberships.[18] The association is dedicated to the development and growth of the Indian textile industry through the promotion of knowledge, education, and research. The association provides a platform for members to interact, share knowledge and experiences, and collaborate on various initiatives. The association organizes various events, seminars, and workshops which facilitate discussions on industry trends, innovations, and challenges among members. Additionally, it offers educational programs to enhance textile professionals' knowledge and skills, ensuring their continuous growth. Overall, it plays a vital role in promoting the growth and development of the Indian textile industry and serving as a key platform for the country's textile professionals.

6.1.3 Indian Technical Textile Association

Established in the year 2010, its formation is facilitated by the office of the Textile Commissioner, Ministry of Textiles, Govt. of India. This is the only association of the Technical Textile Industry in India covering all 12 segments including Composites. ITTA has nearly 400 members as on date, representing the entire technical textile value chain from raw material to finished goods producers, machinery manufacturers, consultants, centres of Excellence and R&D institutes. Its members are spread across the country and contribute more than 70% (FY 2019-20) of the total exports of 207 technical textile items. The objective of ITTA is to promote, support, develop and increase the production, consumption and export of technical textiles to make India a powerhouse of technical textiles in the days to come.[19]

[17] https://cmai.in/
[18] https://www.textileassociationindia.org/
[19] https://www.ittaindia.org/

6.1.4 The Confederation of Indian Textile Industry: Citi India

The Confederation is an apex industry chamber representing all the sub sectors of the textiles sector through its Member Associations, Associate Members and Corporate members. It represents significant regional and industry associations as well as 18 prominent corporate members, effectively spanning the entire textile value chain, from agriculture to garment and textile machinery. CITI serves as an interface between the Indian government and the industry, offering policy recommendations to the government while advocating for the textile and clothing sector's interests through policy amendments. [20]

6.2 Cluster level Industry Associations

There are a number of textile industry associations functional at cluster level to cater to domestic needs of textile industries. These industry associations are generally involved in redressal of grievances, infrastructural development, and addressing environmental preservation and pollution control related activities. With enhanced awareness on energy efficiency over the years, the industry associations further started providing platforms for undertaking activities on technology adoption, energy efficiency improvements and training of textile manufacturing fraternity that would lead to sustainability of individual industries. Table 37 shows key industry associations in the textile sector which are active at cluster level.

Table 36: Clusterwise Industry Associations of the clusters involved in the project

Cluster	Industry association
Ludhiana	- Punjab Dyers Association (PDA) - Bahadur Ke Textiles & Knitwear Association
Panipat	- Panipat Dyers Association (PIA) - Haryana chamber of commerce & industry (HCCI)
Surat	- South Gujarat Textile Processors Association (SGPTA)
Tirupur	- Perundurai SIPCOT Textile Processors Association (PSTPA) - Dyers Association of Tirupur (DAT)
Solapur	- Textile Development Foundation (TDF) - Yantramag Dharak Sang (Power loom Owners Association)
Pali	- Rajasthan Textile Hand Processors Association (RTHPA) - Petroleum Conservation Research Association (PCRA)
Jetpur	- Jetpur Dyeing & Printing Association - Jetpur Chamber of Commerce - Jetpur Cotton Dress Traders Association

[20] https://textilevaluechain.in/directory/confederation-of-indian-textile-industry-citi/

Cluster	Industry association
	- Dhareshwar GIDC Area Association
Bhiwandi	- Bhiwandi Textile Mills Association (BTMA) - Bhiwandi Power loom Weavers Association - Bhiwandi Garment Manufacturers Association - Bhiwandi Merchants Chamber
Ahmedabad	- Ahmedabad Textile Mills Association (ATMA) - Federation of Indian Chambers of Commerce and Industry (FICCI) - The Ahmedabad Cloth Merchants Association (ACMA) - Textile Manufacturers' Association (TMA)
Erode	- Erode District Handloom and Powerloom Cloth Merchants Association - Erode Textile Merchants Association - Erode Textile Processing Exporters Association (ETPEA)

6.3 Research and Development Institutions

India has several research and development institutions dedicated to the textile sector. These institutions play a crucial role in advancing research, development and innovation in various aspects of textile sector including fiber technology, textile manufacturing and product development. Some of the major technical research and development institutions involved in textile sector and related activities are listed below.

6.3.1 Textile Research Associations

The Ahmedabad Textile Industry's Research Association (ATIRA), Bombay Textile Research Association (BTRA), South India Textile Research Association (SITRA), and Northern India Textile Research Association (NITRA) are the technical institutions involved in textile sector related activities.

Ahmedabad Textile Industry's Research Association (ATIRA)

Ahmedabad Textile Industry's Research Association (ATIRA) is an internationally renowned textile research institute for the textile allied industry. Established in 1947[21], the institution covers all aspects from Fiber to finished fabrics in traditional textiles as well as Technical Textiles in the arena of Geo-textiles, Nano – web technology and Composites. With a dedicated focus on textile research, technology, and quality enhancement, it offers a wide spectrum of services, including testing, consultancy, and training, catering to the diverse needs of textile manufacturers.

[21] https://atira.in/about-atira/

Bombay Textile Research Association (BTRA)

Established in 1954 by the Government of India in collaboration with industry associations, BTRA (Bombay Textile Research Association) stands as a pioneering textile research institute with over 65 years of experience.[22] Its primary mission is to enhance research, conduct testing, provide consultancy services, and offer certification services in the realms of textiles, polymers, fibers, and other materials. Currently, the institute receives partial funding from the Ministry of Textiles (Government of India), and its laboratories hold approval and recognition from the Ministry of Textiles. BTRA is recognized (based on earlier experience, expertise and facility) as a Centre of Excellence for Geotech by the Ministry of Textiles, Government of India.

South India Textile Research Association (SITRA)

SITRA established in the year 1956, is governed by a Council of Administration and is supported by the Ministry of Textiles, Government of India. The association consists of member representatives from the Industry, Government and Scientists. SITRA offers consultation services in various areas related to spinning, weaving and knitting. It houses well-equipped testing, electronics and calibration laboratories, pilot mills, library, etc. SITRA has a full range of sophisticated textile testing instruments and modern machines, , positioning itself as one of the most well-equipped textile research organizations globally.

Northern India Textile Research Association (NITRA)

NITRA (Northern India Textile Research Association) stands as one of the foremost textile research institutes in the nation. Established jointly by the textile industry and the Ministry of Textiles, Government of India in 1974, NITRA's primary purpose is to conduct applied scientific research and offer support services to the Indian textile industry.[23] Its core activities encompass research and development, technical consultancy, quality assessment of materials, manpower training, third-party inspection, and the publication of technical books and papers. Additionally, NITRA extends facilitating services to the decentralized power loom sector through its eight centers situated in Tanda, Kanpur, Meerut, Gorakhpur, Varanasi (all in U.P.), Panipat (Haryana), Ludhiana (Punjab), and Bhilwara (Rajasthan)

6.3.2 Wool Research Association (WRA)

Wool Research Association, established in 1963, is the only national institute in the field of Wool Technology.[24] The organization provides technological and scientific solutions to the woollen sector and textiles industry. It is involved in various R&D activities, testing facilities, training facilities and constitutes eco analysis lab as one of the major facility centre.

[22] https://www.btraindia.com/
[23] https://www.nitratextile.org/
[24] https://www.wraindia.com/

Some other institutions include Central Institute for Research on Cotton Technology (CIRCOT), Central Silk Technological Research Institute (CSTRI), The Synthetic & Art Silk Mills' Research Association (SASMIRA), Indian Jute Industries' Research Association (IJIRA), Man made Textile research association (MANTRA), Indian Institute of Technology (IITs) and National Institute of Fashion Technology (NIFTs).

6.4 Government Bodies

The government bodies associated with textile manufacturing and processing industries include respective state designated agencies (SDAs) for Bureau of Energy Efficiency (SDA-BEE), district industries centre (DIC), MSME- Development and Facilitation Offices, and National Small Industries Corporation (NSIC). The government bodies and their key roles are mentioned in the table below.

Table 37: Government bodies and their key roles

Name of organisation	Key roles
State Designated Agencies • Punjab Energy Development Association (PEDA) • Tamil Nadu Energy Development Agency (TEDA) • Haryana renewable Energy Development Agency (HAREDA) • Gujarat Energy Development Agency (GEDA) • Maharashtra Energy Development Agency (MEDA)	– SDAs are statutory bodies set up at the state level to implement the Energy Conservation (EC) Act 2001, under the overall supervision of the BEE. – SDAs coordinate and cooperate with BEE at the central level to ensure a smooth and speedy implementation of the Act.
District Industries Centre (DIC)	– Identify new entrepreneurs and provide assistance for start-ups. – Provide financial and other facilities to smaller blocks for industrialization at district level. – Enhance the rural industrialization and also the development of handicrafts. – Reach economic equality in multiple areas of the district. – Facilitation of government schemes to the new entrepreneurs – De-size regional imbalance of development – Make all the necessary facilities to come under one roof
MSME – DFO (Development and Facilitation Office)	– MSME-DFOs field offices of the Ministry of Micro, Small & Medium Enterprises provide a wide range of extension/ support services to the MSMEs in their respective state of operation.

Name of organisation	Key roles
	- Provide assistance for the promotion and development of micro, small and medium scale industries in their respective states and union territories.
National Small Industries Corporation (NSIC)	- Support and promote MSME sector by providing combined support services encircling finance, marketing, technology and allied services. - Aid, foster and promote the growth of MSMEs all across the country. - Operate across the country through a network of technical centres and offices.

7. Way Forward

Transforming the textile sector of India into an energy and resource efficient industry requires a comprehensive and collaborative approach. The textile industry holds significant potential for decarbonization through the implementation of energy efficiency and renewable energy measures. The energy and resource efficiency options are intended to reduce the energy intensity and improve the competitiveness of the textile sector to a significant extent. The large-scale adoption of energy efficient technologies poses various challenges. These options would require both new and innovative technological solutions as well as skillsets to sustain performance close to global level.

Given the cluster-based composition of the Indian textile industry, industry associations can play an important role for demonstrating collaborative approaches to address cluster specific issues. At cluster level, there is a further need of ESCO partnerships and collaboration with technology and service providers, development of specialized training programs to equip the workforce with the skills required to operate, work with financial institutions to establish tailored financing mechanisms, such as low-interest loans and grants, to facilitate the implementation of energy and resource efficiency measures. These initiatives will not only help in minimizing the transaction costs but also mitigate the risk of investment.

Additionally, there is a specific need to demonstrate successful models of collaboration by bringing together all stakeholders including Bureau of Energy Efficiency (BEE), Ministry of Micro Small and Medium Enterprises (MoMSME), Ministry of Skill Development & Entrepreneurship, Ministry of Commerce and Industry, banks & financial institutions, cluster level industry associations, sector specific apex bodies, etc. on a common platform. Furthermore, policy-level interventions are imperative to establish an enabling environment conducive to the widespread adoption of energy efficiency and renewable energy within the textile sector.

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