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Identification and Assessment of Feasible and Scalable Energy-Efficient Technologies in MSME Industrial Sectors

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FOREWORD

As India advances towards becoming a global manufacturing hub while fulfilling its commitments under the Nationally Determined Contributions (NDCs) and its Net Zero emissions target by 2070, enhancing energy efficiency across the industrial sector has emerged as both an economic priority and an environmental imperative. Among the key drivers of this transition are the country's Micro, Small, and Medium Enterprises (MSMEs), which form the backbone of India's industrial economy. The MSME sector contributes substantially to manufacturing output, exports, employment generation, and inclusive economic development. Strengthening the energy performance of these enterprises is therefore essential not only for improving industrial competitiveness and productivity but also for reducing energy consumption, lowering greenhouse gas emissions, and supporting India's long-term sustainable development goals.

Despite their immense contribution, many MSMEs continue to operate with outdated technologies, limited access to finance, and inadequate awareness of energy-efficient solutions. Addressing these challenges presents a significant opportunity to enhance industrial competitiveness, reduce production costs, strengthen energy security, and accelerate India's transition towards a low-carbon economy.

Recognizing this opportunity, the Bureau of Energy Efficiency (BEE), under the Indo-German Cooperation has undertaken the study "Identification and Assessment of Feasible and Scalable Energy-Efficient Technologies in MSME Industrial Sectors." This report provides a comprehensive assessment of commercially mature and scalable energy-efficient technologies for key energy-intensive MSME sectors, including Foundry, Forging, Rolling, Textile, and Paper & Pulp. The technologies have been evaluated not only for their technical feasibility but also for their economic viability, environmental benefits, and potential for large-scale replication across industrial clusters in India.

Beyond technology assessment, the report highlights practical pathways for accelerating adoption through innovative financing mechanisms, business models, pilot demonstrations, and cluster-based implementation strategies. By identifying technologies with proven performance, attractive payback periods, and significant greenhouse gas reduction potential, the study provides a strong foundation for scaling up energy efficiency investments within the MSME sector.

The findings presented in this report reaffirm that energy efficiency is more than a means of reducing energy consumption it is a strategic driver of productivity, competitiveness, resilience, and sustainable industrial development. Widespread adoption of these technologies will not only lower operating costs for MSMEs but also strengthen India's industrial competitiveness while contributing meaningfully to national climate and energy goals.

I am confident that this report will serve as a valuable resource for policymakers, financial institutions, technology providers, industry associations, ESCOs, and MSMEs seeking to accelerate the deployment of innovative energy-efficient solutions. I encourage all stakeholders to work collaboratively in translating these recommendations into action, enabling India's MSME sector to become more energy-efficient, competitive, and future-ready.

P. Shyam Sunder

Program Director – Bureau of Energy Efficiency (BEE)

FOREWORD

India's Micro, Small, and Medium Enterprises (MSMEs) form the backbone of the nation's industrial economy, contributing significantly to manufacturing output, exports, employment generation, and inclusive economic growth. As India advances towards becoming a global manufacturing hub while pursuing its climate commitments, improving energy efficiency within the MSME sector has become a strategic priority. Enhancing industrial energy performance not only strengthens the competitiveness and resilience of MSMEs but also plays a pivotal role in reducing greenhouse gas emissions and supporting India's transition towards a low-carbon economy.

The Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, has consistently promoted energy efficiency through progressive policies, programmes, and market transformation initiatives across sectors. Recognising the substantial energy-saving and decarbonisation potential within energy-intensive MSME clusters, BEE, in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the project 'Energy Efficiency in India' in India under the Indo-German Cooperation, has undertaken this study to identify and assess commercially viable, scalable, and high-impact energy-efficient technologies suitable for Indian MSMEs.

This report presents a comprehensive assessment of innovative technologies across the Foundry, Forging, Rolling, Textile, and Paper & Pulp sectors. The technologies have been evaluated based on their technical feasibility, financial viability, environmental benefits, technology readiness, and replication potential. Beyond technology assessment, the report provides practical recommendations on pilot demonstrations, financing mechanisms, business models, and implementation strategies that can accelerate technology deployment across industrial clusters. It serves as a valuable resource for policymakers, financial institutions, technology providers, industry associations, and MSMEs seeking to modernise industrial processes while improving energy productivity and reducing operating costs.

I encourage all stakeholders including industry leaders, MSMEs, financial institutions, technology developers, state agencies, and development partners to actively leverage the insights and recommendations presented in this report. I encourage we sincerely appreciate the BEE for this pioneering initiative, which marks a significant step towards advancing energy efficiency, enhancing competitiveness, and promoting sustainable growth in India's MSME sector.

Nitin Jain

Project Director – Energy Efficiency in India
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ACKNOWLEDGEMENT

This report, "Identification and Assessment of Feasible and Scalable Energy-Efficient Technologies in MSME Industrial Sectors," has been developed under the BEE-GIZ Energy Efficiency in India Project as part of the Indo-German Energy Cooperation. The report identifies and assesses commercially proven, energy-efficient technologies for five key MSME Sectors Foundry, Forging, Rolling, Textile, and Paper & Pulp to facilitate technology adoption across MSME clusters in India. The shortlisted technologies have been evaluated based on their technical feasibility, financial viability, environmental benefits, and scalability, providing MSMEs with a practical reference to improve energy efficiency, productivity, and environmental performance.

We extend our sincere gratitude to all stakeholders whose valuable guidance, technical expertise, and continuous support contributed to the successful completion of this assignment. We express our special appreciation to Shri A. K. Asthana, Advisor, IIEC India, for his strategic guidance, technical oversight, and continued support throughout the execution of the assignment.

We also gratefully acknowledge the support of the GIZ project team, including Mr. Siddharth Jain, Energy Advisor; Mr. Nikhil, Energy Advisor; and Mr. Himanshu Chaudhary, Energy Advisor, for their effective coordination, constructive feedback, and valuable technical inputs during the project. We sincerely thank Mr. Nitin Jain, Project Director - Energy Efficiency in India, GIZ, for his leadership, guidance, and constant encouragement.

We would also like to thank Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, for its continued partnership, guidance, and commitment to promoting energy efficiency and accelerating the adoption of advanced technologies in the MSME sector.

Finally, we acknowledge the valuable contributions of technology providers, industry experts, consultants, and other stakeholders who actively participated in consultations, shared technical insights, and provided critical feedback. Their engagement has been instrumental in ensuring that the assessment reflects the practical needs of MSME clusters and offers relevant, scalable, and actionable technology solutions for the sector.

International Institute for Energy Conservation- India (IIEC-India)

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EXECUTIVE SUMMARY

The Micro, Small, and Medium Enterprise (MSME) sector is a cornerstone of India's industrial economy, contributing nearly one-third of the nation's GDP, 45% of manufacturing output, and providing substantial employment opportunities. However, despite its importance, the sector continues to face persistent barriers to improving energy performance due to outdated technologies, limited access to financing, and low awareness of clean and energy-efficient solutions.

This study, conducted under Indo German Cooperation on Energy Efficiency, implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) together with the Bureau of Energy Efficiency (BEE), identifies and rigorously assesses commercially ready, high-impact, innovative technologies that are both cross-cutting and process-specific, suited to the operational and financial realities of India's MSME clusters in Foundry, Forging, Rolling, Textile, and Paper sectors. All the technologies carry a Technology Readiness Level (TRL) of 9 or 10. The assessment covers technical feasibility, financial viability, environmental impact, and replication potential across 25 clusters in 12 states. This report focuses on energy-intensive MSME sub-sectors foundry, forging, rolling, textile, and paper & pulp, which offer significant potential for technology-driven decarbonization. Aligned with India's policy framework under the National Mission for Enhanced Energy Efficiency (NMEEE), the report presents a detailed overview of the selected sectors, including their structure, key production processes, major clusters, and energy consumption patterns.

Based on sector-specific requirements and operational realities of MSME units, the study identifies a set of feasible and high-impact technologies with strong replication potential. As per the assessment, the textile sector presents the single largest scale-up opportunity: 1,81,600 MSME units across clusters, including Tirupur (3,200), Ludhiana (14,000), Panipat (3,095), and Ichalkaranji (80,000–1,20,000), with six applicable technologies.

The table below ranks technologies by investment, payback, and GHG reduction potential:

Technology	Sector	Investment (₹ Lakh)	Payback	GHG Reduction (tCO ₂ e/yr/unit)
IoT in Stenter Machine	Textile	3	0.1 months	280
Pressurised Condensate Recovery System (PCRS)	Textile, Paper	5	1.8 months	621
Electric Grinder (replacement of Pneumatic Grinder)	Foundry	0.5	4 months	16
Gas-fired furnace Self-Recuperative Burner	Foundry, Forging	15	6 months	167
Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	Foundry, Forging, Rolling	100	9 months	580
A One Insulation (Dual Insulation)	Textile, Paper	2.5	9 months	19
Hot Water from Chiller / Compressor	Textile	20	10 months	75
Fabricated Water Ring Vacuum Pumps	Paper, Textile	5	12 months	36

RDF - Fired Boiler	Textile, Paper	1,200	14 months	68,000
Low Consistency Refining (LCR)	Paper	350	17 months	720
Xplate Combustion Technology	Paper	25	18 months	504
Heat Pumps (up to 90°C)	Textile, Paper	110	20 months	345
Waste Heat Recovery from Dye Effluent	Textile	12	22 months	509
Micro Turbines (PRV replacement)	Textile, Paper	118	23 months	616

The technologies assessed are a mix of cross-cutting and process technologies in the segments of Waste heat recovery, energy-efficient utilities, and process improvement. These technologies collectively address the primary thermal and electrical energy hotspots across all five sectors. The barrier to adoption is not the technology case: it is financing access, awareness, and market infrastructure. These are solvable problems, which can be addressed through a cluster-first, evidence-based, phased approach described in the accompanying Implementation Roadmap. The findings of this report demonstrate that the adoption of energy-efficient and low-carbon technologies can significantly reduce energy consumption, improve productivity, lower operating costs, and enhance the competitiveness of MSMEs. At the same time, it supports India's broader decarbonisation objectives by providing a structured framework for scaling up technology adoption across MSME clusters.

Industrial Utilities	Waste Heat Recovery	Process Improvement
- Gas-fired furnace Self-Recuperative Burner - Fabricated Water Ring Vacuum Pumps - Heat Pumps (up to 90°C) - Micro Turbines - RDF - Fired Boiler - Hot Water from Chiller / Compressor	- Pressurised Condensate Recovery System (PCRS) - Waste Heat Recovery from Dye Effluent	- Electric Grinder (replacement of Pneumatic Grinder) - A One Insulation (Dual Insulation) - IoT in Stenter Machine - Low Consistency Refining (LCR) - Xplate Combustion Technology

Priority Clusters for Demonstration

Technology deployment is recommended through a cluster-first model, targeting existing industrial associations as the delivery channel. Key Priority clusters for pilot demonstrations are:

Cluster	Sector	Units	Priority Technologies	Why This Cluster
Tirupur, Tamil Nadu	Textile	3,200	IoT-Stenter, PCRS, WHR Dye Effluent	Export-facing, progressive cluster.
Ludhiana & Jalandhar, Punjab	Forging	1,450	Electric Grinder, Self-Recuperative Furnace	Largest forging cluster; hand tool focus suits grinder demo
Mandi Gobindgarh, Punjab	Rolling	341	Electric Grinder	India's Steel Town; minimal capex
Vapi, Gujarat	Paper	45–50	PCRS, Vacuum Pumps, A-One Insulation, Xplate	Largest organised Paper MSME cluster; Gujarat incentives
Rajkot & Ahmedabad, Gujarat	Foundry	800	Electric Grinder, Self-Recuperative Furnace	Largest foundry cluster; active engineering association

Scale-up opportunity and impact

The identified technologies present significant potential for scale-up, as they are commercially available, technically well understood, and adopted to some extent in industry. The adoption of these technologies by MSMEs may have a transformative impact on the MSME sector.

Cluster		Tirupur, Tamil Nadu	Ludhiana & Jalandhar, Punjab	Mandi Gobindgarh, Punjab	Vapi, Gujarat	Rajkot & Ahmedabad, Gujarat
Sector		Textile	Forging	Rolling	Paper	Foundry
Total Units		3,200	1,450	341	48	800
Priority Technologies		IoT Stenter, PCRS, WHR Dye Effluent	Electric Grinder, Self Recuperative Furnace	Electric Grinder	PCRS, Vacuum Pumps, A One Insulation, Xplate	Electric Grinder, Self Recuperative Furnace
High (60% Penetration)	Investment (₹ Cr)	41.6	14.5	1.11	11.63	8.06
	GHG Reduction (tCO ₂ e/yr)	29,32,800	1,72,569	3,552	36,580	95,160
Medium (30% Penetration)	Investment (₹ Cr)	22.4	7.8	0.6	6.38	4.34
	GHG Reduction (tCO ₂ e/yr)	15,79,200	92,964	1,904	20,060	51,240
Low (10% Penetration)	Investment (₹ Cr)	7.7	2.7	0.21	2.25	1.49
	GHG Reduction (tCO ₂ e/yr)	5,41,440	31,842	656	7,080	17,568

2

BACKGROUND

The Micro, Small, and Medium Enterprise (MSME) sector is a cornerstone of India's industrial economy. It contributes nearly one-third of the nation's GDP, 35% of manufacturing output, 45.73% of exports in the country¹, and provides substantial employment opportunities to over 40 million people directly in textile MSMEs, and hundreds of thousands in energy-intensive sub-sectors such as foundry, forging, rolling, paper, and pulp.

Despite its economic significance, the sector continues to face persistent barriers to improving energy performance:

- Outdated technologies – widespread use of inefficient coke-fired cupolas, fuel oil furnaces, and old electromechanical drives.
- Limited access to financing – small unit sizes, lack of collateral, and high perceived risk by financial institutions.
- Low awareness of clean, energy-efficient solutions, especially in clusters dominated by micro and small enterprises.

Energy-intensive sub-sectors such as foundry, forging, rolling, textile, and paper manufacturing offer significant potential for technology-driven decarbonization. Aligned with India's policy framework under the National Mission for Enhanced Energy Efficiency (NMEEE), the Perform, Achieve and Trade (PAT) Scheme, and the objectives under Indo German Cooperation on Energy Efficiency, this assignment seeks to identify, assess, and recommend scalable energy-efficient and low-carbon technologies that can support MSMEs in reducing emissions while enhancing their competitiveness.

This report addresses these gaps by identifying and assessing the commercially ready, high-impact technologies (Technology Readiness Level 9–10) that align with the operational realities of MSME clusters. The technologies were evaluated for technical feasibility, financial viability, environmental benefits, and replication potential across 25 clusters in 12 states. The study highlights sector-specific opportunities: textiles present the largest scale-up potential with over 180,000 units, while paper & pulp offers a transformative impact through eight applicable technologies despite its complexity. Foundry and forging clusters, with their reliance on inefficient furnaces and grinders, also stand to benefit from targeted interventions.

By situating MSME energy efficiency within India's broader decarbonisation agenda, the report underscores the dual opportunity: reducing greenhouse gas emissions while enhancing MSME competitiveness. The findings provide a structured roadmap for pilot demonstrations, scale-up, and financing models—including ESCO partnerships, demand aggregation, and revolving funds—that can accelerate technology adoption. In doing so, the study supports India's commitments under its Nationally Determined Contributions (NDCs) and positions MSMEs as active contributors to the clean energy transition.

¹ <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2142170>

3

FOUNDRY SECTOR



AI Generated Image

3.1 SECTOR OVERVIEW

India's foundry sector, dominated by ~4,500-5,000 MSME units which constitute over 85% of the industry, is a linchpin of the manufacturing economy as the world's second-largest casting producer with an annual output of 10-11 MMT². These geographically clustered enterprises provide direct employment to 500,000-600,000 workers and are critical suppliers of cast components to automotive, agricultural, pump, and capital goods sectors, contributing significantly to both domestic value chains and exports (USD 2-3 billion annually).³

The sector is characterised by high energy intensity, with specific energy consumption ranging from 1,000 to 1,500 kWh/tonne for grey iron, making energy a primary cost driver (12-20% of production costs). Thermal energy for melting and heat treatment accounts for 65-90% of total consumption, predominantly sourced from inefficient coke-fired cupolas and furnace oil, while unreliable power supply forces reliance on costly diesel generation⁴. This profile reveals a substantial technical energy-



² Indian Foundry Association

³ Sameeksha newsletter

⁴ Scaling up and expanding of project activities in MSME clusters, UNIDO-GEF

saving potential of 20-30%, with melting operations alone offering 15-25% savings, positioning energy efficiency as a critical lever for competitiveness and sustainability in the MSME foundry cluster.

Table 1: Key foundry sector clusters

S. No.	Cluster (State)	Estimated Units	Primary Metal Focus
1	Rajkot & Ahmedabad (Gujarat)	800 - 1,000	Grey & Ductile Iron, SG Iron
2	Kolhapur & Solapur (Maharashtra)	600 - 800	Grey Iron, Alloy Steel
3	Coimbatore & Chennai (Tamil Nadu)	500 - 700	Grey Iron, Aluminium, Steel
4	Ludhiana & Jalandhar (Punjab)	400 - 600	Grey Iron, Malleable Iron
5	Kolkata-Howrah (West Bengal)	300 - 500	Grey Iron, Steel, Non-Ferrous
6	Belgaum (Karnataka)	200 - 300	Grey Iron, Aluminium
7	Delhi-NCR (NCR Region)	200 - 300	Aluminium, Grey Iron

3.2 SHORTLISTED EE TECHNOLOGIES (FOUNDRY)

S. No.	Technology	TRL	TRL Assessment	Description	Invest-ment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
1.	Gas-fired Furnace with Self-recuperative Burner (Heat Treatment Furnaces with Gas firing) [Upto 500 kW burner capacity]	9	Technology is commercially available and implemented in a few industries.	Replacement of the small oil-fired furnace. Complete furnace system combining gas firing (PNG/LPG) with self-recuperative burners (integrated recuperator preheats combustion).	15	6 months	167
2.	Electric Grinder (Replacement of Pneumatic Grinder)	10	Technology is commercially available and implemented in some industries, but further scaling up is required	Replacement of pneumatic grinder. Electric angle grinders (with brushless motors) replace pneumatic grinders for foundry fettling, eliminating compressor losses and air-line leakage, and reducing total grinding energy by 70–90% compared to pneumatic systems.	0.5	4 months	16
3.	Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	10	Technology is commercially available and implemented in some industries, but further scaling up is required	Alternating ceramic accumulators store 70% – 85% flue heat for air preheat (800–950°C), 60% to 80% furnace efficiency.	100	8 months	580

4

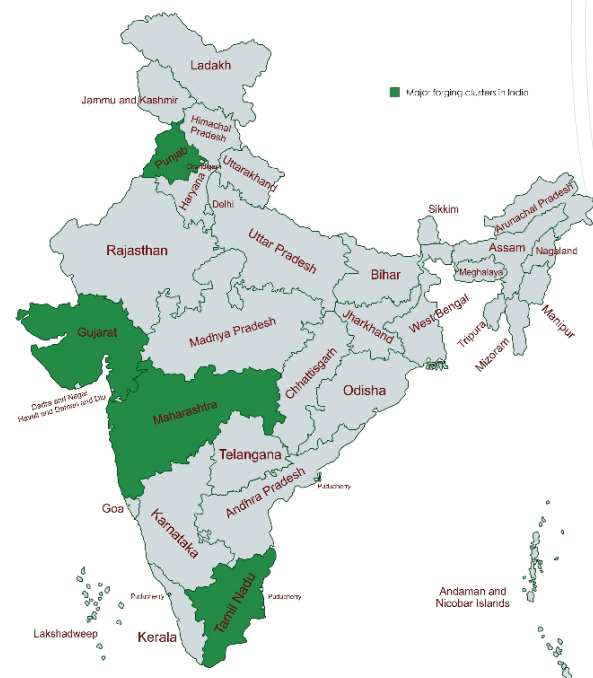
FORGING SECTOR



Source: <https://www.qcforge.com/forging-innovations-blog/is-alloy-steel-strong/>

4.1 SECTOR OVERVIEW

The Indian forging industry has an installed capacity of approximately 38.5 lakh MT, capable of processing diverse raw materials, including carbon steel, alloy steel, stainless steel, superalloys, titanium, and aluminum, to meet varied demands. around 83% of forging units fall into the small or very small categories, while only 8% are classified as very large or large units. The remaining 9% are medium-sized units. This diverse industrial structure reflects the industry's ability to cater to both large-scale industrial demands and smaller, niche requirements.⁵ The forging process is inherently energy-intensive. The primary energy consumption occurs in the heating (forging) and heat treatment stages. A significant portion of MSME units relies on traditional, inefficient fuel-fired furnaces (using furnace oil or natural gas),



⁵ Association of Indian Forging Industry (AIFI) <https://indianforging.org/about-us/about-forging-industry/>

leading to high thermal energy use. Electrical energy is consumed for deformation hammers/presses, machining, and auxiliary equipment. The sector faces persistent challenges, including technological obsolescence with the continued use of manual or semi-automatic equipment, high specific energy consumption, intense cost competition, and increasing quality requirements from original equipment manufacturers (OEMs).

Table 2: Key forging sector clusters

S. No.	Cluster (State)	Estimated Units	Primary Focus
1	Ludhiana, Jalandhar (Punjab)	1,450	Automotive, bicycle, hand tools, fasteners
2	Kolhapur, Pune (Maharashtra)	50	Automotive (axles, gears, wheel hubs)
3	Chennai, Hosur (Tamil Nadu)	50	Precision auto components (70%), non-auto (30%)
4	Ahmedabad, Rajkot (Gujarat)	140	Closed die (62%), ring rolling forgings

4.2 SHORTLISTED EE TECHNOLOGIES (FORGING)

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
1.	Gas-fired Furnace with Self-recuperative Burner [Up to 500 kW burner capacity]	9	Technology is commercially available and implemented in a few industries.	Replacement of the small oil-fired furnace. Complete furnace system combining gas firing (PNG/LPG) with self-recuperative burners (integrated recuperator preheats combustion).	15	6 months	167
2.	Electric Grinder (Replacement of Pneumatic Grinder)	10	Technology is commercially available and implemented in some industries, but further scaling up is required	Replacement of pneumatic grinder. Electric angle grinders (with brushless motors) replace pneumatic grinders for foundry fettling, eliminating compressor losses and air-line leakage, and reducing total grinding energy by 70–90% compared to pneumatic systems.	0.5	4 months	16
3.	Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	10	Technology is commercially available and implemented in some industries, but further scaling up is required	Alternating ceramic accumulators store 70% – 85% flue heat for air preheat (800–950°C), 60% to 80% furnace efficiency.	100	8 months	580

5

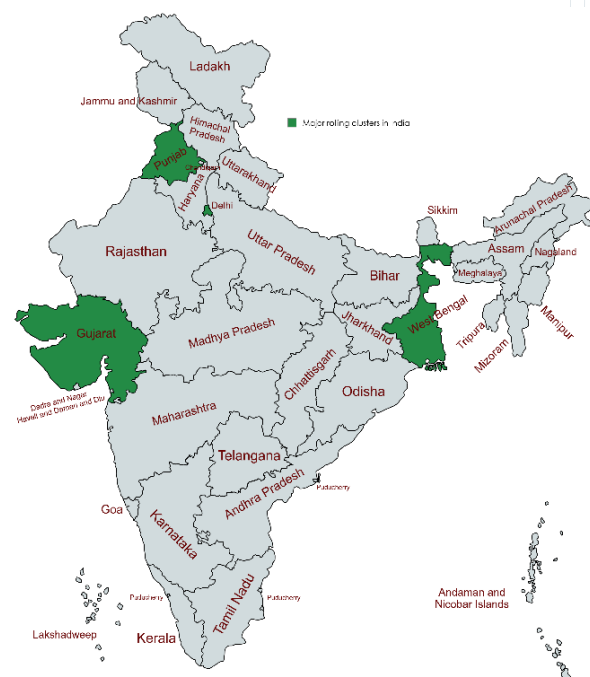
ROLLING SECTOR



Source: Niteenrk/iStock

5.1 SECTOR OVERVIEW

India's rolling mill MSME sector, comprising numerous small-scale rerolling mills and precision rolling units, serves as a critical intermediary in the metal value chain, processing semi-finished steel (billets, blooms) and non-ferrous ingots into finished bars, rods, sheets, and strips. Geographically clustered near steel production centres and consumption hubs such as Mandigobindgarh (Punjab) and Gujarat. The rolling units are characterised by high electrical energy intensity for deformation and significant thermal energy for reheating. The average specific energy consumption (SEC) of the rolling mills in Mandigobindgarh is estimated to be 1.48 MJ per kg of product (equivalent to 0.035 toe per tonne).⁶ The sector faces acute challenges, including



5 https://sameeksha.org/pdf/clusterprofile/Mandi_Gobindgarh_Steel_Rerolling_Punjab.pdf

dependence on primary producers for feedstock, volatile raw material costs, reliance on inefficient, outdated mill drives and furnaces, and intense competition, making modernisation and energy efficiency critical for survival. As essential suppliers to construction, engineering, and hardware industries, rolling MSMEs play a vital economic role but operate under thin margins where energy cost control is a decisive factor for competitiveness.

Table 3: Key rolling sector clusters

S. No.	Cluster (State)	Estimated Units	Primary Focus
1	Mandi Gobindgarh (Punjab)	404 MSMEs (341 re-rolling)	TMT bars, structural sections, bright bars
2	Bhavnagar (Sihor) (Gujarat)	120 Units	Construction-grade mild steel from ship scrap

5.2 SHORTLISTED EE TECHNOLOGIES (ROLLING)

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
1.	Electric Grinder (Replacement of Pneumatic Grinder)	10	Technology is commercially available and implemented in some industries, but further scall-up is required	Replacement of pneumatic grinder. Electric angle grinders (with brushless motors) replace pneumatic grinders for foundry fettling, eliminating compressor losses and air-line leakage, and reducing total grinding energy by 70–90% compared to pneumatic systems.	0.5	4 months	16
2.	Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	10	Technology is commercially available and implemented in some industries, but further scaling up is required	Alternating ceramic accumulators store 70% – 85% flue heat for air preheat (800–950°C), 60% to 80% furnace efficiency.	100	8 months	580

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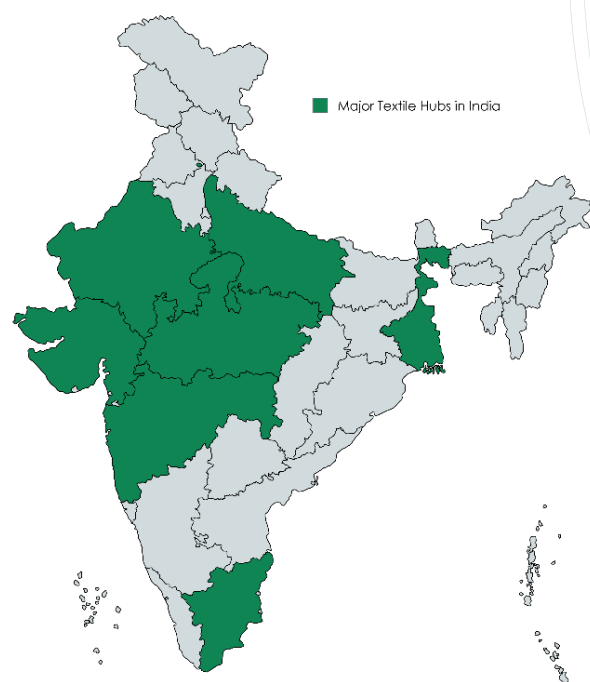
TEXTILE SECTOR



Source: AI-generated image

6.1 SECTOR OVERVIEW

The Indian textile ecosystem is diverse, ranging from integrated mills with modern utilities, energy management systems, and effluent treatment plants to small and medium enterprises in clusters such as Tirupur, Surat, Panipat, Ludhiana, and Ichalkaranji. The sector is dominated by decentralised units, including around 24,00,000 power loom units that produce over 58% of the country's fabric (Ministry of Textiles).⁷ This is supported by approximately 3,500 small spinning mills, more than 2,300 independent processing units, and numerous garmenting clusters. These MSMEs form about 80% of the textile industry's



7. <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2206691>

units and employ over 40 million people directly, making it the largest manufacturing employer in India.

The sector contributes roughly 5% to India's GDP through its extensive operations. It plays a key role in exports, as per the year-end review of the Ministry of Textiles, India's total textile and apparel exports reached \$37.8 billion in 2025. MSMEs drive a significant portion of these exports amid challenges like high energy costs, inefficient machinery⁸, and limited access to green financing. Yet rapid modernisation is underway: initiatives like the PM-MITRA scheme aim to establish integrated textile parks, deploy renewable energy and biomass boilers, promote zero-liquid discharge systems, and encourage real-time energy monitoring.

Table 4: Key textile sector clusters

S. No.	Cluster (State)	Estimated Units	Primary Focus
1	Bhiwandi (Maharashtra)	6,000 power loom units	Powerloom fabrics for garments
2	Surat (Gujarat)	400 processing units	Synthetic sarees, dress materials
3	Erode (Tamil Nadu)	75,000 power looms	Cotton fabrics, home textiles
4	Varanasi (UP)	200+ artisans	Banarasi silk sarees with zari
5	Tirupur (Tamil Nadu)	3,200 MSMEs	Knitwear (T-shirts, undergarments)
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families	Kanchipuram silk sarees
7	Ludhiana (Punjab)	14,000 MSMEs	Woollen hosiery, knitwear
8	Panipat (Haryana)	3,095 MSMEs	Home textiles, blankets
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms	Powerloom cotton, polyester fabrics

6.2 SHORTLISTED EE TECHNOLOGIES (TEXTILE)

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
1	Waste Heat Recovery from Dye Effluent	9	Technology is commercially available and implemented in a few industries.	Plate heat exchanger systems (wide-gap, self-cleaning designs) recover heat from hot textile dyeing effluent (100,000+ LPD at 50–105°C) to preheat process water or boiler feed, achieving 15–40% fuel savings.	12	22 months	509
2	RDF/ Biomass Fired Boiler	10	Technology is commercially available and implemented in industries, but further scale-up is required	Boilers designed/burners modified for Refuse Derived Fuel (RDF from MSW) and biomass pellets/ briquettes (rice husk, bagasse, wood chips).	1,200	14 months	68,000

8. <https://www.in-cai.in/articles/india-s-ministry-of-textiles-year-end-review-2025>

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
3	Micro Turbines	10	Technology is commercially available and implemented in industries, but further scale-up is required	Small gas-fired turbines that generate electricity and usable heat at the same time. Textile and Paper plants use them for combined heat and power (CHP) to supply both steam and power. They improve energy efficiency, reduce reliance on grid electricity, and provide continuous thermal energy. Useful where steam and electricity demand are high.	118	23 months	616
4	Heat Pumps	8 to 9	Technology is commercially available with a few suppliers. A demonstration in a few industries is done.	Heat pumps take low-temperature waste heat (from water, air, compressors, dryers, or cooling systems) and upgrade it to usable heat. In Foundry/ Forging/ Rolling, they reduce boiler fuel by providing hot water for cleaning, degreasing, and preheating. In Paper & Textile plants, they supply hot water for washing, bleaching, or drying. They sharply cut fuel bills and support a shift toward electric heating instead of fossil fuel-based systems.	110	20 months	345
5	A-One Insulation (Hot and Cold Insulation)	9	Technology is commercially available and implemented in a few industries.	The dual insulation technology is a combination of Hot & Cold Insulation, where the process demands are for both Hot & Cold Insulation, and the process lines and equipment are used for both purposes.	2.5	9 months	19

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
6	IoT in Stenter Machine	9 to 10	Technology is commercially available and implemented in 5 to 10 industries in Tripur	IoT sensors + cloud dashboard for stenters (largest energy consumer in textile processing, 40–55 kWh/h, 50–60 kg RPC/h); monitors fabric temperature, exhaust humidity, chamber pressure, VFD speed, energy/batch; enables 5–30% energy savings via auto humidity control, optimal dwell time, and predictive maintenance.	3	0.1 months	280
7	Hot water generation from the chiller and the compressor (generation of 60 to 70 deg C)	9	Technology is commercially available and implemented in a few industries	Generating hot water by recovering waste heat from existing equipment like air compressors and chillers represents one of the most cost-effective and quickest ways to reduce operational costs and carbon footprint. Instead of letting this heat escape into the atmosphere, it can be captured and used directly in processes.	20	10 months	75
8	Fabricated Water Ring Vacuum Pumps	9	Technology is commercially available and implemented in a few industries	Water ring vacuum pumps (also called liquid ring vacuum pumps) are rotary positive displacement machines that use water as the operating liquid to create a vacuum for various paper manufacturing processes.	5	12 months	36
9	Pressurised condensate recovery systems	9	Technology is commercially available and implemented in a few industries.	The Pressurised Condensate Recovery System collects high-temperature condensate (up to 180°C/356°F) and returns it to the boiler under pressure without venting to the atmosphere	5	1.8 months	621

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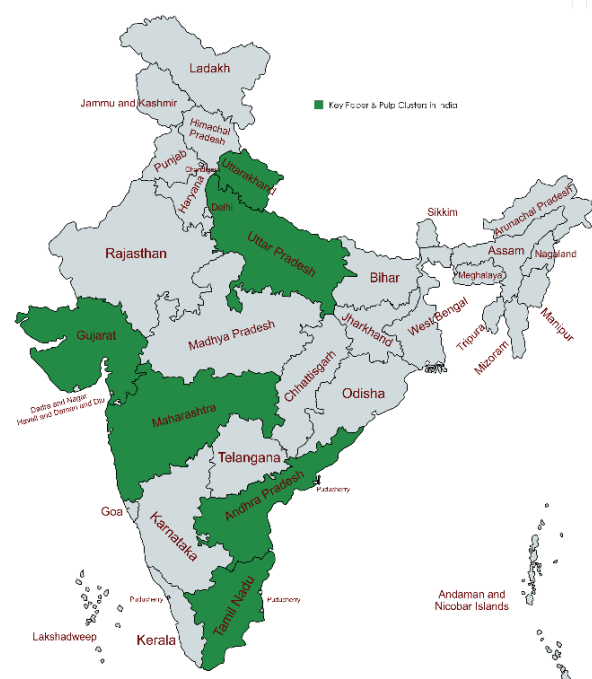
PAPER AND PULP SECTOR



Source: Moreno Soppelsa/Adobe Stock

7.1 SECTOR OVERVIEW

India's paper & pulp MSME sector comprises mostly of MSME units typically operating at 50-200 tonnes per day (tpd) capacity. The demand for paper in India is growing at 6-7% per annum, making it one of the fastest-growing markets in the world. India's share in world production of paper is about 5%, with estimated production of around 22.59 million tonnes per annum of paper, paperboard and newsprint in 2024-25 (as per IPMA) and 24.58 million tonnes in 2024-25 (as per IARPMA)⁹ According to the Central Pulp & Paper Research Institute (CPPRI), the sector's raw material profile is dominantly reliant on wastepaper/recycled fibre



9. <https://ipmaindia.org/>

(~75% of raw material) and agro-residues like wheat straw and bagasse (~20%). The MSME units support regional employment needs and meet the demand for essential grades such as packaging board, writing/printing paper, and speciality papers. However, they face acute challenges of technological obsolescence, high specific energy consumption, and operational inefficiency, with energy costs constituting 15-25% of total production costs, primarily due to reliance on inefficient coal-fired boilers and aged electromechanical drives. This reliance on outdated technologies, combined with environmental compliance pressures and fragmented operations, positions energy efficiency interventions as a key component of strategies to enhance the sector's competitiveness and sustainability.

Table 5: Key textile sector clusters

S. No.	Cluster (State)	Estimated Units	Primary Focus
1	Muzaffarnagar & Saharanpur (UP)	29 units	Agro-based writing/printing paper (creamwove, maplitho)
2	Kashipur (Uttarakhand)	24+ mills	Recycled paperboard, kraft, duplex board
3	Vapi (Gujarat)	45-50 mills	High-grade recycled kraft, duplex board
4	Morbi (Gujarat)	35 mills	Kraft paper, test liner for ceramics
5	Erode-Coimbatore (Tamil Nadu)	30 units	Recycled paperboard from textile waste

7.2 SHORTLISTED EE TECHNOLOGIES (PAPER & PULP)

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
1	RDF/Biomass Fired Boiler	10	Technology is commercially available and implemented in industries, but further scale-up is required	Boilers designed/burners modified for Refuse Derived Fuel (RDF from MSW) and biomass pellets/briquettes (rice husk, bagasse, wood chips).	1,200	14 months	68,000
2	Micro Turbines	10	Technology is commercially available and implemented in industries, but further scale-up is required	Small gas-fired turbines that generate electricity and usable heat at the same time. Textile and Paper plants use them for combined heat and power (CHP) to supply both steam and power. They improve energy efficiency, reduce reliance on grid electricity, and provide continuous thermal energy. Useful where steam and electricity demand are high.	118	23 months	616

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
3	Heat Pumps Low temperature - 90 °C	8 to 9	Technology is commercially available with a few suppliers. A demonstration in a few industries is done.	Heat pumps take low-temperature waste heat (from water, air, compressors, dryers, or cooling systems) and upgrade it to usable heat. In Foundry/ Forging/ Rolling, they reduce boiler fuel by providing hot water for cleaning, degreasing, and preheating. In Paper & Textile plants, they supply hot water for washing, bleaching, or drying. They sharply cut fuel bills and support a shift toward electric heating instead of fossil fuel-based systems.	110	20 months	345
4	A-One Insulation (Hot and Cold Insulation)	9	Technology is commercially available and implemented in a few industries.	The dual insulation technology is a combination of Hot & Cold Insulation, where the process demands are for both Hot & Cold Insulation, and the process lines and equipment are used for both purposes.	2.5	9 months	19
5	Low Consistency Refining (LCR)	9	Technology is commercially available and implemented in a few industries.	Low Consistency Refining (LCR) operates by refining pulp at a consistency of 3-5%. The refining process involves the mechanical treatment of pulp fibres, which improves the pulp's physical properties. The process is carried out in a refiner, where the pulp is subjected to cyclic compression and shear, causing permanent deformation of the fibre wall.	350	17 months	720

S. No.	Technology	TRL	TRL Assessment	Description	Investment (₹ Lakh)	Pay back	GHG Reduction (tCO ₂ e/yr/unit)
6	Fabricated Water Ring Vacuum Pumps	9	Technology is commercially available and implemented in a few industries.	Fabricated Water Ring Vacuum Pumps operate by creating a vacuum using a rotating impeller within a water-filled ring. As the impeller rotates, the water forms a moving seal that compresses and evacuates air and gases from the system.	5	12 months	36
7	Xplate Technology (Xeogenic Plate)	9	Technology is commercially available and implemented in a few industries.	Air/fuel combustion enhancement technology that breaks down oxygen and nitrogen molecular clusters in combustion air into single oxygen molecules with a higher reactive surface area, leading to more complete combustion, reduced fuel consumption (10–25%), and lower emissions (NO _x , CO ₂ , SO _x). It applies flexibly to boilers, industrial furnaces, kilns (ceramic, cement, steel reheating), spray dryers, and gasification.	25	18 months	504
8	Pressurised condensate recovery systems	9	Technology is commercially available and implemented in a few industries.	The Pressurised Condensate Recovery System collects high-temperature condensate (up to 180°C/356°F) and returns it to the boiler under pressure without venting to the atmosphere	5	1.8 months	621

8

DETAILS OF SELECTED TECHNOLOGIES

This section presents the shortlisted energy-efficient and low-carbon technologies applicable to Foundry, Forging, Rolling, Textile, and Paper MSME sectors, with a Technology Readiness Level (TRL) of at least 9 or 10. The selected technologies include process-specific interventions as well as cross-cutting solutions, with identified vendors assessed for on-ground implementation potential, technical feasibility, scalability, and climate co-benefits. Subsequent subsections elaborate on each technology's specifications, applicability, savings potential, financial viability, and its advantages & challenges.

8.1 GAS-FIRED FURNACE WITH SELF-RECUPERATIVE BURNER [UP TO 500 KW BURNER CAPACITY]



Source: <https://thermooedge.com/>

8.1.1 Overview

Gas-fired, self-recuperative heat treatment furnaces use burners with integrated heat exchangers to recover waste heat from flue gases. The self-recuperative burners integrate a heat exchanger that utilises the enthalpy of the flue gases to preheat the combustion air, reducing CO₂ and NO_x emissions by up to 30% compared to the use of cold air. To increase efficiency, the heat exchanger is built in highly conductive materials, such as silicon carbide (SiC), is equipped with grooves and fins, and is interposed between opposite flows of cold air and hot exhausts.

Target Applications

Sector: Foundry, Forging

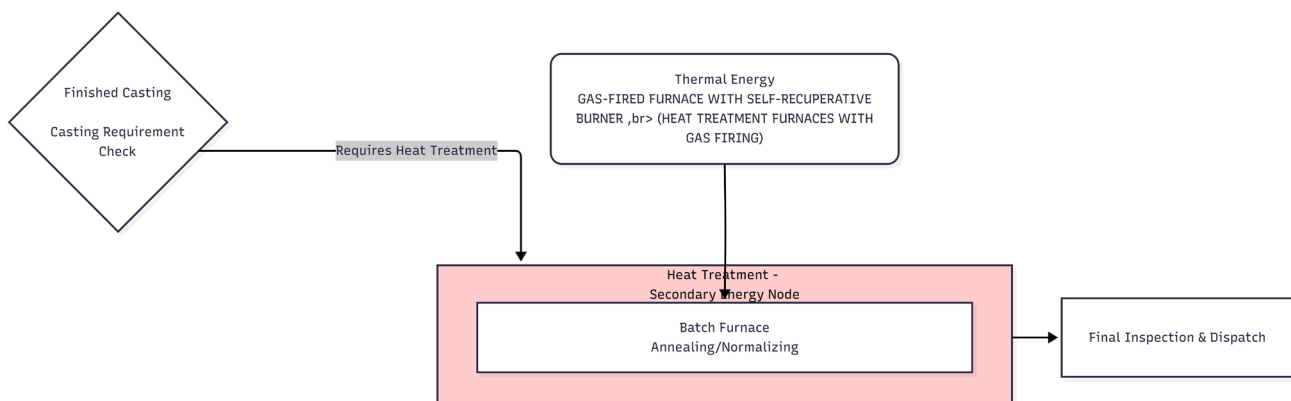
Application: Reheating, forging, heat treatment (annealing, normalising, hardening) of rough castings.

8.1.2 Technology assessment

Heat-treating furnaces are essential tools in manufacturing industries, where precise control over material properties is crucial. These furnaces, whether gas, resistance electric, or induction-based, are designed to treat various materials. Specifically, castings, forgings, and weldments. By utilising controlled heating and cooling cycles, these furnaces facilitate processes like annealing, tempering, and hardening, effectively altering the physical and mechanical properties of materials to meet specific industry requirements. A gas-fired furnace with a self-recuperative burner improves thermal efficiency by up to 15% to 20% by integrating a heat exchanger directly into the burner assembly to preheat combustion air using exhaust gas. These systems reduce fuel consumption and emissions, making them ideal for high-temperature industrial heat treatment where space is limited.

Technology Details:

A recuperative burner is a compact, energy-efficient industrial combustion unit that integrates a heat exchanger, or recuperator, directly into its body to preheat incoming combustion air using waste heat from its own exhaust gases. Its construction features a robust housing containing a metallic or ceramic recuperator, a fuel lance, and ignition and monitoring systems. The fundamental working principle of a 500 kW self-recuperative burner is counter-flow heat exchange, where cold combustion air is pushed into the burner and flows through specially designed passages within an integrated recuperator, simultaneously hot waste flue gases are drawn from the furnace chamber and passed through the recuperator in the opposite direction, transferring heat through the recuperator walls to preheat the combustion air up to approximately 550°C; this preheated air then mixes with fuel at the burner nozzle and combusts, requiring significantly less fuel to reach the desired furnace temperature, and after releasing energy to the furnace load, the exhaust gases are drawn back through the recuperator to repeat the cycle, with some designs additionally using high-velocity combustion gases to create a pressure drop that recirculates furnace gases for more uniform temperature and lower NO_x emissions.



Feasibility Analysis

S. No.	Parameter	Unit	Without a self-recuperative burner furnace	With a self-recuperative burner furnace
1	Rated Burner Capacity	kW	500	500
2	Eq. Gas consumption	SMQ (Lakh)	3.12	2.5
3	Operating hours per year	Hours/year	6,240	6,240
4	Fuel Saving	SCM/year	-	62000
5	Monetary Saving (@50 / SCM)	Rs/Year	-	₹31,00,000
6	Investment (Retrofit Cost)	Rs	-	₹15,00,000
7	Payback	Months	-	6
8	GHG emission reduction	tCO ₂ e/Year	-	167

(burner cost 5L, total cost is inclusive of box-type furnace and control system)

8.1.3 Key Advantages & Challenges

Advantages

- Energy Savings:** Self-recuperative burners utilise waste heat from exhaust gases to preheat combustion air up to 550°C, significantly lowering fuel consumption and achieving energy savings of 15% to 20% compared to conventional systems.
- Environmental Performance:** By reducing fuel usage, these burners directly lower CO₂ emissions. Furthermore, staged combustion and flue gas recirculation keep NO_x emissions low (e.g., below 80 mg/Nm³), making them a cleaner option for industrial firing.
- Operational Excellence:** The design promotes a high flame outlet velocity and flue gas recirculation within the furnace. This ensures uniform temperature distribution, precise temperature control, and consistent high-quality results for heat treatment processes.
- Design Flexibility:** These burners are available in metallic, ceramic, or flat tube versions to suit different temperature requirements. Their modular, maintenance-friendly construction allows for easy installation and simple gas lance replacement to accommodate various fuel types.
- Economic Benefits:** The substantial reduction in energy costs leads to a rapid return on investment. As your calculations demonstrated, despite the higher initial cost, the fast payback period (often under six months) makes it a highly economical choice for continuous operations.

Key Challenges

- High Initial Investment:** The integrated recuperator design results in higher capital costs compared to conventional burners.
- Exhaust Gas Temperature Limitation:** These burners are limited to exhaust gas temperatures below 870°C (1,600°F) due to material constraints, making them unsuitable for certain high-temperature industrial processes.
- Sensitivity to Particulates and Condensable Vapours:** These burners cannot be applied to processes where exhaust gases contain particles or condensable vapours, as these can cause fouling, corrosion, and plugging of the recuperator's heat transfer surfaces.

8.1.4 Technology providers

Encon Thermal Engineers Pvt. Ltd.

Swastik Furnaces Pvt. Ltd.

8.1.5 Replication Potential

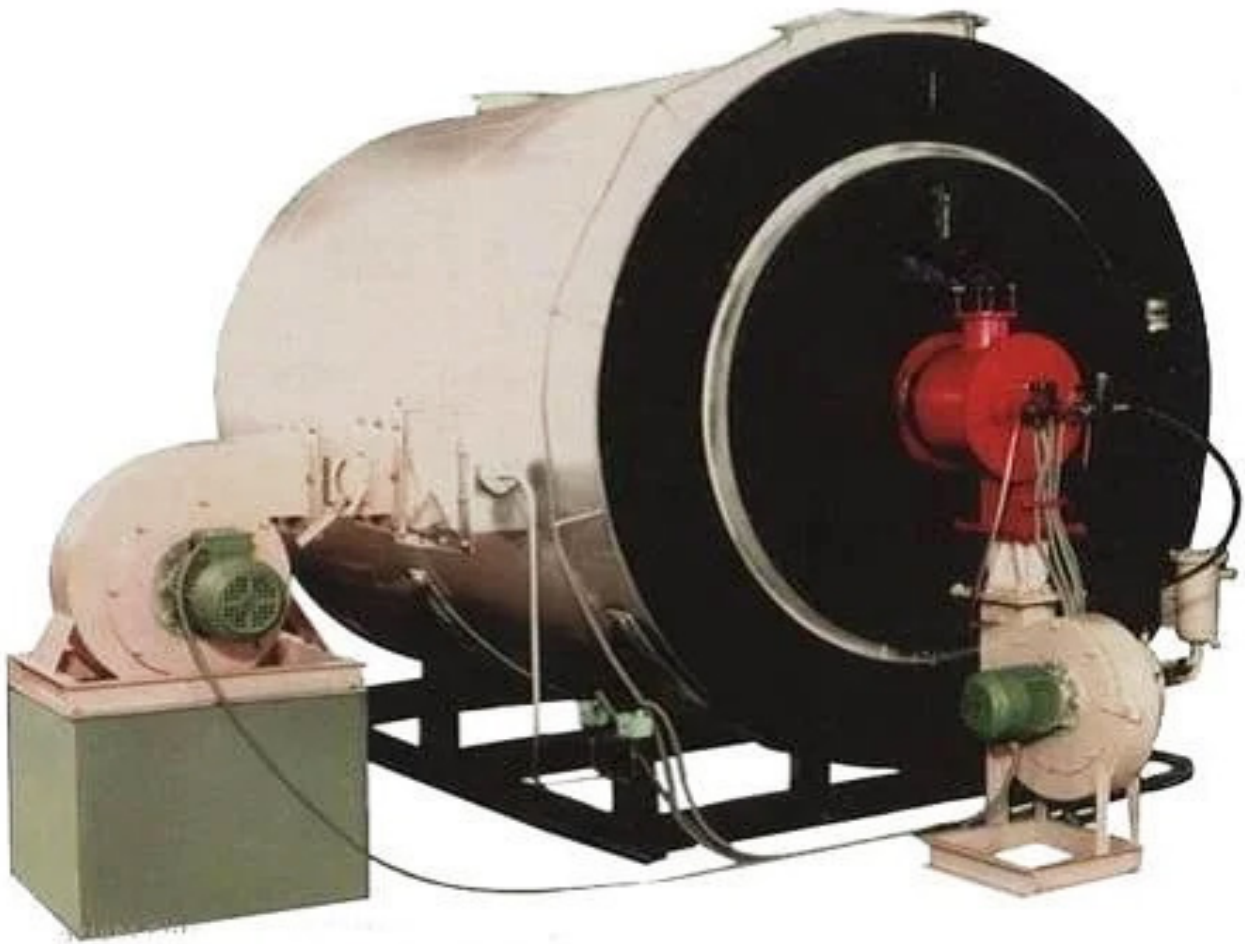
Smaller box-type gas-fired furnaces mostly use self-recuperative burners, which have very high replication potential in MSMEs key sectors where this technology can be adopted, including hand tools, small box furnaces, Heat treatment Furnaces, Small forging furnaces, and foundry

Table 6: Replication Potential of self-recuperative burners in forging clusters

S. No.	Cluster (State)	Estimated Units
1	Ludhiana, Jalandhar (Punjab)	1,450
2	Kolhapur, Pune (Maharashtra)	50
3	Chennai, Hosur (Tamil Nadu)	50
4	Ahmedabad, Rajkot (Gujarat)	140

Table 7: Replication potential of self-recuperative burners in Foundry clusters

S. No.	Cluster (State)	Estimated Units
1	Rajkot & Ahmedabad (Gujarat)	800 - 1,000
2	Kolhapur & Solapur (Maharashtra)	600 - 800
3	Coimbatore & Chennai (Tamil Nadu)	500 - 700
4	Ludhiana & Jalandhar (Punjab)	400 - 600
5	Kolkata-Howrah (West Bengal)	300 - 500
6	Belgaum (Karnataka)	200 - 300
7	Delhi-NCR (NCR Region)	200 - 300



Source: <https://encon.co.in/>

8.2 GAS-FIRED REGENERATIVE BURNERS FOR HIGH-TEMPERATURE FURNACES (MEDIUM & LARGE FURNACES)

8.1.1 Overview

A regenerative burner is a combustion heating system designed for extremely high recovery of waste heat from flue gases (800 to 950 deg C) in industrial furnaces. Unlike conventional burners that simply expel hot flue gases into the atmosphere, regenerative burners capture that thermal energy and reuse it to preheat incoming combustion air. This process is made possible by integrating ceramic heat storage media (such as high-alumina balls or honeycomb structures) directly into the burner body.

The technology has become widely adopted in large high-temperature furnaces, including steel reheating furnaces, forging furnaces, heat treatment furnaces, and melting furnaces.

Target Applications

Sector: Foundry, Forging

Application: Reheating, forging, heat treatment (annealing, normalising, hardening) of rough castings.

8.2.2 Technology assessment

A regenerative burner operates in pairs that fire alternately to achieve exceptionally high waste heat recovery. While one burner fires, the other acts as an exhaust passage: hot flue gases from the furnace flow

through the idle burner's regenerator chamber (packed with ceramic media), which absorbs and stores the heat. After a short cycle (typically 30–60 seconds), the flow reverses. The previously heated burner now receives combustion air, which passes through the hot ceramic bed, raising its temperature to within 200–300 °C of the furnace process temperature. This highly preheated air then mixes with fuel, enabling very efficient combustion and reducing fuel consumption by 35–60% compared to conventional systems. The alternating cycle repeats continuously, ensuring that the firing burner always receives preheated air while the idle burner recovers heat from the exhaust stream

Feasibility Analysis

S. No.	Parameter	Unit	Without a self-recuperative burner furnace	With a self-recuperative burner furnace
1	Production Capacity	Tones/ day	20	20
2	Gas consumption (35% fuel saving through regenerative burner)	SCM /day	2400	1,560
3	Operating hours per year	Hours/year	330	6,240
4	Fuel Saving	SCM/year	-	276000
5	Monetary Saving (@50 / SCM)	Rs/Year	-	₹1,38,00,000
6	Investment (Retrofit Cost)	Rs	-	₹1,00,00,000
7	Payback	Months	-	9
8	GHG emission reduction	tCO ₂ e/Year	-	580

8.2.3 Key Advantages & Challenges

Advantages

1. **Energy Savings:** Regenerative burners can achieve combustion efficiencies of over 85% and typically reduce fuel consumption by 35% to 60% compared to a conventional system without heat recovery.
2. **Uniform temperature distribution:** The technology creates a luminous flame due to the very high preheated air temperature, and the alternating firing of paired burners also agitates the furnace atmosphere, leading to exceptionally uniform temperature distribution.
3. **Durable and reliable design for High-Temperature Service:** Unlike recuperative burners that use metallic heat exchangers, regenerative burners use ceramic media. This eliminates the problem of corrosion and "burnout" of metallic elements

Key Challenges

1. **High Initial Investment:** The complex design, high-grade materials, and valve control system make the upfront cost significantly higher than that of a standard burner.
2. **High Operational Complexity and Maintenance:** The need for the burners to switch every 30-60 seconds places stress on the switching valves. This requires specialized, costly valves that, if not flawlessly designed, can cause mixing of air and fuel, leading to flashback
3. **Significant Space and Installation Requirements:** Retrofitting a regenerative system usually requires more space for the regenerators and support piping than conventional units

8.2.4 Technology providers

Encon Thermal Engineers Pvt. Ltd.

Wesman Thermal Pvt. Ltd.

8.2.5 Replication Potential

The Regenerative burners have very high replication potential in medium enterprises. The key sectors where this technology can be adopted, including hand tools, medium and large furnaces, Heat treatment Furnaces, Small forging furnaces, and foundry units

Table 6: Replication Potential of regenerative burners in forging clusters

S. No.	Cluster (State)	Estimated Units
1	Ludhiana, Jalandhar (Punjab)	1,450
2	Kolhapur, Pune (Maharashtra)	50
3	Chennai, Hosur (Tamil Nadu)	50
4	Ahmedabad, Rajkot (Gujarat)	140

Table 7: Replication potential of regenerative burners in Foundry clusters

S. No.	Cluster (State)	Estimated Units
1	Rajkot & Ahmedabad (Gujarat)	800 - 1,000
2	Kolhapur & Solapur (Maharashtra)	600 - 800
3	Coimbatore & Chennai (Tamil Nadu)	500 - 700
4	Ludhiana & Jalandhar (Punjab)	400 - 600
5	Kolkata-Howrah (West Bengal)	300 - 500
6	Belgaum (Karnataka)	200 - 300
7	Delhi-NCR (NCR Region)	200 - 300



Source: <https://castingssa.com/grinding-techniques-offers-a-total-foundry-solution-for-all-your-abrasive-needs/>

8.3 ELECTRIC GRINDER (REPLACEMENT OF PNEUMATIC GRINDER)

8.3.1 Overview

The foundry industry widely uses pneumatic grinders for finishing the products. The pneumatic grinders are energy-intensive tools as they operate using compressed air, which uses only 10% to 13% of the energy that reaches the point of end-use, while the rest is converted to unusable heat energy. Conversion to electric grinders is an energy-efficient option, as using electrical tools in the industry instead of pneumatic tools will eliminate the process of converting electrical energy into compressed air, leading to significant energy savings.

Target Applications

Sector: Foundry

Application: Cleaning and finishing of rough castings to final products

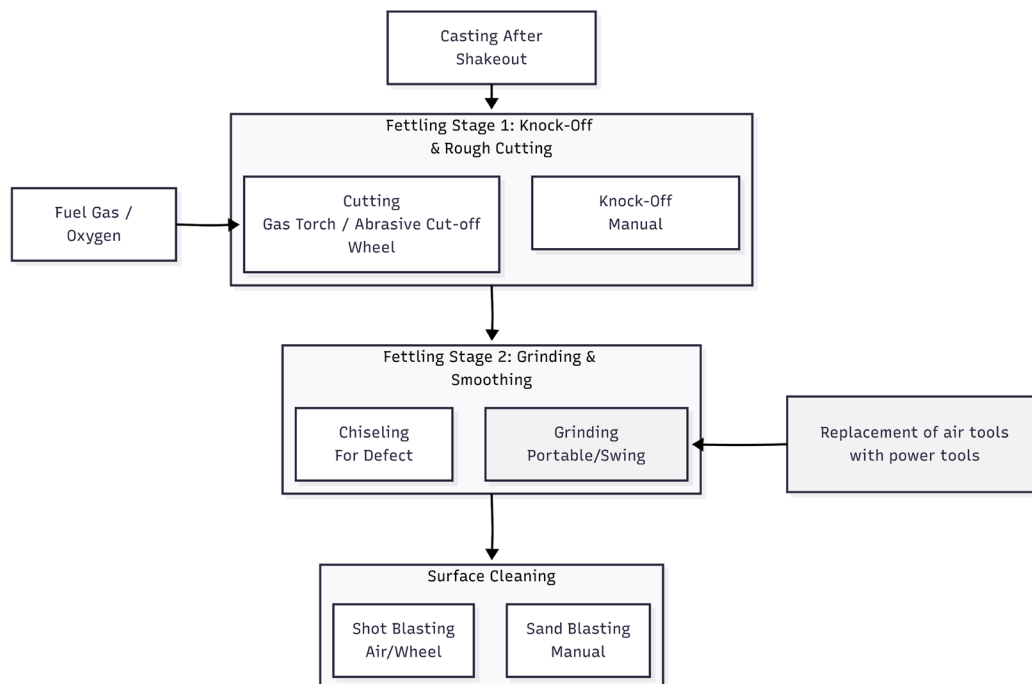
8.3.2 Technology assessment

Compressed air in foundries is used mainly in pneumatic grinders, shot blast, pneumatic rammers, and cleaning. Few units have a semiautomated pneumatic line for moulding. The connected load of the air compressor ranges up to 45 kW. The pressure requirement for all the applications is below 6.1 kg/cm. The pneumatic grinders are energy-intensive; the electrical energy is first converted to pneumatic energy, and then the pneumatic energy is converted to mechanical energy for tool operation. The electrical grinders, on the other hand, convert the electrical energy directly into mechanical thus converting more energy into useful work as compared to pneumatic tools.

Technology Details

Parameter	Typical values
Continuous rating input	2,200W
Wheel Diameter	180 mm (7")
No Load Speed (RPM)	8,500
Vibration Level:	Surface Grinding w/ Anti-Vibration Side Grip: 6.5 m/s ² Surface Grinding w/ Normal Side Grip: 7.0 m/s ² Disc Sanding w/ Anti-Vibration Side Grip: 2.5 m/s ² Disc Sanding w/ Normal Side Grip: 2.5 m/s ²
Sound Pressure Level	91 dB(A)
Sound Power Level	102 dB(A)
Noise K Factor	3 dB(A)
Dimensions (L x W x H)	450x200x145 mm (17-3/4"x7-7/8"x5-3/4")
Net weight	5.57 – 6.08 kg (12.3 – 13.4 lbs.)
Power supply cord	2.5 m (8.2 ft)

Source: <https://makita.in/product/ga7061r/>



Feasibility Analysis

S. No.	Parameter	Unit	Without an electric grinder	With an Electric Grinder
1	Electricity consumption per annum	kWh/year	26,208	3,744
2	Operating hours per year	Hours/year	6,240	6,240
3	Energy Saving	kWh/year	-	22,464
4	Monetary Saving	Rs/Year	-	2,00,000
5	Investment	Rs	-	50,000
6	Payback	Months	-	3
7	GHG emission reduction	tCO ₂ e/Year	-	16

8.3.3 Key Advantages & Challenges

Advantages

1. **Efficiency and Speed:** Electric grinders can complete tasks much faster than manual models, which is crucial for high-volume work in a foundry setting.
2. **Power and Performance:** They are generally more powerful and offer more consistent results, ideal for grinding tough materials like metal castings.
3. **Versatility:** Electric grinders can handle a wide variety of materials and grinding tasks with different attachments.
4. **Ease of Use:** They often feature ergonomic designs and adjustable settings, which reduce the physical effort and fatigue associated with manual grinding.
5. **Large-Scale Project Suitability:** Their robust nature makes them perfect for commercial use and large-scale projects.

Key Challenges

1. Electric grinders have a higher power-to-weight ratio, making them less ergonomic to operate during continuous, long operations.
2. Pneumatic grinders can work in wet environments, unlike electric ones, giving them more versatility.

8.3.4 Technology providers

Denntech Industries
Eastman Cast & Forge Ltd.

8.3.5 Replication Potential

Electric grinders can readily replace pneumatic grinders in small foundry units where finishing of cast products is required.

Table 8: Replication potential of electric grinders in foundry clusters.

Foundry Cluster	State	Number of Operating Units
Agra	Uttar Pradesh	80
Ahmedabad	Gujarat	450
Belgaum	Karnataka	160
Coimbatore	Tamil Nadu	535
Howrah	West Bengal	320
Indore	Madhya Pradesh	45
Jaipur	Rajasthan	110
Kolhapur	Maharashtra	300
Rajkot	Gujarat	60



Source: <https://www.texfabgroup.in/>

8.4 WASTE HEAT RECOVERY FROM DYE EFFLUENT

8.4.1 Overview

The textile dyeing and finishing industry is one of the most energy-intensive sectors globally, with hot water processing accounting for nearly 70% of total energy consumption. During the dyeing cycle, massive volumes of water are heated to temperatures of 90 °C. Traditionally, after the process is complete, this water is discharged into effluent treatment plants (ETP) at high temperatures.

Most textile industries require hot water for the dyeing process, is produced by the boiler in the form of steam. As the dyeing process is over, the hot water is drained at 70 °C. The heat available in this hot wastewater can be recovered using appropriately designed heat exchangers.

Target Applications

Sector: Textile

Application: Waste heat recovery for heating process water

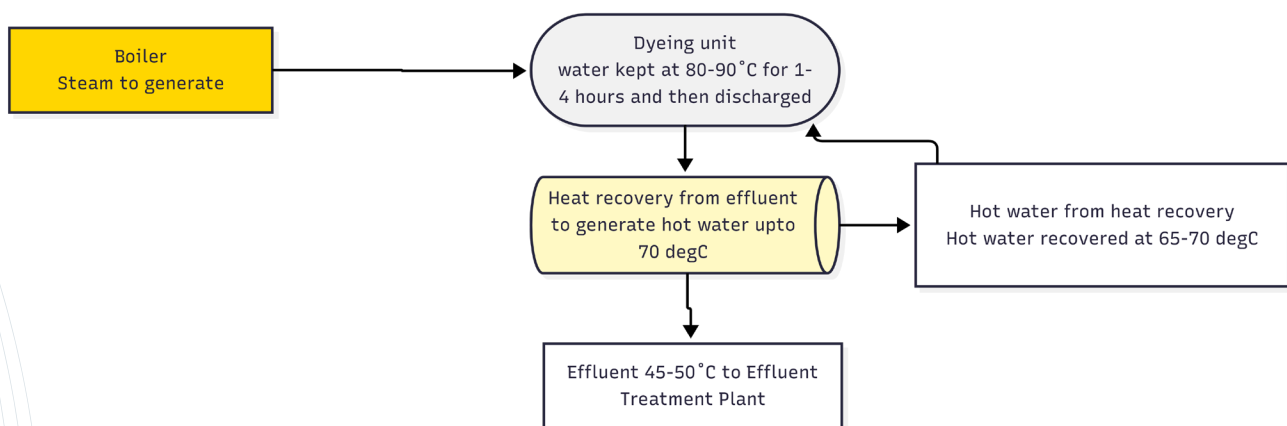
8.4.2 Technology assessment

There is a perception in the textile industry that heat recovery from the effluent causes pH instability, and high levels of suspended solids in the effluent can lead to clogging. This can affect the heat exchanger uptime and efficiency of heat transfer, leading to an increase in maintenance activities. Keeping these challenges in mind, a specialised waste heat recovery system for textile effluents is required. This system ensures the regular cleaning of the plate heat exchanger (PHE), segregation of effluent at various temperatures, and continuous monitoring of heat recovery. The textile waste heat recovery from the dyeing effluent systems can recover upto 85% heat from effluent discharge by using a high efficiency heat exchanger for heating incoming process water or boiler feed water to 60 °C.

Technology Details

Heat recovery technology in textile plants captures thermal energy from hot wastewater (effluent) discharged during dyeing and finishing processes and transfers it to incoming cold process water or boiler feed water. This technology is primarily based on high-efficiency heat exchangers designed to handle "dirty" industrial fluids that often contain mechanical pollutants like fibres, lint, and chemical residues.

The technology operates on the principle of indirect heat transfer, ensuring the polluted effluent never mixes with the fresh process water. The hot effluent and cold fresh water (typically at 25°C) flow through the heat exchanger, often in a counter-current arrangement (entering from opposite sides). In a Plate Heat Exchanger, the fluids pass through alternate parallel corrugated plates. Thermal energy is transferred through the plate walls from the hot effluent to the cold fresh water. In rotary or "spiral flow" designs, rotating surfaces may be used to prevent the accumulation of particulates, maintaining a constant heat transfer rate. The fresh water leaves the exchanger significantly warmer (potentially reaching up to 70°C), while the effluent is cooled to a safer temperature (often below 50°C), suitable for biological treatment in an ETP.



<https://www.scribd.com/document/840108015/8-Promethean-Opportunities-in-textile-units>

Feasibility Analysis

S. No.	Parameter	Unit	Without WHR	With WHR
1	Clear water	kL/Hr	5.1	5.1
2	Hot Effluent Discharge	kL/hr	4	4
3	Temperature of effluent discharged to ETP	OC	70	50
4	Temperature of water (inlet / Outlet)	OC	-	36 / 52
5	Steam saving	Kg/hr	-	160
6	Coal Saved	tons/year		120
7	Investment	₹ Lakhs		12
8	Annual Financial Savings	₹ Lakhs		7
9	GHG Reduction (coal)	tons CO ₂ e/year		509
10	Payback	Months		22

8.4.3 Key Advantages & Challenges

Advantages

1. **Significant Fuel Savings:** Pre-heating fresh process water with waste heat reduces steam demand by 15% to 25%, directly lowering coal, gas, or oil consumption.
2. **Faster Production Cycles:** Since the water enters the dyeing machines at a much higher temperature, the time required to reach the "boil" is shortened, increasing daily factory throughput.
3. **Better ETP Efficiency:** It cools the effluent to a safe temperature (below 40°C) before it reaches the biological Effluent Treatment Plant (ETP), preventing the heat from killing the essential bacteria used for water purification.
4. **Lower Carbon Footprint:** Reducing fuel combustion significantly decreases CO₂ emissions, helping the facility meet environmental regulations and international "green" textile certifications.

Key Challenges

1. **Dye effluent contains microfibres.** Without a self-cleaning rotary filter before the heat exchanger, the plates of the heat exchanger may clog.
2. **Corrosion:** Dye chemicals can be acidic or alkaline. Using 316L Stainless Steel or Titanium plates is essential for longevity.
3. **Batch vs. Continuous:** Dyeing is often a batch process, whereas heat recovery works best when operated continuously. Installing a Buffer Tank helps equalise the flow.

8.4.4 Technology providers

Promethean Energy

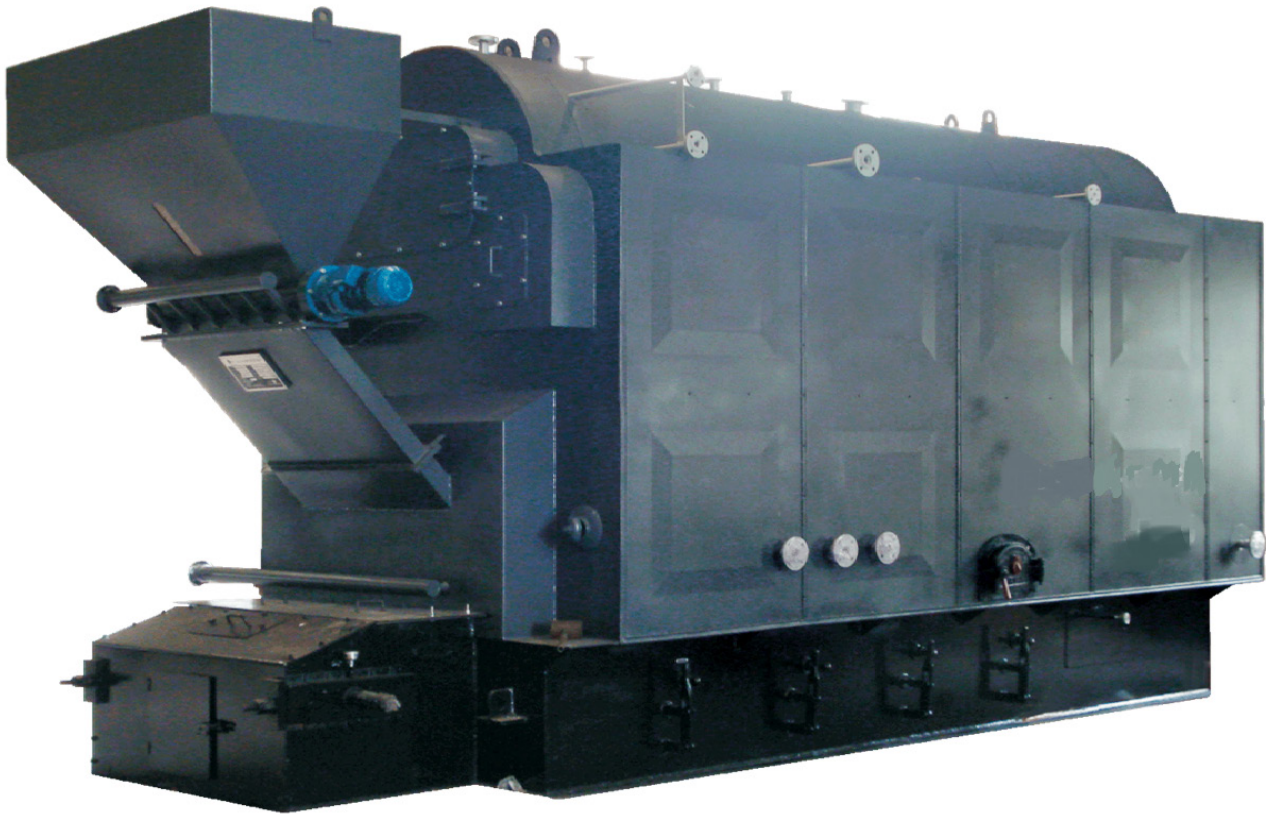
Alfa Laval India Private Limited

8.4.5 Replication Potential

The Waste heat recovery from dye effluent is an add-on technology for energy efficiency improvement and ensuring environmental safeguard by effectively treating the effluent in the ETP. The technology is applicable for all textile units (small, medium and Large), approximately 3000 units.

Table 9: Replication potential of the WHR from dye effluent in the textile industry

S No	Cluster (State)	Estimated Units
2	Surat (Gujarat)	400 processing units
5	Tirupur (Tamil Nadu)	3,200 MSMEs
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms



Source: <https://www.steam-generator.com/biomass-pellets-fired-steam-boilers/>

8.5 RDF FIRED BOILER

8.5.1 Overview

RDF-fired boilers are combustion systems that generate heat or steam by burning processed refuse-derived fuel (RDF). For MSMEs in sectors such as textiles and paper, the most suitable and widely adopted technology is the travelling grate boiler, capable of firing RDF. These systems are valued for their fuel flexibility and ability to handle materials with high ash and moisture content.

The combustion process in these boilers occurs in three distinct stages: drying, devolatilization, and char oxidation. First, the intense furnace heat evaporates the moisture from the fuel. Next, as the dried particles heat, they release volatile gases, which account for approximately 70% of the fuel's heating value. Finally, the remaining solid char (carbon) burns, leaving behind ash. For Indian MSMEs, this technology offers a pathway to replace fossil fuels like coal and furnace oil with renewable alternatives.

Target Applications

Sector: Textile, Paper & Pulp

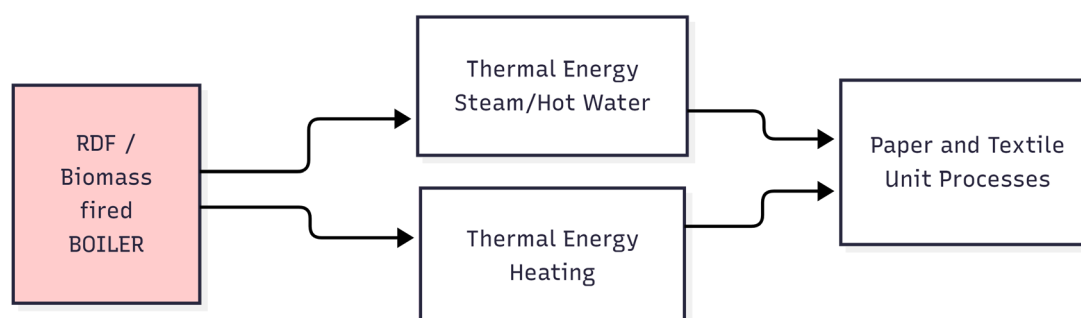
Application: Hot water and steam generation for processes

8.5.2 Technology assessment

For textile and paper MSMEs in India, RDF and biomass-fired boiler technology represents a mature and commercially viable solution for decarbonising thermal energy generation while reducing operational costs. The technology is particularly well-suited to paper and textile MSMEs. It is expected that the demand for boilers capable of firing RDF or biomass and coal will continue to grow in emerging economies. With increasing urbanisation, one of the key strategies for effective waste management is RDF firing in industries.

Technology Details

RDF boiler plants are designed with specific features to handle the unique characteristics of these fuels, including high ash content, low ash fusion points, and the presence of chlorides and other corrosive elements. The most common configurations for MSME-scale applications include grate-fired boilers (travelling grate or reciprocating grate) and fluidised bed combustion systems for larger capacities.



Feasibility Analysis

S. No.	Parameter	Unit	Without RDF fired boiler	With RDF fired boiler
1	Boiler Capacity (at 63 kg/cm ²)	TPH	20	20
2	Coal Consumption	Tones/hr	3.75	0
3	Equivalent RDF consumption	Tones/hr	0	10.6
4	Cost of fuel (coal 8000 Rs/ton & RDF 1500 Rs/ton)	Rs/hr	30,000	15,900
5	Reduction in fuel cost	Rs/hr	-	14,100
6	Boiler operation per year	Hr/year	7260	7260
7	Monetary saving	Crore Rs/year	-	10.24
8	Cost of RDF-fired boiler	Crore	-	12
9	Simple payback	Months	-	14
10	GHG Emission Reduction	t CO ₂ eq		68,000

8.5.3 Key Advantages & Challenges

Advantages

1. These boilers can adapt to a wide variety of biomass fuels, including wood chips, sawdust, straw, agricultural residues, and processed RDF. This flexibility allows businesses to choose fuels based on local resource availability, reducing operating costs
2. RDF fuel costs are typically lower than natural gas and LPG for many industrial users, offering improved fuel resilience and security
3. Reduced Harmful Emissions: Biomass boilers produce much lower sulphur dioxide emissions compared to coal.
4. RDF firing specifically enables the recovery of energy from municipal and industrial waste that would otherwise go to landfill.
5. RDF is considered renewable energy by MNRE. Calorific value is 1700 kcal/kg, and the cost is Rs 1000 / ton
6. It can do a supplementary firing in an existing coal-fired boiler with small modifications in the boiler combustion zone.

Key Challenges

1. Fuel Quality and Consistency Issues: Biomass moisture content significantly affects combustion performance. Moisture above 30% increases drying time and delays ignition, potentially causing a "downward spiral" leading to poor combustion or boiler blackout.
2. RDF firing can cause excessive erosion of smoke tubes due to grit transportation, requiring protective ferrules. Ash accumulation requires frequent maintenance.
3. Significant on-site space is needed for fuel storage (and keeping it dry). Sites with space constraints become dependent on ongoing deliveries, creating operational vulnerability.
4. Technical Complexity and Specialised Design Needs: Different biomass types require specific boiler configurations, reciprocating grates for variable fuels, and chain grates for uniform fuels. RDF combustion requires specialised features like spray-seeding designs, corrosion-resistant materials (Inconel layers), and online cleaning systems (soot blowers). Retrofitting existing boilers for RDF can result in a 2-3% efficiency reduction and loss of generating capacity.

8.5.4 Technology providers

Sitson India Pvt. Ltd.

Cheema Boilers Limited (CBL)

Enneff Solutions Pvt Ltd

Industrial Boilers Ltd.

Thermax Ltd

8.5.5 Replication Potential

The RDF-fired boilers can be a fuel switching option for Paper plants and textile plants.

Table 10: Replication potential of the RDF-fired boiler in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
5	Tirupur (Tamil Nadu)	3,200 MSMEs
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms

Table 11: Replication potential of the RDF-fired boiler in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Picture source <https://turtleturbines.com>

8.6 MICRO TURBINES

8.6.1 Overview

Micro turbines are small-scale gas-fired or steam turbines that simultaneously generate electricity and useful thermal energy for a process. A steam microturbine is a compact power generation system designed to convert the thermal energy of steam into electricity or mechanical work on a small scale.

In industries such as textiles and paper, where low-pressure steam is generated by throttling high-pressure steam through a pressure-reducing valve (PRV) and dissipating the excess energy of the steam as waste, microturbines offer an efficient replacement for PRVs. These microturbines harness the kinetic energy of steam via a back-pressure or extraction design, producing captive power without disrupting the continuous low-pressure steam supply.

Target Applications

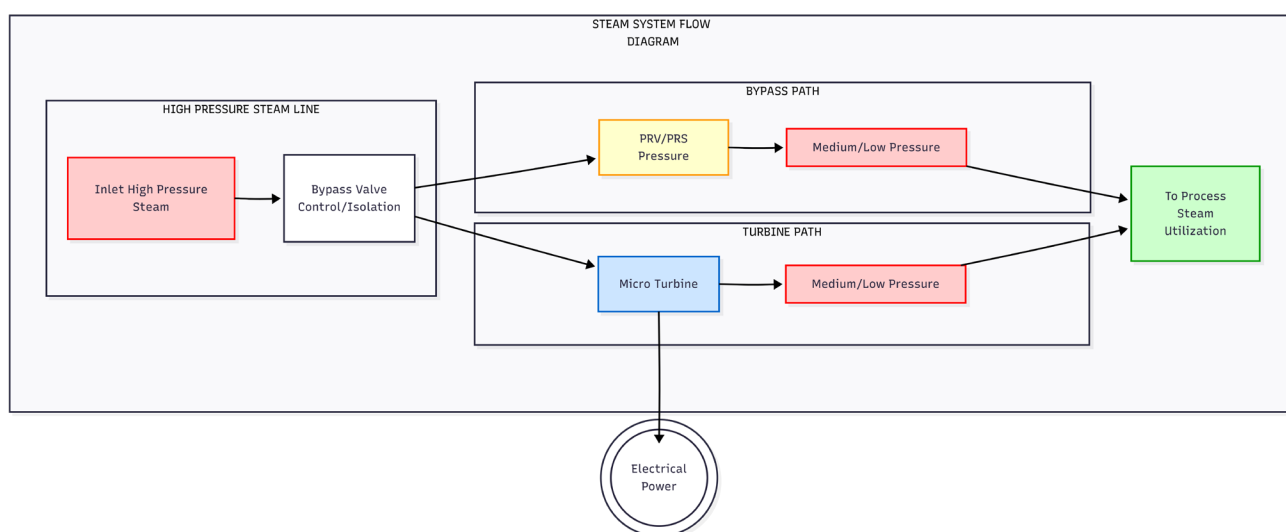
Sector: Textile (process steam for Dyeing, Finishing); Paper & Pulp (process steam for Pulping, Drying)

Application: Waste heat recovery through the replacement of PRV

8.6.2 Technology assessment

Replacing the PRV system with microturbines allows industrial facilities to convert excess thermal energy into electrical energy during the pressure reduction process. Microturbines utilise the high-pressure steam to drive a small turbine, generating electricity while simultaneously reducing the steam pressure to the required levels for downstream use. These systems typically range from 6 kW to 250 kW and are suitable for continuous process industries like textiles and paper. The technology supports distributed energy generation, reduces grid electricity dependence, and enhances overall energy efficiency by capturing energy that would otherwise be wasted. The implementation of microturbines is relatively straightforward due to their modular nature, allowing for direct integration into existing steam headers with a bypass line, requiring minimal plant downtime and civil work. The technology is mature and highly reliable, with global

designs adapted for Indian steam conditions supported by a robust domestic supply chain, with several Indian manufacturers and service providers.



Technology Details

Parameter	Typical Range
Electrical Capacity	30–500 kW (modular)
Electrical Efficiency	25–30%
Thermal Recovery	40–50%
Overall CHP Efficiency	65–85%
Operating Mode	Continuous / Base-load

Feasibility Analysis

S. No.	Parameter	Unit	Without Microturbine (PRV)	With Microturbine
1	Steam flow through PRV (saturated steam 10.0 Kg/cm ² (g) → 3.50Kg/cm ² (g))	Tonne/hour	6	6
2	Operating hours per day	hours/day	24	24
3	Operating days per year	days/year	330	330
4	Annual steam processed	Tonne/year	47,520	47,520
5	Electricity generated by the microturbine (assuming 80% useful electricity)	MWh/Year	0	855
6	Cost of electricity	INR/kWh	7	7
7	Monetary savings (value of electricity)	INR lakh/year	–	59.8
8	Investment required	INR lakh	–	118.75
9	Simple payback period	months	–	23
10	Annual GHG emission reduction potential	t CO ₂ /year	–	615.8

8.6.3 Key Advantages & Challenges

Advantages

1. Fuel flexibility (natural gas, biogas, other gaseous fuels)
2. Compact, lightweight design with small footprint
3. Long maintenance intervals and high reliability
4. Rapid response to load variations
5. Low noise and vibration
6. Reduced grid dependence and improved energy security

Key Challenges

1. High upfront capital cost
2. Lower electrical efficiency compared to large gas turbines
3. Performance sensitive to fuel price and availability
4. Requires stable thermal demand for optimal economics

8.6.4 Technology providers

Turbotech Precision Engineering Pvt. Ltd

Turtle Turbines (P) Ltd.

Triveni Turbine Ltd.

Industrial Boiler Ltd.

8.6.5 Replication Potential

The micro turbine is a very efficient replacement or add-on technology to the PRV system for reducing the pressure of process steam. The technology can be implemented in the textile, Paper, and process industry.

Table 12: Replication potential of the micro turbine in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Tirupur (Tamil Nadu)	3,200 MSMEs
5	Ludhiana (Punjab)	14,000 MSMEs
6	Panipat (Haryana)	3,095 MSMEs
7	Ichalkaranji (Maharashtra)	80,000-120,000 looms

Table 13: Replication potential of the micro turbine in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Source: <https://trigendc.com/high-temperature-heat-pumps-and-dryers/>

8.7 HEAT PUMPS [LOW TEMPERATURE UPTO 90 °C]

8.7.1 Overview

Low-temperature industrial heat pumps (up to 90°C) are electrically driven systems that recover low-grade heat from ambient or process sources and upgrade it to useful thermal energy for industrial applications. These systems operate on the vapour compression cycle and are widely applied where hot water or low-temperature process heat is required.

According to the technology overview published by the International Energy Agency, industrial heat pumps capture waste heat from sources such as wastewater, process cooling water, exhaust air, or ambient air and increase its temperature to meet process heating demands. For low-temperature systems, the output temperature typically ranges between 60°C and 90°C.

Target Applications

Sector: Textile, Pulp & Paper

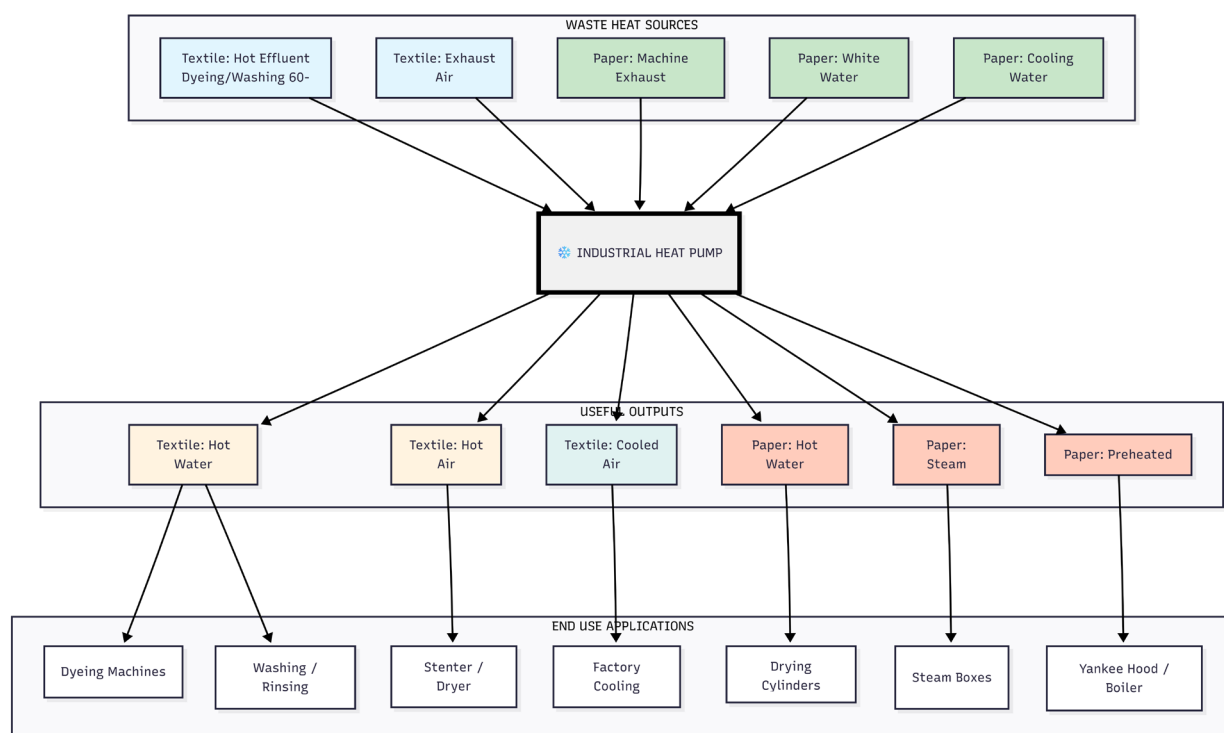
Application: Process hot water generation, washing and cleaning operations, drying processes, and low-temperature space heating.

8.7.2 Technology assessment

Technology Details

Low-temperature industrial heat pumps (up to 90 °C) operate on the vapour compression cycle and are designed to upgrade low-grade waste heat or ambient heat into useful process heat. These systems extract heat from sources such as wastewater, cooling water, exhaust air, or ambient air through an evaporator. The refrigerant absorbs this heat and is compressed by an electrically driven compressor, which increases its temperature and pressure. The high-temperature refrigerant then transfers heat to the process medium in the condenser, typically producing hot water up to 90 °C. After releasing heat, the refrigerant passes

through an expansion valve to reduce pressure and repeat the cycle. The system transfers heat rather than generating it directly, resulting in high efficiency, with coefficients of performance typically above 2, depending on temperature lift and system design.



Feasibility Analysis

S. No.	Parameter	Unit	Without Heat Pump (Boiler, LPG)	With Heat Pump
1	Hot water requirement (Heating water up to 70°C)	Litres/hour	5,000	5,000
2	Operating hours per day	hours/day	24	24
3	Operating days per year	days/year	300	300
4	Annual thermal energy required	MWh/year	1,674	1,674
	Fuel Consumption (LPG)	Kg/year	1,51,500	-
5	Electricity consumed (Assuming average COP of 3.5)	MWh/year	-	465
7	Monetary savings	INR lakh/year	-	65
8	Investment required	INR lakh	-	110.0
9	Simple payback period	months	-	20
10	Annual GHG emission reduction	t CO ₂ /year	-	345

8.7.3 Key Advantages & Challenges

Advantages

1. High energy efficiency as heat is transferred rather than directly generated (COP typically >2 depending on temperature lift).
2. Reduction in fossil fuel consumption and associated CO₂ emissions.
3. Utilisation of low-grade waste heat (wastewater, cooling water, exhaust air).

4. Suitable for process heat applications up to 90 °C, including hot water generation.
5. Electrically driven, enabling integration with renewable electricity sources.

Key Challenges

1. Performance depends on the availability and stability of a suitable low-grade heat source.
2. Efficiency decreases as temperature lift increases.
3. Requires a reliable and continuous electricity supply.

8.7.4 Technology providers

Voltas Limited
Thermax Limited
Kirloskar Chillers Pvt. Ltd.
TRIGeN Decarbonisation Pvt. Ltd
Promethean Energy

8.7.5 Replication Potential

The heat pump technology can be implemented in the Pharma, Textile, food processing, and automobile sectors for providing low-grade heating in processes.

Table 14: Replication potential of the heat pump in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Varanasi (UP)	200+ artisans
5	Tirupur (Tamil Nadu)	3,200 MSMEs
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms

Table 15: Replication potential of the heat pump in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Source: <https://www.kaypeeinsulator.com/types-of-insulation/dual-insulation/>

8.8 A-ONE INSULATION (HOT AND COLD INSULATION / DUAL INSULATION)

8.8.1 Overview

Dual thermal Insulation includes a combined insulation from temperatures getting lower and higher. The insulated containers remain unaffected by temperature fluctuations caused by external factors. The Hot insulation ensures that the containers and pipes don't get affected by increasing temperatures. Meanwhile, the cold insulation ensures that the decreasing temperatures don't affect the container and the substance enclosed in it.

Target Applications

Sector: Paper & Pulp, Textile

Application: Insulation of Pipes and vessels

8.8.2 Technology assessment

Technology Details

Dual thermal Insulation includes a combined insulation that prevents temperatures from getting too low or too high. The insulated containers remain unaffected by temperature fluctuations. The Hot insulation ensures that the containers and pipes don't get affected by increasing temperatures. Meanwhile, the cold insulation ensures that the decreasing temperatures don't affect the container and the substance enclosed in it. Dual Insulation does both tasks under the same setup. The dual insulation technology is a combination of Hot & Cold Insulation, where the process demands are for both Hot & Cold Insulation, and the process lines and equipment are used for both purposes.

Parameter	Typical Range
Product name	Perlite Block and Pipe insulation (hot & Cold)
Advantage	Rigid Insulation / Water Repellent / Fire Resistant /Corrosion Resistant
Temperature Range	-40 to 650°
Thermal Conductivity Range	0.053 – 0.113 W/m · °C

Feasibility Analysis

S. No.	Parameter	Unit	Without Dual Insulation	With Dual Insulation
1	Energy Savings	kWh/ 100 meter/year	–	25000
2	GHG Emission Reduction	t CO ₂ e/100 meter/year	–	19
3	Investment Cost	₹/100 meter	–	2,50,000
4	Annual Monetary Savings	₹/100 meter/year	–	3,70,000
5	Simple Payback	Months	–	9

8.8.3 Key Advantages & Challenges

Advantages

1. Operates reliably across a wide spectrum from sub-zero temperatures (-40°C) to high-temperature process heat (650°C).
2. It is non-combustible, does not produce toxic smoke when exposed to fire, and can protect critical equipment and pipelines in the event of a fire accident.
3. Its extreme water repellent property prevents moisture ingress, eliminating the risk of Corrosion Under Insulation (CUI), a common and costly problem in process plants.
4. High Mechanical Strength, ensuring long-term performance and reducing replacement frequency.

Key Challenges

1. Compared to traditional alternatives like mineral wool, the upfront cost of perlite insulation is higher
2. The pre-moulded sections can be brittle and must be handled with care during transport and installation to prevent breakage
3. To achieve its rated thermal performance, the sections must be fitted tightly with minimal gaps. This requires experienced installers to ensure a "snug fit," especially around complex fittings like elbows and tees.

8.8.4 Technology providers

A One Insulations
Sheth Insulations Pvt. Ltd

8.8.5 Replication Potential

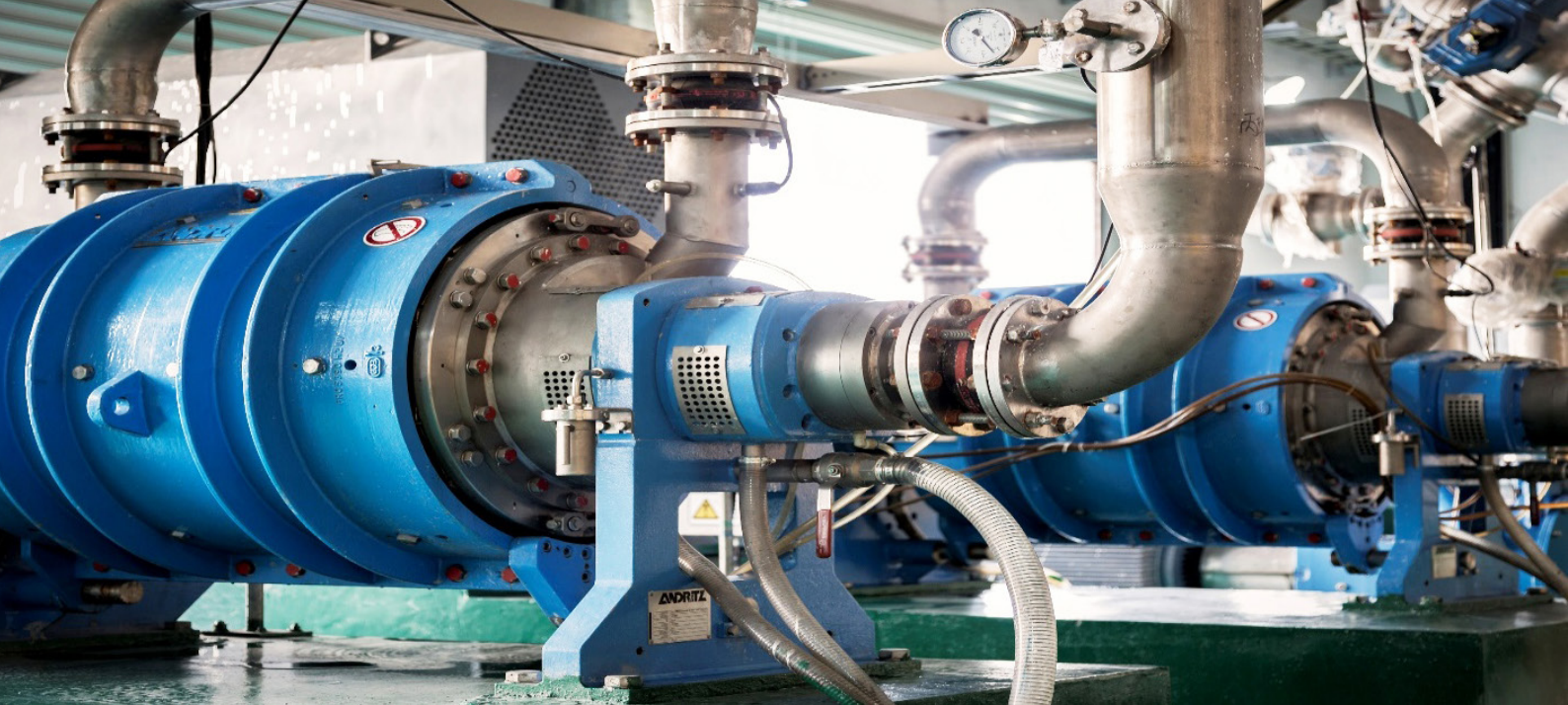
The technology is standardized, mature, and widely used across the Indian industrial sector. The straightforward installation process can be easily replicated by local contractors across multiple MSMEs within a cluster. Successful demonstration projects in a few lead plants can quickly trigger cluster-wide replication.

Table 16: Replication potential of the heat pump in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Varanasi (UP)	200+ artisans
5	Tirupur (Tamil Nadu)	3,200 MSMEs
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms

Table 17: Replication potential of Dual insulation (Hot & Cold Insulation) in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Source: <https://www.andritz.com/products-en/pulp-and-paper/paper-production/stock-preparation/low-consistency-refining>

8.9 LOW CONSISTENCY REFINING (LCR)

8.9.1 Overview

Low Consistency Refining (LCR) is a pulp refining technology in which pulp slurry at low consistency (typically 3–5 % solids) is mechanically treated to develop desired fibre properties such as flexibility, surface area, and bonding potential for papermaking. In LCR, refining is carried out in specialised low-consistency refiners where the pulp fibres are subjected to cyclic compression and shear forces between rotor and stator bars. This mechanical action permanently modifies the fibre walls, improving the physical properties of the pulp.

The lower consistency reduces fibre-to-fibre friction and allows for more uniform fibre treatment with lower specific energy input compared to high consistency refining. As a result, energy reductions of 20–30 % or more have been observed when replacing or supplementing conventional high consistency stages with low consistency refining, with practical energy savings reported in the range of 100–200 kWh/tonne of pulp (which can replace 200–400 kWh/tonne of high consistency refining at similar freeness).

Target Applications

Sector: Pulp & Paper industry

Application: Mechanical and semi-chemical pulp refining to improve tensile strength, flexibility, and freeness, and uniformity for paper and board production.

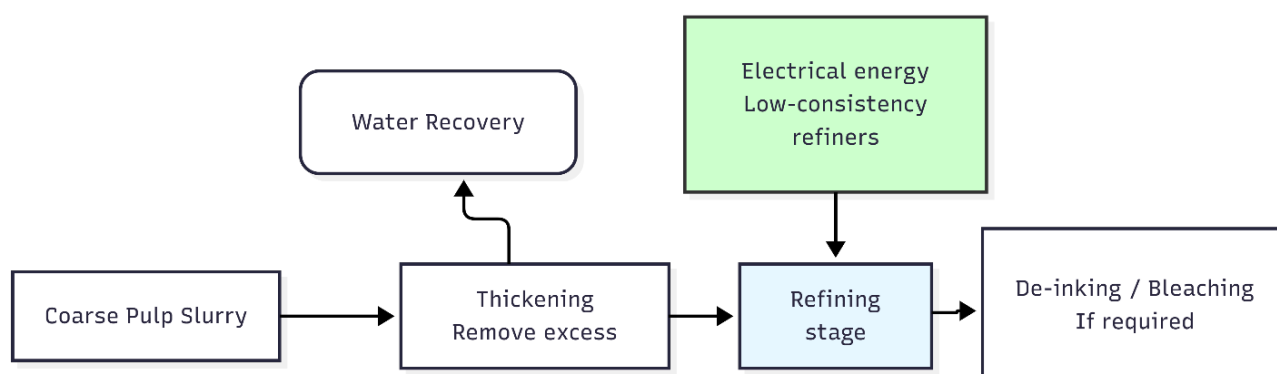
8.9.2 Technology assessment

Low Consistency Refining (LCR) operates by refining pulp at a consistency of 3–5%. The refining process involves the mechanical treatment of pulp fibres, which improves the pulp's physical properties. The process is carried out in a refiner, where the pulp is subjected to cyclic compression and shear, permanently deforming the fibre wall. Energy reductions of 20–30% have been claimed for LCR installed.

Technology Details

In Low Consistency Refining (LCR), pulp is first diluted to 3–5% consistency using water and fed into the system via a pulp feed pump. The low-consistency pulp enters the rotor-stator refiner, where it undergoes

cyclic compression and shear, which modifies the fibre walls, increases fibrillation, and improves bonding properties. The refined pulp is then discharged to a downstream pulp chest or screening system, where it is checked for freeness and quality before being sent to the paper machine or further stock preparation stages. The process is continuous, with consistency control, flow monitoring, and energy input management ensuring uniform fibre treatment and optimal energy efficiency.



Feasibility Analysis

S. No.	Parameter	Unit	Without LCR (Conventional Refining)	With LCR (4.8% Consistency)
1	Quantity of pulp	ton of pulp/day	60	60
2	Operating days	days/year	365	365
3	Annual pulp quantity	ton of pulp /year	21,900	21,900
4	Refining Energy Demand	kWh/ton of pulp	140	90
5	Energy Savings	MWh/year	30,66	19,71
6	Investment Cost	₹ laks /year	–	350
7	Annual Monetary Savings	₹ laks /year	–	250
8	Simple Payback	Months	–	17
9	GHG Emission Reduction	t CO ₂ e/year	–	~720

8.9.3 Key Advantages & Challenges

Advantages

1. Significant energy savings compared to high consistency refining.
2. Improved pulp quality, including better fibre flexibility and strength development.
3. Potential increased production throughput (4 %–12 %).

Key Challenges

1. Requires precise process control to avoid fibre damage (e.g., cutting).
2. Integration with existing refining lines may require retrofit engineering.
3. The capital cost of specialised low-consistency refiners can be high.

8.9.4 Technology providers

Valmet Corporation- Low consistency refiners (e.g., RF 5 series).

Andritz AG- Pulp refining equipment, including low consistency solutions.

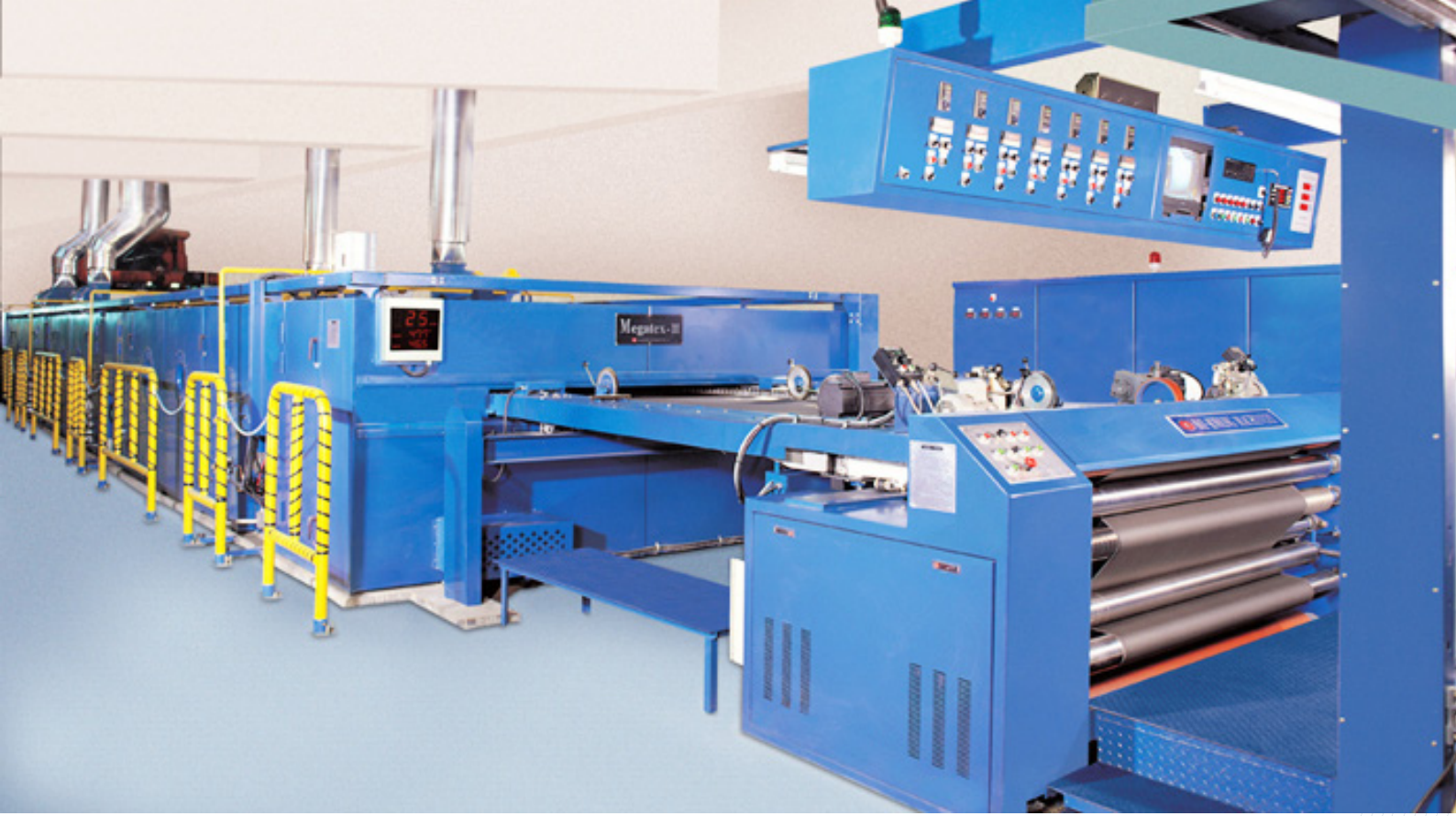
Voith GmbH & Co. KGaA- Refining technologies for mechanical pulp lines.

8.9.5 Replication Potential

The replication potential of the LCR technology is very high across the paper industry.

Table 18: Replication potential of the LCR technology in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Source: <https://autogarment.com/stenter-machine-textile-industry/>

8.10 IOT IN STENTER MACHINE

8.9.1 Overview

IoT (Internet of Things) in Stenter Machines refers to embedding sensors, connectivity, and digital monitoring systems into textile finishing stenters to collect real-time process data, enable automation, and support analytics-driven performance optimisation. A stenter machine, used in textile finishing for drying, heat setting, curing, and controlling fabric width and properties, benefits from IoT by tracking key parameters such as temperature zones, fabric speed, moisture levels, energy consumption, and machine state. IoT solutions improve operational visibility, reduce downtime through predictive maintenance, and allow remote monitoring and control of process parameters across production lines.

The working principle involves attaching sensors (temperature, humidity, speed, vibration, energy meters) throughout the stenter line, connecting them via secure network protocols (Wi Fi / Ethernet / IoT gateways) to a central IoT platform or cloud service, and using software dashboards to visualise machine KPIs, set alarms, and generate reports. Advanced implementations incorporate edge computing, where local hardware pre-processes data before transmission, and machine learning models to detect anomalies or recommend setpoint adjustments.

Target Applications

Sector: Textile

Application: Real-time monitoring & control of fabric temperature and moisture, predictive maintenance, energy optimisation, quality assurance, and production reporting.

8.10.2 Technology assessment

Technology Details

The IoT-enabled stenter process begins when fabric enters the machine and is continuously monitored by a suite of sensors that measure key process variables such as temperature, fabric speed, moisture, and tension. The data collected by these sensors is aggregated and pre-processed by an IoT gateway before being transmitted to a central IoT platform. Operators and supervisors can then access dashboards to monitor the stenter's performance in real time, adjust if necessary, and receive automated alerts for any deviations or potential faults. Analytics tools on the platform assist in stabilising the process, detecting faults, and optimising energy usage. This integrated digital feedback loop improves product consistency, reduces downtime, and provides actionable operational insights without interfering with normal stenter operations.

Feasibility Analysis

S. No.	Parameter	Unit	Without IoT in the Stenter Machine	With IoT in the Stenter Machine
1	Cost of electricity	INR/kWh	10	10
2	Monetary savings (value of electricity)	INR lakh/year	–	50
3	Investment required	INR lakh	–	3
4	Simple payback period	months	–	0.1
5	Annual GHG emission reduction potential	t CO ₂ /year	–	280

8.10.3 Key Advantages & Challenges

Advantages

1. Provides real-time visibility of all key process parameters across the stenter line, allowing operators to monitor performance continuously and make informed adjustments.
2. Automated monitoring and alert systems reduce the need for manual inspections, helping staff focus on critical tasks and improving overall operational efficiency.
3. Energy consumption tracking enables identification of inefficient heating or drive usage, leading to cost savings and reduced greenhouse gas emissions.
4. Predictive maintenance capabilities allow early detection of potential machine faults, minimising unplanned downtime and extending equipment life.

Key Challenges

1. The initial investment in sensors, IoT gateways, and software platforms can be substantial, especially for retrofitting existing stenter machines.
2. Reliable factory-floor connectivity and robust cybersecurity measures are required to ensure uninterrupted data flow and protection against cyber threats.
3. Integrating IoT solutions with legacy PLC or SCADA systems can be complex and may require custom engineering or additional middleware.

8.10.4 Technology providers

Larsen & Toubro Infotech
 KPIT Technologies
 Schneider Electric
 Rockwell Automation

8.10.5 Replication Potential

Table 19: Replication potential of IoT in the stenter machine in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Varanasi (UP)	200+ artisans
5	Tirupur (Tamil Nadu)	3,200 MSMEs
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms



Source: <https://www.hstarschiller.com/>

8.11 HOT WATER GENERATION FROM THE CHILLER AND THE COMPRESSOR (60 TO 70 DEG C)

8.11.1 Overview

Generating hot water by recovering waste heat from existing equipment like air compressors and chillers represents one of the most cost-effective and quickest ways to reduce operational costs and carbon footprint. Instead of letting this heat escape into the atmosphere, it can be captured and used directly in processes. As an air compressor operates, it generates intense heat that must be removed by a cooling medium, either air or a coolant fluid (oil or water). A heat recovery system integrates a heat exchanger (like a brazed plate heat exchanger) into this cooling circuit. Similarly, a standard chiller provides chilled water for processes or space cooling by absorbing heat and rejecting it through a condenser. A heat recovery chiller is designed to capture this rejected heat and put it to work. In heat recovery mode, instead of sending all the hot refrigerant gas from the compressor to the condenser to be cooled, it is first routed to a dedicated heat exchanger (called a desuperheater in air-cooled systems). The heat from this high-temperature refrigerant gas is transferred to a hot water loop circulating through the building or process.

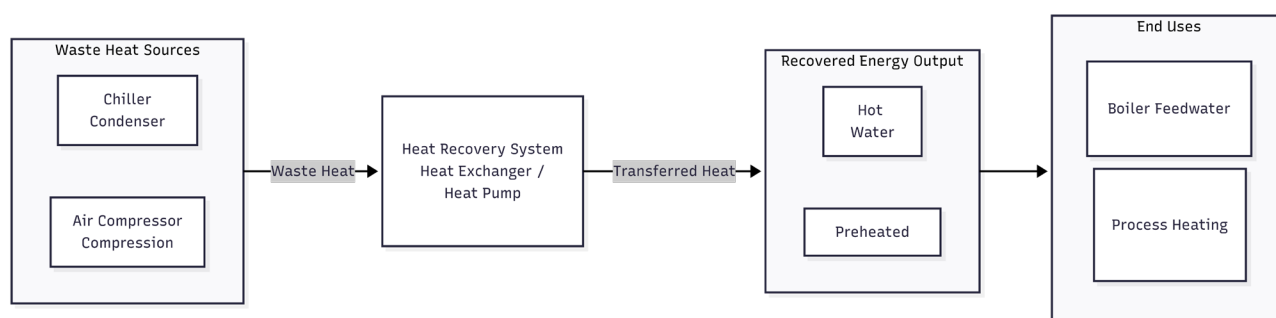
Target Applications

Sector: Textile

Application: preheating boiler feedwater/ process hot water

8.11.2 Technology assessment

Technology Details



Feasibility Analysis

S. No.	Parameter	Unit	Without Heat Recovery Chiller	With Heat Recovery Chiller
1	Hot water source	-	LPG-fired boiler	Waste heat from the chiller
2	Hot water temperature	°C	60	60
3	Annual useful heat required	MWh	277	277
4	LPG Saved	kg	-	25,300
5	Monetary savings (Fuel cost reduction)	₹ lakh/year	-	25.3
6	Investment	₹ lakh	-	20
7	Payback	Months	-	10
8	GHG emission reduction	tCO ₂ /year	-	75

8.11.3 Key Advantages & Challenges

Advantages

1. Recovering waste heat from chillers and compressors allows utilisation of thermal energy that would otherwise be rejected to the environment, improving overall plant efficiency.
2. By capturing and reusing waste thermal energy, operational energy costs are lowered, leading to direct cost savings.

Key Challenges

1. The temperature range recoverable from typical chillers and compressors may not always reach 60–70 °C without additional heat pump staging or booster systems, limiting applicability in some scenarios.
2. Designing an efficient heat recovery loop requires proper integration with existing equipment, including matching flow rates, heat exchanger size, and storage systems.

8.11.4 Technology providers

Johnson Controls
Daikin Industries Ltd.
Trane Technologies
Carrier Global Corporation Voltas Limited
Blue Star Limited
Thermax Limited
Trident Global

8.11.5 Replication Potential

Table 20: Replication potential of Hot water generation from the chiller and the compressor in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Varanasi (UP)	200+ artisans
5	Tirupur (Tamil Nadu)	3,200 MSMEs
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms



Source: <https://graham-mfg.com/solutions/products/ling-ring-vacuum-pumps/>

8.12 FABRICATED WATER RING VACUUM PUMPS

8.12.1 Overview

Water ring vacuum pumps (also called liquid ring vacuum pumps) are rotary positive displacement machines that use water as the operating liquid to create a vacuum for various paper manufacturing processes. In paper mills, these pumps are essential auxiliary equipment for dewatering paper sheets during the forming and pressing sections of the paper machine. The pump operates on the principle of an eccentrically mounted impeller rotating within a cylindrical casing partially filled with water. As the impeller rotates, centrifugal force creates a moving "liquid ring" against the casing walls, forming chambers between the impeller blades that expand and contract to draw in and compress gases. The operating water not only compresses gases but also removes heat from the compression process, uptakes liquids and vapours, and provides a seal between the impeller blades and casing. These pumps are particularly valued in paper manufacturing for their ability to handle wet gases, entrained liquids, and fibrous particles without damage.

Target Applications

Sector: Paper & Pulp, Textile

Application: Dewatering and moisture removal

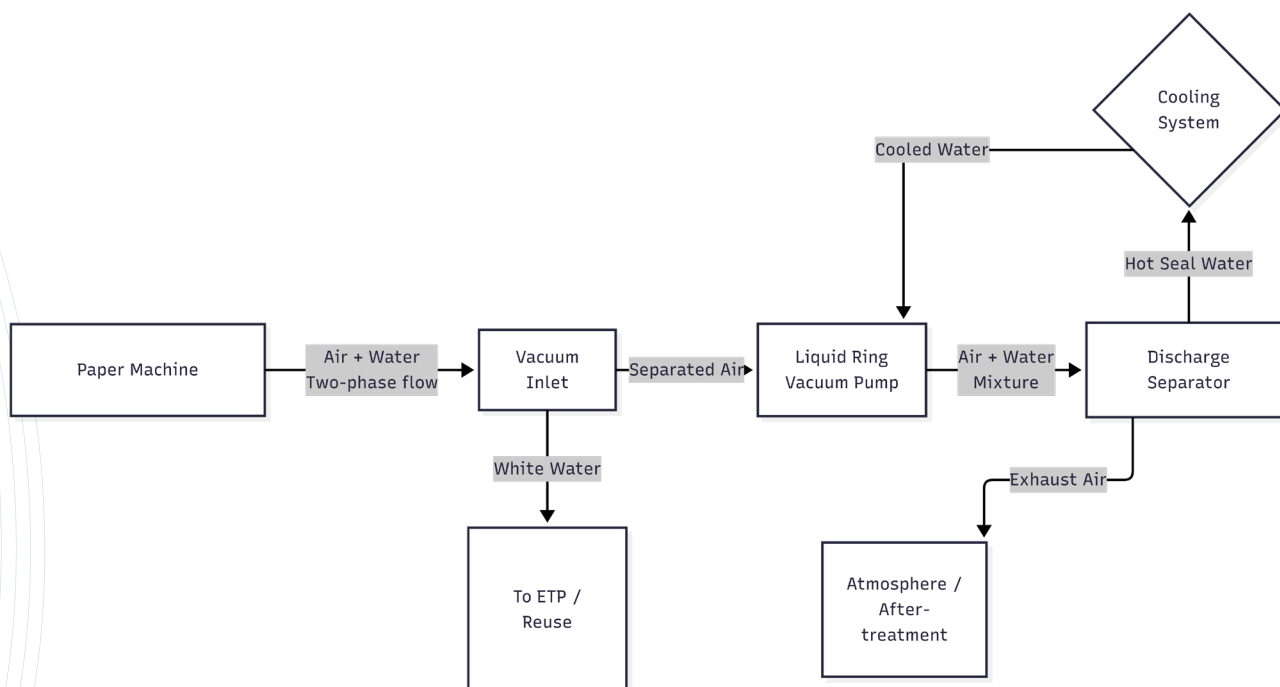
8.12.2 Technology assessment

Fabricated Water ring vacuum pumps are rotary positive displacement machines that use water as a sealing liquid to create a vacuum for critical papermaking processes. The working principle involves an eccentrically mounted impeller rotating within a cylindrical casing partially filled with Water (sealing liquid). Centrifugal force creates a moving water ring against the casing walls, forming chambers between the impeller blades that expand and contract cyclically. As the chambers expand on the inlet side, they draw in gases; as they contract on the discharge side, they compress and expel the gases. The sealing liquid not only compresses gases but also removes heat from the compression process, uptakes liquids and vapours, and provides a continuous seal between the impeller blades and casing, enabling the pump to handle wet, contaminated gases without damage. These pumps can handle liquid slugs and high-temperature gas mixtures, operating at typical speeds of 750–1800 RPM.

Technology Details

Key Technical Specifications

Parameter	Values
Capacity Range	20 - 60,000 m ³ /h (140 - 14,800 ACFM).
Ultimate Vacuum	Down to 33 mbar abs (Single Stage).
Operating Pressure	Maximum 1 to 2.2 bar abs.
Power Consumption	3.7 kW to 132 kW (depending on model/capacity).
Speed	Typically, 750–1800 RPM (50/60 Hz)
Liquid Temperature	Recommended below 40 OC to avoid cavitation



Feasibility Analysis

S. No.	Parameter	Unit	Without the technology	With Fabricated Water Ring Vacuum Pump
1	Cost of electricity	INR/kWh	10	10
2	Monetary savings (value of electricity) (assuming 15% efficiency gain) (for one pump)	INR lakh/year	–	5
3	Investment required (for one pump)	INR lakh	–	5
4	Simple payback period	months	–	12
5	Annual GHG emission reduction potential	t CO ₂ /year	–	36

8.12.3 Key Advantages & Challenges

Advantages

1. Excellent handling of wet gases, entrained liquids, and fibres without damage
2. Simple, robust construction with no metal-to-metal contact
3. Isothermal compression keeps temperatures low
4. Corrosion-resistant material options available
5. Tolerant of liquid and solid carryover

Key Challenges

1. Performance is sensitive to seal water temperature.
2. Requires regular maintenance (bearings, seals).
3. Traditional designs need substantial floor space.
4. Newer, more efficient alternatives exist, but at a higher capital cost.

8.12.4 Technology providers

Atlas Copco

Garuda Pumps Private Limited

Karshak Industries Private Limited (Kakati Vacuum Pumps & Systems)

Gardner Denver Engineered Products India Pvt Ltd (NASH Pumps)

8.12.5 Replication Potential

Medium-scale paper, textile, and other industries.

Table 21: Replication potential of the Fabricated Water Ring Vacuum Pump in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Varanasi (UP)	200+ artisans
5	Tirupur (Tamil Nadu)	3,200 MSMEs
6	Kanchipuram (Tamil Nadu)	10,000-60,000 families
7	Ludhiana (Punjab)	14,000 MSMEs
8	Panipat (Haryana)	3,095 MSMEs
9	Ichalkaranji (Maharashtra)	80,000-120,000 looms

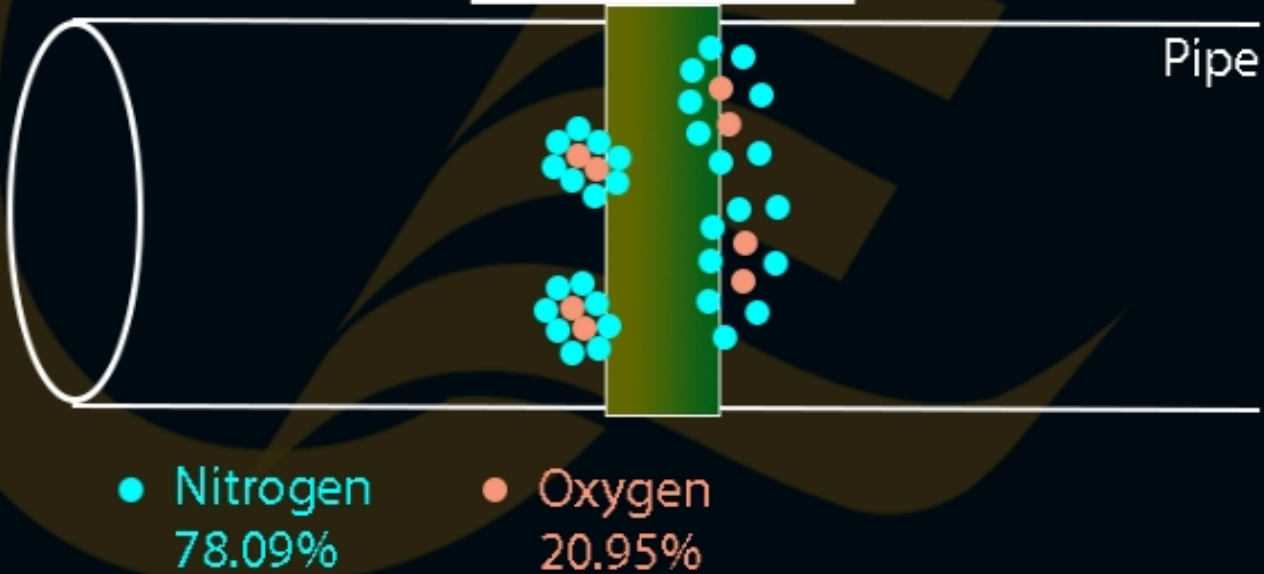
Table 22: Replication potential of the Fabricated Water Ring Vacuum Pump in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units

Air flows in pipe

O₂ molecules are trapped inside air clusters.

Clusters are broken. Single O₂ molecules have more surface areas.



Source: <http://www.solpowerindia.co.in/product05.html>

8.13 XPLATE TECHNOLOGY (XEOGENIC PLATE)

8.13.1 Overview

Xenogenic Plate (XPlate™) is an innovative fuel-saving technology applied to the air side of any industrial combustion processes. XPlate is a nanotechnology-based flexible device that is easy to install at various process applications like industry boilers, thermic fluid heaters, power stations, cement kilns, ceramic kilns, coal gasification units, steel plants, or any industry that uses any fuel for combustion with oxygen and where ambient air is used for the supply of oxygen to the combustion process. This technology works by modifying the molecular structure of air before it enters the combustion chamber.

Target Applications

Sector: Paper & Pulp

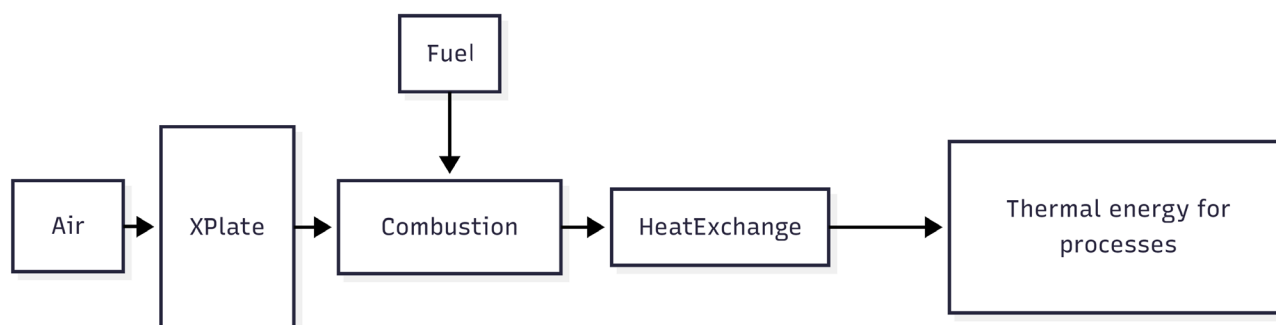
Application: Add-on for combustion improvement.

8.13.2 Technology assessment

Technology Details

The core principle of X-Plate technology is the separation of oxygen and nitrogen molecular clusters into individual molecules at the nano level. When ambient air (gaseous fluid) flows through pipes and fans toward a furnace or burner, oxygen and nitrogen molecules naturally form large clusters due to intermolecular attractive and repulsive forces.

The Xenogenic Plate is installed on the ambient air suction fan (FD Fan). As air passes through the plate, it breaks the large clusters of air molecules into smaller, individual molecules, thus increasing the available surface area of O₂ molecules for effective combustion. The technology can yield fuel savings of 1 to 3% for Natural Gas and 4 to 5 % savings on coal consumption.



(source <http://www.solpowerindia.co.in/downloads/Solpower-India-XPlate-Technology.pdf>)

Feasibility Analysis

S. No.	Parameter	Unit	Without Xplate	With Xplate
1	Coal consumption	Tone/year	26,400	26,136
2	Annual coal consumption saving (assuming 1% saving)	Tone/year	–	264
3	Monetary savings (value of coal)	INR lakh/year	–	17
4	Investment required	INR lakh	–	25
5	Simple payback period	months	–	18
6	Annual GHG emission reduction potential	t CO ₂ /year	–	504

8.13.3 Key Advantages & Challenges

Advantages

1. The technology is highly versatile and can be installed in a wide range of combustion equipment.
2. The device is easy to install with a non-intrusive Installation process. It consists of special metallic plates that operate autonomously without any external power source.
3. Once installed, the Xplate™ device requires no external power and has a long operational lifespan with a total service life of up to 10 years.

Key Challenges

1. The technology is relatively new and requires demonstration and verification in industries.
2. Although the technology is broadly applicable, its performance might be influenced by specific process conditions (e.g., highly variable fuel quality, unique furnace atmospheres), leading to high uncertainty in the actual energy savings that will be achieved.
3. Given the heavy dependence on process conditions, the cost and payback of the technology will also vary according to the scale of operation, local fuel prices, and the achieved savings.

8.13.4 Technology providers

Solpower India Pvt. Ltd

8.13.5 Replication Potential

The replication potential of the LCR technology is very high across the paper industry.

Table 23: Replication potential of the xplate technology in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units



Source: <https://thermodyneboilers.com/>

8.14 PRESSURISED CONDENSATE RECOVERY SYSTEM

8.14.1 Overview

The Pressurised Condensate Recovery System collects high-temperature condensate (up to 180°C/356°F) and returns it to the boiler under pressure without venting to the atmosphere, typically operating above 15 psig. It reduces fuel consumption (often by 5–35%), water treatment, and makeup water costs. In conventional steam distribution networks, condensate from steam traps is often discharged at low or atmospheric pressure, resulting in significant flash steam loss, energy wastage, and high make-up water consumption. PCRS addresses this inefficiency by maintaining the condensate in a pressurised liquid state throughout the return loop, thereby preserving thermal energy content and recovering it efficiently at the boiler house.

Target Applications

Sector: Textile, Paper

Application: preheating boiler feedwater

8.14.2 Technology assessment

A standard condensate recovery system, where condensate is recovered into an atmospheric condensate tank system, has inherent energy losses. The condensate in the standard recovery process is allowed to lose heat, and it is cooled down to 60 -70 OC. A large amount of flash steam is generated in the process, which is allowed to escape to the atmosphere, and flash steam losses increase the quantity of make-up water. On the other hand, the pressurised condensate recovery system is capable of handling condensate at a temperature of more than 100 OC with no losses of heat, resulting in 20 to 30% saving of heat lost in conventional systems recovery system.

Technology Details

Pressurised condensate recovery systems (PCRS or HPRS) maintain condensate at elevated pressures (above 15 psig) to minimise flash steam losses and recover high-temperature condensate efficiently, achieving 15-35% fuel savings compared to atmospheric systems. They are ideal for industrial applications like MSME clusters with high condensate recovery rates (>80%), preserving thermal energy for boiler feed.

Parameter	Typical Values/Details
Operating Pressure	Near boiler pressure (e.g., 50 psig, up to 149 psi)
Condensate Temperature	120-160°C (high-pressure)
Fuel Savings	15-35%
Key Components	Safety valves, flow dividers, IBR-certified traps, pump tailored to motive pressure/back pressure.

Parameters	Conventional/Standard CRS	Thermax PCRS
Condensate Temperature	90-95 Deg. C	120-160 Deg. C
Pipeline & Operating Corrosion	Varies (Condensate comes in contact with air)	Negligible (No contact with air)
Flash Steam Loss	Significant	Negligible
Recovery Applications	Preheating boiler makeup water	Direct recovery to the boiler

Feasibility Analysis

S. No.	Parameter	Unit	With Normal CRS	With PCRS
1	Quantity of condensate	TPH	2	2
2	Condensate temperature	O C	70	115
3	Feed water Temp	O C	20	20
4	Working hours	Hrs/year	7200	7200
5	Heat recovered	Kcal / Hr (Lacs)	1.4	1.9
6	Annual Profit	Rs (Lacs)	24.4	33
7	Investment required	INR lakh	3	5
8	Simple payback period	Months	1.5	1.8
9	Coal Saving	Ton/year	52.6	248.5
10	Annual GHG emission reduction potential	t CO ₂ /year	131.5	621.25

8.14.3 Key Advantages & Challenges

Advantages

1. Significant improvement in boiler feed water quality as condensate is essentially distilled water with near-zero TDS, extending boiler tube life, reducing scaling, and lowering maintenance frequency and downtime.

2. Direct and immediate energy savings from the first day of operation; hot condensate returned to the boiler reduces fuel input proportionally with no operational lag or calibration period required.
3. Highly scalable and modular in design, can be implemented progressively, starting with the highest-loss condensate return points and expanding over time, allowing phased capital investment aligned with MSME cash flow constraints.

Key Challenges

1. Upfront capital investment can be a significant barrier for small MSMEs, particularly for plants with extensive and dispersed steam distribution networks requiring long return piping runs.
2. Technical design complexity increases in facilities with multiple pressure levels, widely dispersed equipment, and mixed process types

8.14.4 Technology providers

Thermax

Armstrong International

Inveno Engineering LLC

8.14.5 Replication Potential

The replication potential of the PCR technology is very high across the paper and textile industry.

Table 24: Replication potential of the PCR technology in the paper industry

S No	Cluster (State)	Estimated Units
1	Muzaffarnagar & Saharanpur (UP)	29 units
2	Kashipur (Uttarakhand)	24+ mills
3	Vapi (Gujarat)	45-50 mills
4	Morbi (Gujarat)	35 mills
5	Erode-Coimbatore (Tamil Nadu)	559 units

Table 25: Replication potential of the PCR technology in the textile industry

S No	Cluster (State)	Estimated Units
1	Bhiwandi (Maharashtra)	6,000 power loom units
2	Surat (Gujarat)	400 processing units
3	Erode (Tamil Nadu)	75,000 power looms
4	Tirupur (Tamil Nadu)	3,200 MSMEs
5	Ludhiana (Punjab)	14,000 MSMEs
6	Panipat (Haryana)	3,095 MSMEs
7	Ichalkaranji (Maharashtra)	80,000-120,000 looms

9

BUSINESS MODELS & FINANCING OPTIONS

Access to affordable capital and awareness of viable delivery mechanisms is a key barrier for Energy efficient technology adoption in MSMEs. The following business models and financing options are curated which are aligned with the MSME operational realities: limited collateral, irregular cash flows, short planning horizons, and low capacity for complex financial transactions.

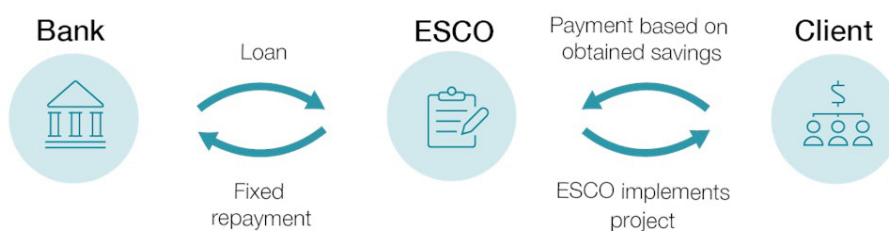
9.1 ESCO MODELS

Energy Service Companies (ESCOs) remove the upfront capital burden from MSME units by financing, installing, and maintaining energy-efficient equipment and recovering their investment from the resulting energy savings over a contract period.

Shared savings model: This model is particularly suited to the higher-investment technologies identified in the assessment. Under a shared savings arrangement, the ESCO retains ownership of the equipment and splits verified energy cost savings with the MSME unit according to a pre-agreed ratio.

The ESCO typically provides the capital investment and assumes most of the risks. The payment arrangements to the ESCO made by the client may be as per the following options:

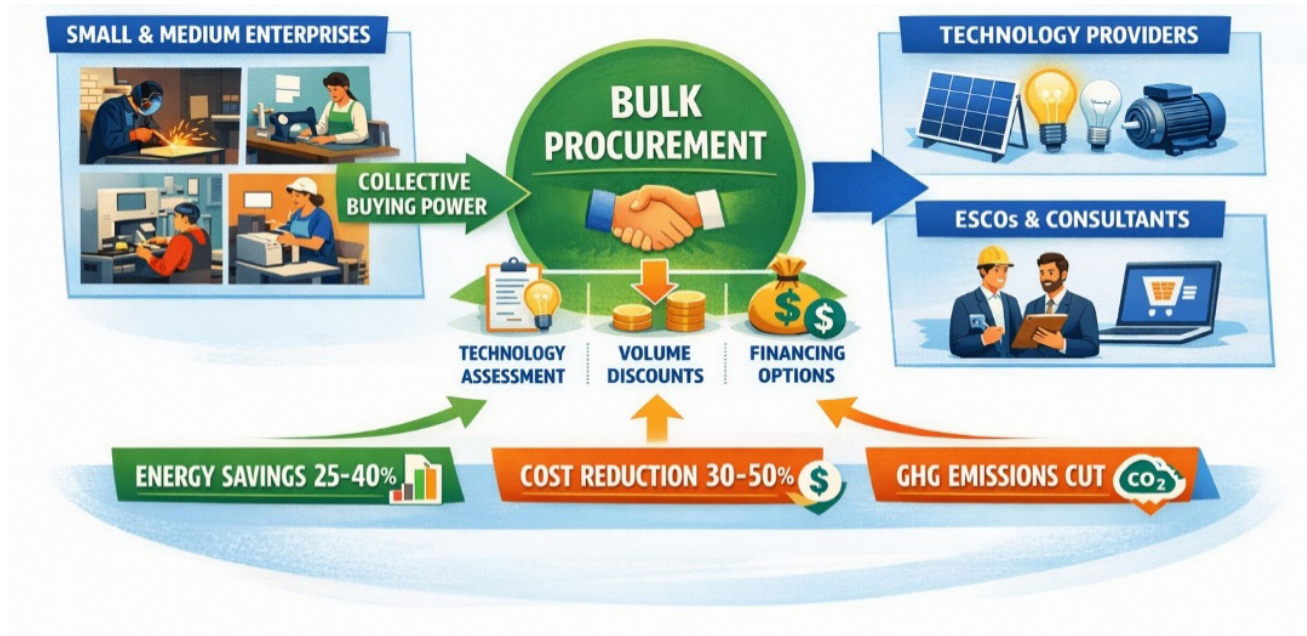
- a) Fixed percentage of savings,
- b) Minimum fee plus a share of the savings,
- c) Scaled fees which decrease over time as the ESCO recoups its investment



Guaranteed savings model: In this structure, the ESCO guarantees a certain level of energy savings, and the client pays the ESCO based on the savings achieved. This model is more attractive to clients who want to mitigate financial risks, as the ESCO assumes the risk of not meeting the projected savings. Guaranteed savings contracts are characterized by a fixed term with a fixed payment schedule in which the ESCO ensures the savings (energy and O&M) will meet or exceed a minimum savings level (guaranteeing a minimum performance after implementation)

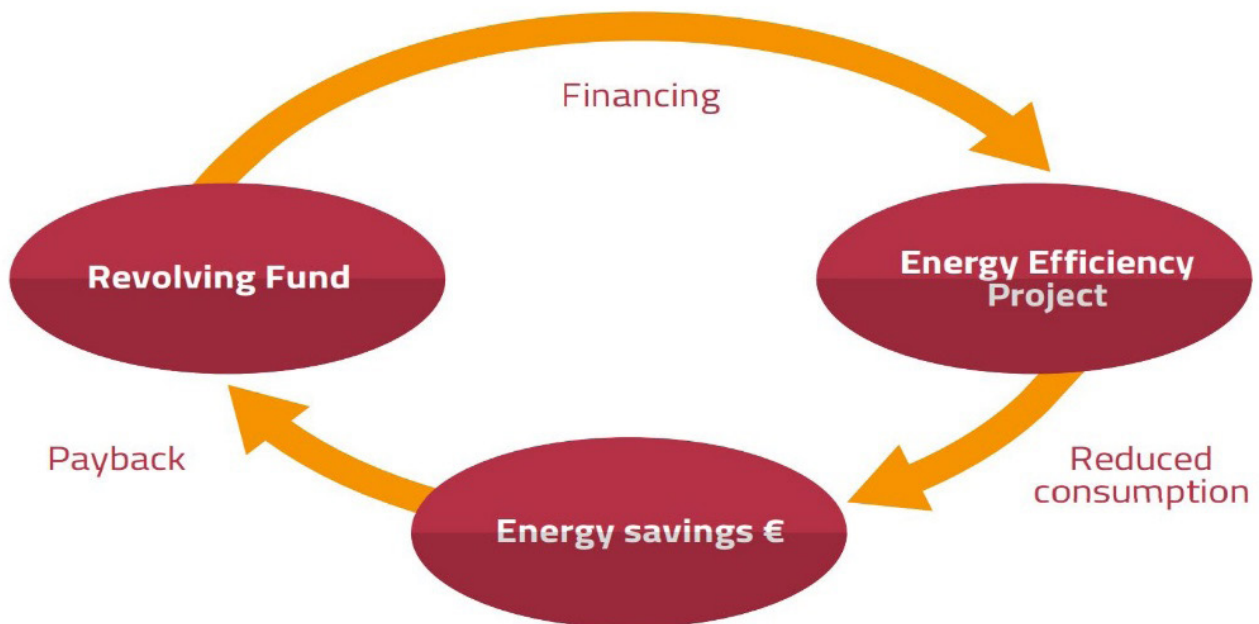
9.2 DEMAND AGGREGATION BUSINESS MODELS

Cluster-level approaches aggregate demand across multiple MSME units, reducing transaction costs, increasing bargaining power with technology suppliers, and enabling financing at a scale attractive to formal lenders. The aggregation can be done by ESCO, Industry association led SPVs or a group of similar industries. Requiring procurement of homogeneous technologies



9.3 ENERGY EFFICIENCY REVOLVING FUND

Revolving Energy Efficiency Funds for MSMEs act as sustainable financial mechanisms, providing loans for energy-saving technologies. As loans are repaid, the capital is re-lent to other MSMEs, ensuring continued investment. Key initiatives include the GEF-SIDBI project, offering concessional lending and risk-sharing to bridge the financing gap in energy-intensive clusters



9.4 TECHNOLOGY PROVIDER-LED FINANCING

Several domestic technology providers have demonstrated capacity and interest in vendor financing arrangements. These arrangements reduce the role of formal lenders and shorten transaction timelines. These financing arrangements include deferred payment model, and instalment-based equipment supply.

No payments for

**30, 90
or 180**

days

Atlas Copco

with rates
as low as

0 %
Financing*

12 or 24 months

First payment due 30, 90 or 180 days
after delivery!

30 and 90 Day Deferral Rates

12 months	24 months	36 months	48 months	60 months
0.08333	0.04167	0.02869	0.02220	0.01849
0% APR	0% APR	1.9% APR	2.9% APR	3.9% APR



Source: <https://www.atlascopco.com/en-us/compressors/general/financing>

10

POLICY LANDSCAPE FOR MSME ENERGY EFFICIENCY

The following table presents a comprehensive overview of key national policies, schemes, and institutional frameworks that support energy efficiency in Micro, Small and Medium Enterprises (MSMEs) in India. These initiatives span regulatory instruments, financial mechanisms, technology deployment programmes, and cluster development measures, reflecting the multi-pronged approach adopted by the Government of India to enhance energy performance and competitiveness in the MSME sector.

Schemes supporting MSME relevant to energy efficiency

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
1.	Bureau of Energy Efficiency Framework	Bureau of Energy Efficiency under Ministry of Power	2002-Present	Reduce energy intensity of the economy and promote energy efficiency	- Formulation of national energy efficiency policies and regulations under Energy Conservation Act - Development of standards & labelling programme for appliances - Design and implementation of sector-specific EE programmes (including MSMEs) - Promotion of energy conservation building codes and industrial efficiency norms - Capacity building through training, certification, and awareness campaigns	All sectors including MSMEs

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
2.	National Programme on Energy Efficiency in MSMEs	Bureau of Energy Efficiency (BEE)	Ongoing	Promote adoption of energy-efficient technologies in MSMEs	• Identification of MSME clusters for intervention • Conduct of detailed energy audits and preparation of cluster-level reports • Benchmarking of energy performance within clusters • Implementation of technology demonstration projects in selected units • Organization of training, workshops, and awareness programmes	MSME clusters (e.g., textiles, foundry, ceramics)
3.	ADEETIE Scheme (Assistance in Deploying Energy Efficient Technologies)	Ministry of Power + BEE	2025- 2028	Accelerate deployment of energy-efficient technologies in MSMEs	• Provision of interest subvention (5% for micro & small, 3% for medium enterprises) • Conduct of Investment Grade Energy Audits (IGEA) for eligible units • Preparation of Detailed Project Reports (DPRs) for EE interventions • Implementation of energy-efficient technologies across clusters • Measurement & Verification (M&V) of achieved energy savings • Support for technology adoption through financial institutions	Udyam-registered MSMEs across identified industrial clusters

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
4.	Energy Efficiency Financing Platform (EEFP)	BEE under National Mission for Enhanced Energy Efficiency	Ongoing	Facilitate financing for energy efficiency projects	• Development of a marketplace linking MSMEs with financial institutions • Engagement with banks, NBFCs, and ESCOs for EE project financing • Standardization of project appraisal and financing mechanisms • Support in structuring bankable EE projects • Promotion of ESCO-based performance contracting models	MSMEs and industry
5.	Framework for Energy Efficient Economic Development (FEEED)	Bureau of Energy Efficiency (BEE)	Ongoing	Develop financial instruments and support large-scale EE investments	• Design of innovative financial instruments for EE projects • Development of risk-sharing mechanisms to reduce lender risk • Support for partial risk guarantee and credit enhancement mechanisms • Facilitation of large-scale investment in EE projects • Strengthening institutional mechanisms for EE financing	Industry including MSMEs

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
6.	BEE SME Programme (National Programme on Energy Efficiency & Technology Upgradation of MSMEs)	Bureau of Energy Efficiency (BEE)	Initiated during XI Five Year Plan (2007-2012); continued activities	Promote energy-efficient technologies, capacity building, and knowledge sharing	- Preparation of ~375 technology-specific Detailed Project Reports (DPRs) across 35 MSME clusters - Implementation of demonstration projects in selected units/clusters - Conduct of training programmes, workshops, and awareness campaigns - Development and strengthening of Local Service Providers (LSPs) - Energy mapping and profiling of MSME clusters (continued post-2017) - Dissemination of best practices and case studies	MSME clusters across India
7.	ZED Certification Scheme (Zero Defect Zero Effect)	Ministry of Micro, Small and Medium Enterprises	Ongoing	Promote quality manufacturing with minimal environmental impact	- Assessment and certification of MSMEs based on ZED maturity model - Financial assistance for certification, consultancy, and handholding - Promotion of quality management systems and process improvements - Encouragement of energy-efficient and environmentally sustainable manufacturing practices - Integration with national initiatives like Make in India	MSMEs across sectors

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
8.	Credit Guarantee Scheme for Micro & Small Enterprises (CGTMSE)	Ministry of MSME + SIDBI	2000-Present	Facilitate collateral-free credit to MSEs	- Provision of collateral-free loans to MSMEs - Credit guarantees cover to banks/NBFCs - Risk sharing in case of loan default - Encouragement to lend to first-generation entrepreneurs	Micro & Small Enterprises
9.	Micro & Small Enterprises Cluster Development Programme (MSE-CDP)	Ministry of MSME	Ongoing	Enhance productivity and competitiveness of MSME clusters	- Establishment of Common Facility Centres (CFCs) - Infrastructure development in clusters - Diagnostic studies and cluster planning - Technology upgradation support - Capacity building and training programmes - Promotion of cluster-based competitiveness	MSME clusters across sectors
10.	Scheme of Fund for Regeneration of Traditional Industries (SFURTI)	Ministry of MSME (KVIC, Coir Board, etc.)	2005- Present	Organize traditional industries into clusters and improve competitiveness	- Formation of traditional industry clusters - Skill development and artisan training - Establishment of Common Facility Centres - Provision of improved tools and equipment - Branding, packaging, and marketing support and promotion of sustainable livelihoods	Traditional MSMEs (khadi, coir, village industries)

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
11.	Assistance to Training Institutions (ATI)	Ministry of MSME	Ongoing	Strengthen training infrastructure for MSMEs	- Financial assistance to training institutions - Strengthening of infrastructure and facilities - Development of training curriculum and modules - Capacity building of trainers	MSMEs & trainees
12.	International Cooperation (IC) Scheme	Ministry of MSME	Ongoing	Enhance global competitiveness of MSMEs	- Participation in international exhibitions and trade fairs - Support for business delegations abroad - Technology exchange and collaboration - Exposure to global best practices	MSMEs
13.	National SC-ST Hub Scheme	Ministry of MSME	2016- Present	Promote entrepreneurship among SC/ ST communities	- Capacity building and training programmes - Vendor development and market linkages - Financial assistance and credit facilitation - Support in public procurement participation	SC/ST MSME entrepreneurs
14.	ASPIRE (Innovation, Rural Industries & Entrepreneurship)	Ministry of MSME	2015- Present	Promote innovation and rural entrepreneurship	- Establishment of Livelihood Business Incubators (LBIs) - Setting up Technology Business Incubators (TBIs) - Promotion of innovation and startups - Skill development and entrepreneurship support	Rural MSMEs & startups

S. No.	Policy/ Scheme	Implementing Agency	Period	Objectives	Key Activities (Detailed)	Target
15.	Coir Vikas Yojana	Ministry of MSME (Coir Board)	Ongoing	Develop coir industry and MSMEs	• Skill development and training programmes • Technology upgradation support • Export promotion activities • Infrastructure development • Promotion of coir-based products	Coir-based MSMEs
16.	MSE-SPICE/ RAMP Programme	Ministry of MSME + World Bank	2022- 2027	Strengthen MSME performance and institutional capacity	• Policy and institutional reforms • Capacity building of MSME ecosystem • Credit facilitation and financial access • Market access improvement • Strengthening of state-level MSME support systems	MSMEs across India

IMPLEMENTATION ROADMAP FOR PILOT DEMONSTRATION AND SCALE-UP

The technology demonstration and scale-up planning are critical steps in market transformation. The Technology Assessment identified 13 commercially ready cross cutting technologies (TRL 9–10) with investment requirements ranging from ₹0.5 lakh to ₹100 lakh per unit and simple payback periods as short as one month. This roadmap translates those findings into actionable strategies for pilot demonstration in focus sectors and making a case for the operational and financial realities of India's MSME clusters

The implementation framework works on technology prioritization and cluster prioritization. assessed technologies are tiered for deployment sequencing based on criteria: of Financial Viability (payback period), Deployment Complexity, and Replication Scale. The clusters are prioritized based on the number of units for each cluster.

Table 26: Technology prioritisation criterion

Parameter	Low	Medium	High
Investment	0 to 20L	20 to 50L	>50L
Payback (Y)	0 to 2	2 to 4	>4

Table 27: List of Identified technologies for priority sectors

S. No.	Technology	Foundry	Forging	Rolling	Textile	Paper
1	Gas-fired Furnace with Self-recuperative Burner (Heat Treatment Furnaces with Gas firing) [Upto 500 kW burner capacity]	✓	✓			
2	Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	✓	✓	✓		
3	Electric Grinder (Replacement of Pneumatic Grinder)	✓	✓	✓		
4	Waste Heat Recovery from Dye Effluent				✓	
5	RDF Fired Boiler				✓	✓
6	Micro Turbines				✓	✓
7	Heat Pumps Low temperature - 90 °C				✓	✓

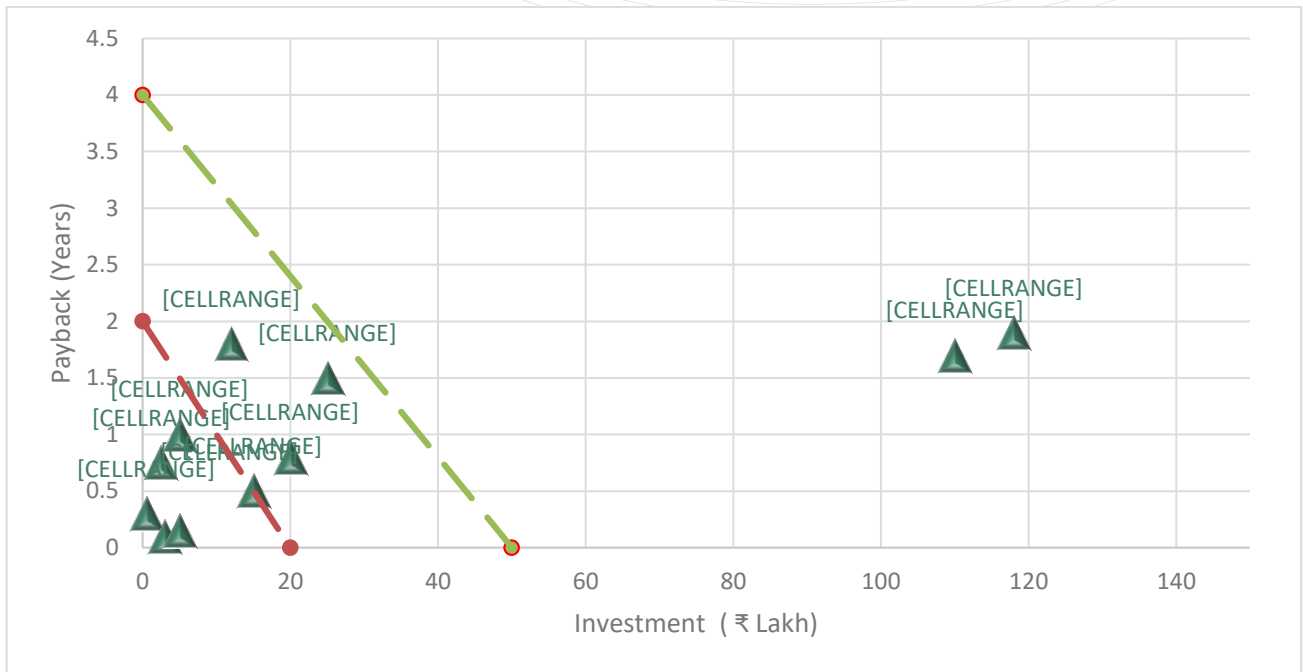
8	A-One Insulation (Hot and Cold Insulation)				✓	✓
9	Low Consistency Refining (LCR)					✓
10	IoT in Stenter Machine				✓	
11	Hot water generation from the chiller and the compressor (generation of 60 to 70 deg C)				✓	
12	Fabricated Water Ring Vacuum Pumps				✓	✓
13	Xplate Technology (Xeogenic Plate)					✓
14	Pressurised Condensate Recovery System				✓	✓

Table 28: Sector wise cluster profiles as per available data (Source: various reports of Bureau of Energy Efficiency)

Sector	Number of Clusters	Total Number of MSMEs
Foundry	7	3000
Forging	4	1690
Rolling	2	524
Textile	7	181600
Paper	5	692

Table 29: List of Selected Technologies with investment, GHG impact and payback

S. No.	Technology	Investment (₹ Lakh)	Payback (Years)	GHG (tCO ₂ e/Year)
1	Gas-fired Furnace with Self-recuperative Burner (Heat Treatment Furnaces with Gas firing) [Upto 500 kW burner capacity]	15	0.5	167
2	Gas-fired regenerative burners for high-temperature furnaces (medium & large furnaces)	100	9	580
3	Electric Grinder (Replacement of Pneumatic Grinder)	0.5	0.3	16
4	Waste Heat Recovery from Dye Effluent	12	1.8	509
5	RDF Fired Boiler	1200	1.17	68,000
6	Micro Turbines	118	1.9	615.8
7	Heat Pumps Low temperature - 90 °C	110	1.7	345
8	A-One Insulation (Hot and Cold Insulation)	2.5	0.75	19
9	Low Consistency Refining (LCR)	350	1.4	720
10	IoT in Stenter Machine	3	0.01	280
11	Hot water generation from the chiller and the compressor (generation of 60 to 70 deg C)	20	0.8	75
12	Fabricated Water Ring Vacuum Pumps	5	1	36
13	Xplate Technology (Xeogenic Plate)	25	1.5	504
14	Pressurised Condensate Recovery System	5	0.15	621.25



Based on the criterion the technologies are tiered into three categories for deployment based on investment required for deployment. The priority technologies that may be focused for deployment are with low investment and low payback.

Technology	Investment (₹ Lakh)	Payback (Years)	GHG (tCO ₂ e/Year)	Sector Applicable
Electric Grinder (Replacement of Pneumatic Grinder)	0.5	0.3	16	Foundry
Waste Heat Recovery from Dye Effluent	12	1.8	509	Textile
A-One Insulation (Hot and Cold Insulation)	2.5	0.75	19	Textile, Paper
IoT in Stenter Machine	3	0.01	280	Textile
Fabricated Water Ring Vacuum Pumps	5	1	36	Textile, Paper
Xplate Technology (Xeogenic Plate)	25	1.5	504	Paper
Pressurised Condensate Recovery System	5	0.15	621.25	Textile, Paper

The demonstration and scaleup of the low investment and quick payback can be the foundational step. The technology demonstrations will involve detailed onsite feasibility studies for the technologies in key clusters.

Table 31 Priority clusters for technology demonstration and scale-up

Cluster (State)	Estimated Units	Primary Metal Focus
Priority clusters for technology demonstration in foundry sector		
Rajkot & Ahmedabad (Gujarat)	800	Grey & Ductile Iron, SG Iron
Kolhapur & Solapur (Maharashtra)	600	Grey Iron, Alloy Steel
Coimbatore & Chennai (Tamil Nadu)	500	Grey Iron, Aluminium, Steel
Ludhiana & Jalandhar (Punjab)	400	Grey Iron, Malleable Iron
Priority clusters for technology demonstration in forging sector		
Ludhiana, Jalandhar (Punjab)	1,450	Automotive, bicycle, hand tools, fasteners
Ahmedabad, Rajkot (Gujarat)	140	Closed die (62%), ring rolling forgings
Priority clusters for technology demonstration in Rolling sector		
Mandi Gobindgarh (Punjab)	404	TMT bars, structural sections, bright bars
Bhavnagar (Sihor) (Gujarat)	120	Construction-grade mild steel from ship scrap
Priority clusters for technology demonstration in textile sector		
Ichalkaranji (Maharashtra)	80,000	Power loom cotton, polyester fabrics
Erode (Tamil Nadu)	75,000	Cotton fabrics, home textiles
Ludhiana (Punjab)	14,000	Woollen hosiery, knitwear
Bhiwandi (Maharashtra)	6,000	Powerloom fabrics for garments
Tirupur (Tamil Nadu)	3,200	Knitwear (T-shirts, undergarments)
Panipat (Haryana)	3,095	Home textiles, blankets
Priority clusters for technology demonstration in Paper sector		
Erode-Coimbatore (Tamil Nadu)	559	Recycled paperboard from textile waste
Vapi and Morbi (Gujarat)	80	High-grade recycled kraft, duplex board

11.1 RECOMMENDATIONS FOR PILOT DEMONSTRATION AND SCALE-UP ROADMAP

Technology Tier 1 - Immediate Pilots (Year 1): Low investment, fast payback, broad replication (Technology demonstration through direct implementation route)

These are the foundational demonstrations. They de-risk the Programme, generate early evidence of savings, and build MSME confidence before asking units to take on larger investments.

Technology	Investment	Payback	Priority Cluster
IoT in Stenter Machine	₹3L	0.01 yr (~4 days)	Tirupur, Surat
Electric Grinder	₹0.5L	0.3 yr	Ludhiana, Rajkot
Pressurised Condensate Recovery	₹5L	0.15 yr	Tirupur, Vapi
A-One Insulation	₹2.5L	0.75 yr	Vapi, Erode-Coimbatore
Fabricated Vacuum Pumps	₹5L	1 yr	Vapi, Morbi

Technology Tier 2 - Demonstrations at Scale(Year 2-4): Moderate investment, viable payback, requires ESCO or leasing model.

These technologies require structured financing but have compelling economics and strong replication potential across large cluster bases. These demonstrations will require a programmatic approach involving the cluster or aggregator approach involving a larger set of stakeholders.

Technology	Investment	Payback	Priority Cluster
WHR from Dye Effluent	₹12L	1.8 yr	Tirupur, Panipat, Ichalkaranji
Gas-fired Self-Recuperative Furnace	₹15L	0.5 yr	Ludhiana (Forging), Rajkot (Foundry)
Hot Water from Chiller/Compressor	₹20L	0.8 yr	Textile clusters
Xplate Technology	₹25L	1.5 yr	Paper clusters (Vapi, Erode-Coimbatore)

Technology Tier 3 High Impact demonstrations with Scale-up: Higher investment, Moderate payback, requiring targeted financing and technical support

These high investment technologies have largest GHG impact with strong economic case. These technologies are slightly complex in implementation as these may require a detailed assessment of the process variables, space requirements, and careful planning.

Technology	Investment	Payback	Priority Cluster
Low Consistency Refining	₹350L	1.4 yr	Vapi, Muzaffarnagar
Heat Pumps	₹110L	1.7 yr	Textile + Paper clusters
Micro Turbines	₹118L	1.9 yr	Tirupur, Bhiwandi, Vapi
RDF-Fired Boiler	₹1,200L	1.17 yr	Erode-Coimbatore, Panipat (cluster-level)

ANNEXURE 1:

FOUNDRY SECTOR PROFILE AND PROCESS OVERVIEW

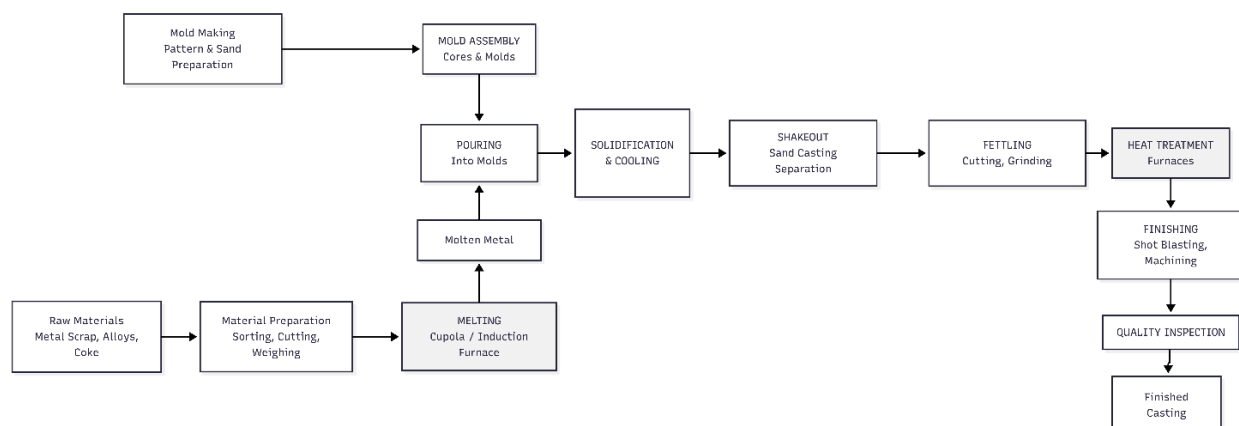
Agra Foundry Cluster (Uttar Pradesh)	Ahmedabad Foundry Cluster (Gujarat)
Speciality: Brass and Non-Ferrous Castings. Overview: This cluster is historically significant for its high-quality brass and bronze castings, primarily used in the manufacture of footwear machinery components, hand tools, architectural hardware, and artistic/religious items. It is integrated with the city's leather and engineering goods industries. Importance: A key centre for specialised, non-ferrous foundry work supporting niche manufacturing sectors and preserving traditional metal craftsmanship. Cluster profile: cluster of small-scale foundries that meet the machinery and spare parts casting requirements of local industries—primarily, manufacturers of diesel generator (DG) sets, automotive components, air compressors, and other engineering sectors. At one time, there were over 100 foundry units, of which only about 80 are presently in operation. Of them, about 40 foundries are micro-sized based on annual production capacity (420 tpa); 23 are small (900 tpa); 15 are medium (3000 tpa); and 2 are large (3000 tpa). About 30 foundries use induction melting furnaces and account for 65% of total cluster-level production (0.07 million tpa), while the remaining 50 foundries use natural gas-fired cupola furnaces and account for 35% of total production (0.04 million tpa). The foundries provide direct employment to about 3000 people.	Speciality: Grey Iron and Ductile Iron Castings. Overview: A major hub supporting Gujarat's robust engineering and automotive sectors. Foundries here produce a wide range of castings for machine tools, pumps, valves, automotive components, and electrical equipment. Importance: Critically supplies the state's heavy engineering and automobile manufacturing base, acting as a vital ancillary industry. Cluster Profile: The MSMEs include about 600 foundry units, of which 450 are operational. About 70% of these foundries (250 units) operate coke-based cupolas, and the remaining 30% (150 units) operate electrical induction furnaces and pit furnaces. Some units use natural gas (NG)-fired furnaces for shell baking and heat treatment. The units are located in areas such as Naroda, Naroda GIDC, Odhav Industrial Estate, Vatva Industrial Estate, Tribhuvan Industrial Estate and Rakhial Industrial Estate. The foundries produce castings for diverse industrial components, including textile machinery (~ 50%), pumps and valves (~ 20%), agricultural machinery (~ 10%) and sanitary equipment (~ 10%). The Ahmedabad foundry cluster produces about 1770 tonnes of castings daily (nearly 6% of India's total castings output) and provides direct employment to around 30,000 people.

Belgaum Foundry Cluster (Karnataka)	Coimbatore Foundry Cluster (Tamil Nadu)
Speciality: Grey Iron and Automotive Castings. Overview: This cluster has a strong focus on precision castings for the automotive industry, including components for commercial vehicles and tractors. It also serves the local pump and sugar mill machinery sectors. Importance: A key supplier to the automotive OEMs and aftermarket in South India, known for quality and technical capability. Cluster profile: Belgaum is a prominent foundry cluster, with about 160 MSME foundry units. These units produce castings mainly for automotive components, as well as for pumps and valves, gears, machine tools, elevators, food processing and other industrial applications. Most of the units are in three industrial estates: (1) Udyambag Industrial Estate, (2) Belgaum Manufacturers Cooperative Industrial Estate Limited (BEMCIEL) and (3) Macche Industrial Estate. The cluster provides direct employment to about 7500 people.	Speciality: Grey Iron, Steel, and Pump Castings. Overview: Often called the "Pump City of India," this cluster is integral to the region's dominance in pump and motor manufacturing. Foundries produce high-grade castings for pumps, compressors, machine tools, and textile machinery. Importance: The backbone of Coimbatore's world-renowned pump and engineering industry, with significant export contributions. Cluster profile: The cluster hosts a number of major automobile manufacturing units in the vicinity like Hyundai, Honda, Leyland, Allwyn Nissan, Pricol, L&T, LMW and Mahindras. There is a great demand for castings from these nearby industries, which are met by foundry units located in the Coimbatore cluster. Of the 535 foundries in the cluster, about 15 are large-scale, 70 are medium-sized, and the remaining units are in the small and micro categories. The foundry units in the cluster have production capacities ranging from 500 tpy to 2000 tpy.
Howrah Foundries (West Bengal)	Indore Foundry Cluster (Madhya Pradesh)
Speciality: Steel, Grey Iron, and Heavy Castings. Overview: One of India's oldest industrial clusters, specialising in heavy and medium castings for railway wagons, rolling mills, construction machinery, and shipbuilding. Many units have capabilities for large-scale, single-piece castings. Importance: Crucial for the eastern region's heavy engineering, steel, and railway infrastructure sectors. Cluster profile: Howrah include a cluster of about 320 foundries that provide direct employment to about 15,000 people. All the units use cupola furnaces for melting; in recent years, a few foundries have also started using induction furnaces. The cluster produces about 2500 tonnes of castings daily. The production capacity of units varies from 50 tonnes per month to 1000 tonnes per month. Over 90% of castings produced in the cluster are cast iron; the remaining are ductile iron and steel castings. The total annual turnover of the cluster is about Rs 1350 crores. The Howrah foundry cluster is renowned for exporting sanitary castings to several countries in five continents.	Speciality: Grey Iron and Alloy Steel Castings. Overview: Supports a diverse industrial base, producing castings for automotive parts, diesel engines, agricultural implements, and mining machinery. The cluster is adapting to serve the growing automotive corridor in the region. Importance: A significant industrial supplier in Central India, with growing importance for the automotive ancillary chain. Cluster profile: The industrial city of Indore is home to a significant foundry cluster. There are about 45 foundry units in the cluster, spread across Indore city and its four industrial areas: Pithampur, Dewas, Ujjain and Sanwar. Initially, the Indore foundry industry emerged to cater to the textile machinery manufacturing units, which in turn served the cotton mills in the area. Subsequently, the foundry units started catering to the demands of the automobile industry (mainly commercial vehicles and construction equipment), which came up in the Pithampur Special Economic Zone (SEZ). The Indore foundry cluster is also famous for the manufacture of ornamental castings, of which a substantial

	portion is being exported. Most of the small foundry units in Indore, Devas and Ujjain use cupola furnaces, while the larger automotive and steel foundries use induction furnaces.
Jaipur Foundries (Rajasthan)	Kolhapur Foundry Cluster (Maharashtra)
Speciality: Grey Iron and Non-Ferrous Castings. Overview: This cluster produces a varied mix of castings for agricultural equipment, machine tools, sanitary ware, and decorative items. It serves both domestic and export markets for value-added finished goods. Importance: Supports regional agriculture and contributes to Rajasthan's engineering and handicraft export economy. Cluster Profile: Jaipur, the 'Pink City', has a sizeable cluster of around 110 foundry units, comprising 80 cupola-based foundries and 30 induction furnace-based foundries. A majority of the units use green sand moulding; a few foundries employ investment casting. Most of the cupola-based foundries are over 30 years old. Although close to 73% of furnaces are cupola-based, induction furnace-based units account for about two-thirds of total production. The cluster provides employment to about 7,000 people.	Speciality: Alloy Steel and Grey Iron Castings. Overview: A technologically advanced cluster renowned for high-quality alloy steel and graded iron castings. It is a leading supplier of critical components for automotive (axle housings, brakes), sugar mill machinery, and high-pressure valves. Importance: A global hub for precision automotive and engineering castings with a strong export orientation and reputation for metallurgical expertise. Cluster Profile: There are around 300 small, medium and large-scale foundries in the cluster, primarily producing ferrous (iron) castings for the automotive sector. Almost 30% of the cluster production is exported. The sector produces Ferrous (iron) castings, comprising spheroidal graphite (SG) iron as well as grey-iron castings for the automotive sector.
Rajkot Foundries (Gujarat)	Saharanpur Foundry Cluster (Uttar Pradesh)
Speciality: Grey Iron, Ductile Iron, and Diesel Engine Castings. Overview: One of India's largest and most dynamic clusters, famously supporting the diesel engine and submersible pump industry. It produces a vast range of castings from small parts to large engine blocks and agricultural machinery components. Importance: The epicentre of India's diesel engine manufacturing is vital for the agriculture, irrigation, and power generation sectors nationwide. Cluster profile: Rajkot hosts a cluster of about 60 aluminium foundry units, located in industrial estates around the city. These units are renowned for their superior quality, precision castings and aluminium extrusion products. The units fall under three broad categories based on products: aluminium sand moulded castings (21 units); aluminium gravity die castings (19 units); and	Speciality: Grey Iron and Woodworking Machinery Castings. Overview: This cluster is uniquely integrated with Saharanpur's world-famous wood carving and furniture industry. Foundries primarily produce castings for woodworking machinery, hand tools, and agricultural implements. Importance: Provides the mechanical backbone for the region's premier timber and handicraft industry, enabling local value addition. Cluster profile: Saharanpur is home to an MSME cluster comprising about 50 operating foundries as well as wood carving units, hosiery units, rubber units, and straw and paper mill units. The foundries produce castings primarily for hand-pumps (60%), sewing machines (25%), and paper mill machinery (10%). They provide direct employment to about 1000 people.

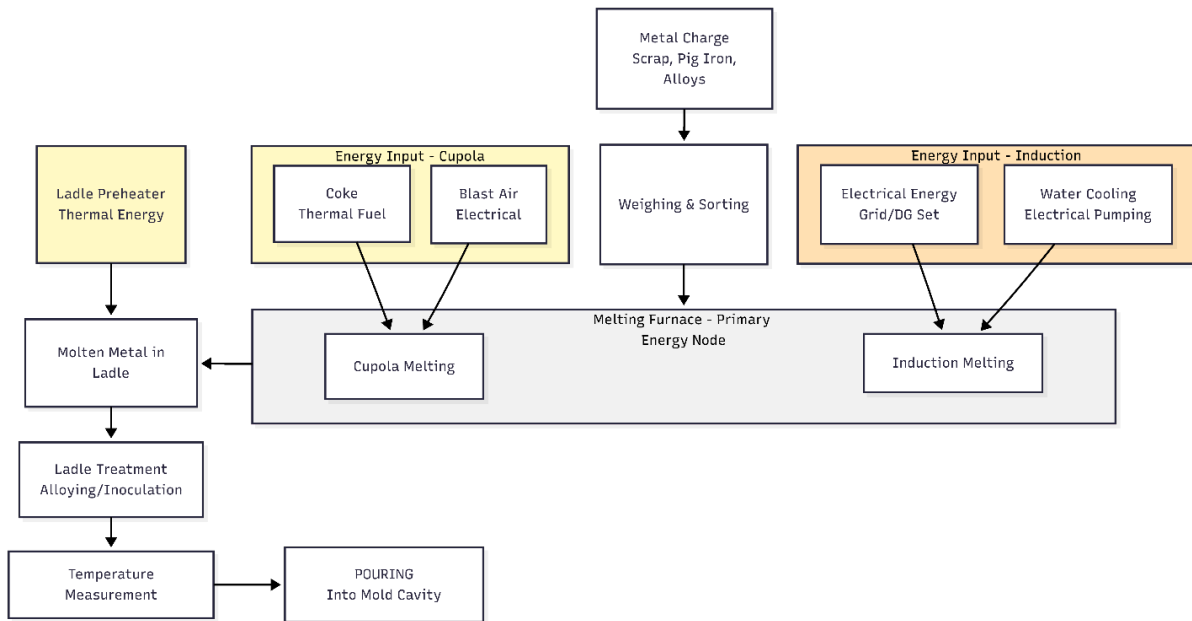
aluminium extrusions (20 units). The cluster caters to a wide range of secondary production industries, including automobile, light and heavy machine tools, compressors, pistons of diesel engines, material handling equipment, dies and patterns for investment casting units, etc. Among the clientele are OEMs such as Atul Auto Ltd, Mahindra & Mahindra, Kirloskar Oil Engines Ltd, and Godrej. The production capacity of units ranges from 1.5 tonnes to 32 tonnes per month. The cluster provides direct employment to about 3000 people.	
Samalkha Foundry Cluster (Haryana)	Shimoga Foundry Industries (Karnataka)
Speciality: Grey Iron and Tractor Parts. Overview: A concentrated cluster catering almost exclusively to the tractor and agricultural machinery industry. Foundries specialise in transmission housings, differential carriers, and other critical tractor components. Importance: A critical ancillary cluster for the major tractor manufacturers located in North India, directly supporting the agricultural economy. Cluster profile: Samalkha is renowned for its MSME foundry cluster, which came up in the late 1940s. There are around 50 foundries in the cluster, of which only 30 are operational. The average monthly production of units ranges from 50 tonnes to 120 tonnes. The foundries provide direct employment to about 2000 people.	Speciality: Grey Iron and Malleable Iron Castings. Overview: A smaller, traditional cluster focused on castings for agricultural implements, pipe fittings, and components for the local coffee and plantation machinery sector. Many units use cupola melting technology. Importance: Supports the rural economy and plantation sector in the Malnad region of Karnataka. Cluster Profile: The district of Shimoga (now renamed Shivamogga), has about 15,000 industrial units. They include a cluster of 45 foundries and associated units, which provide employment to about 5500 people. The technologies/processes include green sand moulding, investment casting, resin-bonded shell moulding and centrifugal casting. Equal quantities of steel and iron castings are produced. The buyers include Cummins, Kirloskar, KSB, BEML, Godrej, Escorts, Emerson, etc. The Shimoga foundry cluster is renowned for exporting quality castings to 26 countries in five continents.

12.1.1 Process overview of a typical MSME unit



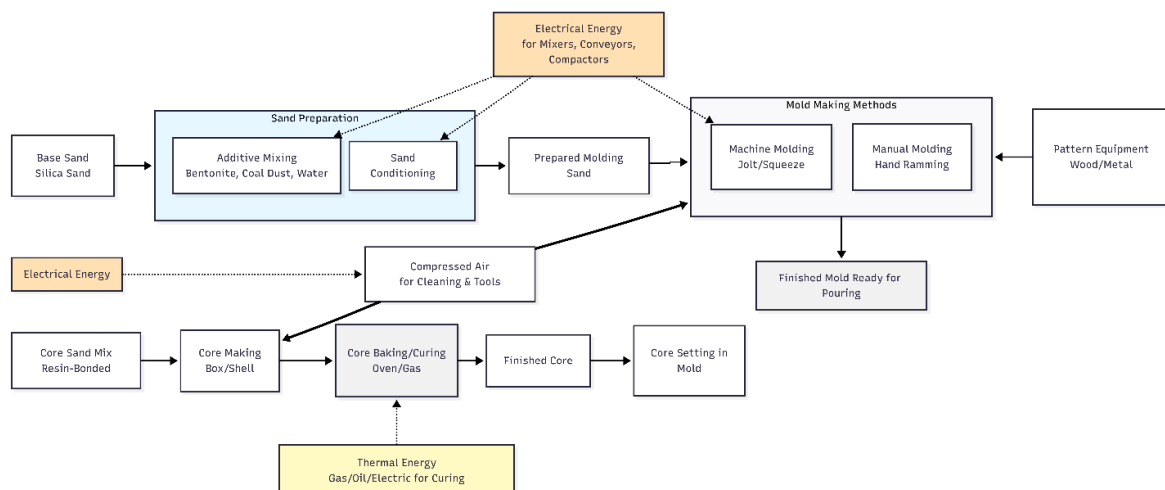
Metal to Molten: Melting & Pouring

The transformation of solid metal charge into liquid metal for casting is achieved primarily through cupola or induction melting. India's MSME foundry sector operates an estimated 3,000-3,500 cupolas and a growing number of induction furnaces, which together melt over 10 MMT of metal annually. Cupola melting, using metallurgical coke, remains dominant in iron casting clusters like Rajkot, Kolhapur, and Howrah due to lower capital cost and high melt rates. Induction melting is gaining share in non-ferrous and quality-focused ferrous clusters like Coimbatore and Ahmedabad, offering better control and efficiency. The melting process alone consumes 55-70% of a foundry's total energy, making it the primary target for efficiency gains, with coke-fired cupolas often operating at just 30-50% thermal efficiency.



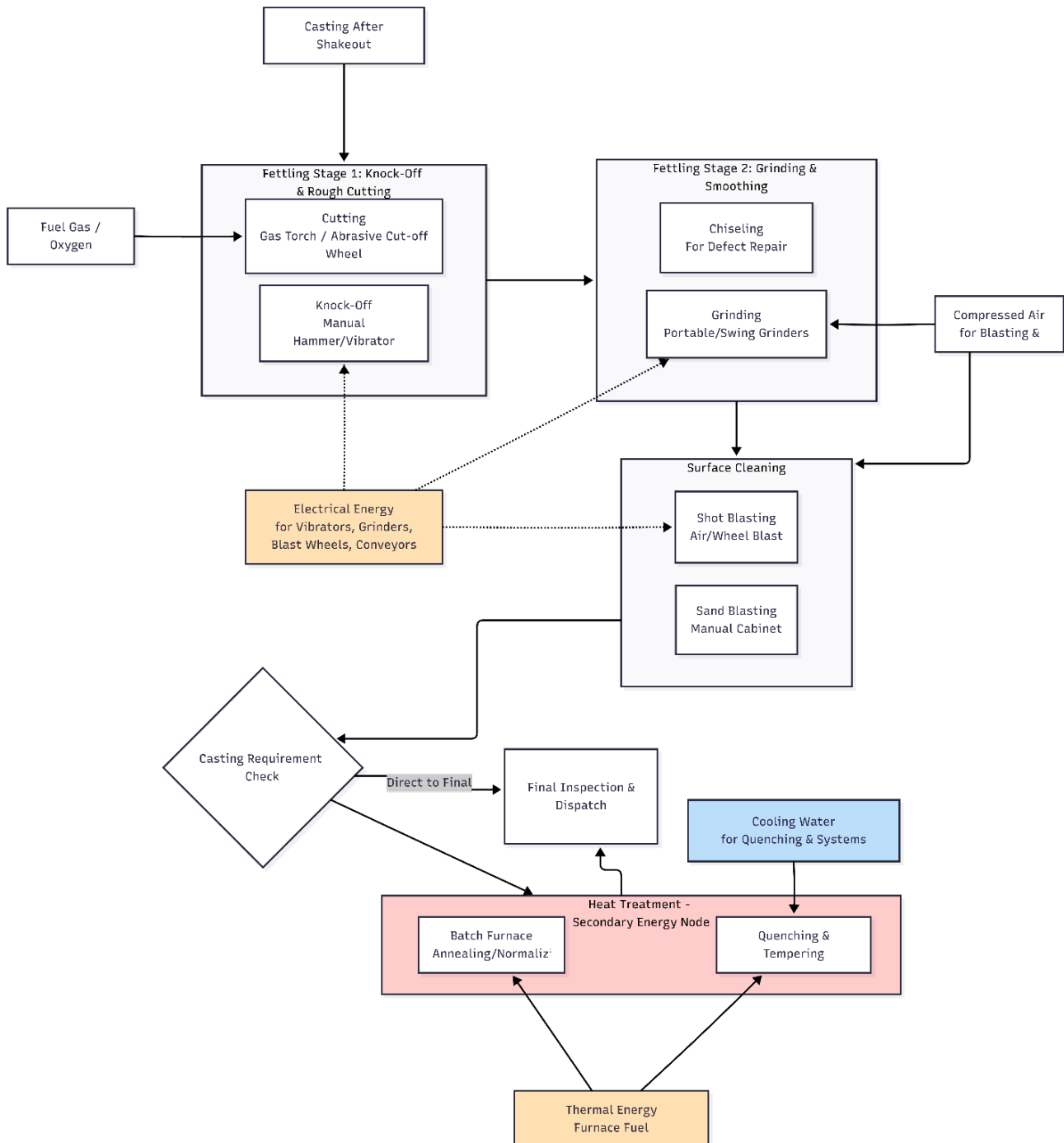
Mould to Form: Moulding & Core Making

The creation of the negative cavity that shapes the molten metal is done through mould and core making, with green sand moulding being the most prevalent technique in MSME foundries. Over 70% of Indian foundries use the green sand process (silica sand, bentonite clay, water) due to its low cost and versatility, supported by thousands of small-scale sand preparation units and pattern shops within clusters. Core making for internal cavities often employs resin-bonded sand processes in more advanced units. This stage is labour-intensive and a significant source of silica dust emissions. Mechanisation levels vary widely, from fully manual floor moulding in smaller units to semi-automatic moulding lines in medium-scale enterprises, with high automation being rare due to capital constraints.



Rough to Ready: Finishing Operations (Fettling & Heat Treatment)

The post-casting processes that transform rough castings into finished components include fettling (grinding, cutting) and often heat treatment. Fettling operations use manual grinders, cut-off wheels, and shot blasting equipment to remove excess metal (gates, risers) and smooth surfaces. Heat treatment (annealing, normalising, hardening) is performed in batch-type furnaces in approximately 40-50% of foundries, particularly those serving automotive and engineering sectors, adding 10-25% to the total energy burden. These finishing stages are characterised by low energy efficiency, high noise and dust pollution, and slow adoption of automated finishing systems, remaining a major bottleneck for productivity and quality consistency in the MSME segment.



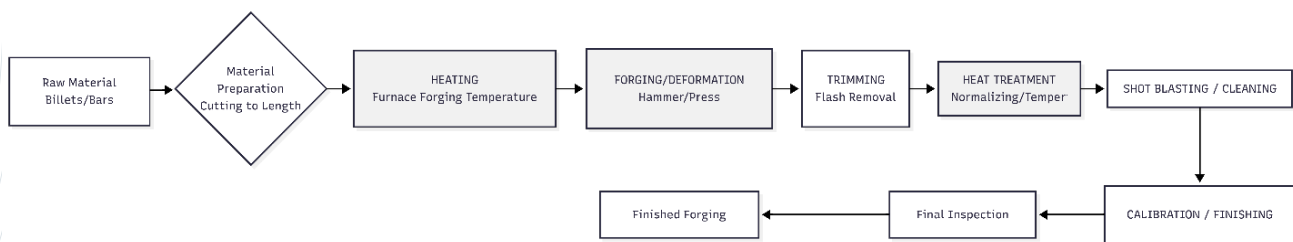
ANNEXURE 2:

FORGING SECTOR PROFILE AND PROCESS OVERVIEW

Punjab (Ludhiana, Jalandhar) Cluster	Maharashtra (Kolhapur, Pune) Cluster
Speciality: Small to medium-sized carbon steel forgings. Overview: A high-density cluster focused on components for the automotive, bicycle, and hand tool sectors, including crankshafts, axle beams, and fasteners, utilizing both hammer and press forging. Importance: Serves as a critical ancillary hub for North India's automotive and agricultural machinery industries, supporting mass manufacturing with cost-competitive production. Cluster profile: Ludhiana is a cluster of about 500 MSME forging units. The cluster provides employment to about 13,000 people. Among them is a cluster of about 500 MSME forging units. The cluster provides employment to about 13,000 people. In Jalandhar there are around 950 units in the cluster, of which about 900 are micro and small-scale units and 50 are medium scale units. Most of the units manufacture an array of hand tools like spanners, screwdriver, pliers, bench vices, tyre levers and hammers and so on. A medium scale unit produces around 50–70 tonnes of material per month. The cluster provides direct employment to about 60,000 people.	Speciality: Heavy and medium precision forgings, alloy steel components. Overview: A technologically advanced cluster producing critical parts for commercial vehicles, tractors, and the oil & gas sector, known for adopting closed-die forging and quality certification. Importance: A key export-oriented cluster that strengthens India's heavy engineering and global automotive supply chain with high-integrity forgings. Cluster profile: The Pune forging cluster accounts for about 20–25% of the total national production of forged components. There are around 50 forging MSMEs located in Pune, employing around 20,000 people. The production levels of the units range between 500–3500 tonnes per annum (tpa). All sectors of the automotive industry are represented in Pune: two-wheelers, auto rickshaws, cars, tractors, tempos, excavators and trucks. These automotive industries require forged products like axles, cams, connecting rods, crown wheels, gears, shafts, wheel hubs and so on, which are manufactured by the forging units in the cluster.

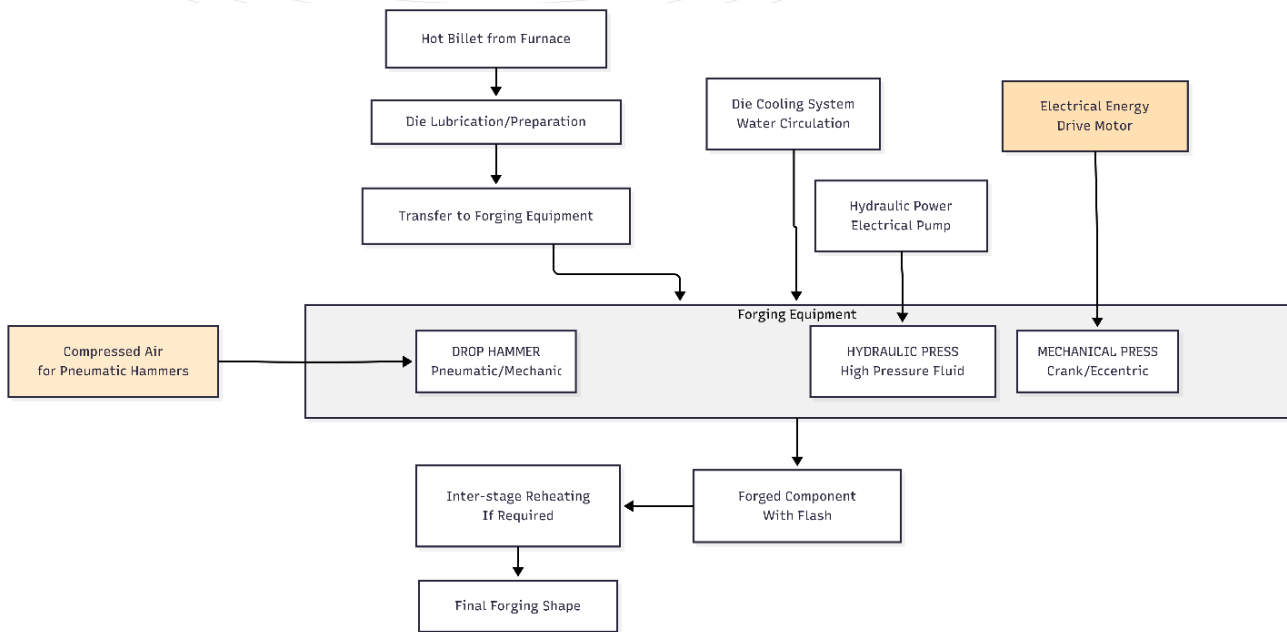
Tamil Nadu (Chennai, Hosur) Cluster	Gujarat (Ahmedabad, Rajkot) Cluster
Speciality: High-volume precision forgings for passenger vehicles. Overview: An integrated automotive forging hub producing transmission parts, connecting rods, and steering components, often operating in tight just-in-time schedules for OEMs. Importance: Directly supports the Chennai automotive corridor, enhancing India's position as a global small-car manufacturing hub. Cluster Profile: Chennai (Tamil Nadu) has a cluster of about 50 forging units, of which 46 are MSMEs and the remaining 4 are large industries. The forging units are in various industrial estates such as SIDCO Industrial Estate in Thirumudivakkam, Ambattur, Thirumazhisai, Ponneri, etc. The Chennai forging units are renowned for their ability to make precision auto components (70% of units) and non-auto components (30% of units). The products are supplied mainly to various large original equipment manufacturers (OEMs). The major raw materials used in the Chennai forging units include carbon steel, alloy steel, and mild steel. The cluster employs about 4500 people, directly or indirectly.	Speciality: Forgings for diesel engines, pumps, and machine tools. Overview: A synergistic cluster often integrated with local foundries, producing engine components, valve bodies, and agricultural machinery parts with a strong export focus. Importance: Bolsters regional engineering exports and complements Gujarat's strong base in automotives and machinery manufacturing. Cluster Profile: In Rajkot, there are 140 number of MSMEs. The forging units fall under two broad categories, based on the type of forgings they produce: (1) closed die forgings (90 units), which account for 62% of total production and (2) ring rolling forgings (50 units), which account for the remaining 38%. The unit-level production varies widely, from 300 tonnes to 36,000 tonnes per year. The total annual production of forgings is about 434,200 tonnes. The total turnover is estimated at over 0.4 billion rupees (4000 crores). The cluster employs about 15000 people directly or indirectly.

13.1.1 Process overview of a typical MSME unit



Material to Hot Metal: Billet Heating

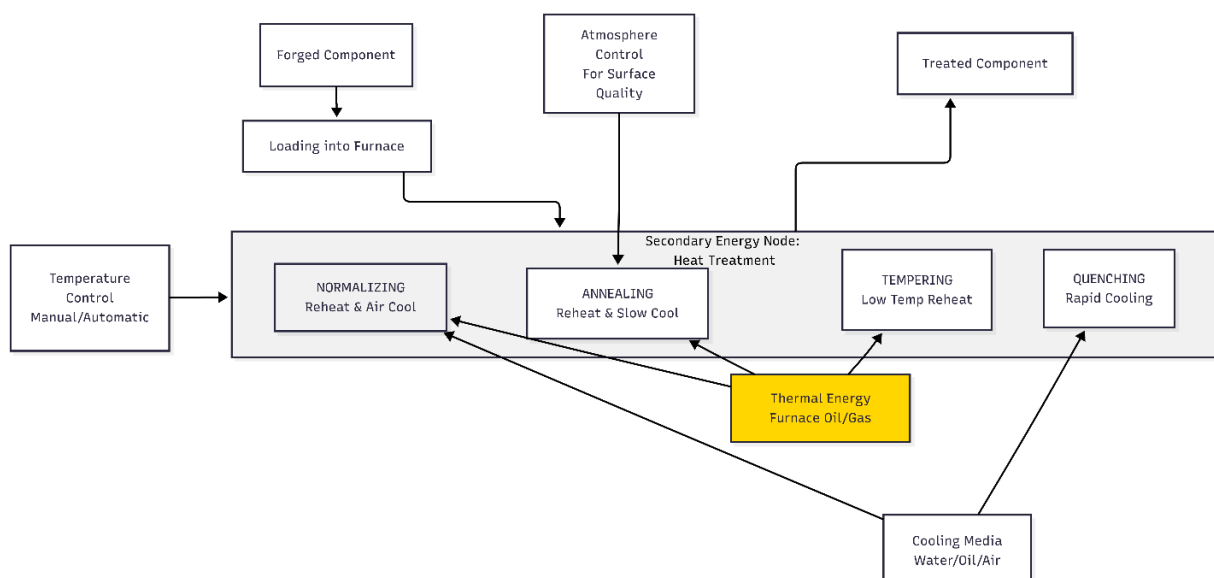
The first critical stage involves heating raw billets or bars to a plastic state (forging temperature) suitable for deformation. In MSME units, this is primarily achieved through oil-fired (furnace oil) or gas-fired (LPG/CNG) batch-type furnaces, with a growing adoption of induction heaters in more advanced units. This stage is the most energy-intensive, consuming an estimated 60-70% of a forging unit's total energy. The prevalence of manually controlled poorly insulated furnaces with significant radiant and exhaust heat losses makes this the prime target for efficiency gains. The choice between fuel-fired and induction heating represents a major technological crossroad for the sector, balancing initial cost against thermal efficiency and control.



Shaping the Component: Forging, Deformation & Heat Treatment

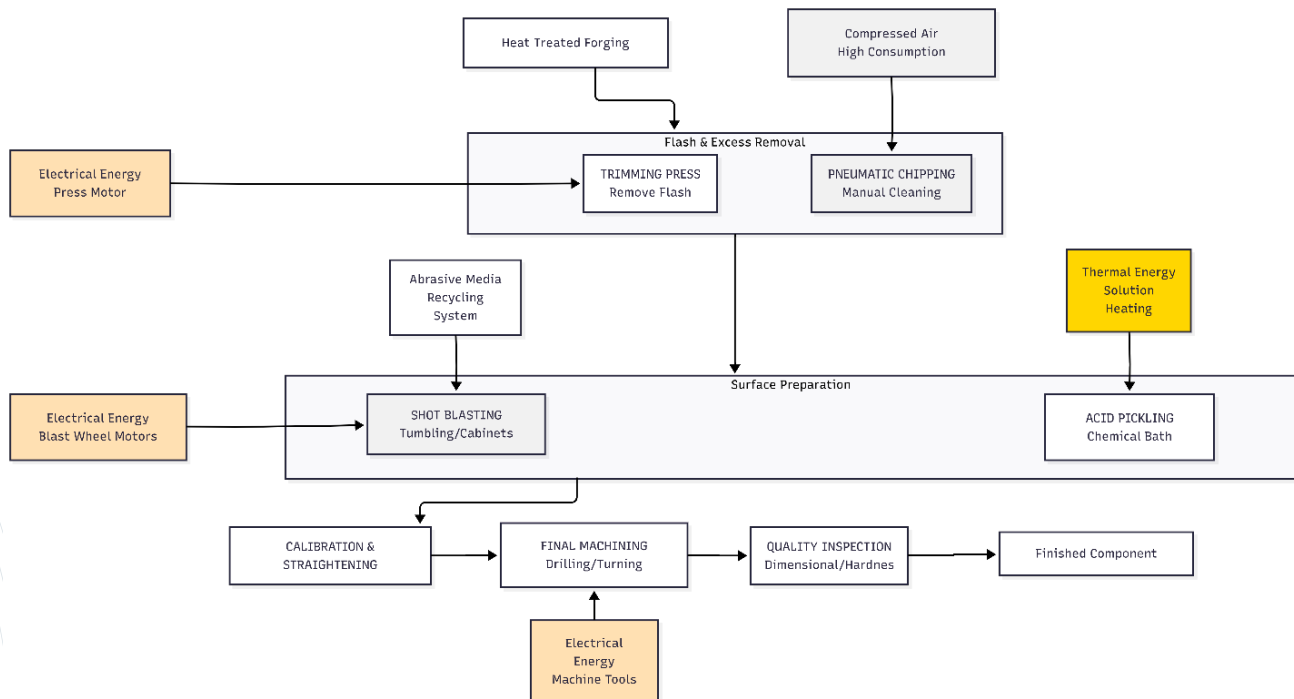
The actual shaping of the heated metal occurs in this stage using compressive force. MSMEs predominantly employ mechanical hammers (drop hammers) or hydraulic/mechanical presses fitted with die sets to form the component. The process is characterised by high instantaneous power demand per deformation stroke, though total energy consumption is secondary to heating. Pneumatic systems powering hammers often rely on inefficient, leak-prone compressed air networks. This stage is highly skill-dependent, with operators manually handling hot metal, and its efficiency is directly tied to achieving correct forging temperature and minimising the number of blows or strokes required.

Following forging, components often undergo heat treatment to achieve the required mechanical properties, such as hardness, strength, and toughness. Common treatments in MSMEs include normalising, annealing, and tempering, conducted in batch-type furnaces similar to those used for heating. This stage is a secondary thermal energy hotspot, accounting for 15-25% of total energy use. Inefficiencies mirror those of heating furnaces, compounded by often-oversized furnace capacity for small batch sizes. The quality and consistency of output here are critical for meeting automotive and engineering sector specifications but are frequently hampered by manual process control.



Rough to Ready: Finishing Operations

The final stage transforms the rough forged and heat-treated component into a finished part. This involves trimming excess flash in a press, shot blasting to remove scale, and often calibration or light machining. These operations are electrically intensive, driven by motors for blasting turbines, grinders, and machine tools. The stage is labour-intensive and contributes to overall energy consumption through often-optimised auxiliary systems, such as compressed air and dust collection. Efficiency in finishing directly impacts product quality, rejection rates, and final energy cost per kilogram of shipped component.

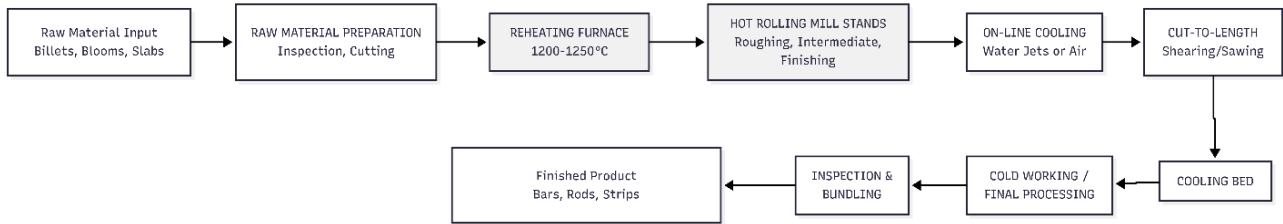


ANNEXURE 3:

ROLLING SECTOR PROFILE AND PROCESS OVERVIEW

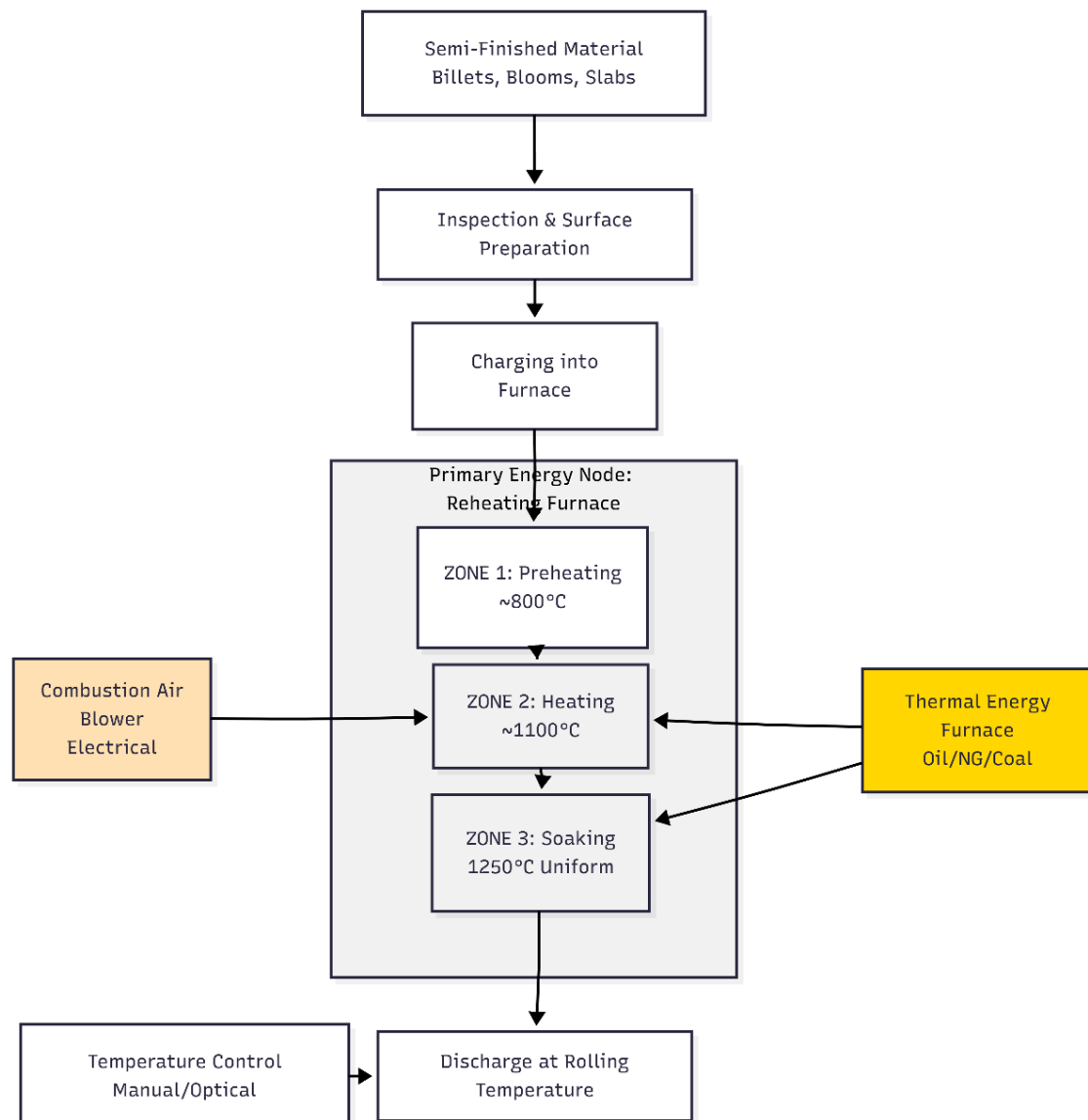
Mandi Gobindgarh (Punjab) – "Steel Town"	Bhavnagar (Sihor) Cluster
Speciality: Re-rolled TMT bars, structural (angles, channels), and bright bars. Overview: One of India's largest and most historic clusters, with a high concentration of small-scale re-rolling mills processing billets into construction-grade steel, supported by numerous induction and coal-based furnaces. Importance: The primary supplier of reinforcement steel and structural sections for the construction industry across North India, forming the backbone of the region's infrastructure development. Cluster Profile: Mandi Gobindgarh is known as 'Steel Town' for its largest cluster of steel re-rolling mills in the country. The cluster has about 404 MSMEs, of which about 341 are small and medium scale steel re-rolling units. The steel re-rolling industry is supported by around 500 traders and allied industries like induction furnaces, foundries, pipe plants, etc. The cluster provides direct and indirect employment to over 25,000 people.	Speciality: Hot-rolling scrap into construction-grade mild steel products. Overview: Located in Sihor taluka near Asia's largest ship-breaking yards at Alang-Sosiya, the cluster emerged from downstream processing of ship scrap sheets and local steel melting unit outputs like billets/ingots. Importance: Supplies Gujarat's infrastructure, tower/structure fabrication, and retail markets via distributors, linking ship-breaking (raw scrap) to value-added steel. Cluster Profile: located in Sihor taluka of Bhavnagar district, Gujarat, alongside Asia's largest ship-breaking yards at Alang and Sosiya. The raw material for the steel re-rolling units comes from the ship-breaking industries in the form of sheets, as well as from the steel melting units in the form of ingots and billets. There are about 120 re-rolling mills in the cluster, of which 90 are operational. Most of the units are in GIDC (Sihor).
Delhi NCR (Ghaziabad, Faridabad) Cluster	Ahmedabad (Gujarat) Cluster
Speciality: Precision cold-rolled strips, sheets, and value-added coated products. Overview: A cluster focused on downstream, value-added rolling, including cold rolling and galvanizing, serving the automotive, consumer durable, and capital goods sectors with higher-grade finishes. Importance: Supplies high-precision flat products to OEMs and the export market, acting as a critical link for quality-conscious manufacturing in the NCR region.	Speciality: Stainless steel sheets, strips, and non-ferrous rolled products (copper, brass). Overview: A technologically diverse cluster with units engaged in hot and cold rolling of speciality metals, catering to the chemical, fabrication, and architectural sectors. Importance: A key hub for corrosion-resistant and non-ferrous rolled products, supporting Gujarat's process industry, architectural demand, and export-oriented manufacturing.

14.1.1 Process overview of a typical MSME unit



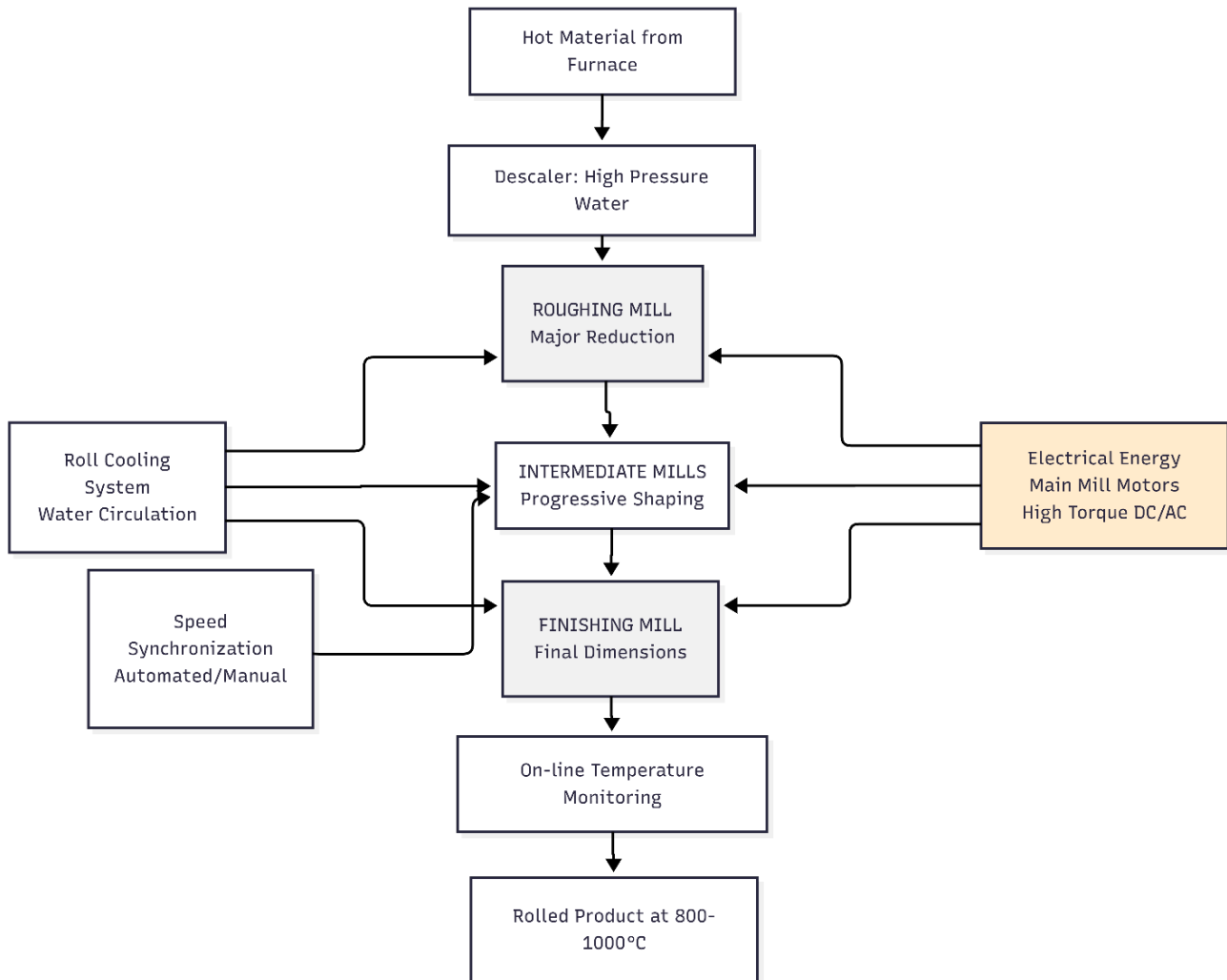
Material to Malleable: Billet/Ingot Reheating

The initial and most energy-critical stage involves raising the temperature of raw feedstock—steel billets, blooms, or non-ferrous ingots—to a plastic deformation range (typically 1100–1250°C for steel). In MSME rolling mills, this is predominantly carried out in fuel-fired reheating furnaces (using furnace oil, coal, or natural gas), which are often batch-type or pusher-type with manual controls and poor insulation. This stage is the primary thermal energy sink, consuming 50–70% of the mill's total energy, with significant losses occurring through furnace walls, open charging/discharge doors, and high-temperature exhaust flue gases. The efficiency of this stage sets the baseline for the entire rolling operation, impacting both quality and downstream energy use.



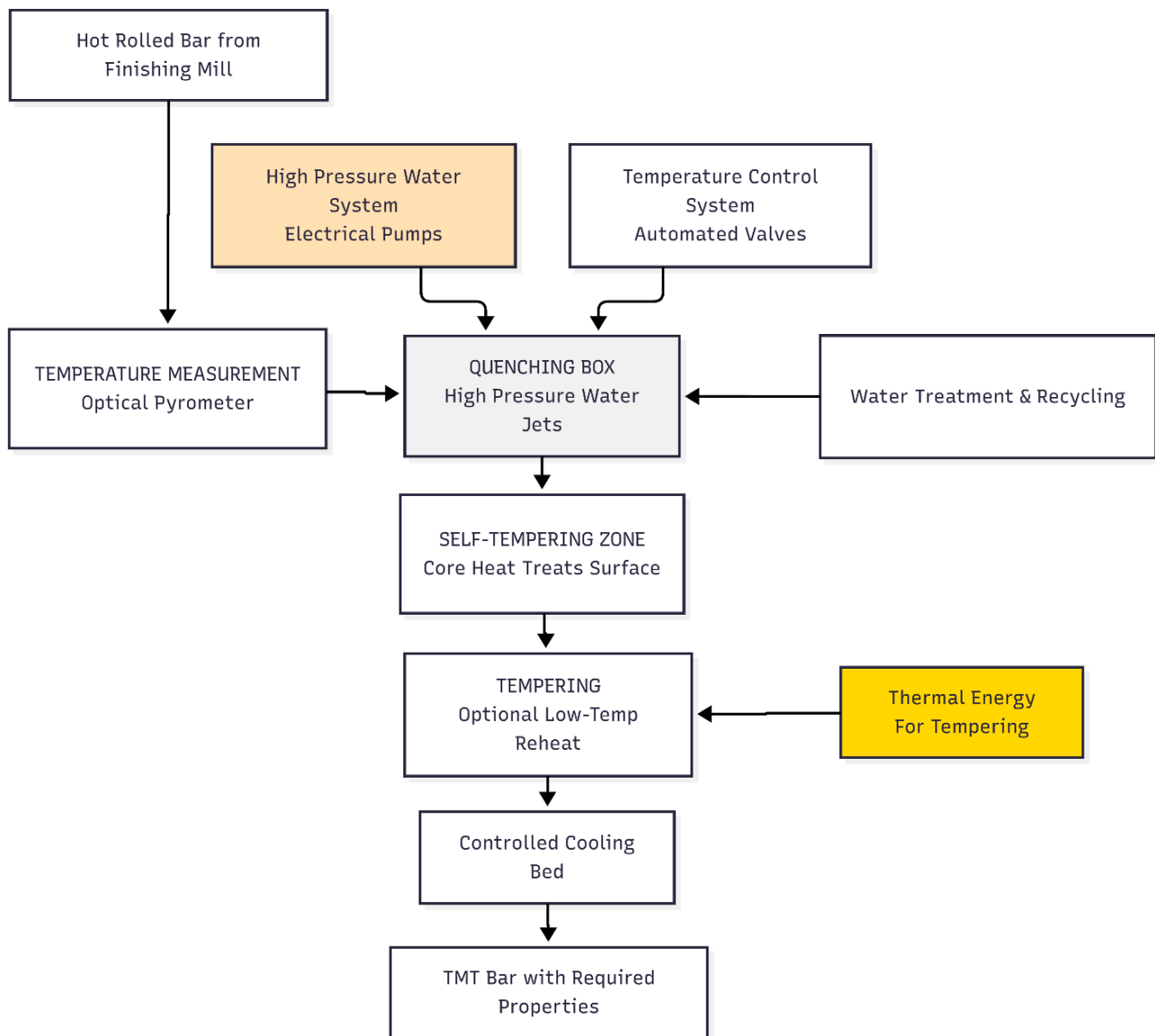
Shaping the Profile: Hot Rolling Deformation

The core shaping process involves passing the reheated material through a series of rolling mill stands to achieve the desired cross-sectional profile—such as bars, rods, angles, or strips. MSME units typically operate with 2-high or 4-high rolling stands, driven by older DC or constant-speed AC motors arranged in a roughing, intermediate, and finishing sequence. This stage is the primary electrical energy consumer, accounting for 20–30% of total energy, dominated by the high torque required for plastic deformation. Operational efficiency is hampered by outdated drive systems, poor power factor, and manual roll gap adjustments, leading to suboptimal load management and material wastage.



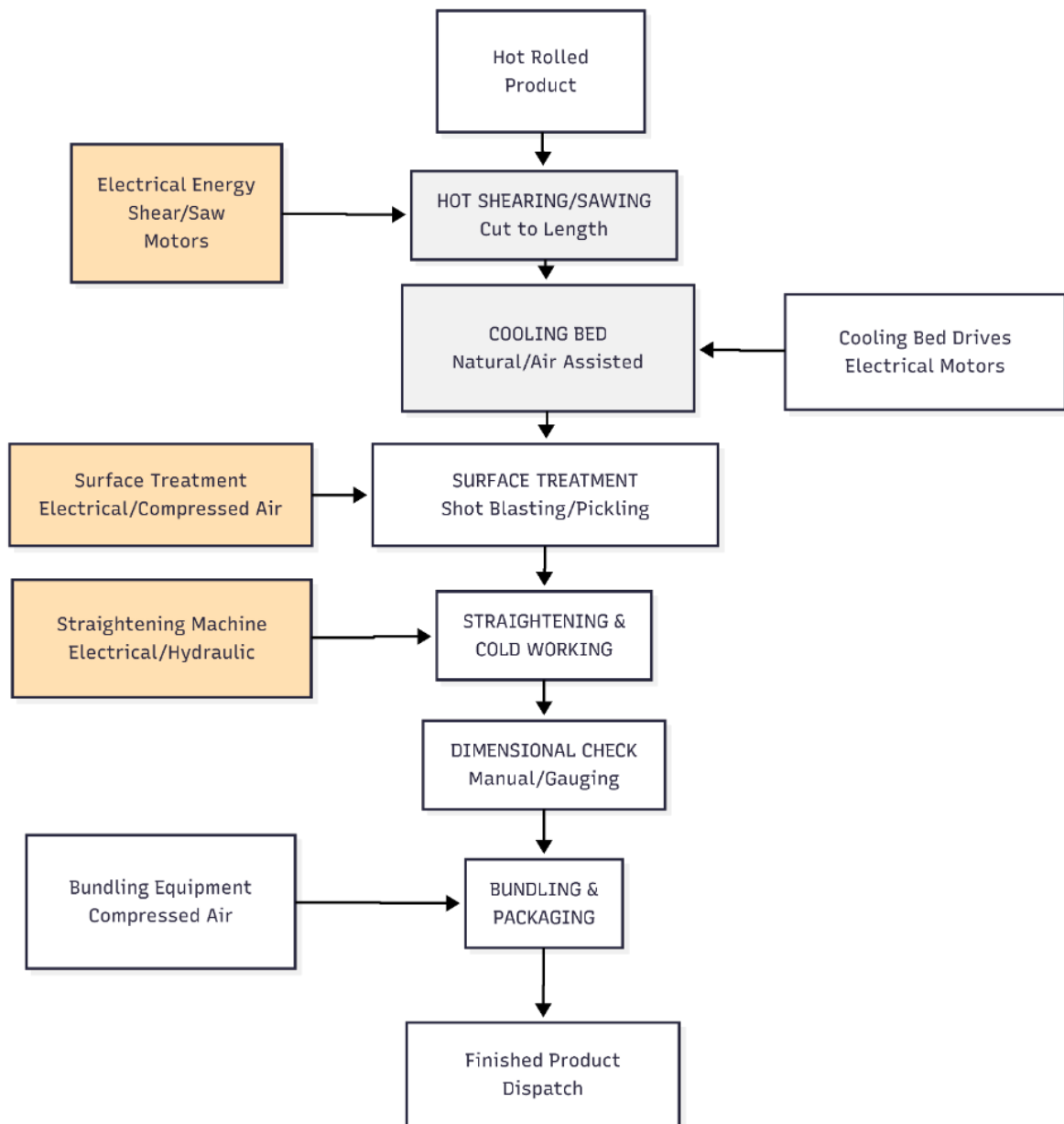
Achieving Final Properties: On-line Thermo-Mechanical Processing

For specific products like TMT (Thermo-Mechanically Treated) bars, an integrated on-line process follows hot rolling. This involves rapid quenching of the surface with controlled water jets, which hardens the outer layer while the core remains hot, allowing for subsequent self-tempering. This stage replaces the need for separate heat treatment furnaces but introduces a significant auxiliary electrical load for high-pressure water pumps and precise control systems. In MSMEs, this process is often adapted with simpler, less controlled systems, which can lead to inconsistent material properties and wasted pumping energy.



Rough to Ready: Cutting, Cooling & Finishing

The final stage converts the long, hot-rolled product into a market-ready commodity. It involves cutting to length (with hot shears or saws), controlled cooling on a cooling bed, and potential cold-working operations like straightening or surface cleaning. In MSME mills, this stage is characterized by moderate electrical consumption for shear motors, cooling bed drives, and bundled finishing equipment, but it is also a major source of delayed thermal energy waste as heat from the product dissipates unused into the environment. Efficiency here is often low due to manual handling, idling equipment, and a lack of heat recovery from the cooling phase.



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ANNEXURE 4:

TEXTILE SECTOR PROFILE AND PROCESS OVERVIEW

Bhiwandi (Maharashtra) Cluster	Surat (Gujarat) Cluster
Speciality: Powerloom Overview: Known as the “Manchester of India,” Bhiwandi is home to one of the largest power loom sectors. This cluster produces a wide variety of fabrics used for different applications and has become a major supplier of raw fabrics to garment manufacturers across the country. Importance: Bhiwandi’s fabric production is essential for India’s textile industry, especially for manufacturing lower-cost fabrics. Cluster Profile: In Bhiwandi, there are about 6000 power loom units located in Bhiwandi and nearby areas, most of them MSMEs, operating about 1.5 million power looms. The main raw materials are grey cotton yarn and white cotton yarn. The cluster provides direct employment to about 0.5 million people and indirect employment to around the same number of people.	Speciality: Synthetic Fabric and Sarees Overview: Surat is one of India’s largest textile hubs, especially for synthetic fabric. Known for its exquisite sarees, this city combines traditional saree-making with modern synthetic fibre production, making it a hub for polyester and nylon fabrics. Importance: Surat’s textiles are popular in both the domestic and international markets, and the cluster is an integral part of the synthetic fabric supply chain. Cluster Profile: One of the largest textile manufacturing clusters in India is located in Surat (Gujarat). The Surat cluster accounts for over 18% of the total manmade (synthetic) fibre exports and 40% of manmade fibre production in the country. The products primarily comprise synthetic sarees & dress materials and cotton dress materials. There are about 400 textile processing units in the cluster, operating over 600,000 power looms and providing employment to around 12 lakh workers.
Erode (Tamil Nadu) Cluster	Varanasi (Uttar Pradesh) Cluster
Speciality: Cotton Fabric and Handloom Overview: Erode is widely recognised for its cotton fabrics and handloom products, such as bedsheets, towels, and dhotis. This cluster is home to thousands of looms and a large number of dyeing and bleaching units. Importance: Erode’s cotton products are well-regarded for quality and serve a vast market across South India.	Speciality: Banarasi Silk Overview: The Varanasi cluster is famous for its luxurious Banarasi silk sarees, known for intricate zari work and delicate patterns. These sarees are a hallmark of Indian wedding attire and are highly valued for their craftsmanship. Importance: Varanasi’s Banarasi silk sarees are integral to India’s cultural heritage and are in high demand worldwide, representing India’s rich textile artistry.

Cluster Profile: Erode, located in Tamil Nadu, is a major textile hub specialising in cotton fabrics, home textiles (bedsheets, towels), and garments. It is a massive SME-driven cluster featuring ~75,000 power looms, 160 spinning units, and 300+ dyeing units.	Cluster Profile: The Varanasi (Uttar Pradesh) textile cluster is a globally renowned, century-old hub specialising in premium Banarasi silk sarees, characterised by intricate Zari work. The cluster includes over 200 artisans and 10 self-help groups (SHGs), supporting a major, traditional handloom industry.
Tirupur (Tamil Nadu) Cluster	Kanchipuram (Tamil Nadu) Cluster
Speciality: Knitwear Overview: Often called the "Knitwear Capital of India," Tirupur is known for its high-quality T-shirts, undergarments, and other knitwear products. This cluster specializes in cotton-based knitwear and exports to major global markets. Importance: Tirupur contributes significantly to India's apparel exports, making it a vital centre for India's economic growth in textiles. Cluster Profile: In Tiruppur, there are an estimated 3200 MSMEs in the cluster, specializing in different aspects of the production process like dyeing, compacting, knitting, embroidery, bleaching, stitching and finishing. Most units do job work against orders from export houses, which in turn cater to the requirements of overseas brand marketers.	Speciality: Kanchipuram Silk Sarees Overview: Renowned for its vibrant silk sarees, Kanchipuram combines traditional weaving techniques with high-quality silk and pure zari. These sarees are often associated with auspicious occasions and have a distinct reputation worldwide. Importance: The Kanchipuram silk industry supports thousands of artisans and maintains India's traditional silk weaving heritage. Cluster Profile: Kanchipuram, known as the "Silk City of India" in Tamil Nadu, is a premier handloom cluster renowned for producing authentic, GI-tagged mulberry silk sarees with heavy Zari work. Over 10,000 to 60,000 families are involved in this traditional industry.
Ludhiana (Punjab) Cluster	Pochampally (Telangana) Cluster
Speciality: Woollen Textiles and Hosiery Overview: Ludhiana is India's largest producer of woollen garments and hosiery products, including sweaters, scarves, and gloves. The city's textile sector includes both small-scale and large-scale manufacturers. Importance: Ludhiana is essential for winterwear in India and is also a significant exporter of woollen products, especially to colder regions. Cluster Profile: Ludhiana, in Punjab, is an important textile manufacturing cluster, with around 14000 MSMEs of which 9800 are micro (70%), 2800 are small-scale (20%) and 1400 are medium-sized (10%) enterprises. Knitwear manufacturers (including manufacturers-cum-traders/ exporters) form the core of the cluster. Spinners, dyers and subcontracting knitting units provide backward process support. The Ludhiana knitwear industry is highly labour-intensive. Including the large-scale	Speciality: Ikat Weaving Overview: Known for its traditional Ikat dyeing and weaving techniques, Pochampally creates beautiful sarees and textiles with geometric patterns and vibrant colours. Importance: Pochampally's unique Ikat designs have earned it international recognition, and it is a UNESCO-designated heritage site for its weaving tradition. Cluster Profile: Pochampally, located in Telangana's Yadadri Bhuvanagiri district, is a world-renowned handloom cluster famous for its unique Ikat tie-and-dye sarees and fabrics. Often called the "Silk City of India," it is a major hub of traditional, hand-woven cotton and silk textiles (GI protected) created by the

industries, the cluster provides direct and indirect employment to about 400,000 people.	
Bhagalpur (Bihar) Cluster	Panipat (Haryana) Cluster
Speciality: Tussar Silk Overview: Bhagalpur, often referred to as the "Silk City," is famous for Tussar silk, which is a coarser but durable silk with a rich texture. The weavers in Bhagalpur use age-old techniques to create sarees and dress materials. Importance: Bhagalpur's Tussar silk products are in high demand for their unique look and quality, especially for making sarees and scarves. Cluster Profile: Bhagalpur, known as the "Silk City of India" in Bihar, is a historic textile hub famous for weaving Tussar silk and Bhagalpuri sarees, producing over 2 million meters of silk annually. Situated along the Ganga, this 200-year-old cluster centres on artisan-driven production (65% dress materials, 20% home furnishings) and holds a Geographical Indication (GI) tag	Speciality: Home Textiles Overview: Known as the "City of Weavers," Panipat specialises in home textiles like bed linen, carpets, and curtains. The city produces a large share of India's home furnishings and exports to several countries. Importance: Panipat's home textiles industry is a significant contributor to India's exports, particularly in the home furnishing sector. Cluster Profile: Panipat, a city in Haryana, is an important cluster of industrial units manufacturing textile products. There are about 3095 MSMEs in this cluster, of which 1915 units (62%) manufacture home furnishing products. Panipat accounts for about 75% of the total blankets produced in India. A majority of the units are located in the industrial areas of Sector 25 (I&II) and Sector 29 (I&II), Haryana Urban Development Authority and the Panipat industrial area.
Ichalkaranji (Maharashtra) Cluster	
Speciality: Powerloom, Airjet and Cotton Fabric Overview: Known as the "Manchester of Maharashtra," Ichalkaranji has established itself as a significant centre for power loom textiles, producing high-quality cotton fabrics and specialised textiles like suiting and shirting materials. Importance: Ichalkaranji's innovations in textile production and technology have enhanced its reputation, making it a vital supplier of high-quality fabrics for both domestic and export markets. Cluster Profile: Ichalkaranji, known as the "Manchester of Maharashtra," is a premier textile hub in Kolhapur district, renowned for its massive power loom industry, which produces approximately 14–15 million meters of fabric daily. The cluster features over 80,000–120,000 power looms, specialising in cotton, polyester, and denim, with a strong focus on technical upgrades like airjet and rapier looms.	

15.1.1 Process overview of a typical MSME unit

India's textile manufacturing follows a sequential value chain, starting from fibre and ending with finished apparel. The chain is a mix of large integrated units and MSMEs, with the latter dominating sectors like weaving, dyeing, and garmenting. The textile production chain begins with spinning, converting natural (cotton, wool, silk) or man-made fibres into yarn using the world's second-largest capacity of over 48 million spindles and 0.9 million rotors as of 2022, with cotton dominating 60% of fibre use mainly in organised mills in Tamil Nadu, Gujarat, and Maharashtra. Yarn then transforms into fabric via weaving on ~2.5 million power looms (producing >60% of cloth, clustered in Bhivandi, Surat, Malegaon) or knitting in export hubs like Tiruppur and Ludhiana, complemented by 2.37 million handlooms and 4.33 million weavers. Energy and water-intensive fabric processing (scouring, bleaching, dyeing, printing, finishing) occurs in over 2,500

MSME units in Tiruppur, Jetpur, Surat, and Pali. Finally, labour-intensive garmenting—cutting, stitching, embroidery, packaging—adds value through India's RMG sector, which drives 36% of textile/apparel exports (\$36.6B in FY25), employs 12 million (many women), and spans formal exporters and informal MSMEs.

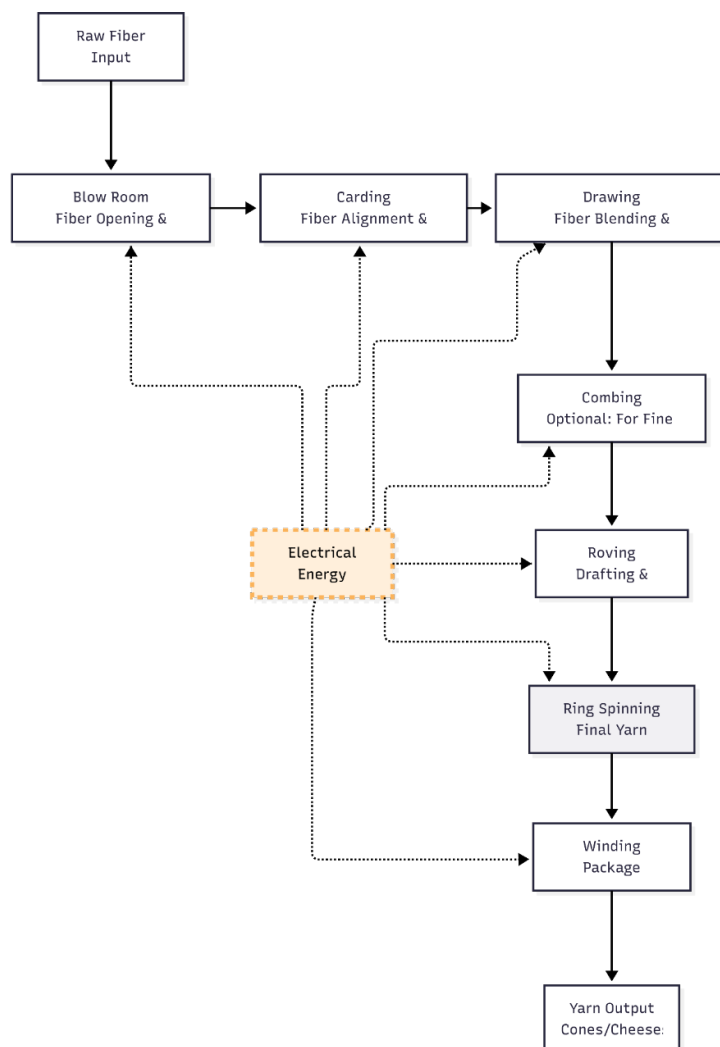
In many textile units, particularly in dyeing and finishing, energy costs constitute a substantial share of production expenses, typically ranging between 15–20%⁷. The total energy intensity of a finished textile varies based on the fibre that is used. For instance, cotton fibre needs 54 – 60 MJ/kg of fibre, and nylon fibre production requires 120 – 140 MJ/kg of fibre.

Key process stages of the textile industry:



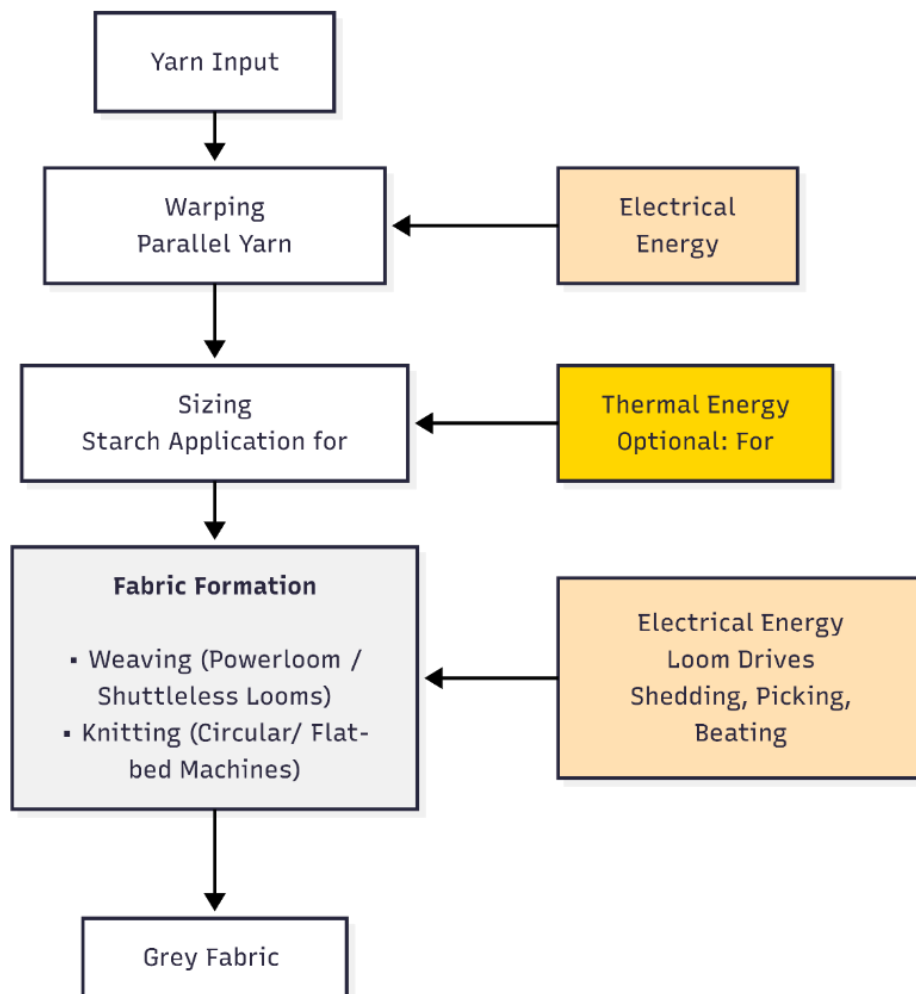
Fibre to Yarn: Spinning

Spinning is the first major step, where natural (cotton, wool, silk) or man-made (polyester, viscose) fibres are converted into yarn. India possesses the second-largest spinning capacity globally, with over 48 million spindles and 0.9 million rotors installed as of 2022. Cotton remains the dominant raw material, constituting approximately 60% of the country's total fibre consumption, as per the Ministry of Textiles' Annual Report (2023–24). Yarn production is carried out largely in an organised setup in states like Tamil Nadu, Gujarat, and Maharashtra.



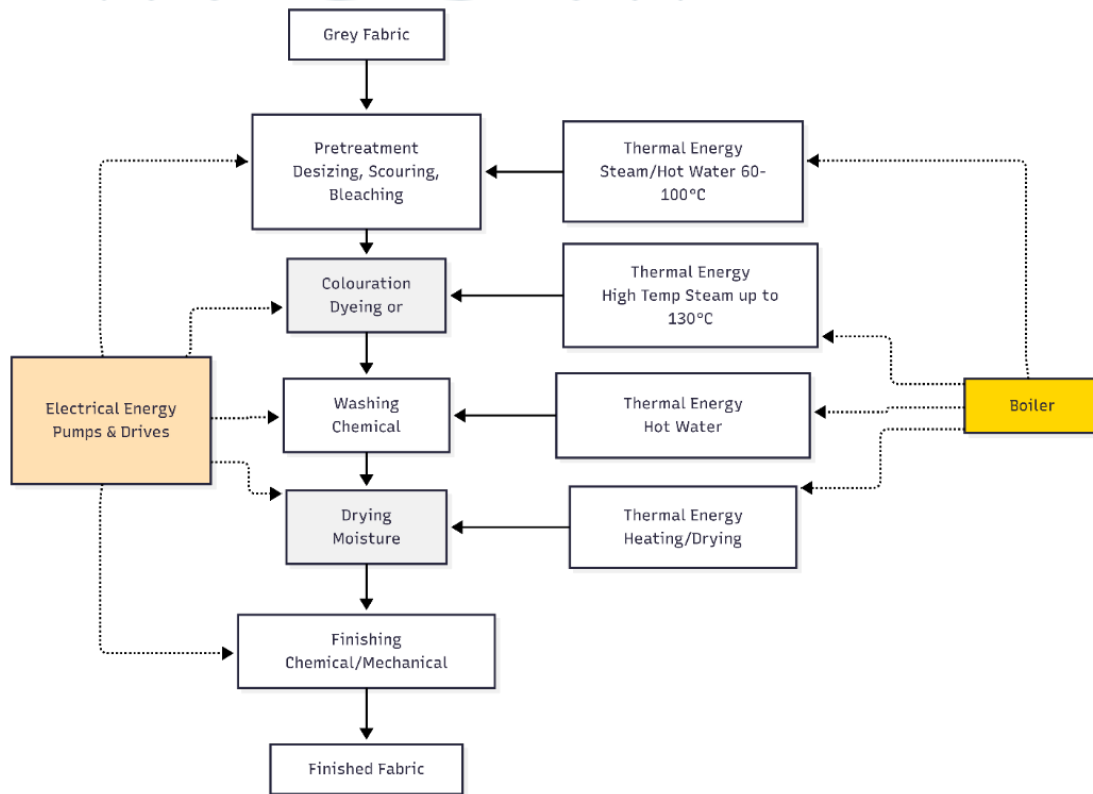
Yarn to Fabric: Weaving and Knitting

The conversion of yarn into fabric occurs through weaving (interlacing yarns) or knitting (looping yarns). India houses around 2.5 million power looms, which account for over 60% of the total cloth production, employing over 5.7 million people, predominantly within MSME units. While power loom activity is concentrated in clusters like Bhiwandi, Surat, and Malegaon, handlooms continue to play a vital role, with 2.37 million active handlooms and 4.33 million weavers, as reported in the Fourth All India Handloom Census. Knitting, on the other hand, is more prevalent in export-oriented hubs such as Tiruppur and Ludhiana, known for their cotton hosiery and woollen garments, respectively. This segment has seen faster adoption of modern technology compared to the traditional weaving sector.



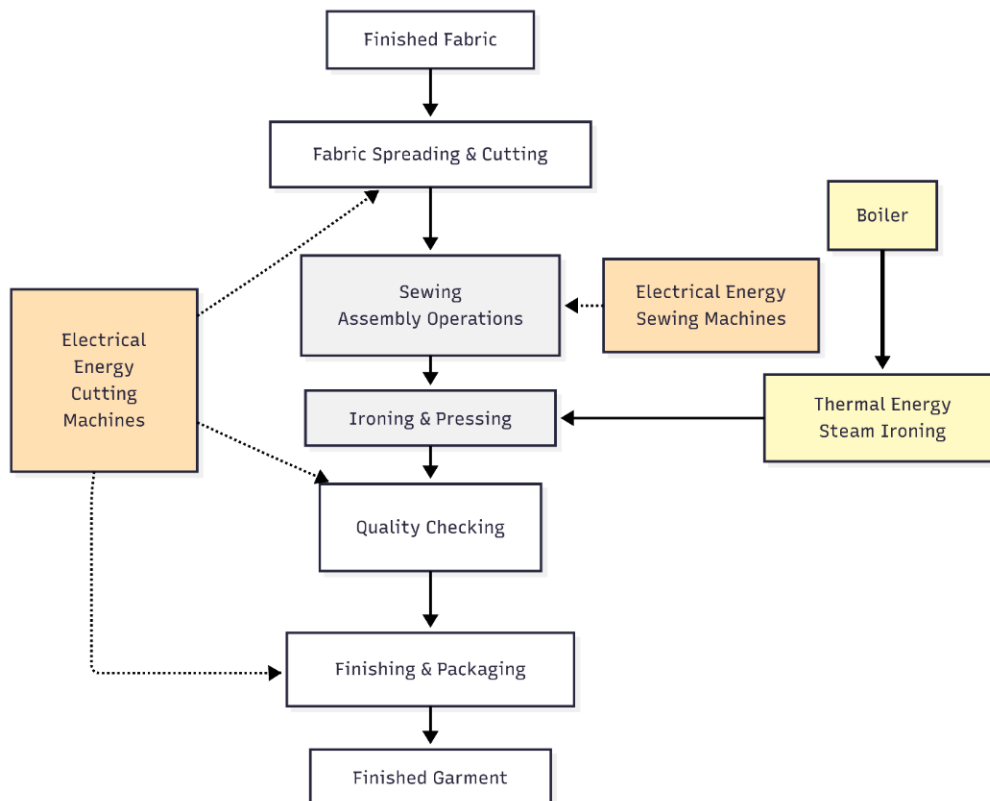
Fabric Treatment: Dyeing, Printing, and Finishing

Fabric treatment process is one of the most energy- and water-intensive segments of the textile chain. It involves preparatory steps like scouring and bleaching, dyeing or printing, and chemical or mechanical finishing processes. The sector is predominantly dominated by small and medium enterprises, with over 2,500 processing units spread across India. Major hubs include Tiruppur (knitwear), Jetpur, Surat (synthetics), and Pali (cotton blends).



Fabric to Garment: Apparel Manufacturing

Garmenting is the final stage of value addition and is highly labour-intensive. It includes cutting, stitching, embroidery, and packaging. India's readymade garment sector (RMG) contributes 36% of the country's total textile and apparel exports, employing around 12 million workers, with a significant representation of women. Garmenting units are spread across both formal export houses and informal MSMEs, catering to the domestic market.



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ANNEXURE 5:

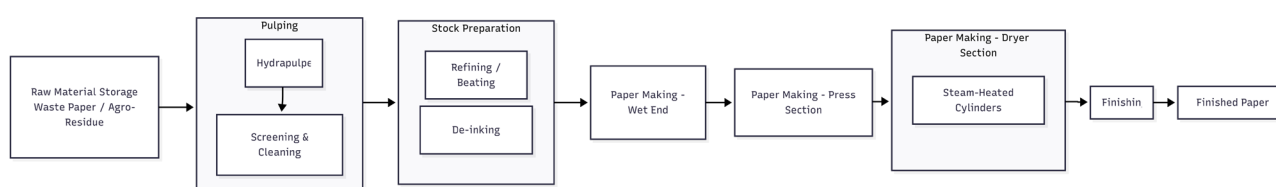
PAPER SECTOR PROFILE AND PROCESS OVERVIEW

Muzaffarnagar & Saharanpur (Uttar Pradesh) Cluster	Kashipur (Uttarakhand) Cluster
Speciality: Agro-based writing and printing paper (Creamwove, Maplitho). Overview: A traditional cluster in the sugarcane and wheat belt, utilising agricultural residues like wheat straw, bagasse, and sarkanda as primary raw material. The units typically employ a soda or soda-AQ pulping process and are characterised by small to medium-scale operations. Importance: Critical for valorising agricultural waste, providing rural employment, and supplying cultural and printing papers to the large North Indian market. Faces significant challenges related to water consumption and chemical recovery. Cluster Profile: The industrial town of Muzaffarnagar, in western Uttar Pradesh, hosts an important paper manufacturing cluster. It has 29 small and medium sized paper units that vary in capacity from 1750 tonnes per annum (tpa) to 87,500 tpa. The units use agro residues (like bagasse and wood chips) and recovered paper (waste paper in the form of tightly compressed bales) for paper production. To meet their energy needs, the paper units use electricity as well as coal and biomass (mainly rice husk, pith and bagasse). Most of the units have installed biomass/coal-based cogeneration systems to meet their demands for steam and power simultaneously.	Speciality: Recycled paperboard and packaging grades. Overview: A compact cluster of mills primarily processing wastepaper/cardboard to produce kraft paper and various grades of board (duplex, triplex). Many units are micro or small-scale with semi-automated processes. Importance: Serves the packaging needs of the state and surrounding regions, playing a role in urban waste paper recycling. Its location in an ecologically sensitive area underscores the need for strict environmental compliance. Cluster Profile: The Kashipur cluster is home to over 24 pulp and paper mills based on agro residues and waste paper and producing a variety of grades of paper like writing and printing, newsprint, packaging (kraft and duplex board) and other speciality grades of paper. Among these mills, over 17 mills are producing only packaging grade of paper, mainly from waste paper, in view of the ever-increasing demand and market for packaging paper. The pulp and paper mills in this cluster are of varying production capacity, ranging from 50 to 250 tpd.

Vapi (Gujarat) Cluster	Morbi (Gujarat) Cluster
Speciality: High-grade recycled paperboard, kraft paper, and speciality packaging paper. Overview: One of India's largest and most organised paper MSME clusters. Units are relatively more technologically advanced, focusing on producing consistent quality board for value-added packaging. Relies almost exclusively on imported and domestic wastepaper. Importance: Acts as the primary packaging material supplier to Gujarat's massive pharmaceutical, FMCG, and chemical export industries. A key example of a modern, recycling-based cluster with scale. Cluster Profile: The town of Vapi, about 40 sq. kms in area, abounds in paper mills. About 45-50 paper mills are manufacturing Kraft, Writing and Printing, Duplex Board and Newsprint varieties of Paper.	Speciality: Recycled kraft paper and test liner for the ceramic industry. Overview: This cluster is a direct ancillary to Morbi's giant ceramic tile industry. Numerous small mills produce lower-grade kraft paper and liner used to make cardboard boxes for tile packaging. Raw material is lower-quality mixed waste paper. Importance: Demonstrates a highly localised, symbiotic industrial ecosystem. Its energy efficiency is closely tied to the fortunes of the ceramic sector. Cluster Profile: Morbi cluster with swiftly emerging new identity in the form of booming paper industry, presently scaling a quantum of over 16,00,000 tonne per annum. The paper industry here remains largely underreported, probably because of the small sizes of individual mills and their old-school production methods. There are presently 35 operating mills with capacities ranging from 40-400 TPD, the majority producing kraft paper with a few making duplex board. Combined together, these mills churn out around 4500 TPD of kraft paper and duplex board.
Erode-Coimbatore (Tamil Nadu) Cluster	
Speciality: Recycled paperboard and pulp from cotton waste/trader waste. Overview: A dynamic cluster leveraging the region's textile industry waste (thread waste, clipping) as a fibrous raw material, blended with waste paper. Produces boxboard and other packaging materials. Importance: Provides a sustainable outlet for textile waste, supports the region's export-oriented garment and textile industry with packaging, and showcases circular economy principles. Cluster Profile: The cluster hosts around 559 units of Paper and Paper Products.	

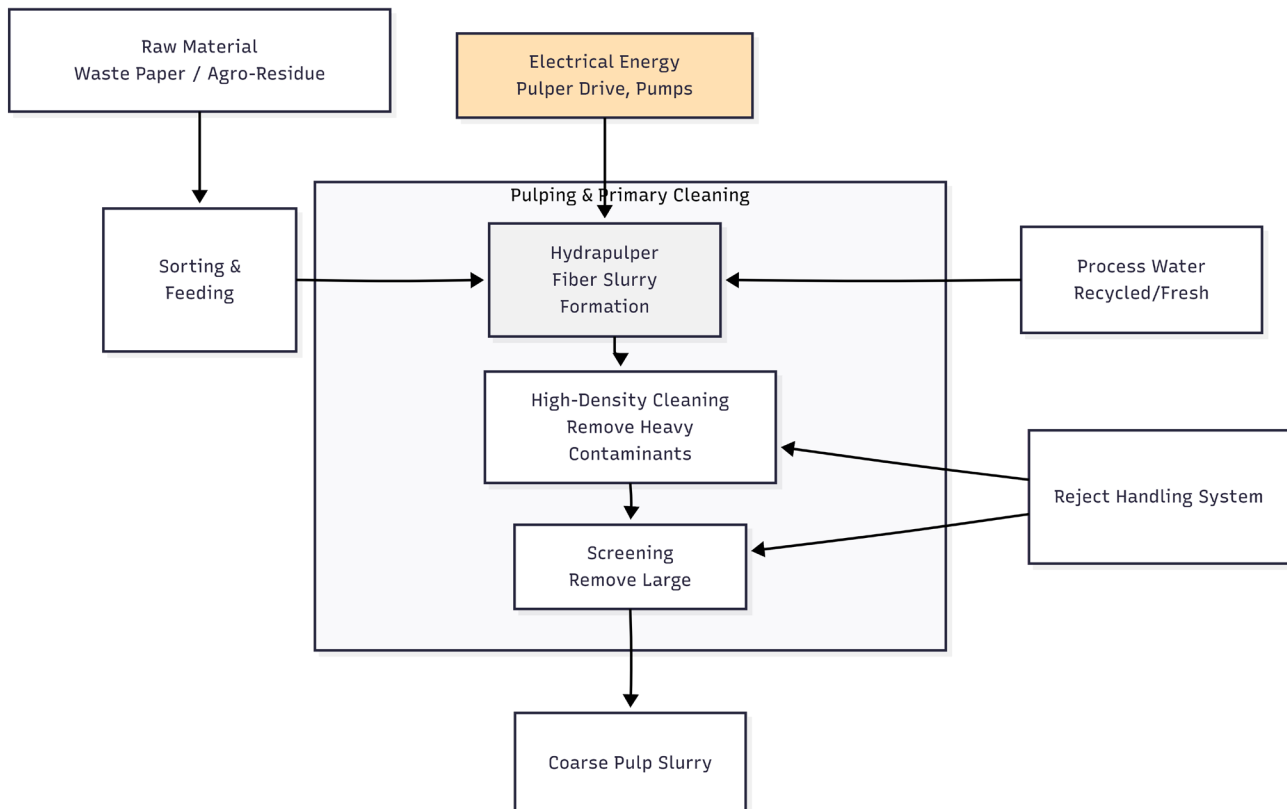
16.1.1 Process overview of a typical MSME unit

The paper and pulp industry is a small segment in the industrial sector with an energy consumption of around 1% to 2% of the total industrial energy. Paper is produced mainly by three input materials: agro-based, forest-based and waste-based. The typical MSME paper mill in India is a batch or semi-continuous, integrated manufacturing facility centred on converting raw material (wastepaper or agro residue) into a finished paper roll. The process is broadly linear, with significant thermal and electrical energy demands at specific stages. The schematic below outlines the key stages, with primary energy consumption zones.



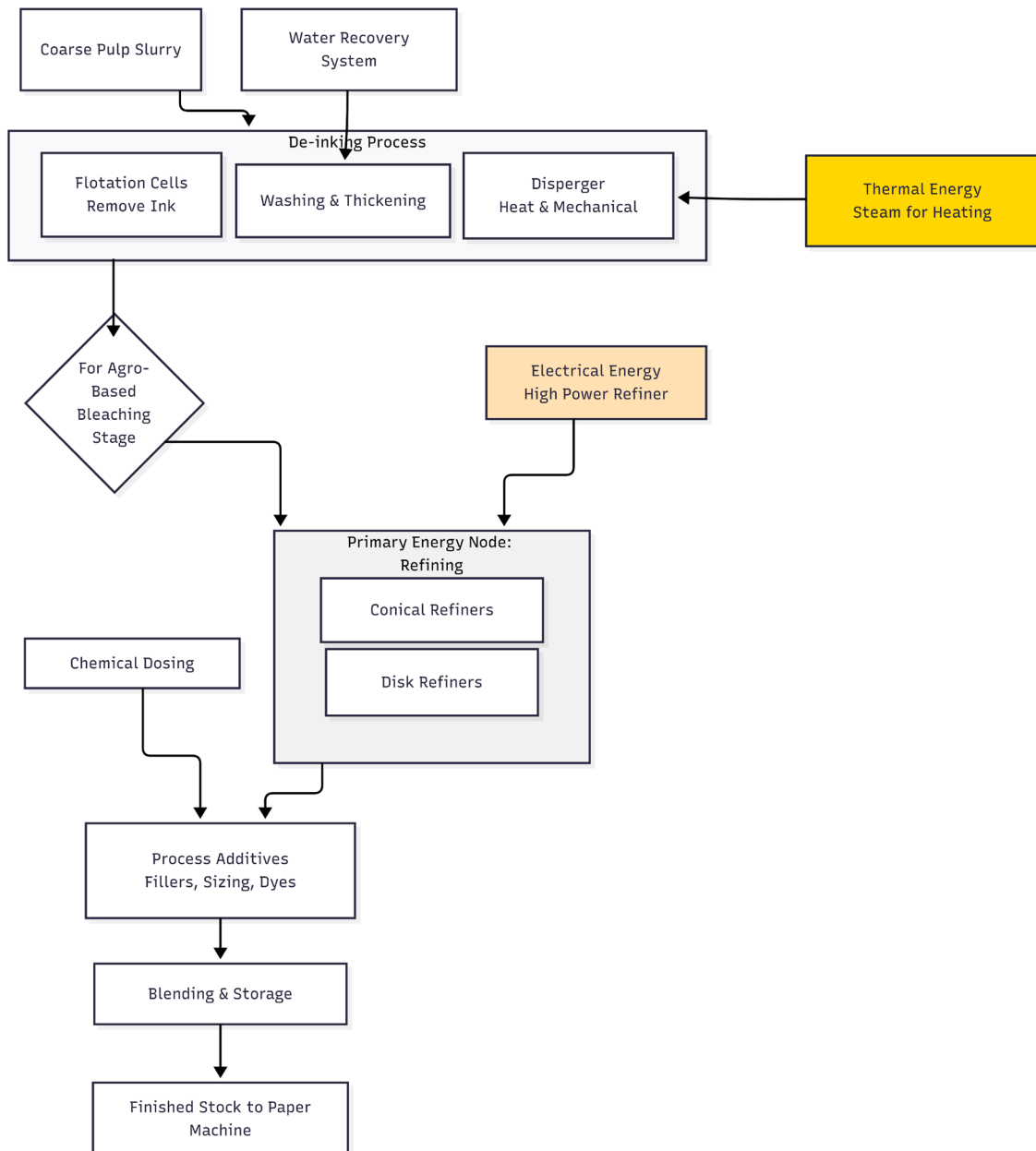
Raw Material to Pulp: Pulping & Cleaning Process

This initial stage converts raw materials (waste paper or agro-residues) into a fibrous pulp slurry. Waste paper is mixed with water in a hydropulper to separate fibers, while agro-residues undergo chemical or mechanical digestion. The resulting slurry is then cleaned through screens and centrifugal cleaners to remove contaminants like plastics, staples, and sand. The output is a coarse pulp ready for further refinement. Theoretical Energy Assessment: This stage is characterized by moderate electrical energy consumption for driving the pulper, conveyors, and cleaning pumps, but has minimal thermal demand unless hot water is used, making it a secondary target for electrical efficiency improvements.



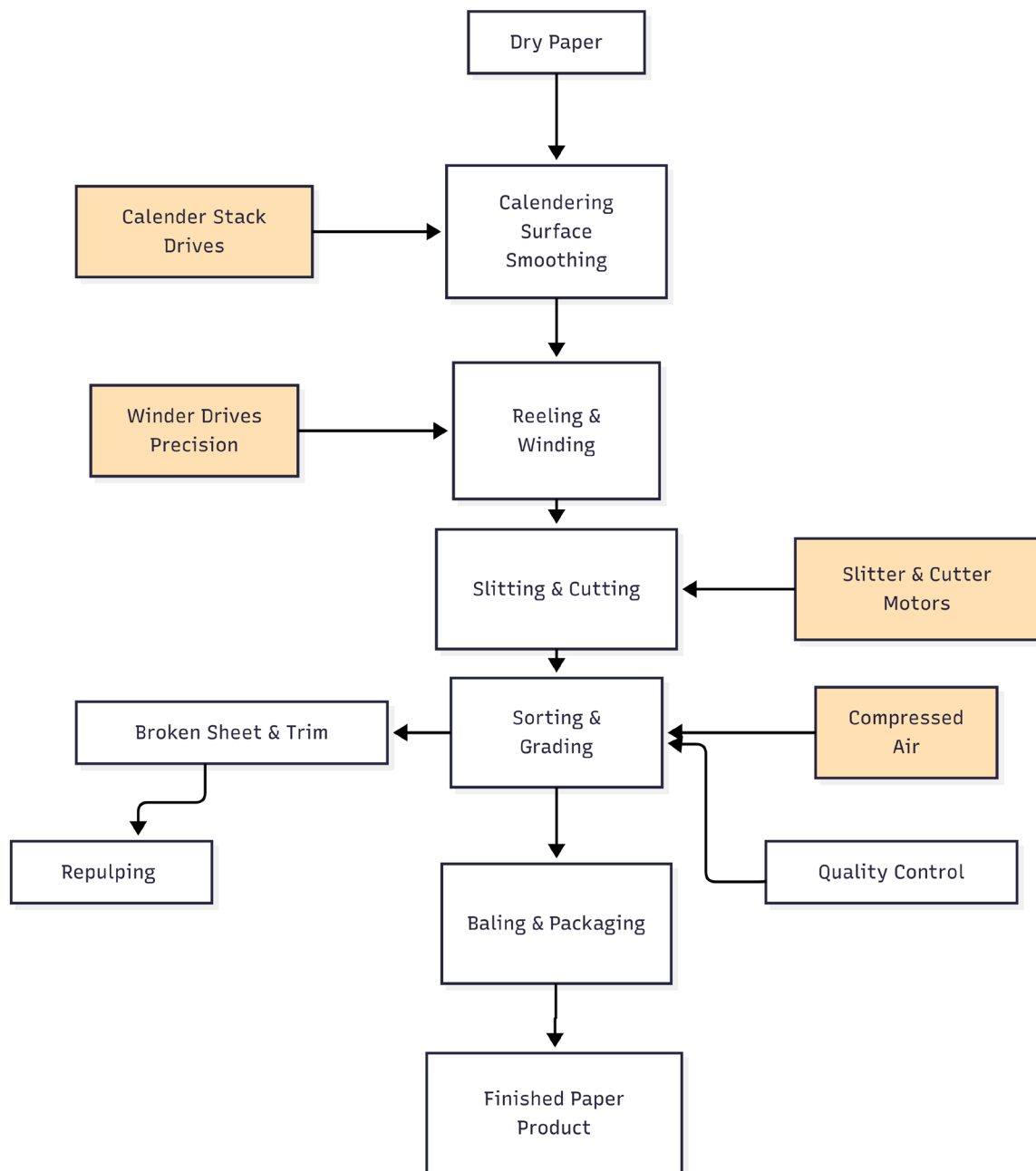
Stock Preparation: Refining & Process Adjustment

The coarse pulp undergoes mechanical treatment to develop the fibers' bonding potential. In refiners or beaters, fibers are physically frayed, which is crucial for paper strength but highly energy-intensive. For whiter grades, a de-inking process using flotation cells and washers is added. Additives like fillers, sizing agents, and dyes are mixed in to achieve specific paper properties. This stage tailors the pulp slurry for the paper machine. Theoretical Energy Assessment: This is a primary electrical energy-intensive stage due to the high-power demand of refiners and beaters; if a de-inking plant is operational, it adds a significant secondary thermal load for heating process water, establishing this step as a major focus for both electrical and thermal efficiency.



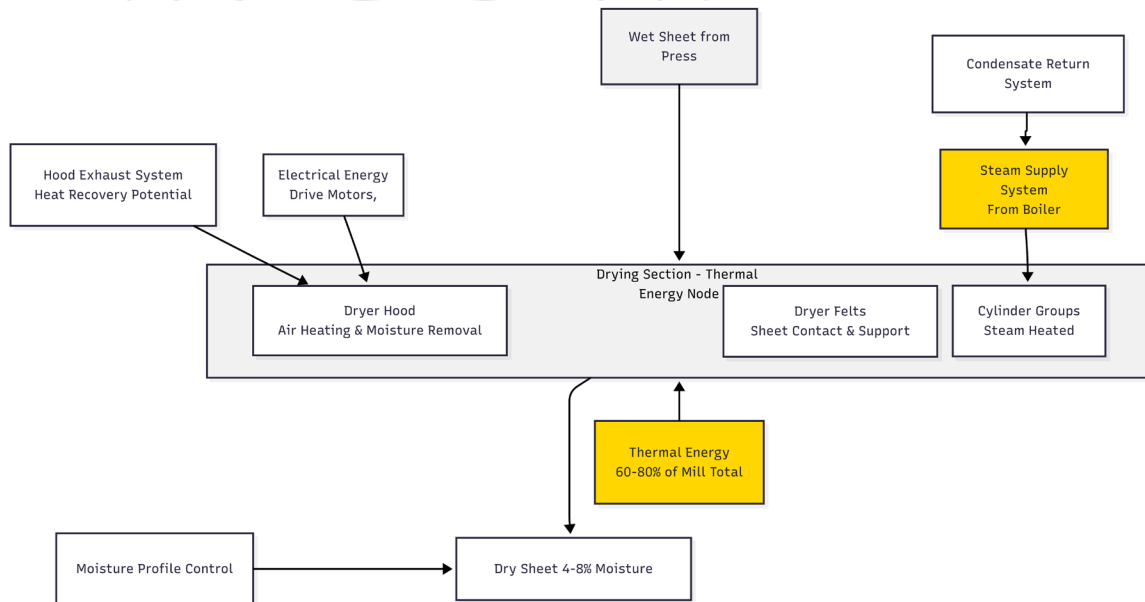
Paper Formation: Wet End & Press Section

The prepared stock is diluted and spread evenly onto a moving wire mesh (Fourdrinier table), where water begins to drain by gravity and vacuum suction, forming a continuous wet sheet. This sheet then passes through press rolls, which mechanically squeeze out more water, reducing moisture from ~80% to ~50-55%. This section defines the basic sheet formation and removes as much water as possible before the energy-intensive drying stage. Theoretical Energy Assessment: This stage is electrically intensive, primarily due to the high load from vacuum pumps and the drives for the forming wire and press rolls, but requires negligible thermal energy, positioning it as a key area for electrical system optimization to reduce downstream drying load.



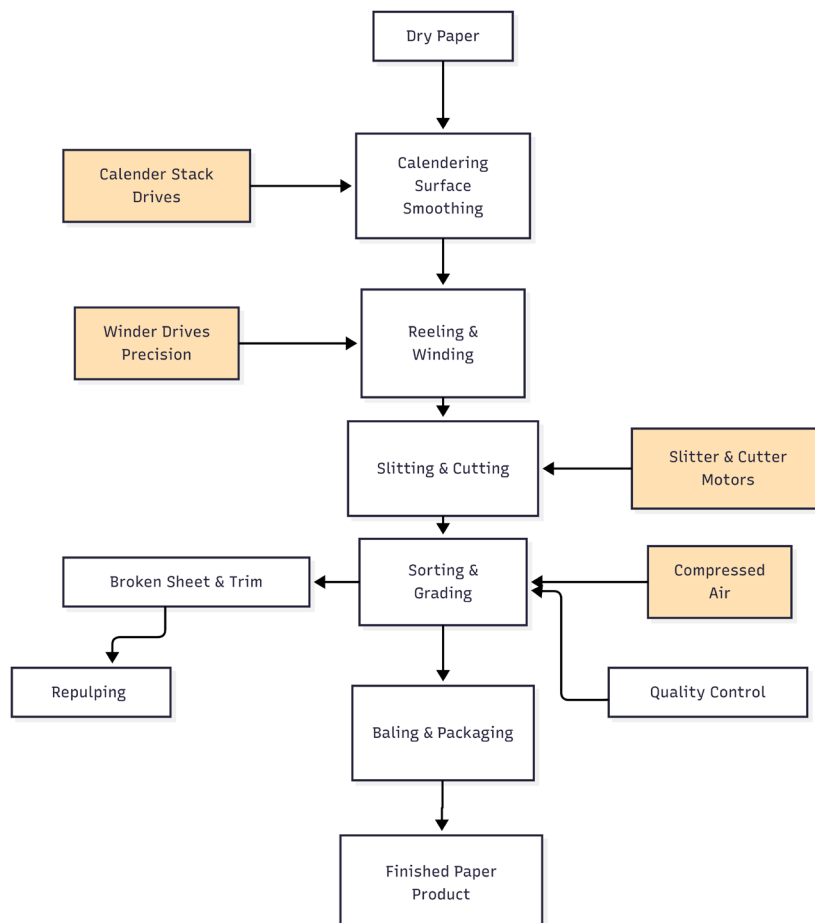
Wet Sheet to Dry Paper: Drying Section

The pressed sheet passes over a series of steam-heated rotating cylinders. This evaporates the remaining water, reducing moisture to the final 4-8%. This is the most thermal energy-intensive stage in the mill, consuming 60-80% of the total steam. The drying process sets the final sheet properties and moisture profile. Efficient heat transfer and condensate removal are critical for energy performance. Theoretical Energy Assessment: This is the primary and most intensive thermal energy sink of the entire manufacturing process, with a relatively moderate auxiliary electrical load for cylinder drives and hood ventilation, making it the most critical area for thermal efficiency interventions and waste heat recovery.



Finishing & Converting Operations

The dry, continuous paper web is smoothed by calendaring rolls, wound onto reels, and then slit or cut into specified sizes and formats. The paper is sorted, graded, and inspected for quality before being baled, wrapped, and packaged for dispatch. This stage adds the final commercial value and format, transforming the paper roll into a market-ready product. Theoretical Energy Assessment: This stage is characterised by moderate electrical energy consumption for precision winding, cutting, and handling drives, alongside a negligible thermal load, classifying it as a tertiary target for efficiency gains through improved motor controls and compressed air system management.



ANNEXURE 6:

LIST OF KEY TECHNOLOGY SUPPLIERS FOR SHORTLISTED TECHNOLOGIES

Gas-fired Furnace with Self recuperative Burner

Company	Location	Contact Details
Encon Thermal Engineers Pvt. Ltd.	Faridabad, Haryana	Address: 297, Sector-21B, Faridabad
Swastik Furnaces Pvt Ltd	Thane, Maharashtra	Address: 229, Vedant Commercial Complex, Vartak Nagar, Thane (W)

Regenerative burners for high-temperature furnaces (medium & large furnaces)

Company	Location	Contact Details
Encon Thermal Engineers Pvt. Ltd.	Faridabad, Haryana	Address: 297, Sector-21B, Faridabad
Swastik Furnaces Pvt Ltd	Kolkata, West Bangal	Wesman Center, 8 Mayfair Road Kolkata 700019, India

Electric Grinder (Replacement of Pneumatic Grinder)

Company	Location	Contact Details
Denn Tech Industries	Coimbatore, Tamil Nadu	Vilankurichi, Coimbatore - 641035, Tamil Nadu, India
Eastman Cast & Forge Ltd	Ludhiana, Punjab	Address: G.T. Road, Near Airport NH-1, Ludhiana, Punjab 141120

Waste Heat Recovery from Dye Effluent

Company	Location	Contact Details
Promethean Energy	Navi Mumbai, Maharashtra	A-451, S Central Rd, MIDC Industrial Area, Mahape, Navi Mumbai, Maharashtra 400710
Alfa Laval India Private Limited	Pune, Maharashtra	Address: India Customer Center, Pune

RDF Fired Boiler

Company	Location	Contact Details
Sitson India Pvt. Ltd.	Dombivli, Maharashtra	Address: W-76, MIDC Phase - II, Dombivli East, Thane
Cheema Boilers Limited (CBL)	Mohali, Punjab	Address: Industrial Plot No. D-188, Phase 8B, Industrial Focal Point, S.A.S. Nagar, Mohali
Enneff Solutions Pvt Ltd	Pune, Maharashtra	Address: PRIVIA BUSINESS CENTER, near RTO, Jal Vayu Vihar, PIMPRI, Pimpri-Chinchwad, Pune, Maharashtra 411070
Industrial Boilers Ltd.	Ahmedabad, Gujarat	227-228, Industrial Township, GIDC, Vapi, Gujarat 396195
Thermax Ltd	Pune, Maharashtra	Address: D-13, MIDC Industrial Area, R. D. Aga Road, Chinchwad, Pune 411019, Maharashtra, India

Micro Turbines

Company	Location	Contact Details
Turbotech Precision Engineering Pvt. Ltd	Bengaluru, Karnataka	Address: Survey No. 8/2, Honnasandra Village, Kasaba Hobli, Nelamangala Taluk,, Bengaluru Rural, Karnataka 562123
Turtle Turbines (P) Ltd.	Pune, Maharashtra	Continuum, Plot No. 2, S.No. 52/5/2, Off Sus Road, Baner, Pune - 411 045 INDIA
Triveni Turbine Ltd.	Noida, Uttar Pradesh	Address: BPTP Capital City, Sector 94, Noida, Uttar Pradesh – 201 301
Industrial Boilers Ltd.	Ahmedabad, Gujarat	227-228, Industrial Township, GIDC, Vapi, Gujarat 396195

Heat Pumps (Low temperature up to 90°C)

Company	Location	Contact Details
Thermax Ltd	Pune, Maharashtra	Address: D-13, MIDC Industrial Area, R. D. Aga Road, Chinchwad, Pune 411019, Maharashtra, India
Armstrong International Private Limited	Chennai, Tamil Nadu	Address: Mahindra World City, P 46, Eighth Avenue, Anjur Village, Natham Sub Post Chengalpattu 603 002 Tamil Nadu.
TRIGeN Decarbonisation Pvt. Ltd	Chennai, Tamil Nadu	Address: D3-2, IITM Research park, Taramani, Chennai - 600113, Tamil Nadu, India.
Promethean Energy	Mumbai, Maharashtra	Address: A-451, S Central Rd, MIDC Industrial Area, Mahape, Navi Mumbai, Maharashtra 400710

A One Insulation (Hot and Cold / Dual Insulation)

Company	Location	Contact Details
A One Insulations	Surat, Gujarat	Address: Shop No. 2, Central Park Shopping Centre, B/s. Decent Restaurant, G.I.D.C., Pandesara, SURAT-394 221
Sheth Insulations Pvt. Ltd	Ahmedabad, Gujarat	Address: 402/ B, opp. Water Tank, nr. Manish Chemicals, Vinoba Bhave Nagar, Dibiyapur, Phase II, Vatva GIDC, Ahmedabad, Gujarat 382445

Low Consistency Refining (LCR)

Company	Location	Contact Details
Valmet Corporation	Gurugram, Haryana	Address: Valmet Technologies Private Limited, 15th Floor, Building No. 9, Tower A, DLF Cybercity, Phase III.
Andritz AG	Chennai, Tamil Nadu	Address: The Lords, Plot No. 1 & 2, (NP), Thiru-Vi-Ka Industrial Estate, Jawaharlal Nehru Road, Ekkatuthangal, Guindy, Chennai
Voith GmbH & Co. KGaA	Faridabad, Haryana	Address: 113/114 A, Sector 24, Faridabad-121005, Haryana, Delhi NCR, India.

IoT in Stenter Machine

Company	Location	Contact Details
Larsen & Toubro Infotech	Mumbai, Maharashtra	Address: L&T House, Ballard Estate, P. O. Box: 278, Mumbai 400 001, India
KPIT Technologies	Pune, Maharashtra	Address: KPIT Technologies Limited. Plot No. 17, Rajiv Gandhi Infotech Park, MIDC SEZPhase-III, Hinjawadi, Tal Man, Sub district Mulshi, Pune, Maharashtra, India, 411057, Phone:
Schneider Electric	Gurugram, Haryana	Address: 15th Floor, Block – 4, DLF Downtown, Sector – 25A, Gurgaon - 122002, Haryana.
Rockwell Automation	New Delhi, Delhi	Address: 131 Functional Industrial Estate New Delhi, Delhi 110092. India.

Hot Water Generation from Chiller and Compressor

Company	Location	Contact Details
Johnson Controls	Pune, Maharashtra	Address: B-2, 3rd Floor, Cerebrum IT Park, Kalyani Nagar, Pune, Maharashtra 411014
Daikin Industries Ltd.	Gurugram, Haryana	Address: Tower A, 12th floor, Building No. 9, DLF Cyber City, DLF Phase 3, Gurugram, Haryana 122002
Trane Technologies	Gurugram, Haryana	Address: DLF Cyber City, Tower A, Building 5, 12th Floor, DLF Phase 2, Sector 24, Gurugram, Haryana 122002.
Carrier Global Corporation	Gurgaon, Haryana	Address: 1st Floor, Pearl Tower, Plot No – 51, Sector – 32, Gurgaon, Haryana – 122001
Voltas Limited	Mumbai, Maharashtra	Address: Voltas House 'A', Dr. Babasaheb Ambedkar Road, Chinchpokli, Mumbai - 400033.
Blue Star Limited	Mumbai, Maharashtra	Address: Bandbox House, 4th Floor, 254 D, Dr Annie Besant Road, Worli, Mumbai - 400 030
Thermax Ltd	Pune, Maharashtra	Address: D-13, MIDC Industrial Area, R. D. Aga Road, Chinchwad, Pune 411019, Maharashtra, India

Fabricated Water Ring Vacuum Pumps

Company	Location	Contact Details
Atlas Copco	Gurugram, Haryana	Address: First Floor, UNITECH BUSINESS PARK, Sector 17-B, Block F, South City I, Sector 41, Gurugram, Haryana
Garuda Pumps Private Limited	Kheda, Gujarat	Address: Survey No. 13, At Village Kuna, Ta, Kheda - Mahemdabad Rd, Mahemdavad, Gujarat 387110
Karshak Industries Private Limited (Kakati Vacuum Pumps & Systems)	Hyderabad, Telangana	Address: Road No 1, IDA Nacharam, Hyderabad, Telangana - 500076, India.
Gardner Denver Engineered Products India Pvt Ltd (NASH Pumps)	Bangalore, Karnataka	Address: #115/3, 4th Floor, M.L. Chambers, 6th Main, Yeshwanthpur Indl Suburb II Stage, Bangalore

Xplate Technology (Xeogenic Plate)

Company	Location	Contact Details
Solpower India Pvt. Ltd	Delhi	Address: D 100, Vikas Marg, Laxmi Nagar, Swasthya Vihar, Delhi, 110092

Pressurised Condensate Recovery System (PCRS)

Company	Location	Contact Details
Thermax Ltd	Pune, Maharashtra	Address: D-13, MIDC Industrial Area, R. D. Aga Road, Chinchwad, Pune 411019, Maharashtra, India
Armstrong International Private Limited	Chennai, Tamil Nadu	Address: Mahindra World City, P 46, Eighth Avenue, Anjur Village, Natham Sub Post Chengalpattu 603 002 Tamil Nadu.
Inveno Engineering LLC	Florida	Inveno Engineering LLC, 16215 Marsilea Place, Unit 320, Naples, Florida 34110
Gardner Denver Engineered Products India Pvt Ltd (NASH Pumps)	Bangalore, Karnataka	Address: #115/3, 4th Floor, M.L. Chambers, 6th Main, Yeshwanthpur Indl Suburb II Stage, Bangalore

**Registered Offices**

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