Forging a Greener Future Together:

DECARBONISING KOLHAPUR'S FOUNDRIES

One Step at a Time

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ABOUT ASAR

Asar Social Impact Advisors is a startup in the environment and social justice impact space with a commitment to building climate resilience and ambitious climate action. We identify challenges and opportunities, research them, verify ground truths, and understand local contexts, in order to build innovative strategies that are rooted in reality. Asar convenes multi-stakeholder conversations and helps build relationships between various key actors to be able to sustain collaborations essential to deliver real-world impact. In this critical decade, implementation is our focus. We believe local ecosystems of motivated climate actors can build resilient models for change ground up.

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EXECUTIVE SUMMARY

India's Micro, Small, and Medium Enterprises (MSMEs) are vital to the nation's economic growth and climate action, contributing over 30% of the GDP, employing more than 110 million people, and accounting for nearly half of India's exports. As global trade regulations become more stringent and energy costs increase, MSMEs face pressure to reduce their carbon footprint while maintaining competitiveness.

Maharashtra, home to the largest number of MSMEs in India, is at the forefront of this transition. The Kolhapur Foundry Cluster comprises over 300 units producing about 600,000 tonnes of castings annually, with nearly a third exported. Its energy-intensive processes make it a crucial area for decarbonisation efforts.

The cluster-based approach for MSME decarbonisation is effective, leveraging geographic concentration for shared infrastructure, technical support, and knowledge transfer. The Kolhapur Foundry Cluster was selected for a pilot due to its industrial output, energy and emission intensity, and export relevance. The pilot study was conducted with three units across 2 industrial estates in the cluster. It involved detailed energy audits, electrical safety audits, carbon footprint estimation (Scope 1 and 2 emissions) with CBAM-readiness assessment, mitigation roadmap development, and technical support for implementation.

The Kolhapur pilot demonstrated a clear roadmap for low-carbon growth and future-readiness through a carbon and energy baseline assessment for the selected units with a detailed report recommending energy efficiency (EE) and renewable energy (RE) solutions. Simple EE measures, such as furnace and transformer optimisation, can bring between 9% to 45% energy savings at no cost with immediate payback periods. Technology upgrades like high-efficiency motors, compressors, and digital monitoring systems offer attractive returns within two years. Given that over 70% of Kolhapur's foundries use induction furnaces, where electricity consumption accounts for up to 96% of emissions, energy efficiency and clean power adoption are critical. While rooftop solar is suboptimal due to operational dust, off-site and ground-mounted solar systems remain viable solutions.

While the pilot indicated significant energy savings potential through energy conservation measures (ECMs) and renewable energy integration, it also yielded crucial learnings for scaled interventions. These included the need for continuous nudging and handholding, finance as a persistent implementation barrier (despite clear business cases), substantial savings potential across multiple dimensions, the critical need for ecosystem alignment, green job creation potential, and business margin enhancement through sustainability.

Decarbonisation is not just a necessity but also a significant opportunity for MSMEs. Cleaner operations result in reduced costs, attract green finance, and prepare businesses for global trade requirements like the EU Carbon Border Adjustment Mechanism (CBAM). The Kolhapur pilot proves that decarbonisation is achievable and scalable within the Kolhapur cluster and other MSME clusters across India. By adopting this model, businesses can cut emissions, enhance their competitiveness in both domestic and global markets, and build a more sustainable and resilient future.

01 INTRODUCTION

India's ambitious climate goals, as outlined in its updated Nationally Determined Contributions (NDCs) and global commitments under the Sustainable Development Goals (SDGs), have placed industrial decarbonisation at the center of the country's development agenda. The industrial sector accounts for the largest share of energy consumption, contributing 42% (MOSPI, 2024) of the country's electricity usage and around 38% (NITI Aayog, n.d.) of total greenhouse gas (GHG) emissions. Simultaneously, the sector remains a vital economic pillar, contributing an estimated 27-30% (MOSPI, 2025) to India's GDP.

Within the industrial sector, Micro, Small, and Medium Enterprises (MSMEs) play a crucial role in driving inclusive economic growth. In 2022–23, MSMEs accounted for over 30% (PIB, 2025) of the national GDP, making them indispensable for employment, manufacturing, and exports. MSMEs are defined under the MSME Development Act of 2006, the enterprises are categorised based on investment in plant, machinery, and turnover thresholds, updated to reflect the changing scale of operations and competitiveness in domestic and global markets. The investment threshold for MSME classification has been raised by 2.5 times, and the turnover limit has been doubled, enabling enterprises to scale operations and access improved resources.

Table 1: Revised MSME classification (Budget 2025-26)

Enterprise	Investment in Plant and Machinery or Equipment		Turnover	
	Old	New	Old	New
Micro Enterprise	Less than INR 1 crores	Less than INR 1 crores	Less than INR 5 crores	Less than INR 10 crores
Small Enterprise	Less than INR 10 crores	Less than INR 10 crores	Less than INR 50 crores	Less than INR 100 crores
Medium Enterprise	Less than INR 50 crores	Less than INR 50 crores	Less than INR 250 crores	Less than INR 500 crores

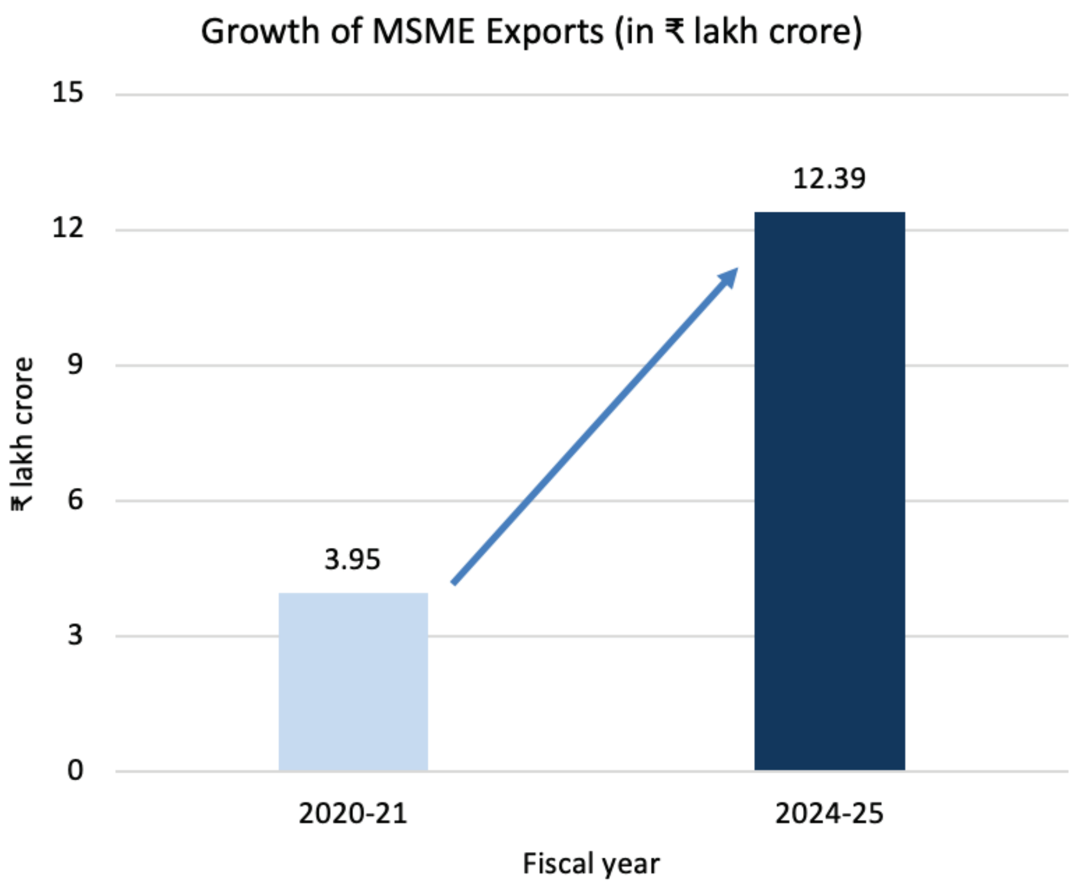
India's MSME sector is the backbone of local economies, contributing nearly 30% to the nation's GDP and employing over 110 million people (Ministry of MSMEs, 2023).

As India progresses toward its climate targets such as reducing emissions intensity of GDP by 45% by 2030 and achieving 50% cumulative electric capacity from non-fossil fuel sources, the decarbonisation of MSMEs becomes both a necessity and an opportunity. In particular, improving energy efficiency, enhancing access to clean technology, facilitating low-carbon industrial processes, and encouraging the uptake of renewable energy are critical enablers. These align closely with various SDG targets, particularly those under Goals 7 (Energy), 9 (Industry, Innovation, and Infrastructure), and 13 (Climate Action), and are essential for building long-term resilience.

1.1 Market advantages through decarbonisation

India's export market has experienced notable growth in recent years, supported by rising global demand, diversification of products, and enhanced trade facilitation. A major contributor to this trend has been the MSME sector, with exports rising sharply from ₹3.95 lakh crore in 2020-21 to ₹12.39 lakh crore in 2024-25. The number of exporting MSMEs has also increased more than threefold, from 52,849 in 2020-21 to 1,73,350 in 2024-25. Their share in India's total exports has steadily climbed, accounting for 43.59% in 2022-23, 45.73% in 2023-24, and 45.79% in 2024-25 (as of May 2024). These figures highlight the sector's growing integration into global value chains and its critical role in positioning India as a key global manufacturing and export hub (PIB, 2025).

Figure 1: Growth of MSME Exports in India (PIB, 2025)



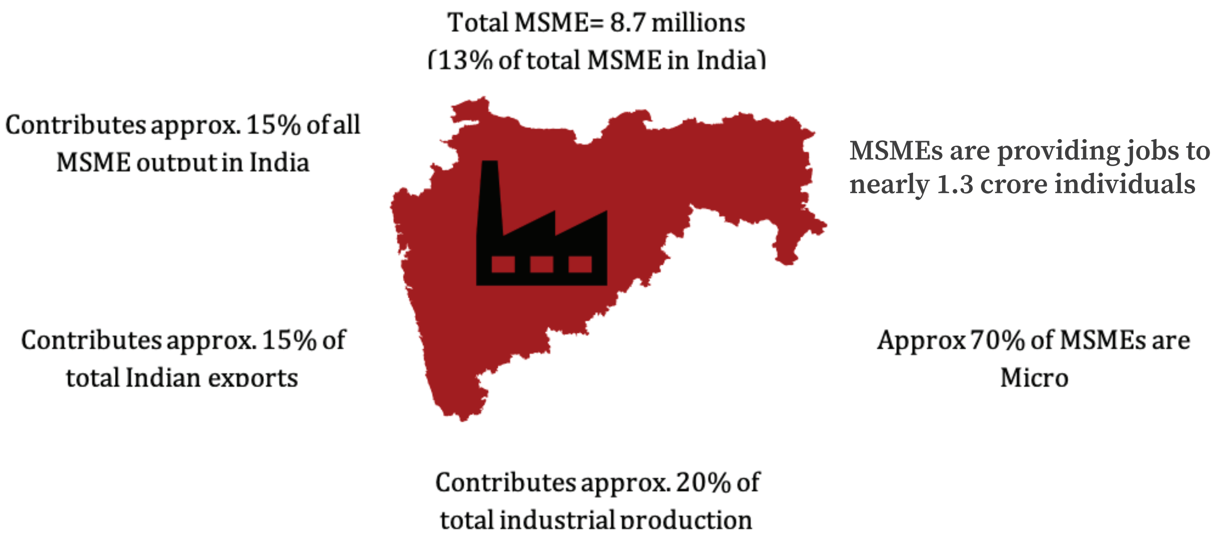
In this expanding export landscape, decarbonisation offers MSMEs not just environmental benefits but tangible value for business continuity. Adopting energy-efficient technologies and renewable energy can significantly lower operational costs, improve reliability, and shield businesses from fossil fuel price volatility. Furthermore, with global markets, especially in Europe, introducing stricter climate regulations like the Carbon Border Adjustment Mechanism (CBAM), the ability to produce low-carbon goods is becoming critical for maintaining and enhancing export competitiveness. For MSMEs, early decarbonisation also opens doors to green finance and government incentives, helping them recover investments faster and build long-term resilience. Thus, in a rapidly growing export ecosystem, decarbonisation emerges as both a compliance imperative and a strategic lever for sustainable growth.

1.2 Maharashtra: A key industrial state with high energy and emission footprint

Maharashtra, one of India's most industrialised and export-oriented states, continued to play a pivotal role in the country's trade performance in FY 2023-24. The state's industrial sector includes various industries such as cement, textiles, pharmaceuticals, agro-based industries, food processing, chemicals, among others. The state recorded exports worth approximately US$67.2 billion (Directorate General of Foreign Trade, n.d.) contributing 15.4% of India's total exports, is India's second-largest exporting state. Maharashtra holds a prominent position in India's industrial and MSME landscape, with substantial contributions to energy consumption, economic output, and employment.

As per the State Energy Efficiency Index (SEEI), the state's Total Final Energy Consumption (TFEC) for the year 2021–22 stood at 35.89 million tons of oil equivalent (MTOE), accounting for approximately 10% of the national TFEC. The industrial sector is a major consumer of electricity, has utilised 70,914 GWh in 2022–23, which represents 42.3% of the state's total electricity consumption (CEA, 2024).

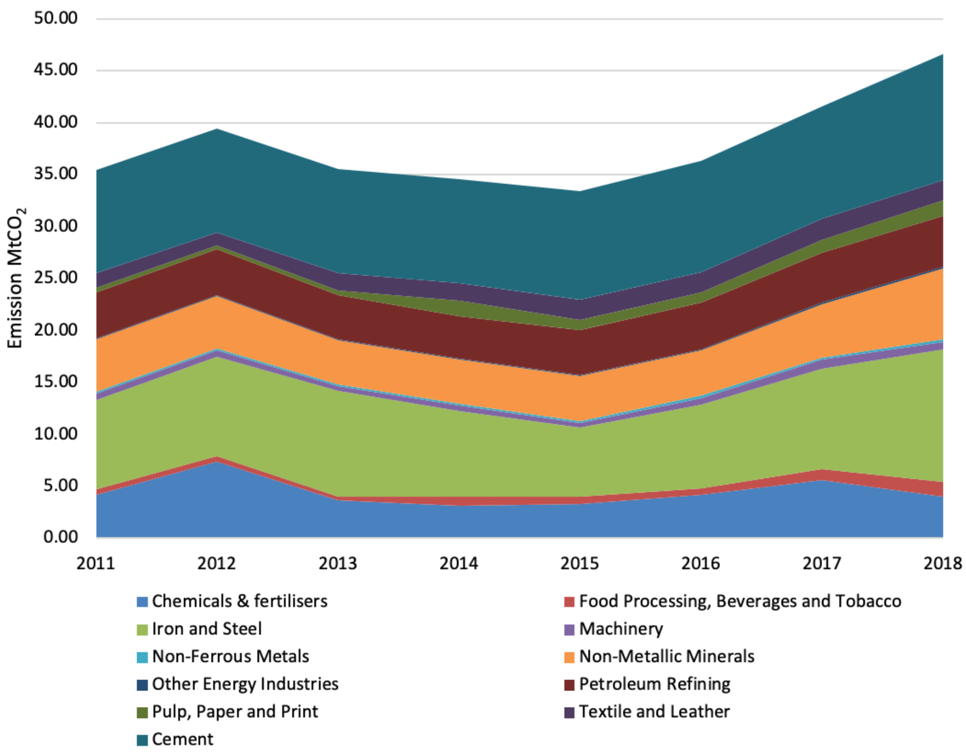
Figure 2: Overall MSME scenario in Maharashtra



In economic terms, Maharashtra reported a Gross State Domestic Product (GSDP) of ₹36.45 lakh crore for the financial year 2022–23. The state is home to 47.78 lakh Micro, Small and Medium Enterprises (MSMEs), the fourth highest in the country. These enterprises provide employment to 90.77 lakh individuals, also the fourth highest nationally (RBI, 2024). Maharashtra is presently home to the largest number of MSMEs in India, with approximately 8.7 million Udyam-registered units representing around 13% of the country's total MSMEs across India (Ministry of MSMEs, n.d.)

The energy intensive sectors have high emissions intensity because of their use of fossil fuels. According to the Maharashtra State Action Plan on Climate Change (MH SAPCC) 2.0, Maharashtra has witnessed an 80% rise in emission over the last fifteen years, reaching 290 MtCO2 in 2020. The energy sector accounts for the largest share (approximately 82.13%) in the state's total GHG emissions. The total CO2 emissions are estimated to rise from 203 MtCO2 to 256 MtCO2 from 2020 to 2030, a 26% increase. The industry sector accounts for 17% of these GHG emissions. Over the next decade (2020-2030), industry sector energy demand is projected to increase by 1.7 times, resulting in an increase in the total emissions from about 43.66 MtCO2 in 2020 to 72.96 MtCO2 in 2030 (Government of Maharashtra, 2025). Iron & steel is the largest industrial emitting sector. Iron & steel sector witnessed a steep growth since Covid-19. Total emission in 2021-22 was 21.2 MtCO2. Cement sector is the second largest emitting industrial sector.

Figure 3: CO2 emissions across different industries in Maharashtra (GHG Platform India, n.d.)



1.3 Sub-National target related to energy and emission reduction

Maharashtra has laid out robust sub-national targets to reduce industrial energy consumption and emissions, as detailed in the State Action Plan on Climate Change (SAPCC), State Energy Efficiency Action Plan (SEEAP), and the BEE UNNATEE Report. The SAPCC outlines a strategic push toward low-carbon industrial development through measures such as preferential plot allotment to green industries, adoption of Best Available Techniques (BAT), and establishment of a green hydrogen hub targeting 0.5 GW electrolyser capacity and 0.5 MTPA green hydrogen production by 2030. It also promotes green belt development around industrial zones and aims for a 30% renewable energy share in Effluent and Sewage Treatment Plants (ETPs and STPs) by 2030. In parallel, the SEEAP estimates energy savings of 6.51 MTOE (moderate) to 7.91 MTOE (ambitious) (Government of Maharashtra, 2020) in the industrial sector, through various strategies like Deepening & Widening of PAT Scheme, MSME decarbonisation through cluster approach, and Green Hydrogen, while the BEE UNNATEE report projects an even higher saving potential of 8.1 MTOE (BEE, 2019). These integrated strategies reflect Maharashtra's commitment to decarbonising industry while enhancing energy efficiency and aligning with national climate goals.

02 CLUSTER CONTEXT AND OPPORTUNITY

2.1 Cluster Approach

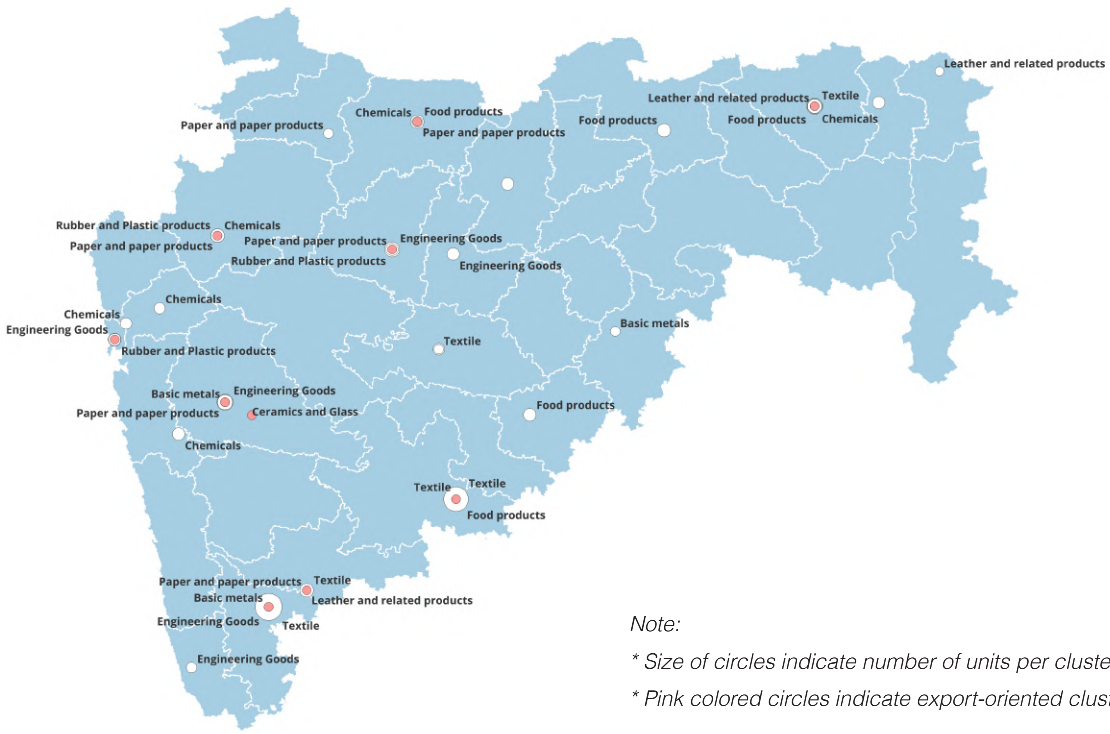
MSMEs fall within the domain of states in India's federal framework under the constitution. "Industries" are included in the legislative and executive domains of the states. A sub-national and cluster-based approach is therefore adopted to address the decarbonisation of MSMEs and the associated up-skilling and reskilling efforts as part of this program. A cluster-based strategy for benchmarking the industries and facilitating the energy efficiency interventions will have a high energy saving potential.

Clusters refer to geographically concentrated groups of micro and small enterprises that share common production technologies, supply chains, markets, and labor pools (UNIDO, 2016). These clusters typically arise organically and are often rooted in traditional skills, craft practices, or local resource advantages. According to the Ministry of MSME's Cluster Development Programme, clusters can range from artisan-based units to informal manufacturing hubs and industrial micro zones (UNIDO, 2015).

2.2 Energy Intensive & Export Oriented Sectors in Maharashtra

Maharashtra is one of the most industrialised states in the country. The State has identified industrial sectors like Auto, Engineering, Electronics, Textile and Defense as focus sectors considering the national and international trends and potential of the resources in the State.

Figure 4: Spread of MSME clusters in Maharashtra
(Office of Development Commissioner, Ministry of MSMEs, n.d.)



Note:

* *Size of circles indicate number of units per cluster*

* *Pink colored circles indicate export-oriented clusters*

Basic Metals contribute the highest share to the state's industrial output as shown in the graph below.

Figure 5: Share of industries contribution in % (Annual Survey of Industries)

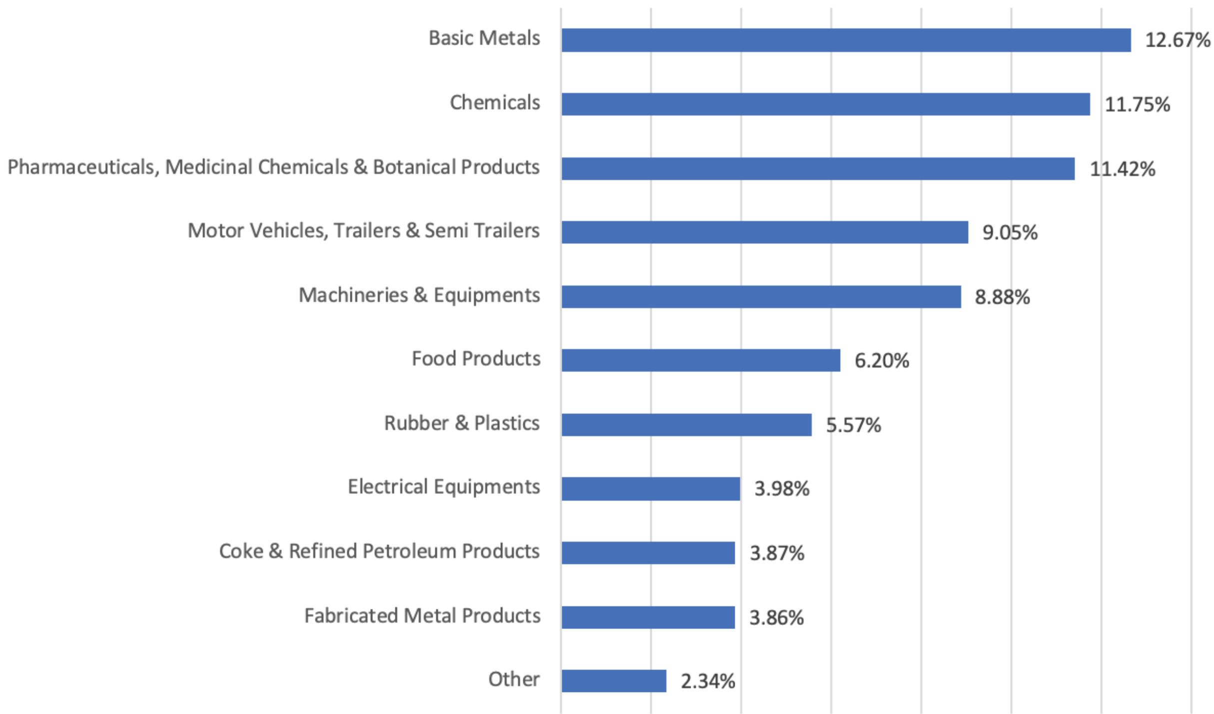
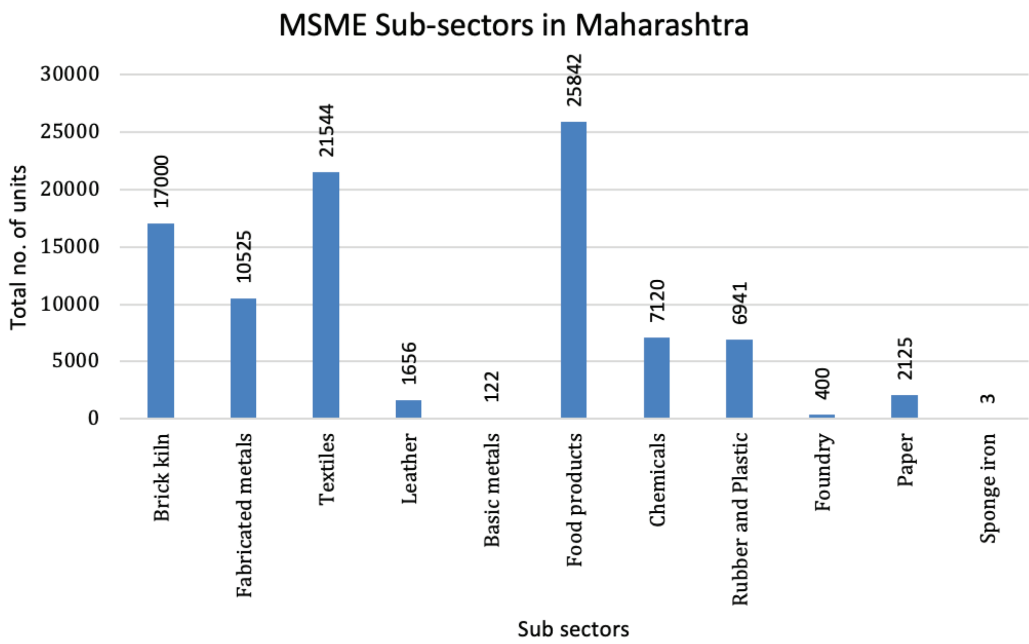
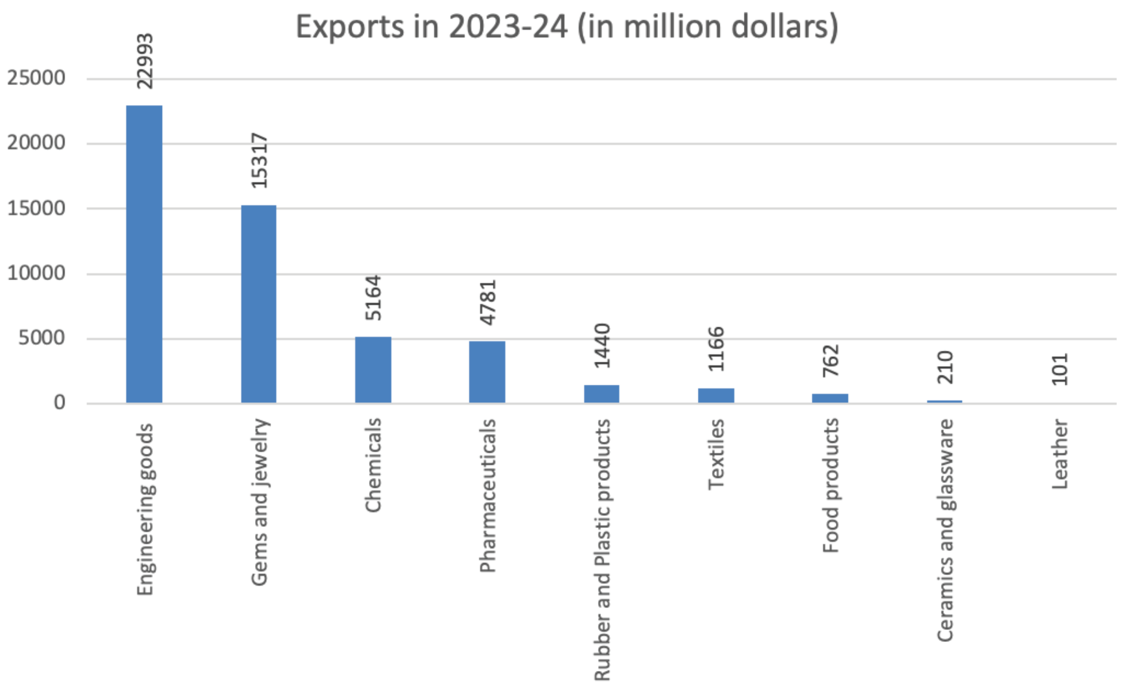


Figure 6: MSME Sub-sectors in Maharashtra (Development Commissioner MSME, n.d.)



The state has exported products worth of Rs. 5,76,970 crores in 2023-24 which is around 15% of total export from India. Engineering goods constitute the largest share (35%) of exports in terms of value (approximately Rs. 2 lakh crores).

Figure 7: Sector wise exports in 2023-24 (Directorate General of Foreign Trade, n.d.)



2.3 Identification of Foundry Cluster in Kolhapur

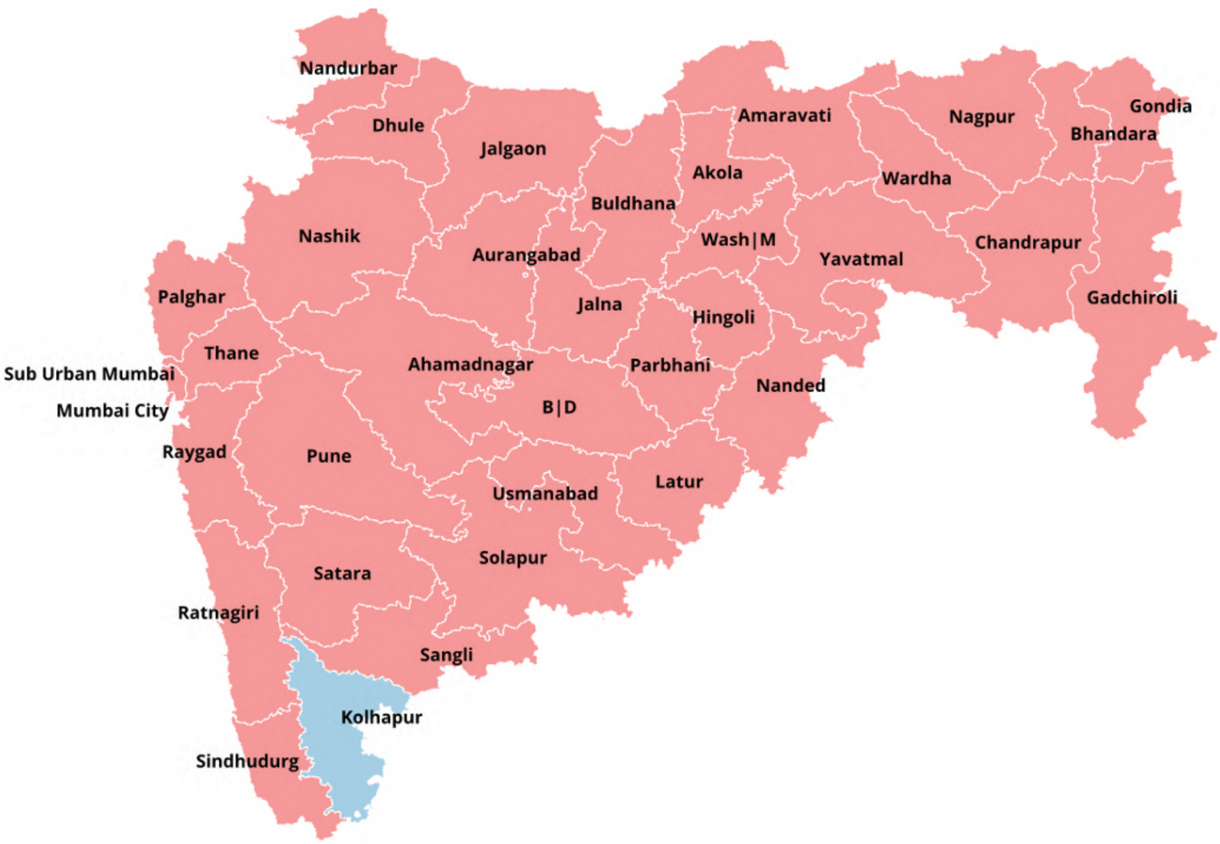
The identification of Foundry Cluster for decarbonisation in Kolhapur, Maharashtra follows a multi-dimensional approach. Key parameters considered include industrial output, energy and emission intensity, export market relevance. According to the State Energy Efficiency Action Plan (SEEAP) of Maharashtra, the estimated energy saving potential for Kolhapur Foundry Cluster by 2031 is 0.066 MTOE in the moderate scenario and 0.088 MTOE in the ambitious scenario.

The foundry sector is a crucial part of India's industrial landscape, particularly within the Micro, Small, and Medium Enterprises (MSMEs). Foundries manufacture various types of metal castings. The castings are used in different industries such as automobiles, railways, pumps, compressors and valves, diesel engines, cement, textile machinery, sanitary pipes and fittings, power generation, construction, etc. The foundry sector is inherently energy-intensive due to processes such as metal melting, heat treatment, and core baking. These processes consume substantial amounts of electricity and thermal energy, making them ripe for energy efficiency improvements and cleaner fuel alternatives.

India stands as the second-largest producer in the global foundry industry, with an annual production exceeding 12 million tonnes. The sector is estimated to have annual revenue exceeding USD 20 billion, a significant part of it coming from exports. The sector is a major contributor to the nation's greenhouse gas (GHG) emissions, accounting for approximately 15% of emissions from the metals value chain, which includes mining, steel, and aluminium production, as well as casting, forging, and foundry operations. There are approximately 4,500 foundry units in the country out of which 90% can be classified as small-scale units, 8% as medium-scale units, and 2% as large-scale units. The foundry industry is dispersed across various geographical clusters, of which the Kolhapur cluster is one of the major ones.

Kolhapur is one of the fastest-growing cities in Maharashtra and is one of the highest per capita income cities in India. The city is a hub for industry, comprising over 1000 energy-intensive industries covering different sectors. These industries comprise mainly of automotive, foundries, engineering spares, sugar industries, and textile mills. There are nine industrial estates in Kolhapur, of which three are Maharashtra Industrial Development Corporations (MIDC) and six are corporate industrial estates.

Figure 8: Map of Maharashtra with highlighted area for pilot project



The Kolhapur Foundry Cluster stands as a critical hub within India's metallurgical landscape, comprising over 300 foundry units with an annual casting output of approximately 600,000 tonnes. The cluster predominantly serves the automotive, agriculture, and heavy machinery sectors, with nearly 30% of its production exported to regions such as Europe, Southeast Asia, and the Middle East.

A technical illustration of the manufacturing process of a typical foundry unit in the Kolhapur cluster is presented below:

Figure 9: Typical manufacturing process of a foundry *(Source: VSL Prayag)*

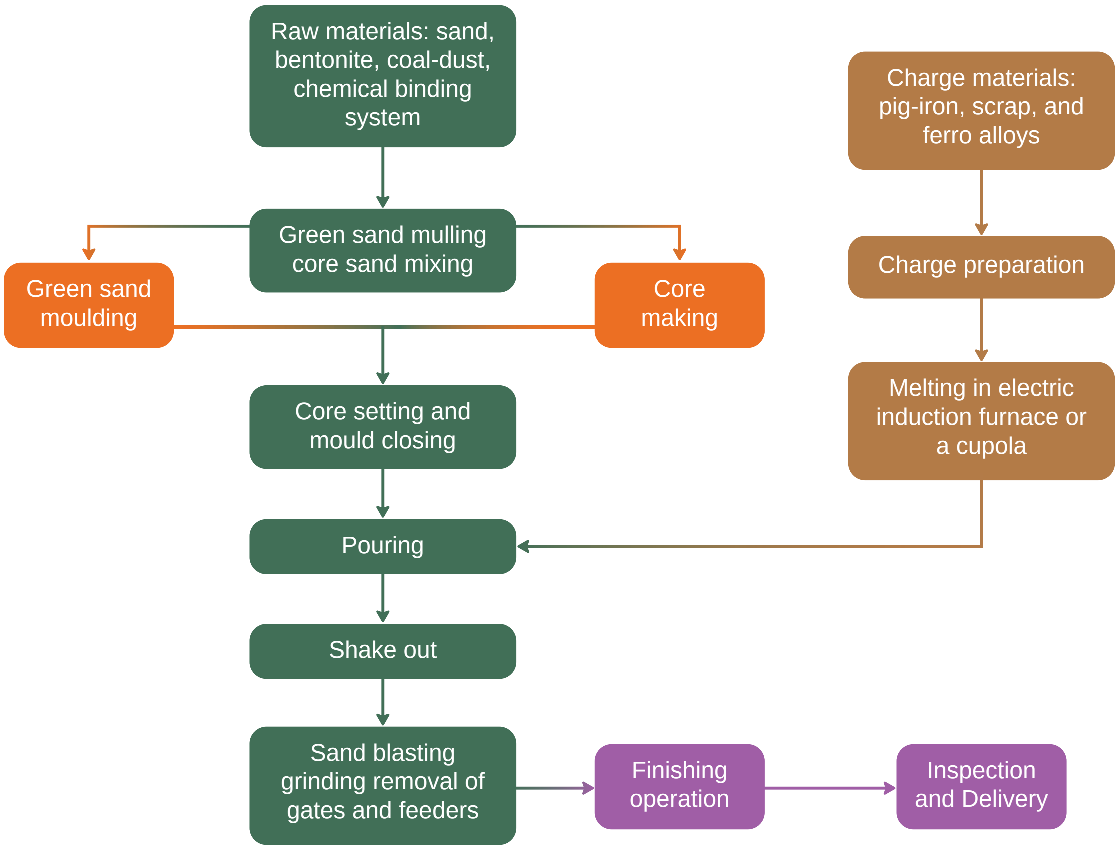


Figure 10: Sand mould preparation in foundry

Figure 11: Charge material preparation for melting

03 PILOT APPROACH

3.1 Selection of Foundry Units

Kolhapur foundries use the conventional sand-casting production method which involves several processes such as preparation, melting, and finishing. The processes are highly energy consuming and energy intensive. Approximately 300 foundry units are estimated to be located in the Kolhapur and Sangli districts of the region. Out of the 300 foundries present in and around Kolhapur, about 250–275 units are present in the Kolhapur district and 20–25 units in the Sangli district. While units in Sangli are located mainly in the Miraj and Palus industrial areas, foundries in the Kolhapur district are spread across eight major industrial estates namely, Kolhapur city, Shiroli MIDC, Gokul Shirgaon MIDC, Kagal 5-star MIDC, Ichalkaranji industrial estate, Jaisingpur industrial area, Laxmi industrial area, and Hatkanagale industrial area (TERI, 2012).

Based on diversity in size, scale and mode of operations, the following 3 (three) units were shortlisted for the pilot study.

1. **M/s. MAHALAXMI FERRO CAST PVT LTD, Kagal 5-Star MIDC**
2. **M/s. RAMKRISHNA FOUNDRY PVT LTD, Kagal 5-Star MIDC**
3. **M/s. KOHINOOR METALLICS, Shiroli MIDC**

Figure 12: Map of Kolhapur with highlighted project foundry units

Figure 13: Three pilot foundry units studied under the decarbonisation programme

Table 2: Profile of the foundry units (at the time of the study)

Unit Details	Ramkrishna Foundry	Mahalaxmi Ferro Cast	Kohinoor Metallics
Installed capacity	1000 MT/month	550 MT/month	450 MT/month
Casting weight range	1 kg to 60 kg	0.2 kg to 100 kg	0.5 kg to 85 kg

3.2 Framework for Pilot

This pilot project presents a decarbonisation strategy for a small selection of MSME foundries in Kolhapur, Maharashtra, addressing both energy efficiency and decarbonisation. The pilot adopted a two-pronged approach - with detailed assessments for energy and carbon - for the selected units. Broadly, the energy assessments included comprehensive energy audits and renewable energy feasibility assessments and the carbon assessments included Scope 1 & 2 GHG inventorying and CBAM readiness assessment for the units.

1. Integrated assessment for operational improvements including Energy Audit:

A detailed energy audit was undertaken in three foundry units to assess energy-saving opportunities and develop techno-economic feasibility reports. The assessment involved performance evaluations in selected operational areas using advanced energy audit instruments.

2. Conduct of Electrical Safety Audit:

A comprehensive Electrical Safety Audit was conducted across the foundries' electrical infrastructure, encompassing panel rooms, distribution boards (DBs), and associated systems. The audit was carried out in accordance with IEC, NFPA, NEC, and State Electrical Inspectorate standards and best practices. Additionally, a Thermal Imaging Inspection compliant with NETA standards was performed to identify safety risks and recommend measures to enhance reliability and energy efficiency.

3. Estimation of Carbon Footprint (Scope 1 and 2 Emissions) & Assessment of CBAM-Readiness:

An extensive assessment of carbon emissions study was conducted at the facility level, covering Scope 1 (direct) and Scope 2 (indirect) emissions. The evaluation also comprised a product-level CBAM readiness assessment ensuring alignment with international carbon accounting frameworks, particularly the European Union's Carbon Border Adjustment Mechanism (CBAM) requirements.

4. Mitigation Roadmap & Feasibility Analysis:

A structured decarbonisation roadmap was developed, outlining short-, medium-, and long-term interventions. The roadmap balances cost-effectiveness with regulatory compliance, providing a strategic pathway for reducing carbon emissions.

5. Implementation Support:

The pilot project includes hands-on technical support for implementing energy efficiency measures, renewable energy technologies, and other decarbonisation interventions. This phase also encompasses third-party verification of emission reductions achieved.

6. Scalability for MSMEs:

The pilot initiative is designed to serve as a replicable model for other foundries and MSME units, contributing to enhanced industrial competitiveness and export readiness while reducing sectoral specific energy consumption (SEC) and with it, its carbon intensity.

Figure 14: Typical framework for pilot project

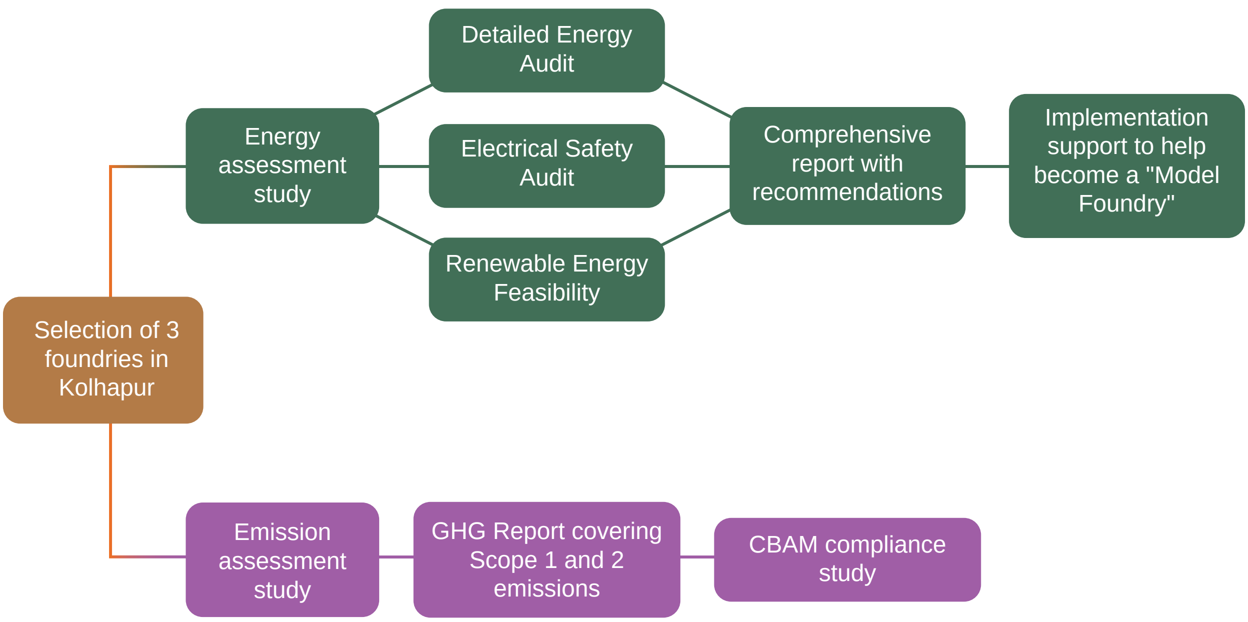


Figure 15: Energy audit being conducted as part of the decarbonisation pilot

3.3 Renewable Energy Integration Analysis: Solar Feasibility

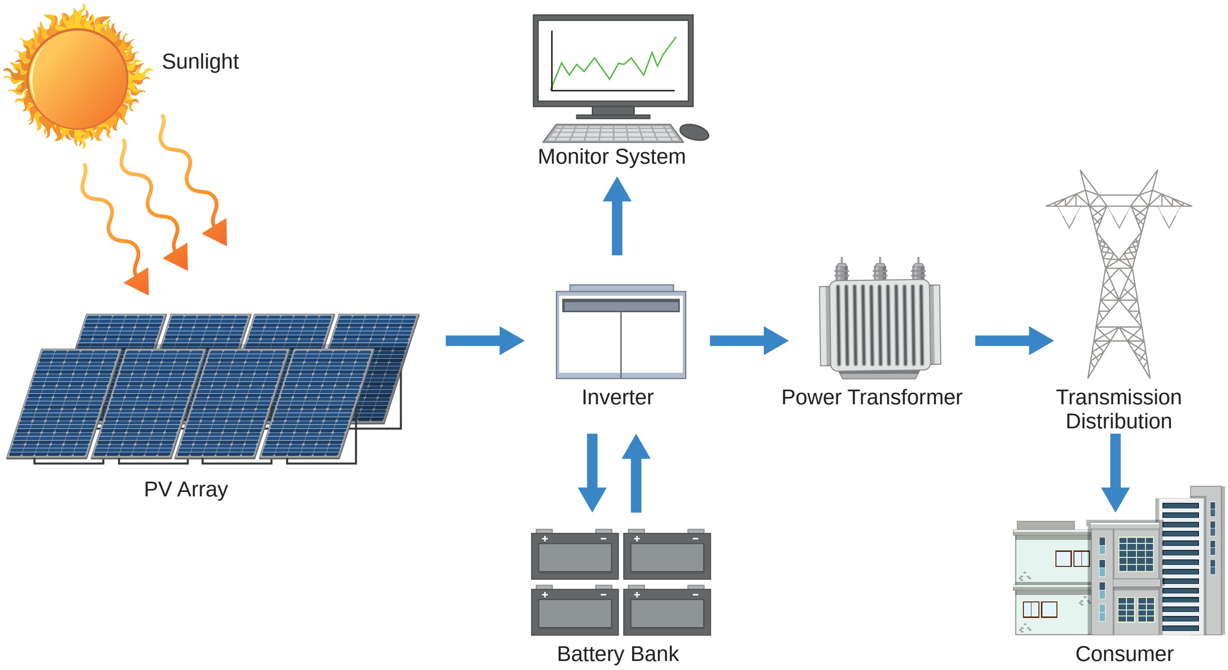
As part of the effort to enable low-carbon transitions in the foundry sector, a renewable energy feasibility analysis was conducted for the selected foundry units. The solar feasibility matrices were developed to evaluate the technical potential and operational suitability of solar photovoltaic (PV) systems, with a focus on reducing dependence on grid electricity and mitigating carbon emissions.

The analysis considered multiple factors, including average energy consumption patterns, available rooftop space, solar radiation potential, production schedules, and alignment with ongoing energy efficiency measures. The recommended solar capacities were intended to complement energy conservation efforts by offsetting a portion of the units' power demand through renewable sources.

However, rooftop solar integration was found to be unfeasible across all assessed units due to one significant operational barrier: high levels of industrial dust and particulate matter. The nature of foundry operations, particularly those using sand casting methods, generate considerable airborne dust, which leads to the frequent soiling of solar panels. This not only reduces the efficiency and energy yield of the PV systems but also increases the frequency of maintenance and associated costs, compromising the overall viability of rooftop installations.

Given these constraints, the analysis recommends considering off-site solar procurement through open access and potential for solar power pooling, wherein a group of foundries can pool together and set up a larger, ground-mounted solar power plant enabling mutual benefits for all stakeholders.

Figure 16: Typical solar power system



04 KEY FINDINGS

4.1 Energy Conservation Measures

In the context of energy assessment studies, the integration of Key Performance Indicators (KPIs) is essential to ensure a systematic and data-driven evaluation of energy performance across industrial operations. KPIs serve as quantifiable metrics that facilitate the identification of inefficiencies, benchmarking of operational performance, and formulation of targeted energy conservation measures (ECMs).

Benchmarking and Diagnostic Analysis:

KPIs such as Specific Energy Consumption (SEC) and Total Effective Equipment Performance (TEEP) provide reference points to benchmark existing energy usage patterns against industry norms or historical baselines. This enables the identification of energy-intensive processes and helps prioritise areas for in-depth assessment.

Facilitating Targeted Energy Interventions:

Operational KPIs, including Process Yield, Overall Equipment Effectiveness (OEE), and resource-related indicators such as sand consumption offer critical insights into process inefficiencies that influence energy demand. Lower productivity, excessive rework, or high material consumption often correlates with increased energy usage, thus presenting opportunities for targeted improvements.

Insights:

The feasibility of the suggested energy conservation measures (ECMs) was assessed on parameters: Energy Saving Potential (w.r.t their current baselines), Investment Cost (low being anything less than INR 2 lakhs and high being anything more than 10 lakhs), and Payback Period. The scope for implementing each of the identified ECMs for the foundry cluster was tabulated in the form of a feasibility matrix, shown in the following table.

Table 3: List of Potential ECMs with feasibility matrix

List of Potential ECMs	Energy Savings Potential	Investment Cost	Payback Period
Optimisation through Energy Management	7-9%	Nil	Immediate
Industrial Internet Of Things (IIOT) Energy Monitoring Systems (EMS)	10-20%	High	<18 months
Optimisation of Specific Energy Consumption (Furnace & Auxilliaries) through Best Practices	35-45%	Nil	Immediate
Reduction of Furnace losses	5-10%	Low	<6 months
Optimisation of Energy Consumption of Compressed Air System	10-15%	Medium to High	<12 months
Pump operational optimisation	2-6%	Low to Medium	<18 months
Intelligent Motor Efficiency Controllers	3-7%	Medium	<12 months
Energy efficient motors	4-8%	Medium to High	<24 months

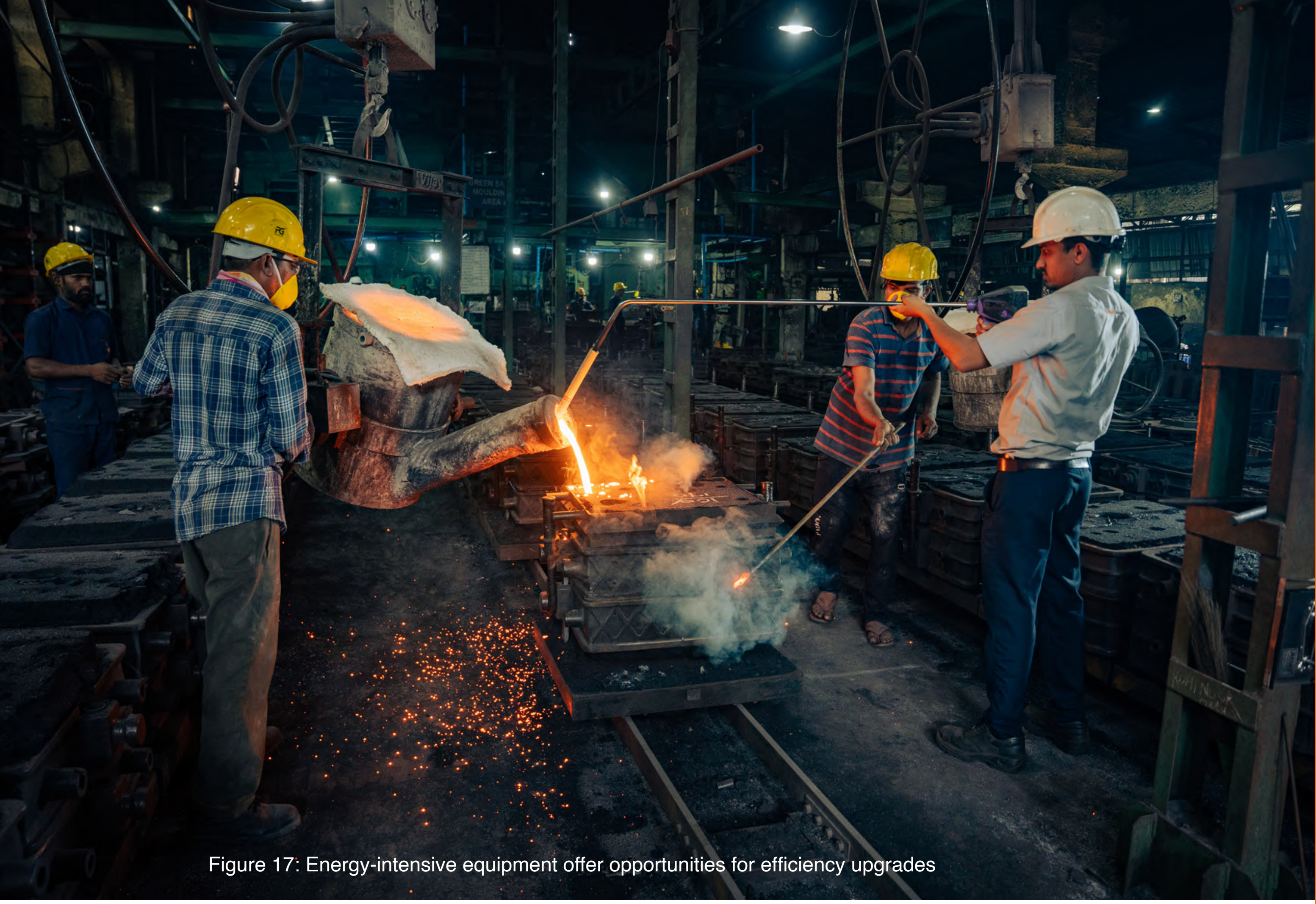


Figure 17: Energy-intensive equipment offer opportunities for efficiency upgrades

4.2 Renewable Energy Integration

As part of the renewable energy integration strategy, all foundry units were assessed for the feasibility of solar power adoption. The recommended solar plant capacities for each unit were determined by evaluating key parameters such as annual electricity consumption, local solar radiation availability, production patterns, and the impact of existing or proposed energy efficiency interventions.

The table below outlines the proposed solar plant capacities along with estimated annual solar energy generation, indicative project costs, projected annual financial savings, and the corresponding payback periods. These recommendations aim to support long-term energy cost reduction and enhance the sustainability of operations through clean energy adoption.

Table 4: Potential for Renewable Energy

RE Potential	Potential Capacity	Investment Cost	Emissions Avoided/ Offset Potential	Payback Period
Installation of Solar PV System	1.5-3 MW	High	High	<5 Years

4.3 Green House Gas (GHG) Baseline

The GHG assessment conducted as part of the pilot focused on two primary emission categories: Scope 1 and Scope 2, in alignment with the GHG Protocol.

Scope 1 Emissions: Direct On-site Fuel Combustion

Scope 1 emissions refer to direct greenhouse gas emissions from sources owned or controlled by the facility. In the context of the pilot foundry units, these emissions primarily arise from the combustion of fossil fuels such as coal, furnace oil, and LPG used in the melting furnaces, heat treatment equipment, and other thermal processes. Melting operations were the most emission-intensive activity under this category, contributing to the majority of the direct emissions across all units.

Scope 2 Emissions: Indirect Emissions from Electricity Use

Scope 2 emissions account for indirect GHG emissions associated with the purchase and use of electricity from the grid. These emissions are not produced on-site but are a consequence of electricity generation at the utility level. In the pilot units, major contributors to Scope 2 emissions included induction melting furnaces, air compressors, pumps, and lighting systems. The emission intensity under this category varied based on the units' operating hours and their dependency on grid-supplied power.

GHG inventory study conducted in alignment with the GHG Protocol and principles of the Kyoto Protocol. The GHG assessment shows that electricity use (Scope 2) is the dominant source of emissions in the pilot foundries, while Scope 1 sources such as diesel, LPG, and furnace oil contribute a smaller share. This means electricity use, especially for melting and other equipment, is the main driver of emissions in these units. The following table presents the Scope 1 and Scope 2 emission baselines estimated for the three pilot foundries

Table 5: Estimated GHG emissions distribution

Parameters	List of attributes	Estimated Emission (%)
Scope 1	Diesel/ CO2/ LPG/ GPC/ Company-owned car/ Fire extinguisher/ Refrigerant	4-10%
Scope 2	Grid Electricity	90-96%

Figure 18: Electricity-driven induction furnace melting - the dominant source of emissions

4.4 CBAM-Readiness

The European Union's Carbon Border Adjustment Mechanism (CBAM) is reshaping global trade by pricing the carbon emissions embedded in carbon-intensive imports like iron and steel. For Maharashtra's foundry and steel exporters, this directly affects cost competitiveness in EU markets. Exporters will need transparent and verifiable data on carbon intensity, aligned with EU ETS methodologies and emerging domestic frameworks such as India's Green Steel Taxonomy (≤ ~2.2 tonnes CO_2/tonne steel for low-carbon benchmarks).

This pilot study with the three units showed that the units are still in the early stages of CBAM readiness. While awareness exists, structured carbon accounting remains limited, particularly since many smaller units lack organised or digital records. To address this, training sessions were held, and data collection tools were simplified. Foundries were supported in translating their basic energy and material use including electricity, fuels, and furnace-level operations into CBAM-compatible product-level intensity values. This exercise showed that with the right technical guidance, even smaller units can begin building compliance systems.

The assessment highlighted that electricity use in induction furnaces is the dominant source of emissions, with diesel, LPG, and furnace oil contributing comparatively less. Therefore, the most effective strategies for CBAM preparedness lie in adopting renewable electricity and improving energy efficiency.

Beyond compliance risks, CBAM also signals a market opportunity. Global buyers, including Tier-1 suppliers, are demanding emissions data across supply chains, which means that even non-exporters must respond. Early adopters who invest in monitoring, reporting, and verification (MRV) systems, and in clean energy solutions, will be better positioned to maintain competitiveness, access new markets, and enhance their reputation as part of a forward-looking, low-carbon manufacturing hub.

4.5 Key learnings from the Pilot

The hands-on experience of initiating decarbonisation interventions across the three foundry units in Kolhapur has yielded crucial insights that can inform both the design of scaled interventions as well as the broader approach to MSME transitions. These learnings highlight the gap between the technical potential for energy and emissions reductions and practical implementation while identifying the enabling conditions to trigger a successful cluster-level transition.

1. Need for Continuous Nudging and Handholding - Reality of Implementation

Despite strong initial interest and compelling business cases, foundry units require sustained technical handholding throughout the implementation process. The transition from energy audit recommendations to actual equipment upgrades and operational changes involves multiple decision points where enterprises benefit from expert guidance and reassurance which are grounded in their unique enterprise-level contexts. This includes the stage at which their respective businesses are in terms of growth, their respective goals and ambitions. The pilot experience demonstrates that knowledge transfer alone is insufficient; foundries need accompaniment through procurement decisions, technology selection, contractor management, and performance monitoring. While isolated assessments are valuable, this validates the need for the creation of a sustained support infrastructure to go all the way. This finding underscores the importance of an ecosystem approach, where ongoing technical support is embedded within the cluster transformation model rather than treated as a one-time intervention.

2. Finance as a Persistent Implementation Barrier - Capital Access Constraints

While foundries recognise the economic benefits of energy efficiency investments, access to appropriate financing remains the primary implementation bottleneck. Traditional lending approaches struggle to assess the risks and returns of energy efficiency projects, particularly for smaller enterprises with limited collateral and financial documentation. The pilot foundries, despite having clear payback periods of less than 2 years for almost all the interventions, face challenges in securing financing at appropriate terms and timelines. Catalytic capital mechanisms and risk-sharing instruments could potentially bridge this financing gap while building demonstration effects for mainstream financial institutions. This learning reinforces the need to integrate blended finance approaches and partner with development finance institutions like SIDBI, for example.

3. Substantial Savings Potential Across Multiple Dimensions - Multi-faceted Value Creation

The pilot assessments reveal energy saving potentials ranging around 30% through furnace optimisation alone, with additional opportunities across multiple operational areas. Beyond direct energy cost reductions, foundries benefit from improved process reliability, reduced maintenance requirements, and enhanced product quality. These compounded benefits create compelling business cases that extend beyond simple energy cost calculations. This learning establishes that decarbonisation interventions have the potential to deliver immediate operational benefits while building long-term competitiveness.

4. Critical Need for Ecosystem Alignment - Coordinated Stakeholder Engagement

Successful implementation requires alignment across multiple stakeholder groups primarily including foundry owners along with policymakers, financial institutions, technology as well as service providers, and regulatory authorities. Aligned expectations and processes can significantly accelerate implementation by leveraging the technical and economic feasibilities of decarbonisation. Creating a shared understanding of the objectives of such interventions, implementation timelines and performance indicators across all stakeholders will be a crucial enable of scaling this transition.

5. Green Jobs Creation Potential - Employment Expansion Opportunities

The implementation of energy management systems, renewable energy installations, and advanced monitoring technologies creates new employment categories within the foundry sector. These include opportunities for energy auditors, EMS operators, solar system maintenance technicians, and carbon accounting specialists. The cluster-based approach amplifies this local job creation potential by creating sufficient market demand to support specialised service providers as well.

6. Business Margin Enhancement Through Sustainability - Core Economic Logic

For energy and carbon-intensive industries like foundries, decarbonisation fundamentally equals margin improvement. The pilot demonstrates that energy efficiency measures and renewable power adoption could directly translate to enhanced profitability while simultaneously addressing environmental objectives.

This insight reveals that decarbonisation should be positioned as much as a business optimisation strategy as it is an environmental compliance requirement. The foundries' positive response to interventions framed as cost reduction and operational improvement validates this approach and suggests that sustainability messaging should emphasise economic benefits alongside environmental outcomes. Successful MSME decarbonisation requires integrated approaches that address technical, financial, and institutional barriers simultaneously.

05 DECARBONISATION MODEL

The Kolhapur foundry cluster decarbonisation pilot aimed to understand the buy-in and feasibility of a collaborative, ecosystem-driven approach towards decarbonisation that addresses the unique challenges faced by MSMEs in India's manufacturing landscape.

5.1 Ecosystem-Driven Approach

The decarbonisation model emerging from the Kolhapur experience highlights the critical need for an ecosystem approach that goes beyond individual unit interventions. This pilot revealed that foundry MSMEs in the cluster, the smaller units in particular, face common and interconnected barriers including limited access to capital, gaps in technical expertise, and insufficient knowledge of sustainability frameworks. The pilot experience underscores that addressing these challenges requires coordinated action across multiple stakeholders including foundries, government departments, financial institutions, and civil society organisations.

The model's potential strength lies in its ability to create collective action mechanisms that reduce individual adoption costs while building shared technical capacity. As observed in the pilot, foundries would benefit significantly from shared learnings, joint problem-solving, and aggregated demand for technical services.

5.2 Financial Integration and Blended Finance

The pilot experience highlights the essential role of financial mechanism integration in enabling MSME transitions. The model demonstrates how targeted interventions can prepare foundries for subsequent investment in energy efficiency and renewable energy technologies through separate funding mechanisms. This staged approach aligns with SIDBI's expanding green finance portfolio, which has achieved 168% growth in green loans (during FY2022) and supports MSMEs through schemes like the Decarbonisation Challenge Fund and various international credit lines.

The ecosystem approach facilitates access to blended finance options by creating bankable projects through comprehensive baseline assessments and capacity building. This addresses the critical financing gap identified in MSME decarbonisation, where traditional lending approaches struggle to assess risks and returns in sustainability projects.

5.3 CBAM Readiness Integration

A key differentiator of the Kolhapur model is its integration of Carbon Border Adjustment Mechanism (CBAM) compliance support. Given that CBAM will impose at least 15-30% additional costs on metal exports unless low-carbon production is demonstrated, the model's focus on GHG inventory development and emissions tracking provides immediate market relevance. For foundries in the Kolhapur cluster, where 25-30% of production is exported to Europe, this compliance capability represents a critical competitive advantage.

The pilot's comprehensive approach to Scope 1 and 2 emissions assessment coupled with comprehensive energy audits creates the data foundation necessary for CBAM reporting while building internal capacity for ongoing emissions monitoring. This dual benefit of compliance readiness and operational insight demonstrates the model's alignment with both regulatory requirements and business improvement objectives.

06 SCALING STRATEGY

6.1 Scaling across Geographies and Sectors

The Kolhapur pilot establishes a transferable framework that can be adapted across India's foundry sector, which comprises approximately 4,500 units nationwide, with 90% classified as MSMEs. This systematic approach to baseline assessment, capacity building, and implementation support provides a replicable blueprint for various stakeholders across different regional contexts and sectoral characteristics.

Geographic Expansion Potential:

Priority expansion regions could include Punjab, Tamil Nadu, Jharkhand, and West Bengal, where such rollouts could potentially achieve cumulative preparedness improvements across more than 500 foundry units. This cluster-based approach leverages the geographic concentration that characterises India's MSME landscape, where proximity enables shared infrastructure, technical support, and knowledge transfer mechanisms. Kolhapur's and then Maharashtra's experience could help demonstrate that successful replication benefits from integration with state energy efficiency programs, industrial development policies, and MSME support schemes, requiring multi-level governance coordination between national policies, state programs, and local implementation mechanisms.

Cross-Sectoral Application:

While the pilot focuses on foundries, the underlying methodology suggests broad applicability to other energy-intensive MSME sectors. Secondary steel, accounting for 40% of India's steel production with 8,259 MSME units in Maharashtra alone consuming 11.8 Mtoe energy annually, represents a natural expansion opportunity. The framework's emphasis on baseline assessment, capacity building, and ecosystem development could be effectively adapted to other hard-to-abate sectors including cement, textiles, and chemicals. This cluster-based approach reduces transaction costs and creates economies of scale in technical support and financing, suggesting that sector-specific customisation could unlock significant decarbonisation potential across India's industrial landscape.

6.2 Technology, Innovation, and Implementation Readiness

Digital Platform Integration:

The lack of systematic, up-to-date data organisation and management systems for both energy and production in smaller enterprises is a significant gap across units. The pilot experience suggests that energy management systems and emissions tracking have substantial potential for technology-enabled scaling that could serve multiple clusters simultaneously. Cloud-based monitoring systems, shared databases, and remote technical support capabilities could reduce geographic constraints that typically limit MSME support programs, dramatically reducing per-unit implementation costs while improving service quality.

Innovation Ecosystem Development:

The framework creates opportunities for systematic innovation scaling through demonstration of emerging technologies and business models. Successful interventions being documented in initial units and potentially at a cluster level could create proof points that reduce risk perceptions and accelerate adoption in subsequent implementations. This highlights the importance of knowledge management and documentation as integral components of scaled implementation strategies.

Implementation Readiness Assessment:

Successful framework replication requires systematic assessment of local stakeholder ecosystems, including industry associations, technical service providers, financial institutions, and government agencies. Implementation readiness varies significantly across regions, necessitating preliminary ecosystem mapping and capacity assessment before intervention design in new geographies. Phased implementation strategies enable refinement of methodologies while building demonstration effects that attract broader industry participation and institutional support.

Resource Mobilisation Framework:

Scaling requires coordinated resource mobilisation across multiple funding sources, including government programs, development finance, international climate finance, and private sector investment. The pilot experience suggests that blended finance approaches combining public, philanthropic, and private capital create optimal conditions for sustainable baseline assessments and implementation at scale. SIDBI's expanding green finance portfolio and risk-sharing facilities provide established channels that could support framework replication, requiring systematic engagement with participating financial institutions, commercial banks, and emerging green finance mechanisms.

6.3 Policy Enablers: MSME Schemes for Green Technology Adoption

For many MSMEs, the biggest hurdles to adopting cleaner technologies are the high upfront costs and the lack of in-house expertise. Government-backed schemes such as the Credit Linked Capital Subsidy Scheme (CLCSS), SIDBI’s Green Financing programs, and Maharashtra’s renewable energy subsidies can help bridge this gap. These initiatives make it easier for foundries to invest in energy-efficient equipment and renewable energy solutions without straining their finances. For export-focused clusters like Kolhapur, tapping into these schemes is also becoming a necessity to stay competitive, especially with new trade regulations like the EU Carbon Border Adjustment Mechanism (CBAM) that place a cost on carbon-intensive imports. By linking the cluster's decarbonisation efforts with available incentives, foundries can cut costs, meet global market expectations, and make the shift to low-carbon manufacturing a practical and profitable journey.

Table 6: List of potential schemes/loans for MSMEs for Energy Efficiency (EE) and Renewable Energy (RE)

Theme	Scheme/ loan	Implementing agency	Scheme details
STATE LEVEL SCHEMES			
EE	Save Energy Programme	MEDA	▪ Provides financial assistance for detailed energy audits conducted by MEDA's empaneled consultants. ▪ Eligible facilities must be located in Maharashtra and be regular electricity bill payers. ▪ Assistance amount is linked to the facility's annual electricity bill.
EE	State Energy Conservation Fund (SECF)	MEDA	▪ Established under EC Act 2001 for - promoting efficient use of energy and supporting energy conservation projects within states. ▪ SECF is funded through contribution from central and state govt. ▪ The fund is used to provide financial assistance, often in the form of loans or subsidies, for projects aimed at improving energy efficiency. ▪ A major portion of SECF is earmarked as RIF (85%)
EE	Package Scheme of Incentives (PSI) 2019	▪ Joint Director of Industries for Mumbai ▪ DIC for other districts	▪ Promote industrial growth and a competitive environment in Maharashtra through fiscal and non-fiscal incentives for MSMEs. ▪ Applies to MSMEs as per the MSMED Act, 2006, and other units with a Gross Fixed Capital Investment up to ₹50 crores. ▪ Financial assistance for technology up-gradation (5% up to ₹25 lakhs), quality certification (75% up to ₹1 lakh), and cleaner production measures (25% up to ₹5 lakhs). ▪ Financial assistance for projects related to water, energy, and environmental conservation, including audits and new equipment.

Theme	Scheme/ loan	Implementing agency	Scheme details
NATIONAL LEVEL SCHEMES			
EE	Micro & Small Enterprise Cluster Development Program (MSE-CDP)	MoMSME	▪ Enhance productivity, competitiveness, and capacity building of MSEs through cluster-based development and shared infrastructure. ▪ GoI grant up to 70% (or 80–90% for special category clusters) for projects up to ₹30 crore to set up common facility center (CFC) ▪ GoI grant up to 60% (or 70% for special categories) for new/upgraded industrial estates and flatted factory infrastructure development
EE	Technology and Quality Upgradation (TEQUP) Scheme	MoMSME	▪ Sensitise MSMEs to upgrade their manufacturing processes towards the usage of Energy Efficient Technologies (EET) ▪ Provides financial support up to 25% of the project cost, for implementation of EET (minimum energy saving15%) as per the approved Detailed Project Report (DPR) subject to maximum of Rs.10 lakhs per project.
EE	Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE)	MoMSME & SIDBI	▪ Facilitate collateral-free credit to Micro and Small Enterprises (MSEs) by providing guarantee cover to lending institutions. ▪ Financing up to ₹5 crore ▪ Coverage up to 85% for micro enterprises (loans ≤ ₹5 lakh); 90% for women-owned MSEs; 80% for units in NE region and aspirational districts; 75% for other MSMEs ▪ Annual guarantee fee ranges from 0.75% to 1.0% of the sanctioned credit facility.

Theme	Scheme/ loan	Implementing agency	Scheme details
FINANCIAL INSTITUTION SCHEMES			
EE	End to End Energy Efficiency (4E) scheme	SIDBI	▪ Promotes energy efficiency in MSMEs through technical audits and concessional financing. ▪ Includes walk-through and detailed energy audits, DPR preparation, and post-implementation verification. ▪ Financing from ₹10 lakh to ₹150 lakh, covering up to 90% of project cost at concessional interest rates; repayment up to 5 years. ▪ MSMEs operational for ≥3 years, profitable in last 2 years, with no loan defaults and compliance with environmental norms. ▪ Fundable Activities: Energy-efficient equipment, rooftop solar systems, installation, and minor civil works based on DPR recommendations.
EE	Baroda Energy Efficiency Project (BEEP) Finance	Bank of Baroda	▪ Finance SMEs for acquiring energy-efficient equipment and services to enhance energy conservation. ▪ Financing from ₹5 lakh to ₹15 crore per project and coverage up to 75% of project cost; repayment up to 5 years
EE	Scheme for Energy Savings for MSMEs	Canara bank	▪ Finance MSMEs for energy-saving equipment and conservation measures. ▪ Financing up to ₹100 lakh per project and coverage up to 90% of project cost; repayment 5-7 years including moratorium of 6 months ▪ MSMEs with energy cost ≥20% of production cost and valid energy audit report.
EE + RE	IDBI Green Bond Framework	IDBI	▪ Mobilise funds for environmentally sustainable projects aligned with the Green Bond Principles (GBP). ▪ Green Bond will be allocated exclusively for lending in eligible Green Projects: Renewable energy, Energy efficiency, Sustainable water management, Sustainable waste management projects, Sustainable transportation projects, Sustainable land use projects ▪ Review and approval of the project based on initial evaluation and screening

07 CONCLUSION

7.1 Strategic Importance and Market Imperative

The Kolhapur foundry cluster decarbonisation pilot represents a critical inflection point in Maharashtra's and potentially India's industrial decarbonisation journey. With the foundry sector contributing approximately 15% of industrial emissions from the metals value chain and facing immediate pressure from CBAM regulations, this pilot's demonstrated approach addresses both environmental imperatives and economic competitiveness. The model's success in creating measurable emissions reductions while building business cases for sustainability investments demonstrates that MSME decarbonisation is not only necessary but economically viable when supported by enabling ecosystems.

CBAM Timeline Urgency:

The definitive CBAM regime beginning in 2026, with full implementation by 2027, creates an immediate timeline for scaling interventions. Indian foundries exporting to the EU face potential cost increases of $55-145 per MT, representing 9-22% of current domestic steel prices (ASSOCHAM, 2025). The financial burden could potentially erode profit margins. This regulatory timeline transforms decarbonisation from a long-term sustainability goal into an immediate competitive necessity, creating a market pull for the cluster-based intervention model.

7.2 Ecosystem Readiness and Institutional Alignment

The pilot's success demonstrates the ecosystem readiness for scaled intervention across Maharashtra and other industrial states. SIDBI's expanded green finance portfolio, growing from traditional energy efficiency schemes to comprehensive decarbonisation support, provides institutional capacity for financing scaled interventions. State-level policy frameworks, including Maharashtra's SEEAP with its 55.15 million metric tonnes CO_2 reduction target, create enabling environments for cluster-based approaches.

Financial Ecosystem Development: The integration of international climate finance, including the $215.6 million Green Climate Fund allocation and $100 million AFD-SIDBI credit facility, demonstrates growing financial sector readiness to support MSME transitions. These funding mechanisms, combined with emerging risk-sharing facilities from development finance institutions, commercial bank green lending programs, and blended finance approaches from impact investors, create a diversified financial ecosystem necessary for scaling beyond pilot interventions. Multiple institutional players including public sector banks, private financial institutions, non-banking financial companies (NBFCs), and emerging green finance platforms are increasingly developing MSME-focused sustainability products that can support cluster-level decarbonisation initiatives.

7.3 Stakeholder Convergence

The pilot's systematic documentation of methodologies, learnings, and solutions creates a replicable framework that urgently needs adoption across sectors and geographies. This approach's emphasis on local capacity building, stakeholder engagement, and institutional partnership development ensures that scaled interventions build sustainable capabilities rather than creating dependencies on external support.

Growing Stakeholder Interest:

The pilot experience has generated considerable enthusiasm from multiple stakeholders including industry associations, financial institutions, state governments, and development organisations. Foundry owners recognise the immediate business benefits of reduced energy costs and CBAM compliance readiness, while financial institutions see emerging opportunities in green MSME lending. State governments view cluster-based decarbonisation as a pathway to achieve emission reduction targets while supporting industrial competitiveness, creating a convergence of interests that facilitates scaled implementation.

Win-Win Value Proposition:

This framework delivers mutual benefits across all stakeholders. MSMEs achieve cost reductions, operational efficiency, and market access; financial institutions develop profitable green lending portfolios; governments advance climate commitments while supporting employment and industrial growth; and civil society organisations contribute to systemic environmental impact. This alignment of economic, environmental, and social objectives creates sustainable incentives for widespread adoption rather than requiring external pressure.

With India's 1,664 foundries and broader MSME sector contributing 30% of GDP while generating significant emissions, the scaling imperative represents both a substantial opportunity and an urgent necessity for national climate commitments. The model's integration with existing policy frameworks, including the state energy efficiency programs, creates immediate pathways for systematic integration into India's broader decarbonisation strategy.

The Kolhapur foundry cluster pilot represents not merely a local intervention but a scalable solution across different regions and sectors. Its success demonstrates that appropriate ecosystem support, financial mechanisms, and institutional partnerships can simultaneously achieve environmental objectives and economic competitiveness. The widespread adoption of this model across India's industrial landscape offers a viable pathway for the country to achieve its climate commitments, while strengthening the competitiveness and resilience of its critical MSME sector.

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