International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Developing a Cluster-Level Framework Design for Identifying High-Impact Decarbonisation Pathways in MSME-Intensive Industrial Regions of Uttar Pradesh

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Abstract

Micro, Small and Medium Enterprises (MSMEs) are a major part of Uttar Pradesh's industrial economy but operate with diverse technologies and high dependence on fossil fuels. Due to this variation, decarbonisation requires a structured, cluster-based approach rather than isolated interventions. This paper develops a cluster-level assessment framework to identify high-impact decarbonisation pathways across multiple industrial clusters. The framework evaluates clusters based on energy intensity, fuel mix, emission reduction potential, technological readiness, and access to finance. Selected clusters are further analysed to demonstrate practical application of the approach.

The study combines secondary data review, stakeholder consultations, and mapping of existing government schemes. Key barriers identified include limited access to finance, low awareness, slow technology adoption, and weak institutional coordination. The paper proposes a practical and replicable framework that connects technical decarbonisation opportunities with financing mechanisms to enable scalable low-carbon transition in MSME-intensive regions.

Keywords: MSMEs, decarbonisation, cluster assessment, financing mechanisms, energy efficiency.

1. Introduction

Micro, Small and Medium Enterprises (MSMEs) play a critical role in Uttar Pradesh's industrial growth, particularly through cluster-based production systems across sectors such as foundry, glass, ceramics, textiles, and engineering goods. However, many MSMEs rely heavily on fossil fuels and operate with varying levels of technological efficiency, contributing to significant energy consumption and carbon emissions. Although several government schemes support modernization and energy efficiency, interventions are often fragmented and lack a structured cluster-level prioritisation mechanism. Given the diversity among clusters in terms of energy intensity, production scale, and financial readiness, a systematic approach is required to identify where decarbonisation efforts can achieve the highest impact. This study develops a structured cluster-level prioritisation and decarbonisation pathway framework for

MSME-dominated industrial regions. The framework integrates technical assessment, financing analysis, and institutional considerations to support scalable and practical low-carbon transition strategies. By integrating technical potential with financing analysis, the paper proposes a structured decision-support model for policymakers and financial institutions.

This paper aims to:

1. Analysis of Financing Landscape, and institutional barriers to MSME decarbonisation.
2. Develop a structured cluster prioritisation methodology for the Decarbonisation Pathway.

2. Literature Review:

Several national and international studies supported the preparation of the present scoping study on decarbonisation of MSME clusters in Uttar Pradesh.

UNIDO–GEF (with BEE) (2011–2021), through the project on promoting energy efficiency and renewable energy in MSME clusters, provided important insights into technology demonstration, market transformation, and cluster-level capacity building. The experience from clusters such as Khurja ceramics helped in understanding sector-specific energy intensity and adoption barriers.

The Roadmap for Green Transition of MSMEs (NITI Aayog,2026) provides a comprehensive assessment of the structural, financial, and institutional challenges associated with decarbonising the MSME sector. The report proposes a structured institutional mechanism, including the establishment of a National Project Management Agency (NPMA), cluster-level SPVs, demand aggregation strategies, ESCO-based implementation models, and credit-guarantee backed risk mitigation frameworks to accelerate green transition.

EESL–UNIDO–GEF–Ministry of MSME (2017), under the market transformation initiative, demonstrated the effectiveness of ESCO-based business models and quantified energy, cost, and emission savings. These findings supported the financial and implementation framework considered in the present study.

The BEE–SME Programme (Ongoing) provided cluster-level energy mapping, conservation guidelines, and technology demonstration data across key UP clusters such as Kanpur (pharma), Agra (foundry), Muzaffarnagar (paper), and Firozabad (glass). These reports supported baseline understanding of energy consumption patterns.

Studies by TERI and Shakti Foundation (2017–2021) offered detailed diagnostic assessments and energy audit findings in clusters such as Agra foundry and Ghazipur brick manufacturing, contributing to the technical assessment framework of this report.

Overall, these reports collectively supported the preparation of the present study by providing baseline diagnostics, technology options, financial insights, and institutional learnings.

3. Methodology for Cluster Selection and Framework Design

The decarbonisation pathway framework was developed using a structured three-stage cluster assessment methodology. The approach integrates technical, economic, and institutional considerations to ensure that selected clusters demonstrate high mitigation potential, implementation feasibility, and scalability.

3.1 Stage 1: Preliminary Screening of Clusters

The first stage involved preliminary screening of identified industrial clusters to eliminate those with limited relevance for structured decarbonisation intervention. Clusters characterized by low energy consumption, predominantly manual operations, and minimal scope for energy efficiency improvement

were excluded from further assessment. This screening ensured that subsequent analysis focused only on energy-intensive clusters where decarbonisation measures could yield measurable emission reduction and cost optimization outcomes.

Table 1. Preliminary Screening Criteria:

Parameter	Description	Assessment Basis	Decision Rule
Energy Consumption Level	Overall energy use within the cluster	Review of secondary data and sector reports	Clusters with low energy use excluded
Nature of Industrial Operations	Degree of mechanization and process energy dependence	Sectoral profiling	Manual-dominated clusters excluded
Energy Saving Potential	Preliminary assessment of efficiency improvement scope	Technical review	Clusters with limited potential excluded

3.2 Stage 2: Multi-Criteria Cluster Assessment

In the second stage, the shortlisted clusters were evaluated using a structured multi-criteria scoring framework to narrow the selection to approximately five clusters. A three-level scoring system (Low, Medium, High) was adopted to provide clear differentiation across clusters.This stage assessed energy intensity, decarbonisation potential, and institutional readiness to support implementation. The inclusion of institutional parameters ensured that selected clusters were not only technically viable but also capable of coordinated action through organized industry associations.

Table 2.: Multi-Criteria Scoring Framework

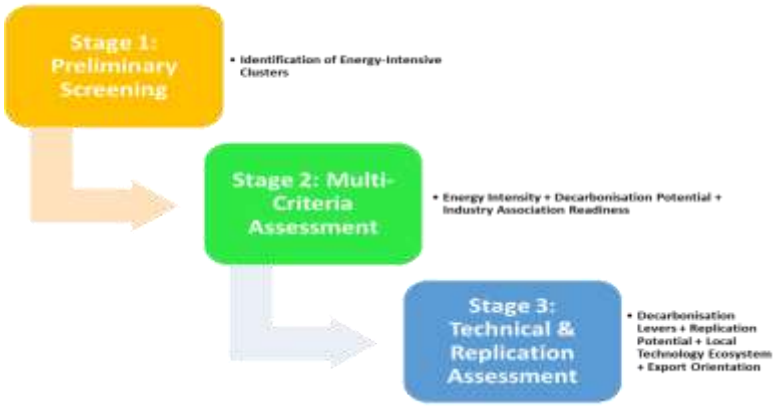
Criterion	Objective	Key Indicators	Scoring Scale
Energy Intensity of the Cluster	To assess the share of energy cost in total production cost	Percentage of energy cost in production cost	Low - Medium- High
Decarbonisation Potential	To evaluate emission reduction scope at cluster level	Energy saving potential; fuel switching options (PNG, electricity, hydrogen, biomass); fossil fuel reduction	Low - Medium- High
Availability of Industry Association	To assess presence of a registered and functional cluster-level body	Existence of formal association and coordination structure	Low - Medium- High
Willingness of Industry Association	To assess readiness to facilitate project implementation	Demonstrated interest and commitment	Low - Medium- High
Previous Implementation Experience (if applicable)	To assess exposure to prior development or energy-related projects	Past project engagement	Low - Medium- High

3.3: Technical Feasibility and Replication Assessment

The shortlisted clusters were further evaluated to identify final clusters for detailed decarbonisation pathway development. This stage focused on practical feasibility, scalability, and ecosystem readiness. The assessment was conducted through stakeholder consultations, site visits, interaction with MSMEs, and discussions with technology suppliers. The objective was to ensure that selected clusters demonstrate availability of low-carbon measures, strong replication potential within the cluster and at state level, and adequate local technical support infrastructure.

Criterion	Objective	Assessment Approach	Scoring Scale
Availability of Decarbonisation Levers	To assess presence of feasible low-carbon technologies and measures	Stakeholder consultation and technical review	Low-Medium-High
Replication Potential (Cluster & State Level)	To evaluate scalability across similar units	Number of adoptable units and sectoral spread	Low-Medium-High
Availability of Local Technology Suppliers and Service Providers	To assess ecosystem readiness for implementation	Mapping of suppliers and service network	Low-Medium-High
Export-Oriented Production (if applicable)	To assess competitiveness and market alignment	Sectoral trade profile	Low-Medium-High

The three-stage structured methodology ensured a systematic, transparent, and objective selection of clusters based on technical, economic, and institutional parameters. By integrating energy intensity assessment, decarbonisation potential evaluation, and ecosystem readiness analysis, the approach enabled identification of clusters with high implementation feasibility and scalability.



Framework Flowchart for cluster selection

4 Analysis of Financing Landscape and Policy Mapping:

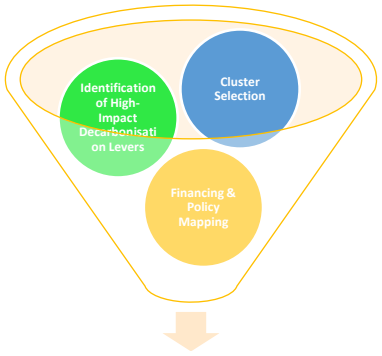
A structured mapping of central and state-level schemes was undertaken to assess the financial and institutional readiness of MSME-intensive clusters in Uttar Pradesh for low-carbon transition. The analysis

covered energy efficiency, renewable energy, technology upgradation, circular economy, and cluster development programmes relevant to decarbonisation pathways.

Scheme / Programme	Implementing Agency	Type of Support	Relevance to Decarbonisation Pathways
National Programme on Energy Efficiency and Technology Upgradation of SMEs (BEE-SME Programme)	Bureau of Energy Efficiency (BEE)	Technical assistance, capacity building	Promotes adoption of energy-efficient technologies
Framework for Energy Efficient Economic Development (FEEED)	BEE	Risk mitigation, financing instruments	Supports scaling of energy efficiency investments
4E Scheme (End-to-End Energy Efficiency Scheme)	SIDBI	Financial support for EE projects	Enables implementation of efficiency measures
MSME Sustainable ZED Certification	Ministry of MSME	Certification, performance incentives	Encourages resource-efficient and low-carbon manufacturing
Micro & Small Enterprise Cluster Development Programme (MSE-CDP)	Ministry of MSME	Cluster infrastructure support	Enables modernization and common facilities
Comprehensive Handicrafts Cluster Development Scheme	Ministry of Textiles	Cluster development assistance	Sector-specific modernization
Scheme of Fund for Regeneration of Traditional Industries (SFURTI)	Ministry of MSME	Cluster development funding	Strengthens traditional MSME clusters
ADEETIE	Ministry of Power	Financial instruments + audit support	Facilitates adoption of energy-efficient technologies
Green Investment and Financing for Transformation (GIFT) Scheme	Ministry of MSME	Concessional green finance	Supports clean technologies and green projects
Scheme for Promotion and Investment in Circular Economy (SPICE)	Ministry of MSME	Financial and technical support	Promotes circular economy practices

The mapping of central and state-level financing schemes is integrated into the proposed cluster-level framework to assess implementation feasibility of identified high-impact decarbonisation pathways. While the technical assessment identifies priority low-carbon interventions, the financing landscape analysis evaluates the availability of institutional support, concessional finance, and policy incentives required for large-scale adoption within MSME-intensive clusters of Uttar Pradesh. This integrated

approach ensures that the proposed pathways are not only technically robust but also financially viable and scalable at cluster level.



Integration into Cluster-Level Decarbonisation Pathway

5. Barriers to Decarbonisation:

Based on available data and stakeholder consultations with cluster representatives and an extensive literature review, several structural and operational bottlenecks were identified that constrain the uptake of energy efficiency (EE) measures and decarbonisation technologies within MSME-intensive industrial regions of Uttar Pradesh.

S. No.	Barriers	Description	Implication for Decarbonisation Pathways
1	Lack of Awareness	MSMEs have limited knowledge of available schemes, financial instruments, and climate finance structures. Benefits of low-carbon technologies are not well understood.	Low participation in schemes and slow adoption of energy-efficient technologies.
2	Low Demand for Green Technologies and Finance	Energy efficiency and decarbonisation are not perceived as business priorities. Investments are often viewed as expensive rather than cost-saving.	Weak market pull for clean technologies and limited uptake of green finance.
3	Limited Technical Skills and Capacity	Inadequate technical expertise to evaluate, implement, and manage advanced energy-efficient technologies. Limited handholding support and demonstration projects.	Hesitation in technology adoption and reduced scalability of interventions.
4	Lack of Data and Compliance Mechanisms	Absence of reliable data on energy use, emissions, and process efficiency. Limited monitoring and reporting systems.	Difficulty in designing targeted interventions and measuring decarbonisation impact.

5	Limited Creditworthiness	High proportion of unregistered MSMEs with weak financial documentation and no credit history.	Restricted access to institutional finance and concessional lending schemes.
6	Limited Access to Local Technology Suppliers	Weak local ecosystem of technology providers due to low demand for cleaner technologies.	Higher transaction costs and slower technology diffusion at cluster level.

8. Conclusion:

This study proposes a structured cluster-level framework to identify high-impact decarbonisation pathways in MSME-intensive industrial regions of Uttar Pradesh. Considering variations in energy use, technology levels, and institutional capacity across clusters, a three-stage filtering methodology was applied to prioritise clusters with strong emission reduction potential and implementation readiness.

The findings highlight that technical potential alone is insufficient; financial access, institutional coordination, stakeholder engagement, and technology availability are equally important for successful transition. Although multiple central and state schemes support green transition, their integration at the cluster level remains limited.

The proposed framework integrates technical assessment, financing mapping, and barrier analysis into a practical decision-support tool. It enhances feasibility and scalability of decarbonisation interventions and can be replicated in other MSME-intensive regions.

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