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Green Technology Adoption by MSMEs in India: Barriers, Drivers, and the Role of Entrepreneurship and Skill Development

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Abstract

The Micro, Small and Medium Enterprises (MSMEs) are one of the key pillars in Indian economy contributing 30% to GDP, 36% to manufacturing output and nearly 46% to total exports employing over 250 million people. However, 2022 statistics show that the sector is still largely reliant on fossil fuels — with a total emissions output of around 135 $MtCO_2e$/year. Green technologies ranging from energy-efficient equipment and rooftop solar, to waste recycling systems and cleaner alternative fuels not only save substantial costs (up to 30% in electricity bills) but also help meet India's national climate pledges of reaching net-zero by 2070 as well as a 45% reduction in carbon intensity over the decade (by 2030). However, even with federal stimulus schemes like the MSE-GIFT scheme, ZED certification, MSE-SPICE and the RAMP programme, uptake has remained dismally low across MSME. Major barriers include the high upfront capital cost, limited access to institutional finance, low levels of technical know-how among owner-managers, resistance to change within organisations and weak enforcement of regulations. The current paper performs an exploratory conceptual and thematic review of academic studies, which includes government reports and policy documents mapping the existing situation of green technology adoption among Indian MSMEs. Using the Technology Organisation Environment (TOE) framework and entrepreneurship skill development theory, it explores the main barriers and enablers of adoption alongside assessing their potential for scaling green transitions. The paper suggests that green entrepreneurship Modules should be incorporated into existing MSME Skill development programmes (through cluster-based ESCO models, awareness campaigns and enhanced concessional finance) to accelerate adoption. Findings that are of interest to policy makers, educators, financial institutions and to MSME owner–managers working to realise sustainable industrial transformation.

1. Introduction

MSMEs is always dubbed as the backbone of the national economy, when we talk about India. MSMEs consist of around 69 million registered units across urban, peri-urban and rural geographies and contribute nearly 30% to India's Gross Domestic Product (GDP), approximately 36% share in manufacturing output and about 46 % share in the country's aggregate exports as per Ministry of MSME,2024. Apart from economic statistics, this sector also forms the largest employer in the non-farm economy and sustains the livelihoods of over 250 million workers — a majority of whom come from socio-economically marginalised communities (Nautiyal et al., 2025). Thus, the sector is indeed a key lever not only for India's economic growth but also for inclusive and equitable development across the country.

Sustainability of the economic health is being compensated by huge environmental degradation. The entire manufacturing life cycle and operations of India's Micro, Small & Medium Enterprises (MSME) is mainly dependent on non-renewable energy sources. As per the report of NITI Aayog (2026), the cumulative emission of carbon dioxide equivalent ($MtCO_2e$) in 2022 was approximately 135 million tonnes, ranking them as the third largest contributor of industrially emitted greenhouse gas (GHG) in the nation. With India's commitment towards a reduction of at least 45% of CO2 emission by 2030 and net-zero carbon by the year 2070, the strategically significant MSME sector decarbonisation must go hand-in-hand.

The MSMEs reduced environmental footprint may be achieved with the help of adoption of green technologies which are practical and cost-effective route to reducing their environmental footprint. They include energy-efficient equipment and processes such as rooftop solar PV, advanced waste management and recycling systems and cleaner alternative fuels that can replace fossil and other non-renewable energy sources. This will also have environmental advantages such as enterprises benefits from energy conservation, reduction in electricity cost up to 30% and investment in solar energy have also proven lucrative with even good returns on investment apart from cost cutting and energy conservation mechanism. (Bhuyan, 2025; Nautiyal et al., 2025). New markets may also become available by moving closer to greener production technologies especially since some of the forthcoming international trade measures, and related carbon costs, will impact exports from enterprises that do not comply with new requirements (with large competitors including the European Union through its Carbon Border Adjustment Mechanism which will take an enterprise with emissions non-compliance in 2026).

Despite this strong case for adoption, India MSMEs remain stubbornly low in green technology uptake. Of the 69 million MSME units in India, just a tiny fraction follows carbon management or use renewable energy. The constraints are recognised and complex: widespread high upfront capital cost, limited access to institutional credit where bank's view MSMEs as higher-risk borrowers for green investments, lack of technical capacity and skills amongst owner-managers, some organisational inertia and weak or sporadically enforced environmental regulations (Loo et al., 2023; Ikram et al., 2026). Moreover, as practices of environmental sustainability are generally not obligatory for smaller enterprises, immediate profit motives often trump long-term sustainable goals (Nautiyal et al., 2025).

The Government of India has launched multiple specific schemes to spur the green transition of MSMEs. The measures include the 2% interest subvention scheme on loans for green technology investments - MSE Green Investment and Financing for Transformation (MSE-GIFT), the MSE-SPICE scheme focused on promoting circular economy, the Zero Defect Zero Effect (ZED) certification framework, and Raising and Accelerating MSME Performance (RAMP) programme supported by World Bank. The 2026 roadmap for green MSME transition developed by NITI Aayog identifies three main pathways for reducing emissions, including better energy efficiency, a switch to green electricity (mostly through solar) and replacement of conventional fuels with cleaner alternatives (NITI Aayog100). Scaling these interventions is projected to deliver reductions of 75-87 $MtCO_2e$ from MSMEs over a decade and catalyse more than 55,000 new green jobs (Roadmap).

In light of this, the current study provides a conceptual and thematic review with the aim to: (i) portray an up-to-date picture of green technology adoption among Indian MSMEs; (ii) explore, identify and classify barriers and drivers of adoption based on a well-established theory; (iii) understand how entrepreneurship skills & training impact the green transition process; and especially (iv) develop policy-oriented recommendations. Design/methodology/approach: The theoretical underpinning for the study is formed by Technology–Organisation–Environment (TOE) framework, with additional support from parts of entrepreneurship theory and literature on sustainable development. An important contribution of this paper is the focus on green entrepreneurship and skill development — an area which, as per the authors knowledge, has not been sufficiently covered in both academic literature and policy discourse in India

2. Literature Review

2.1. MSMEs and Sustainable Development: Conceptual Linkages

In the last two decades, sustainable development and small medium enterprises (SMEs) have received attention from some scholarly circles. The structural features of small firms — their limited financial resources, constrained managerial capacity and a short planning horizon focused on profit maximisation as opposed to long-term growth in the interests of all stakeholders, alongside a strong owner-manager orientation (Loo et al., 2023) — are fundamentally different from those of large corporations; thus giving rise to unique sustainability adoption behaviour. As highlighted by several researchers, MSMEs collectively are major contributors to industrial pollution per unit of output, yet they exhibit specific flexibilities and agilities that can enable swifter uptake of sustainable practices when an appropriate enabling environment exists (Basit et al., 2024 (Springer publisher date: 2025)).

The idea of green entrepreneurship has thus become an especially fruitful lens through which to gain insight into how owner-managers can utilize environmental challenges as business opportunities. Schaltegger & Wagner (2011) categorise between green entrepreneurs and sustainability-oriented businesses deliberately pursuing sustainability as part of their business model. This divergence matters in the context of MSMEs as it will define the extent, longevity and scalability of green practices followed by the enterprise. More recent scholarship shows encouraging evidence that SMEs could potentially capture a competitive advantage over their larger counterparts, not through lower costs or labour/labour costs (which ironically have been shown to spike as firms grow), but rather by engaging in green innovation — the development and commercialisation of products, processes and services that are environmentally superior to alternative solutions (Ali & Singh, 2024; Environment, Development and Sustainability, 2025).

2.2. Theoretical Framework: The TOE Model

The Technology–Organisation–Environment (TOE) framework proposed by Tornatzky and Fleischer (1990)—which describes the factors surrounding adoption decisions at organisation level—has become one of the most widely used theories in technology adoption research (Chatterjee et al., 2021). According to the framework, technology adoption is influenced by three contextual domains: the technological context (the technologies available for an organisation both internal and external to it and their perceived relative advantage, compatibility with existing structures, and complexity); organisational context (characteristics of the firm including size, management structure, human resources and financial capacity) and environmental context (industry structure, regulatory pressures on firms to adopt certain technologies or innovations as well as competitive forces system within which a firm operates).

The TOE framework has been widely utilized in research pertaining to green technology and sustainable innovation adoption within SMEs. Empirical studies in high-impact journals have consistently established that relative advantage, regulatory pressure, government support, management commitment and customer pressure are significant predictors of adoption across national and sectoral contexts (Alam et al., 2024; Towards a Circular Economy, 2024; Technological Innovation, Sustainable Green Practices and SMEs, 2022). The framework is especially relevant in the Indian context considering that any MSME owner-manager who wants to adopt AI technology has multiple institutional influences — central government schemes, state-level policies, industry association networking and markets. A recent work conducted by Al-Emran and Griffy-Brown (2023) complemented this perspective, highlighting the relevance of technology adoption to sustainability development and providing evidence that in certain contexts it is not only technologies themselves but also context-specific institutional enablers what shapes green transitions.

2.3. Barriers to Green Technology Adoption in MSMEs

The literature provides a comprehensive account of barriers preventing the adoption of green technologies across MSMEs. Ikram et al perform a systematic review Based on data from developing countries contexts, pointed to barriers in financial, organisational, technological and policy dimensions (2026). Financial challenges — especially in terms of high initial investment costs and limited access to credit — often emerge as the foremost barriers. For this, the banks and financial institutions generally treat MSMEs as high-risk borrowers for green projects based on their perception about technology performance and repayment capacity (Bhuyan, 2025) in Indian context.

The second major category of impediments is that of organisational barriers. A path-analytic study of Indian MSMEs by Nautiyal, Kumar, and others (2025) revealed that single-oriented barriers were driven more significantly by organisational factors — namely due to a lack of commitment from

owner-managers, resistance to operational change, and engaging an emphasis on short-term profits over long-term strategic planning than financial constraints. This is important since it indicates that in MSMEs in India, both awareness and behavioural change interventions can have a larger impact than financial subsidies alone. This is consistent with the finding that since green behaviour is not mandatory for most small founding firms, owners are under little pressure to invest in them (Nautiyal et al., 2025).

A third dimension revolves around the technological — this can relate to existing machinery which is old or incompatible, how complex newer green technology is, and a lack of aquisition regarding technical support. By employing a hybrid Fuzzy AHP-TOPSIS framework, Abdullah et al. (2023) identified technological compatibility and skilled technical personnel availability as key determinants of SMEs' sustainable manufacturing adoption. Another commonly cited barrier focuses on issues with human capital: these relate to the fact that most MSME owner-managers and their workforce lack the technical education and practical skills needed to assess, install, and operate green technologies (Loo et al., 2023).

Fourth, the policy and regulatory barriers are also an important dimension. Awareness and usage remain low, despite a slew of government schemes. According to a survey conducted by ESG News (2025), nearly one-third of MSMEs are still unaware of the green schemes that exist, indicating a fundamental disconnect between policy design and effective outreach. In addition, the most environmental compliance requirements imposed on smaller enterprises are generally not mandatory, providing a limited barrier to adoption. However, these calculations for export-oriented MSMEs may soon start changing because of CBAM-related recent international market pressures.

2.4. Drivers and Enablers of Green Technology Adoption

On the positive side, multiple drivers have been identified that can motivate and enable green technology adoption among MSMEs. Market-based incentives — particularly the prospect of reduced energy costs and improved competitiveness — are frequently cited as primary motivators for green investments (Bhuyan, 2025). Solar rooftop installations in industrial clusters in Jodhpur and energy efficiency measures in Rajkot's foundry cluster have demonstrated that green investments can generate measurable cost savings and productivity improvements within relatively short payback periods. Enterprises that have adopted green practices also report improved access to export markets, particularly in Europe, where green supply chain requirements are becoming increasingly stringent.

Government financial incentives play a critical enabling role. The MSE-GIFT scheme's 2% interest subvention on green loans, capital subsidies under MSE-SPICE, and performance-based incentives under ZED certification collectively lower the effective cost of green investments. NITI Aayog's cluster-based ESCO model — in which energy service companies finance and implement efficiency improvements and recover their costs from the resulting energy savings, without requiring upfront capital from the MSME — is particularly promising as it directly addresses the financial barrier (NITI Aayog, 2026).

Peer effects and cluster dynamics also serve as powerful enablers. When a few enterprises within a cluster successfully adopt green technologies and demonstrate tangible benefits, knowledge spillovers and competitive pressures motivate neighbouring units to follow suit. This mechanism aligns with the RAMP programme's focus on cluster-based handholding and capacity-building support. The literature on green innovation in Indian SMEs further highlights that entrepreneurship competencies — particularly opportunity recognition, risk tolerance, and the ability to access external networks and resources — significantly mediate the relationship between awareness and actual adoption (Ali & Singh, 2024).

3. Methodology

However, there are there number of drivers have been recognized, that can act as enablers and motivators for MSMEs to emerge green technological agents. Market incentives and opportunities — especially the availability for lower energy costs, as well as competitiveness — have often been emphasized to be some of the main drivers for green investments (Bhuyan 2025). In 18 months, solar rooftop installations in the industrial clusters of Jodhpur and energy efficiency measures in Rajkot's foundry cluster have succeeded in showcasing that green investments can produce quantifiable cost savings and productivity gains over relatively short payback periods. Large enterprises that have the green practices also enjoy better access to export markets where regulations governing supply chains having green-credentials are tightening, particularly in Europe.

The enabling role is played by government financial incentives. MSE-GIFT scheme provides for 2% interest subvention on green loans, capital subsidies under MSE-SPICE, and performance-based incentives under ZED certification as all combined take the effective cost of green investments lower. NITI Aayog’s cluster-based ESCO model where energy service companies bear the cost of a project (that pays for energy efficiency improvements) and recoup their investment through savings on future energy bills —without any pre-investment by the MSME at risk, hits at the heart of this financial barrier well (NITI Aayog, 2026).
Peer effects, and cluster dynamics also work as enhancers. Once a handful of enterprises within a cluster effectively adopt green technologies and show verifiable benefits, neighboring units quickly become motivated by both knowledge spillovers and competitive pressures to do the same. This is consistent with the scheme of cluster-based handholding and capacity-building support as envisaged under RAMP programme. Past studies on green innovation in Indian SMEs also underscore the key role of entrepreneurship competencies — namely opportunity recognition, risk tolerance, and the ability to access external networks and resources; such factors serve as strong mediators between awareness and actual adoption (Ali & Singh 2024).

4. Current Status and Feasibility Analysis

4.1. State of Green Technology Adoption among Indian MSMEs

The overall image of green technology adoption among Indian MSMEs is one of a sector in early transition — with islands of legitimate progress surrounded by large areas of little uptake or awareness. ESG News (2025) cites that nearly 21% of Indian MSME have installed rooftop solar power as of 2024 and more than 40% had confirmed a green energy transition initiative, including the installation of solar panels and commercial vehicle electrification among enterprises in either the manufacturing or service sector. While these numbers are a positive step-up from the very low base of

previous years, they also reveal an immense untapped space across the other 60% and more of the MSME universe.

MSME green adoption is supported by a macroeconomic backdrop for India's overall renewable energy trajectory In the year 2025, India has reached 227 GW of renewable energy installed capacity and achieved a significant increase in the renewable energy share of the total installed electricity generation capacity from 12.92% during March 2013–14 to 45.50% by March,2025 (IBEF, 2025) As utility-scale solar has become one of the lowest-cost sources of new electricity generation in the world, the cost curve for solar technology is steadily pushing down the financial barrier to entry for even smaller businesses looking at rooftop and ground mounted installations. If SA and three main green transition pathways (energy efficiency, green electricity, alternate fuels) expand successfully, NITI Aayog estimates that MSME emissions could fall by 75–87 $MtCO_2e$ in a ten year horizon with an unprecedented availability of >55,000 green jobs.

Yet, cases of such clusters demonstrate that it is possible to undertake green transitions when the right conditions are in place. The adoption of rooftop solar has not only saved on electricity costs for the participating enterprises at Jodhpur industrial cluster but also reduced carbon emissions. There would also be lower per unit consumption of energy: Anand Vartak, in centre-based foundry cluster Rajkot has adopted measures to save whilst maintaining maximum efficiency. These cases are congruent with the cluster-based ESCO model suggested by NITI aayog (2026) which states that aggregating demand in clusters of MSME units, will bring down green transactions costs significantly and enhance the risk profiles of both enterprises and financiers.

4.2. Barriers: A TOE Framework Analysis

This structured analysis helps to identify key barriers using the TOE framework in the Indian MSME context. Major barriers in the technological sphere are: high complexity new green technologies compared to existing capacities of most MSME owner-managers; incompatibility between advanced green equipment with lagging age machinery and production processes and lack of affordable localised technical support for installation, operation and maintainment. Abdullah et al. Perceived complexity is a notable barrier to adoption for first-time entrepreneurs who have been unable to pursue formal training in technology (2023).

On the organisational the largest barriers are:low owner-manager greenness awareness of technological and financial opportunities; aversion to activity disruption from installation/ commissioning of new equipment; short-term profit maximisation undermining long-term financial and environmental gains; and lack of technical competence among employees to operate green technologies (Nautiyal et al., 2025). The fact that the majority of environmental compliance standards for small businesses are voluntary supports a perception but a lack of urgency to act. Interestingly, Nautiyal et al. In a study controlling for organisational and regulatory factors (2025), perceived cost was not statistically significant as a predictor of adoption, suggesting that interventions to reduce organisational barriers may have higher cost-effectiveness than subsidies alone.

These barriers comprise (i) weak regulatory enforcement of environmental standards for MSMEs, (ii) under-developed green finance ecosystems predicated on conservative risk assessments on the green MSME loan portfolios pursued by banks, and finally (iii) a structural challenge of operating with highly competitive and price-sensitive markets making it difficult to pass costs related to green investments. Yet a changing environment also seems poised to create powerful new incentives for adoption: by 2026, the EU's CBAM will begin to impose an effective carbon cost on much of India's export base; there are increasing expectations that larger listed companies will require their MSME supply chain partners to disclose ESG performance; and major international institutional investors are increasingly requiring sustainable performance as well (ESG News, 2025).

4.3. Drivers and Opportunities: Enabling Green Transition

Green technology adoption in Indian MSME is driven by multi-level facilitators. For energy-intensive Micro, Small & Medium Enterprises (MSMEs), low-cost energy has been established at the enterprise level: It constitutes up to 20–40% of total operating costs, making a strong business case for energy efficient and renewable investments. The significantly falling levelised cost of solar energy has resulted in residential rooftop solar installations being financially viable without Government support in every state outside Uttarakhand (where a 10% subsidy is offered) — most Indian states are seeing commercial and industrial payback periods of 4–6 years.

The Government of India has built a progressively extensive range of enabling systems at the policy level. MSE-GIFT scheme is expected to provide 2% interest subvention on loan for investments in clean green technology, which will directly address the higher cost of capital which MSMEs face. The ZED certification scheme generates market-based incentives for quality and sustainability improvement. It is based on a cluster-level handholding support approach, with technical assistance and advisory services to enable better outcomes through the RAMP programme backed by World Bank financing. The National Institute for Transforming India, or NITI Aayog, has developed a roadmap for the green transition for MSMEs that brings all of these disparate instruments into alignment toward common emissions reduction objectives (NITI Aayog, 2026).

The ability to spot a market opportunity and act on it, mobilising external resources (government schemes, credit facilities or technical assistance) and managing the organisational change process triggered by technology transitions is now seen as an increasingly relevant mediating factor in the adoption process. Green innovation adoption in Indian SMEs is significantly mediated by the entrepreneurial orientation of owner-managers, with risk-taking propensity and proactiveness identified as very important predictors (Ali & Singh, 2024). This suggests that targeted entrepreneurship training programmes could serve as an instrument for speeding up the green advent.

5. Role of Skill Development in Facilitating Green Technology Adoption

This intersection between developing skills and green technology adoption in the MSME context is one of the most neglected pillars of sustainability transition literature in India. Various skill development frameworks such as the Pradhan Mantri Kaushal Vikas Yojana (PMKVY), SANKALP, STRIVE and National Apprenticeship Promotion Scheme have had enourmous impact on improving employability and technical capabilities of millions in India, By the same token, while legal literacy (Rai & Jain, 2026) is now receiving attention out in front in terms of curricula being developed and implemented there are still very few courses designed to incorporate green technology competences on death — whether this be through design — into mainstream skill development packages.

The Skill Council for Green Jobs (SCGJ) —an initiative by CII, with support from the Ministry of New and Renewable Energy (MNRE) and the Ministry of Skill

Development and Entrepreneurship (MSDE)—is the most comprehensive institutional effort to plug this gap. The SCGJ has formulated National Occupational Standards (NOS) as well as Qualification Packs (QPs), for multiple categories of green jobs and the skill development programme implemented by MNRE offers three months residential training in Solar installation with an effective mix of classroom education, laboratory practicals and on-the-job training. Nonetheless, the scale of such initiatives is small compared to the MSME sector, and mostly aim at technically skilled operatives rather than owner managers who make adoption decisions.

Studies show that effective manager and owner training interventions can regressively increase green adoption levels. According to a field experiment by Loo, Ramachandran and Raja Yusof (2023), comparison of technology uptake among MSMEs whose owner-managers undergone training programs in technology adoption and innovation compared with the control group respectively proves that the breadth of owners have adopted technologies was significantly higher than those without being exposed to training. However, the greatest success in shifting awareness to action comes from training programmes that blend knowledge with a component of financial literacy all while giving clarity on how certain market mechanisms work — e.g., the mechanics of certain schemes by government; calculating return on investment for specific green technologies and explaining how weaker sections may access concessional finance (Bhuyan 2025).

RAMP programme's role in providing handholding and advisory support for tailoring solutions to MSMEs at the cluster level can be viewed a scaling mechanism for skill building at scale. RAMP-style interventions support the deployment of trained cluster development facilitators who can work directly with enterprises to diagnose energy consumption patterns, identify appropriate green technologies and help navigate the application process for financial schemes thus lowering the information cost and transaction costs associated with green adoption. Such a design represents a high-leverage intervention opportunity, embedding green entrepreneurship modules covering key issues such as opportunity identification, technology evaluation, financial analysis and change management into existing cluster-based programmes.

6. POLICY RECOMMENDATIONS

6.1. Integration of Green Entrepreneurship in Skill Development Curricula

This will result in a more coordinated response and the least daunting option amongst policies is to mainstream green skills competencies into MSME development programmes as an immediate intervention. This would need green tech adoption to be woven into the NSQF as a mandated skill at all levels for entrepreneurship-related Vocational programmes. Curricula should specifically include: (i) an awareness of available environmental technologies and associated business case; (ii) training on energy auditing and carbon footprint assessment; (iii) knowledge of government financial mechanisms and how to access them, such as grants or other payments incentives there might be; (iv) financial literacy training focused more broadly but especially here for decision making around investment appraisal for green projects in particular, or for the maintenance and operation of kit that drive emissions down, our graduate students need to know what the payback period is generally with capex spend; change management skills to facilitate their adoption that means they can play positive roles when these operational changes get made. Both of these competencies should not `merely' be by means of didactic instruction, rather, they must be done through applied learning mechanisms — site visits to green enterprises and interactive simulations in peer learning networks.

6.2. Scaling the Cluster-Based ESCO Model

Cluster-based ESCO model developed by NITI Aayog shows great potential to resolve both financial and technical barriers of green adoption. In this model, ESCOs arrange the financing and execution for energy efficiency upgrades across a basket of MSME units in a cluster and recoup their investment through the aggregated savings without any upfront capital required from the enterprises. The government should focus on scaling up this model by: (i) creating a separate ESCO empanelment and quality assurance framework for the MSME sector; (ii) facilitating in reducing credit risk perception factor of ESCOs with guarantees; and, (iii) embedding it into operational mechanisms of RAMP and other cluster development schemes.

6.3. Strengthening Financial Inclusion for Green MSME Investments

The financial constraints still represent one of the most consistent obstacles to the green adoption. Therefore, an agenda for policy interventions may include: increasing the coverage of MSE-GIFT scheme and raising subsidy from 2% to at least 4% interest subvention for priority sectors; a certain percentage of Priority Sector Lending to MSMEs have to be directed towards green investments; creation of Green MSME Credit Guarantee Scheme that reduces risk perception of financial institutions; devising green bonds and impact investment instruments targeted specifically in this segment. The RBI's Priority Sector Lending framework can be progressively calibrated to sustainability standards so that banks are incentivised to scale up green lending to MSMEs.

6.4. Enhanced Awareness and Outreach

Since around 33% of MSMEs still do not know of existing green schemes (ESG News, 2025), more awareness campaigns are needed. Recommendation 4 : The Ministry of MSME and MSDE can collaborate to develop hygiene-focused awareness campaigns that are multilingual, multimedia in nature, disseminated through regional industry associations, common facility centres, and digital platforms. Use simple language as campaigns launch, with relatable examples of small business success stories from peer enterprise within those sectors and regions — lend real-life hands-on evidence to the green transition to expedite understanding how it applies directly to small businesses. Create around district level MSME facilitation centres funded by the government to provide free advice on green tech options and financial schemes and application processes.

6.5. Technology Linkages and Research and Development Support

The green technology ecosystem for MSMEs in India is still nascent, resulting in access to the right technology being limited either through local procurement or being prohibitively expensive when imported. The government should support: (i) R&D funding to academic and research institutions focused on developing green technology solutions that are appropriate for MSMEs; (ii) affordable technology transfer agreements where advanced

green technologies could be made available to domestic manufacturers; and (iii) the establishment of green technology demonstration centres in existing MSME clusters, allowing enterprises to assess technologies in realistic operating conditions prior to investment. These centres may be collocated with ITIs or Polytechnics to act as regional Skill Development Hubs.

7. Conclusion

Indian MSMEs hold a prime spot somewhere between economic growth and environmental stability. At 69 million units, employing more than 250 million people and producing an annual carbon footprint of 135 MtCOCO2 e, the size of this sector alone will drive much of India's green transition trajectory. The aim of this paper has been to explore the current state of adoption of green technology in this sector by identifying barriers and drivers using the TOE framework, as well as exploring entrepreneurship and skill development as enablers for a successful transition.

The analysis shows a sector that is still mostly underdeveloped. Though there are pathbreaking instances — be it solar clusters in Jodhpur or energy-efficient foundries in Rajkot or the evolving landscape of taxation and subsidy schemes from government — adoption remains painfully low at scale. These obstacles are multi-dimensional in nature, limited to money matters, process stagnation, technology challenges and lack of awareness. A comprehensive, systematic and not just one-dimensional policy response is also needed to tackle these barriers: a coordinated set of approaches encompassing financial, technical, informational and educational interventions.

A key takeaway from this paper is that entrepreneurship and the development of skills are largely untapped resources as far as green adoption is concerned but should be important levers for accelerating change. The awareness-action gap is reduced to the extent that an MSME owner-manager is informed about green technologies, possesses competencies and networks to (i) assess their validity for the enterprise: (ii) access enabling schemes; and (iii) manage organizational change for adoption. Integrating green entrepreneurship into mainstream MSME's skill development programmes — through the National Skills Qualification Framework, sector skill councils and RAMP-style cluster interventions — is a simple, scalable and high-impact policy leap at low-cost.

Empirical studies of the propositions in this theoretical analysis should serve as future research to take these ideas forward. Additional primary data research based on MSME owner-managers' survey, skill development intervention experimental evaluations and longitudinal tracking of cluster-wide green adoption rates could be used to inform policies in this area more robustly. Research focused on sectoral workings—given the heterogeneity of MSME universe across manufacturing sectors, services, and locations—would also be useful. This green transformation of India's MSMEs is not just the imperative for environmental sustainability but an immediate business opportunity, a competitiveness opportunity and an opportunity to create more resilient and inclusive patterns of economic growth.

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