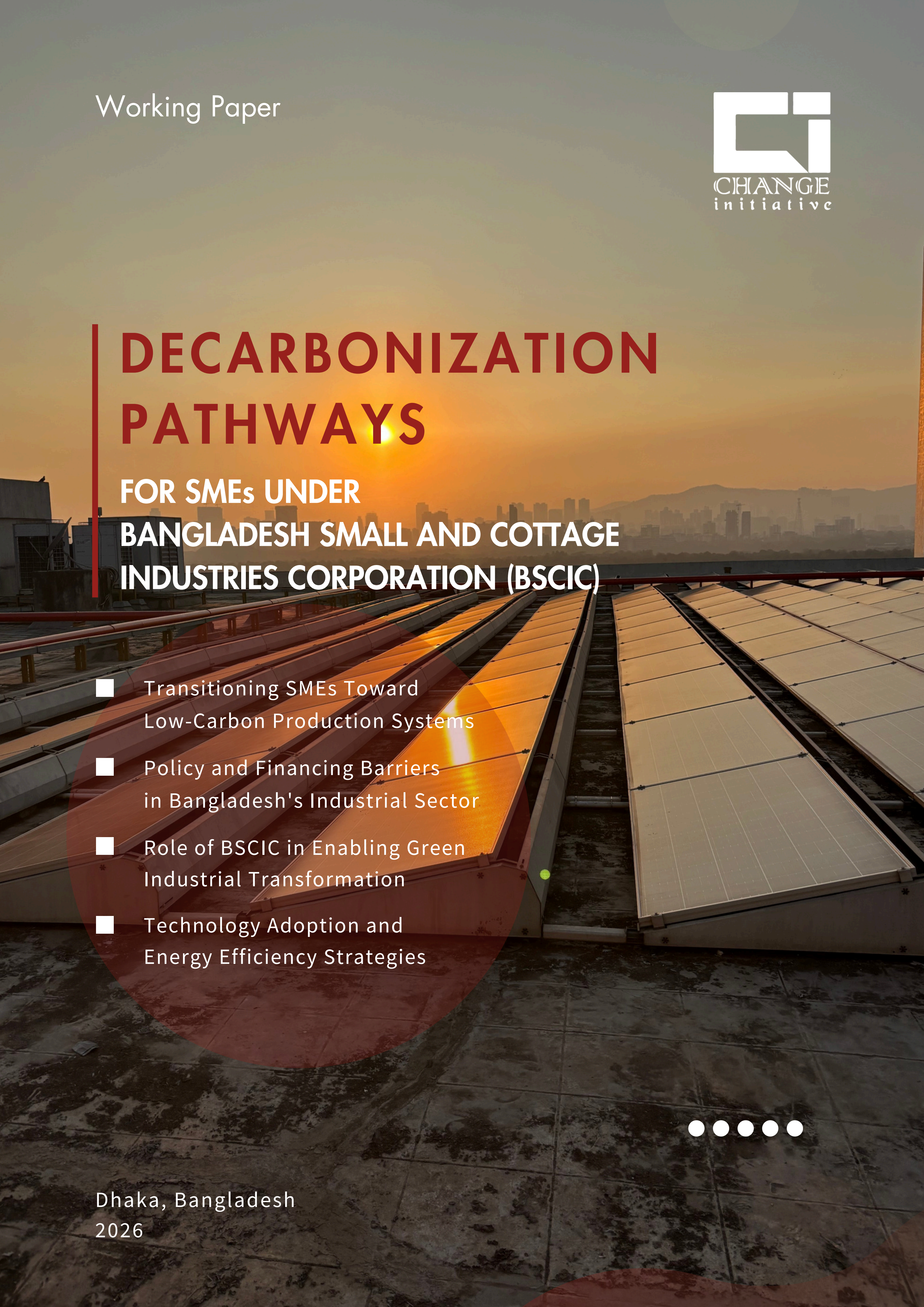

Working Paper

CHANGE
initiative

DECARBONIZATION PATHWAYS

FOR SMEs UNDER BANGLADESH SMALL AND COTTAGE INDUSTRIES CORPORATION (BSCIC)

- Transitioning SMEs Toward Low-Carbon Production Systems
- Policy and Financing Barriers in Bangladesh's Industrial Sector
- Role of BSCIC in Enabling Green Industrial Transformation
- Technology Adoption and Energy Efficiency Strategies

Dhaka, Bangladesh
2026

Decarbonization Pathways for SMEs under BSCIC: A Sectoral Analysis and Financing Framework

Change Initiative is a Bangladesh-based research and advocacy organization focused on designing practical, nature-smart, and policy-driven solutions for sustainable development. This study explores decarbonization pathways for SMEs under BSCIC, integrating technological, financial, and governance reforms to enable scalable low-carbon industrial transition.

Independently published in Bangladesh in 2026 by Change Initiative

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List of Abbreviations

BSCIC -	Bangladesh Small and Cottage Industries Corporation
BCR-	Benefit Cost Ratio
CAPEX -	Capital Expenditure
CETP-	Central Effluent Treatment Plant
CNC-	Computer Numerical Control
DoE -	Department of Environment
ESCO-	Energy Service Company
IDCOL -	Infrastructure Development Company Limited
IE3 / IE4 -	International Efficiency Class 3 / 4 Motors
IRR-	Internal Rate of Return
GDP-	Gross Domestic Production
KII-	Key Informant Interview
kWh -	Kilowatt-hour
NPV-	Net Present Value
MtCO2e-	Million Tons of Carbon Di Oxide Equivalent
MW -	Megawatt
MWh -	Megawatt-hour
OPEX -	Operational Expenditure
PPA -	Power Purchase Agreement
PV -	Photovoltaic
SCADA -	Supervisory Control and Data Acquisition
SME -	Small and Medium Enterprise
SPV -	Special Purpose Vehicle
tCO_2e -	Tonnes of Carbon Dioxide Equivalent
UNIDO -	United Nations Industrial Development Organization
VFD -	Variable Frequency Drive
VSD -	Variable Speed Drive

Executive Summary

Global industrial systems are undergoing a structural transition driven by decarbonization pressures, where emissions performance is increasingly tied to market access, financing conditions, and competitiveness. For developing economies, this shift is not abstract; it is filtering directly through global value chains, placing new compliance and cost burdens on smaller firms that lack the capacity to respond. In Bangladesh, this challenge converges sharply within the small and medium enterprise (SME) sector, which forms the backbone of industrial production while simultaneously operating under severe energy and technology constraints.

SMEs account for more than 90 percent of industrial units, employ roughly 85% of the industrial work force, and contributes around 25-30% of annual GDP. Despite this centrality, their production systems remain heavily dependent on fossil fuel-based electricity, with approximately 95.16% of national power generation derived from such sources. This structural dependence places SMEs at the core of Bangladesh's emissions trajectory, particularly as industrial expansion continues to accelerate.

National climate commitments reinforce the urgency of transformation. Under the Third Nationally Determined Contribution (NDC 3.0), Bangladesh aims to reduce 69.84 $MtCO_2e$ from the energy sector by 2035. However, implementation gaps remain pronounced at the SME level.

Production systems are characterized by outdated machinery, high electricity tariffs, unreliable supply, limited access to concessional finance, and weak institutional coordination. These constraints collectively create a structural disconnect between national climate ambition and operational realities within industrial clusters.

Industrial estates under the Bangladesh Small and Cottage Industries Corporation (BSCIC) represent a strategic entry point for resolving this disconnect. With more than 80 estates hosting thousands of enterprises across sectors such as tannery, plastics, packaging, and light engineering, these clusters concentrate energy demand, infrastructure, and governance authority within defined geographic boundaries. This spatial concentration enables the design of scalable, collective decarbonization interventions that would be difficult to achieve through firm-level approaches alone.

Analysis of four high-emission sectors-tannery, plastic manufacturing, plastic packaging, and light engineering-reveals both the scale of the challenge and the magnitude of opportunity. Combined annual emissions from these sectors are estimated at approximately 46.99 $MtCO_2e$, representing a significant share of industrial emissions. At the same time, technical and process-based interventions could reduce emissions by approximately 14.1 $MtCO_2e$ annually, with sector-specific reduction potentials ranging from 15 to 49 percent.

A central pathway for achieving these reductions lies in the deployment of solar photovoltaic (PV) systems at the industrial estate level. Scenario analysis indicates that allocating 10 percent of available estate space to solar infrastructure could generate approximately 82,969 MWh of electricity annually, reducing emissions by over 51,000 tCO_2e. Expanding this allocation to 20 percent could double both generation and emission reductions, reaching over 165,000 MWh and 102,000 tCO_2e annually. Beyond emissions mitigation, such systems offer a structural advantage by lowering long-term electricity costs, thereby directly improving SME profitability and competitiveness.

Complementary technological interventions further strengthen this transition pathway. Adoption of high-efficiency motors, inverter-based systems, CNC machinery, advanced molding technologies, and process optimization measures can significantly reduce energy intensity while enhancing production efficiency. These upgrades not only lower emissions but also improve product quality and operational reliability, positioning SMEs more favorably within increasingly carbon-sensitive global markets.

However, technological feasibility does not automatically translate into adoption. Structural barriers remain decisive. Limited access to affordable finance constrains capital investment in renewable energy and efficient machinery. Technical knowledge gaps prevent accurate assessment of energy-saving opportunities. The absence of standardized energy auditing and emissions reporting systems undermines planning and monitoring. Fragmented institutional responsibilities further dilute accountability and coordination across agencies.

Addressing these constraints requires an integrated transformation approach anchored in three interdependent shifts. First, decarbonization must move from isolated firm-level upgrades to cluster-based infrastructure solutions, particularly through shared renewable energy systems. Second, financing models must evolve toward mechanisms that reduce initial costs, including operational expenditure (OPEX) models and concessional renewable energy finance instruments. Third, institutional frameworks must be strengthened to support coordinated planning, technical assistance, and data-driven decision-making across industrial estates.

The transition pathway is not solely environmental; it is fundamentally economic. Reductions in energy costs translate directly into lower production costs, higher margins, and expanded production capacity. This, in turn, creates conditions for employment growth within industrial clusters, reinforcing the broader development impact. At scale, SME decarbonization becomes a lever for aligning climate commitments with industrial competitiveness, energy security, and inclusive growth.

What emerges is a reframing of the problem itself. The constraint is not simply emissions intensity, but a deeper structural inefficiency embedded in energy use, technology adoption, and institutional design. Addressing this inefficiency unlocks simultaneous gains across climate, economic, and social dimensions, positioning Bangladesh’s SME sector to compete within a rapidly evolving low-carbon global economy.

1. Introduction

1.1 Background

Greenhouse Gas emissions reached approximately 53.2 gigatons of CO2-equivalent in 2024, and almost three-quarters of these emissions were of fossil fuels. Power generation is the largest contributor of about 30 percent, industry about 25 percent and transport about 15 percent thus energy and industry are the primary contributors of emissions in the world. Fossil fuel emissions have grown by nearly three-quarters since 1990, with a very small fraction taken up by natural systems. This demonstrates the necessity to reduce the emissions more quickly (European Commission, 2025). Meanwhile, 142 countries and 1,185 large corporations have already engaged in net zero goals (Net Zero Tracker, 2023). There are also changing global supply chains. The large firms are now obliging smaller firms to quantify and cut emissions. Small businesses in other countries such as the US and EU must adhere to such requirements to remain in global markets (UNCTAD, 2024). This puts a great pressure on the developing nations such as Bangladesh where minor firms make a significant contribution and yet are less able to react.

Small and medium enterprises (SMEs) are very critical in the industrial economy in Bangladesh. Under the national policy, SMEs are defined in terms of employment, capital investment, as well as turnover. In production, a small business usually employs approximately 50 people, whereas a medium business can employ up to 300 people with increased levels of investment. Government agencies and financial institutions use these definitions to support their policy and finance (SME Foundation, 2013). More than 90 percent of industrial units are considered SMEs, which employ approximately 85 percent of the country's industrial workforce, and 25-30 percent of annual GDO are generated by SMEs (State of Economy, 2025). This demonstrates that both economic growth and industrial production of Bangladesh follow SMEs.

The Bangladesh Small and Cottage Industries Corporation (BSCIC) was founded in 1957 and has been instrumental in building SMEs through the establishment of industrial estates, provision of infrastructure, and technical and financial support (BSCIC, 2024). Another area that the SME foundation has assisted is in the field of entrepreneurship through funding access and building capacity. Currently BSCIC controls over 80 industrial estates, thousands of SMEs conduct their activities there and in such spheres as leather tanning, light engineering, plastics, food processing, ceramics and metal works. The industrial clusters are giant economic hubs, particularly in Dhaka, Gazipur, Narayanganj, and Chattogram.

However, this does not mean that all SMEs have abandoned their relevance because most of them continue to use old machines, low levels of automation, and poor access to modern technology. As one case, there are approximately 3,000 plastics factories, 98% of which are SMEs with a contribution of approximately 1 percent of GDP and an employment of approximately 500,000 individuals (Islam, 2014). It however has issues like shortage of skilled labor, ineffective testing facilities and ineffective certification systems. The other area that has been challenged is the light engineering industry, also known as the mother industry due to the use of obsolete machinery, inadequate funding, and poor institutional backing. In industries, SMEs are generally confronted by poor energy supply, expensive power, inaccessibility to finances, poor technical expertise, poor research, and insensitivity to environmental regulations. These issues make them less likely to invest in cleaner technologies and be competitive in the global markets.

The primary source of energy in SME clusters is grid electricity, produced to a significant part of fossil fuels. Approximately 95.16 percent of the electricity produced in Bangladesh in 2022 was fueled by fossil fuels, which contributes to the high indirect emission of activities due to industrial production (BPDB, 2026). The total amount of CO2 emitted by coal-based power is around 1892 kg of CO2 per MWh, which is significant when considering electricity consumption. The NDC 3.0 of Bangladesh shows that in 2022, the number of emissions in the country was 252.04 million tons of the CO2-equivalent, of which the energy sector makes almost 49. Industrial growth and the growing energy demand will likely lead to further emissions. Research indicates that the processes of industrialization and urbanization contribute to higher levels of emissions, and renewable energy and technology can decrease them (Raihan, 2022).

Even though Bangladesh is signatory to international climate regulations like the Paris Agreement, the NDC 3.0, and National Adaptation Plan, little has been done at SME level. In most factories, there are no adequate mechanisms of measuring or reporting emissions. There is a lack of institutional coordination and there is still minimal access to cheap green finance. Here, BSCIC and the SME Foundation are significant as they will be able to facilitate cluster-based solutions, common infrastructure, and aligned financing. This paper is undertaken to relate national climate objectives to the real-life industrial activities through creation of energy and emission base, identification of obstacles as well as the development of feasible low-carbon directions of SMEs in Bangladesh.

1.2 Rationale

Small and medium enterprises (SMEs), which fall under BSCIC industrial cluster, are significant contributors to manufacturing economy in Bangladesh producing components, leather, plastics, packaging and other products, both to the domestic market and to the global market. The national industrial policy and NDC 3.0 of Bangladesh show that enhancing the efficiency of industrial energy and greater utilization of renewable energy sources are the priorities to reduce emissions and keep the economic growth (Ministry of Environment, Forest and Climate Change, 2025). Nevertheless, most of the SMEs continue to rely on old machines, ineffective production processes and grid electricity that is powered by fossil fuel, hence resulting to high-energy prices, low-level production, and rising carbon emissions.

Within the recent few years, there has been an added strain on the small and medium factories due to the increasing electricity tariffs, volatile fuel prices, and the growing environmental compliance demands. In comparison to large industries, SMEs tend to work with minimal capital, and they cannot afford to spend money on the use of modern equipment or alternative energy mechanisms easily. This directly raises the cost of production hence low competitiveness on both the local and export markets due to high energy cost. The use of renewable energy sources, particularly rooftops solar and energy efficient machines, can save a lot of money during power consumption in the long run, potentially decreasing production cost, raising the profit margin, and enabling factories to operate more. More capacity to produce may also lead to the creation of new jobs, as it is relevant to industrial clusters where SMEs go a long way to provide jobs.

The absence of sector-specific decarbonization planning of SMEs is still observed, even with the presence of BSCIC and the SME Foundation, which is an institutional platform. Majority of the factories lack access to the energy audit, renewable energy system feasibility studies and expert advice on efficient machinery. Moreover, no high-quality information on factory-level energy consumption and emissions is often known, which is why the priority spheres cannot be observed and the effective investment program cannot be developed. Financial institutions and policymakers cannot be assured to promote the adoption of low-carbon technologies without having the baseline information.

It is on this basis that the present study was conducted to produce realistic energy utilization and emission bases with regard to the chosen SME clusters, evaluate the feasibility of renewable energy alternatives, and come up with viable upgrading sources to priority sectors like tannery,

light engineering, plastics, and packaging. The study will provide evidence that decarbonization is not only an environmental imperative but an economic prospective, which will lower the cost of energy, enhance the competitiveness of industries, and contribute to the longer-term employment of the SMEs operated by BSCIC. The results should be useful in policy formulations, climate finance initiatives, and scalable low-carbon transition plans of small and medium industries in Bangladesh.

1.3 Scopes and Limitations

This study focuses on SMEs located in selected BSCIC industrial clusters, particularly in the tannery, light engineering, plastics, and packaging sectors. The scope of the study includes estimation of energy consumption, preparation of a carbon emission baseline, and assessment of renewable energy and energy-efficient technology options. In this paper, the target SMEs are those in BSCIC industrial clusters, especially tannery, light engineering, plastics and packaging industries, because on the field, these sectors have high potential of electricity consumption and emission based on the field visit and interview with BSCIC officials, SME Foundation, and the Department of Environment. The study will involve estimation of energy consumption, formulation of a carbon emission base, and analysis of renewable energy and energy efficient technology alternatives that would lower the cost of peration and emissions with respect to the cost of operation and emissions.

The research is limited in a number of ways. Some of the calculations were not as accurate as they could have been since, in many factories, detailed energy records, production, and financial information were not entirely accessible. The selection of clusters also restricted the analysis to several clusters and thus the findings are not likely to be a complete representation of all BSCIC industrial estates in Bangladesh. Nevertheless, the competitive industries chosen are typical of the production pattern that is prevalent in most SME clusters, and thus, the results can still have an informative implication on future decarbonization planning.

1.4 Study Objectives

- Identify the sources and status of carbon emissions from selected SME clusters under BSCIC.
- Create a baseline and establish a benchmark for measuring and reporting carbon emissions.
- Identify Emission Reduction Potential
- Develop sector-specific decarbonization strategies to reduce carbon emissions for SME’s Under BSCIC.

2. Methodology

This study has a mixed data collection approaches for all the analysis of carbon emission baseline, just transition overview and solar based decarbonization planning ranging from field visits, qualitative data collection, quantitative data collection, Key Informant interviews and desk reviews. Data collection and analysis of decarbonization pathways were collected in four sectors, tannery, light engineering, plastics manufacturing, and packaging, based on secondary data, consultation with the stakeholders and the fact that these sectors consumed significantly high amounts of energy in BSCIC clusters. These industries are commonly found in industrial estates, are very dependent on production with electricity and demonstrate great possibilities of decreasing emissions by becoming energy efficient and adopting renewable energy.

2.1 Analytical Framework

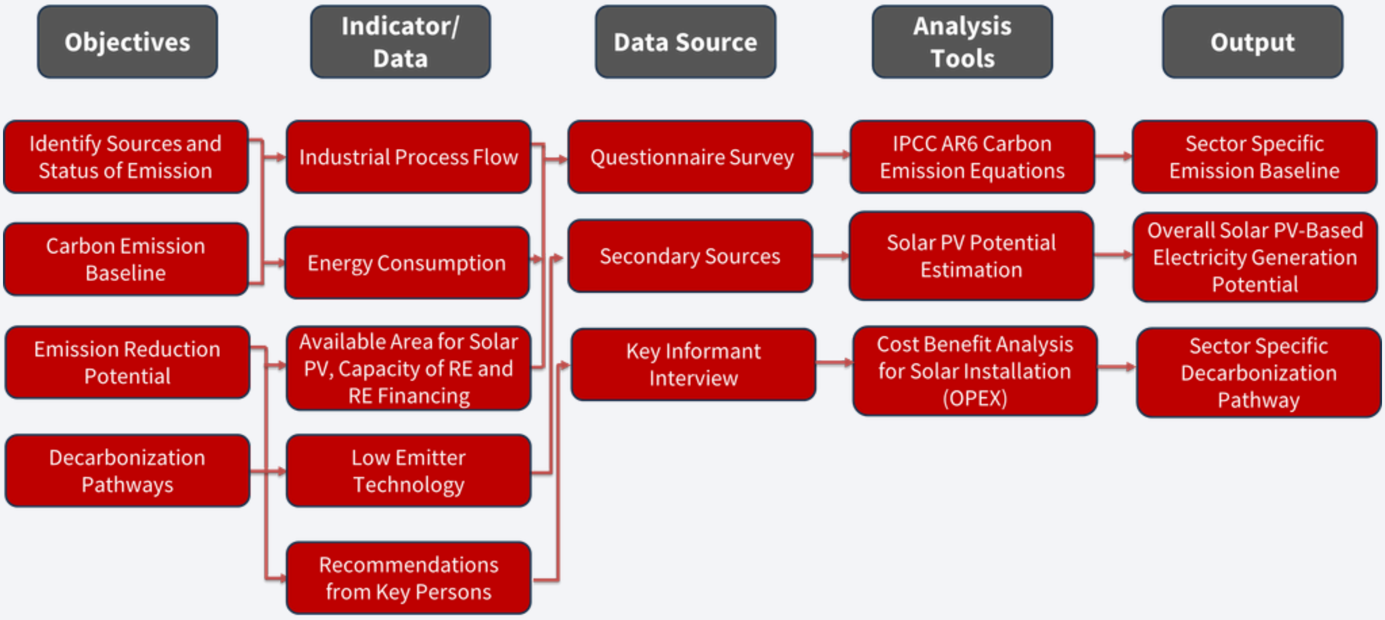


Figure 1: Analytical Framework

2.2 Carbon Emission Baseline Development

2.2.1 Field Visits and Primary Data Collection

Several respondents working in various organizations were used as key informants in the Key Informant Interviews (KIIs), with the respondents being chosen on basis of direct participation in SME development, industrial management, energy systems, financing, and environmental compliance. According to these consultations, it was found that the tannery, light engineering, plastics, and packaging sectors had a high level of energy consumption and emission potential. In the Savar and Keraniganj BSCIC Industrial Estates with the permission of the BSCIC, the field visits were conducted in the selected small and medium factories. Structured questionnaires addressing production process, machinery, utilization of fuel and electricity were used to gather primary data, accompanied by a walkthrough audit of the factory, interviews with managers and technical representatives, and recording of machine power ratings to approximate equipment level energy demand.

ENERGY USE & EMISSIONS STUDY

SME Energy Audit Methodology

A multi-layered data collection framework designed to attribute energy use to specific industrial activities.

PHASE 01: INSTITUTIONAL SCOPING

Key Informant Interviews (KIIs)

BSCIC | SME Foundation | Dept. of Environment

PHASE 02: SELECTION & ACCESS

TARGET SECTORS	LOCATION CLUSTERS
Tannery & Light Eng.	Savar BSCIC Estate
Plastics & Packaging	Keraniganj BSCIC Estate

PHASE 03: ON-SITE DATA COLLECTION

- Factory Walkthrough Audits & Interviews
- Machine Power Rating Documentation
- Review of Monthly Electricity Bills

ULTIMATE OUTPUT

Granular Activity-Based Energy Attribution

Mapping complete production cycles from raw material input to final output, linking specific machinery to energy consumption rather than using aggregated estimates.

KEY DATA PARAMETERS COLLECTED

- Production Processes
- Energy Sources
- Raw Material Use
- Machinery Count
- Electricity Consumption
- Production Volume

FIELD DATA COLLECTION METHODOLOGY | INDUSTRIAL ENERGY EFFICIENCY

Figure 2: Methodological Flowchart

Electricity bills were also reviewed to verify reported consumption and cross-check energy use data. The data collection covered production processes, process-wise machinery, number of machines, energy sources, monthly electricity consumption, raw material use, and production volume. For each factory, the complete production process was mapped from raw material input to final output, linking each process step with its corresponding machinery, enabling energy use to be attributed to specific industrial activities rather than relying on aggregated estimates.

2.2.2 Process Mapping and Energy Consumption Assessment

For each factory, the full industrial process was mapped step by step, starting from raw material preparation to final output. Each process was linked with the specific machines used, allowing the energy demand to be traced directly to individual production activities. Energy consumption was calculated using a bottom-up approach, beginning at the machine level. For each machine, data on motor power, number of units, average operating hours per day, and operating days per month were collected or validated during field visits. Monthly electricity consumption was then calculated for each machine and assigned to its corresponding process step. Machine-level electricity use was aggregated to estimate total energy consumption for each process step and for the entire factory. Electricity consumption per unit of monthly production, was also derived to enable comparison across factories and sectors. Monthly energy use (kWh) for each machine was calculated as:

$$Energy\ Consumption = Machine\ Power \times Operating\ Hours \times Load\ Factor\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$Energy\left(\frac{\mathrm{kWh}}{\mathrm{month}}\right) = Power\ (KW) \times Operating\,\frac{hours}{day} \times Operating\,\frac{days}{month} \times Numberof\ Machines\ldots\ldots(2)$$

Carbon Emission Calculation

Carbon emissions were estimated using Bangladesh's national grid emission factor of 0.62 tCO_2e per MWh. Total electricity consumption was converted from kilowatt-hours to megawatt-hours and multiplied by the emission factor to calculate carbon emissions.
Total electricity consumption (kWh) was converted to MWh and multiplied by the emission factor to estimate:

$$CO_2\ emissions\ (tCO_2e) = Electricity\ Use\ (MWh) \times Grid\ Emission\ Factor\ \ldots\ldots\ldots\ldots(3)$$

2.2.3 Data and Variables

The data and variables sourced from various primary and secondary data sources used in analysis of this report are listed in Table-1.

Table 1: Sources of Data

Indicator / Data	Assumed Value	Unit	Data Source
Production volume	_	ton/month	Field visit
Number of machines	_	count	Field visit

Indicator / Data	Assumed Value	Unit	Data Source
Motor power	_	kW	Machine catalogue Alibaba Raviraj Engineering
Operating hours	_	hour/day	Field Visit
Electricity consumption	_	kWh/month	Calculated
Electricity per unit production	_	kWh/ton	Calculated
Grid emission factor	0.62	tCO_2e/MWh	DoE
Carbon emission calculation method	_	_	IPCC AR6
Machine energy share for each sector	_	%	Calculated
Solar system capacity	620	Watt	KII
Grid/Commercial Tariff	12	Tk/unit	KII
BSCIC Area	_	sqft	BSCIC website
OPEX/PPA solar tariff	9.6	Tk/unit	KII
Daily energy generation	79	unit	KII
Project Lifetime	20	Years	IRENA (2021), Renewable Power Generation Costs
Module Degradation Rate	0.5% per year	% per year	Jordan & Kurtz (2013), Progress in Photovoltaics
Annual O&M Cost	1-2% of OPEX (1.5% used)	%	IRENA (2021), Renewable Power Generation Costs
Discount Rate	10%	%	World Bank (Energy Project Appraisal Practices, South Asia); Bangladesh Bank Green Finance Guidelines
Residual Value	5-15% of OPEX (10% used)	%	Asian Development Bank (2019), Guidelines for Economic Analysis of Projects

2.2.4 Cost Benefit Analysis:

Net Present Value (NPV)

NPV measures the present value of total benefits minus total costs over the project lifetime.

$$NPV = \sum \frac{Cash\ Flow_t}{(1+r)^t} - Initial\ Investment \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (4)$$

Where r = discount rate (10%)

Internal Rate of Return (IRR): IRR represents the discount rate at which NPV becomes zero. It indicates the effective return of the investment.

$$0 = \sum_{t=1}^{T} \frac{Cash\ Flow_t}{(1+IRR)^t} - Initial\ Investment \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (5)$$

Where,

t = each individual year
T = the final year of the project
IRR is the discount rate that makes NPV = 0.

Simple Payback Period

$$\text{Payback Period} = \frac{Initial\ Investment}{\text{Annual Net Cash Flow}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (6)$$

Discounted Payback Period

$$\text{Discounted Payback} = \text{Time when} \sum_{t=1}^{n} \frac{Cash\ Flow_t}{(1+r)^t} \geq \text{Initial Investmet} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

Cost Benefit Ratio (BCR):

$$BCR = \frac{Present\ Value\ of\ Benefits}{Present\ Value\ of\ Costs} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$

If BCR>1, the project is financially viable.

Annual O&M Cost

$$O\&M_t = \alpha \times CAPEX \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9$$

Where:

$\alpha = 1.5\%$ (used value)

2.2.5 Solar PV Potential Estimation

The estimation of solar PV-based electricity generation potential was carried out by applying a land-allocation approach to the total BSCIC zone area in each division, where either 10% or 20% of the available land was assumed to be suitable for PV deployment. The usable land area was then converted into installed capacity using a fixed land-to-capacity coefficient, and annual electricity generation was derived from the resulting capacity using standard operating hours and an assumed capacity factor. Accordingly, the calculation can be expressed as:

$$E = A \times s \times \alpha \times 8760 \times CF \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (10)$$

where E is annual electricity generation (MWh/year), A is total zone area (acres), s is the share of land allocated to solar PV (10% to 20%), α is the land-to-capacity conversion factor (MW/acre), and CF is the capacity factor. This framework enables a comparative assessment of divisional solar generation potential under two alternative land-use scenarios.

3. Sector Profile and Industrial Process Mapping

3.1 SME Scale Local Tannery Industries

The SME Scale Local Tannery sector in Bangladesh supplies leather for domestic products such as belts, bags, shoes, and garments, as well as for export markets. Field visits to the BSCIC Tannery Industrial Estate in Savar (Hemayetpur), Dhaka, show that the main production process is similar across factories, with differences mainly in technology quality, chemical use, and environmental compliance.

Raw hides, mainly cowhide and some buffalo hide, are collected from warehouses across Bangladesh and brought to the estate. Processing starts with soaking, unhairing, and liming in rotating drums, followed by fleshing to remove fat and control thickness. Some solid waste is sold, while the rest is disposed of. Chrome tanning is then done in blue drums, and wastewater is sent to the CETP, though treatment quality varies.

After tanning, the hide goes through process samming (water removal process), splitting, shaving, and finishing steps such as retanning, dyeing, pressing, and trimming. Export-quality leather requires more processing, while local products follow a shorter process.

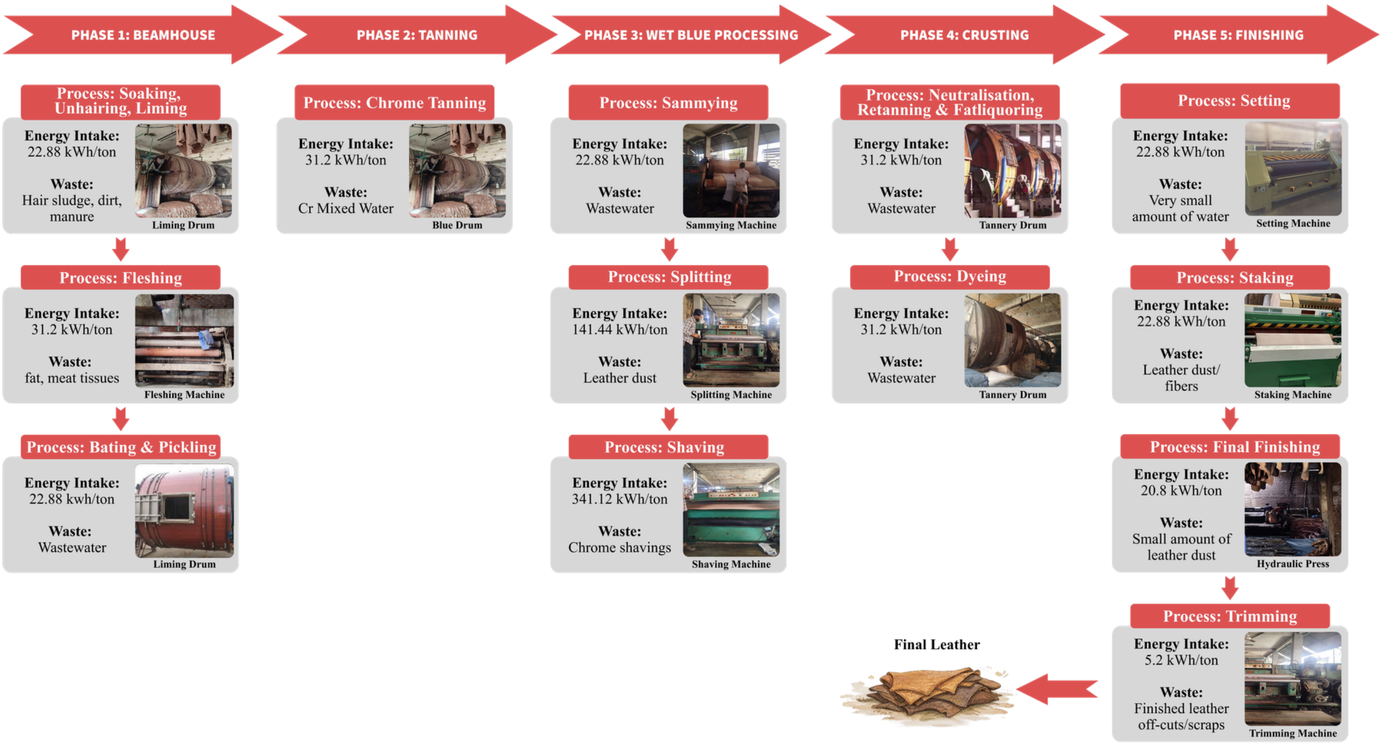


Figure 3: Industrial Process Flowchart of a SME Scale Local Tannery

3.2 Light Engineering Industries

The light engineering industry in Bangladesh is a small- and medium-scale manufacturing sector that produces components, spare parts, and hardware for construction, furniture, agriculture, and household markets. It is often called the “mother industry” because it supports many other sectors through basic metalworking. Field visits to a LE factory reflect typical production in clusters around Dhaka, Gazipur, and Narayanganj.

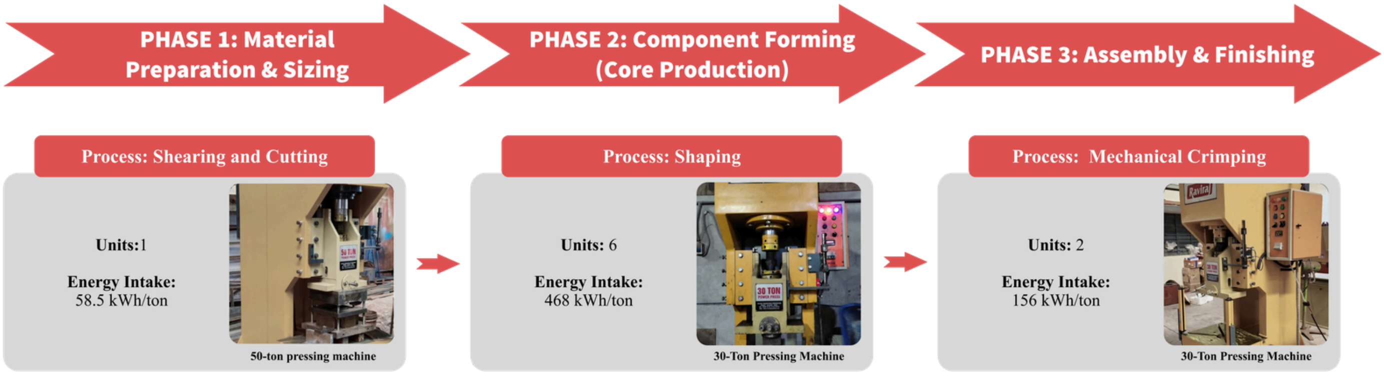


Figure 4: Industrial Process Flowchart of a Light Engineering Factory

Metal sheets are first cut using a 50-ton press, then shaped by 30-ton presses through bending and flanging. Parts are assembled by crimping, inspected manually, and packed for distribution.

The process is fully mechanical and powered by electricity. Factories use scrap or imported metal sheets from Dhaka, Chittagong, or overseas. No water, chemicals, or fuel are used, so direct emissions are very low. Production usually runs two shifts, about 12 hours daily.

3.3 Plastics Manufacturing Industries

The plastics manufacturing sector in Bangladesh mainly consists of small and medium factories producing items like disposable spoons, plates, hangers, packaging materials, and industrial accessories. Field visits to plastics manufacturing factories shows a typical injection-molding system used in Dhaka and other urban clusters.

Production starts with virgin plastic pellets such as PP, ABS, and HIPS, mostly imported from China and bought locally from dealers in areas like Chawkbazar. Small factories usually use about 8–10 tons of raw material per month. Pellets are mixed with color pigments in a mixer, then fed into the injection molding machine.

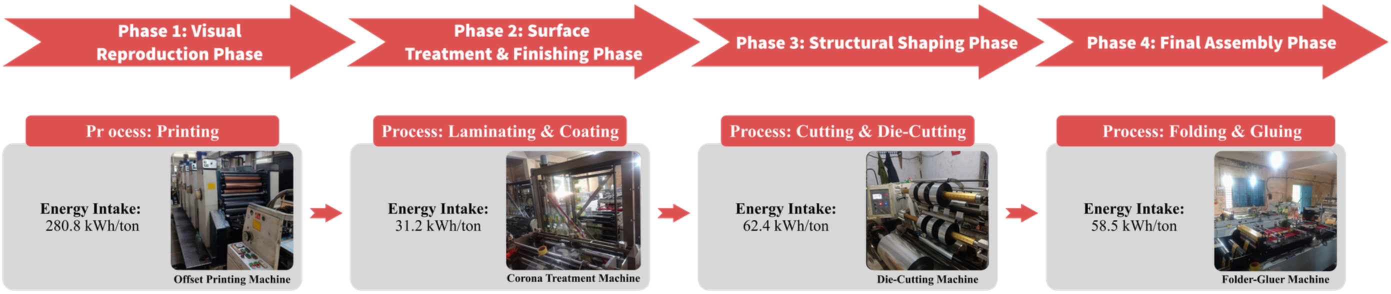


Figure 5: Industrial Process Flowchart of a Plastic Manufacturing Factory

Inside the machine, plastic is melted and injected into molds using a rotating screw system. Products are cooled by a chiller with circulating water, then ejected. Extra plastic is crushed and reused for non-food products, while food-grade items use only virgin material.

3.4 Packaging Industries

The packaging industry in Bangladesh is a growing sector supporting food, consumer goods, pharmaceuticals, garments, and e-commerce. Most factories are small to medium-sized and produce cartons, boxes, labels, and printed packaging using mainly electricity-driven printing and mechanical finishing processes.

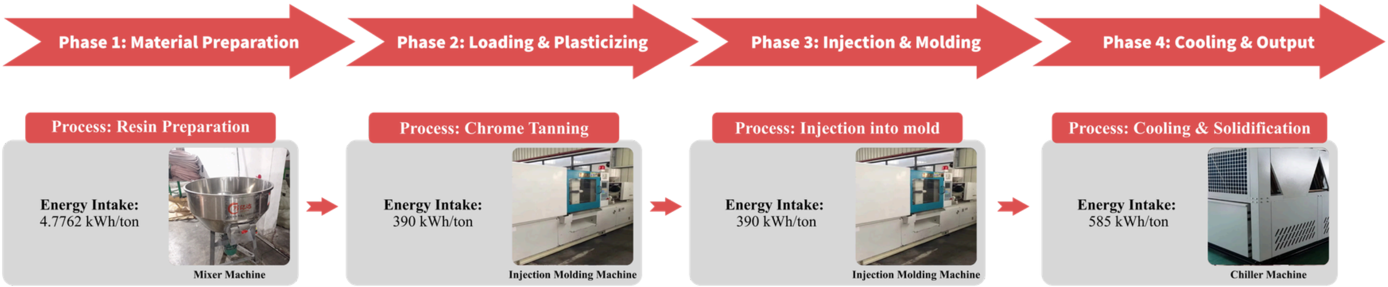


Figure 6: Industrial Process Flowchart of a Plastic Packaging Factory

Production usually follows three stages: printing, cutting, and folding/gluing. Paper sheets are first printed using offset machines with 4–10 colors, sometimes followed by laminating or surface treatment. Sheets are then die-cut into shape and finally folded and glued into boxes. Paper waste is collected for recycling, and ink mixing is often done manually in small factories.

4. Carbon Emission Baseline

The carbon emission baseline analysis shows clear differences in emission levels across the selected SME sectors under BSCIC. Among them, plastic manufacturing records the highest emissions at 29.16 $MtCO_2e$/year, reflecting its heavy reliance on energy-intensive processes and fossil-fuel-based electricity. With a 30% reduction aligned with international standards, emissions in this sector could decrease to 20.41 $MtCO_2e$/year.

Light engineering is the second highest emitter at 10.60 $MtCO_2e$/year, which could be reduced to 7.42 $MtCO_2e$/year. SME-scale local tannery contributes 5.39 $MtCO_2e$/year, with a potential reduction to 3.77 $MtCO_2e$/year. In comparison, plastic packaging shows the lowest emissions at 1.84 $MtCO_2e$/year, which could decline to 1.29 $MtCO_2e$/year after reduction measures.

4 sectors: 46.99 MtCO2e/year
- 11.23% of national emissions
- 40.12% of industrial emissions (Manufacturing + IPPU)

Reduction potential: 14.097 MtCO2e/year
- 16.4% of NDC target
- 0.03% of total emissions

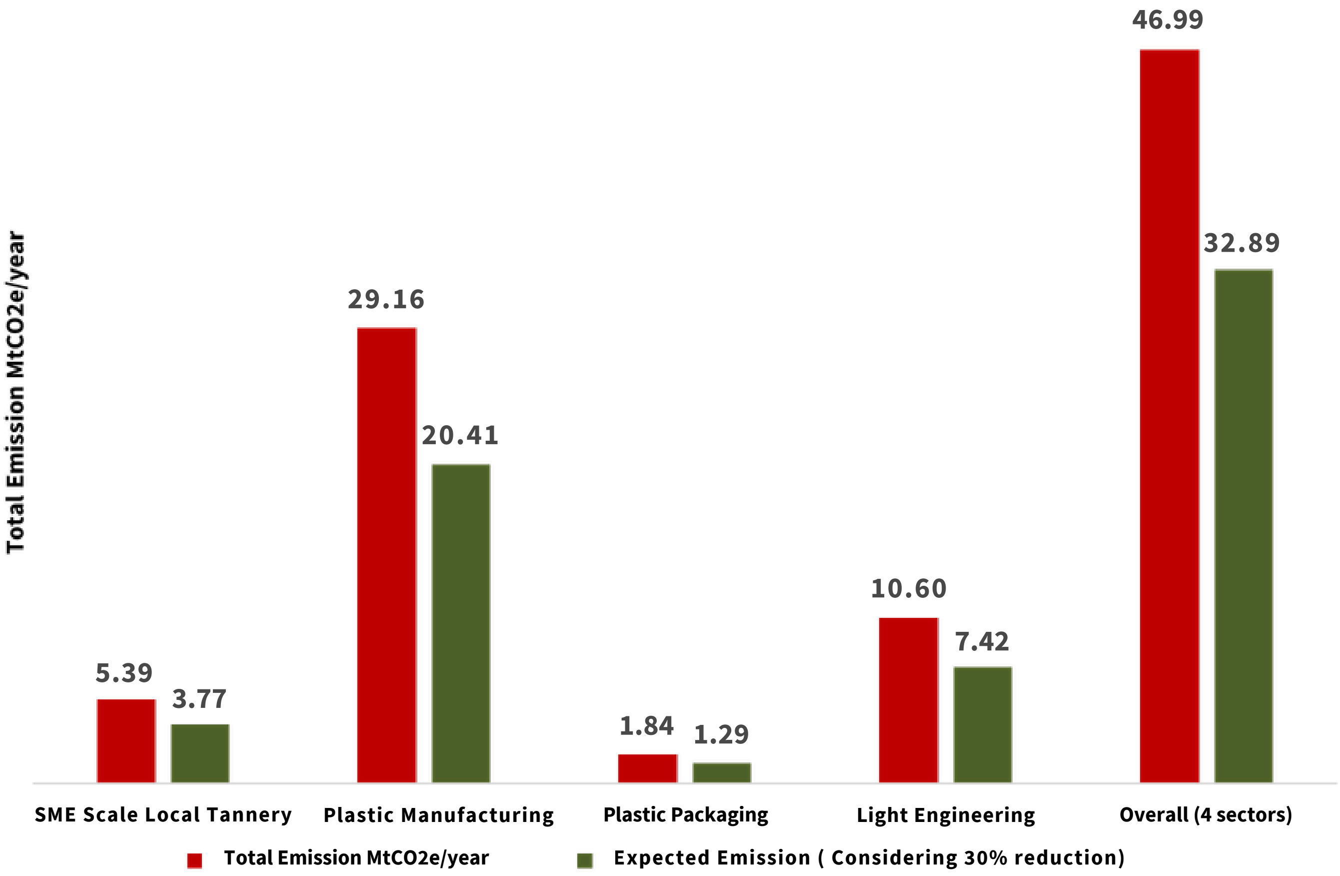


Figure 7: Sector Specific Emission Intensity

4.1 SME Scale Local Tannery Sector: Energy Use and Carbon Emission

All major machines in the SME scale local tannery process are powered by electricity. Energy consumption was calculated based on motor capacity, daily operating hours, and a production level of 25 tons per month with 26 working days. For the full process line, total electricity use is about 18,694 kWh per month, equivalent to 747.76 kWh per ton of hidden processed hide. On average, the listed machines consume around 719 kWh per day.

Table 2: Energy Use and Carbon Emission of a SME Scale Local Tannery

Process	Machine	Electricity consumption per month (kwh)	Carbon Emission tCO2/month
Soaking, Unhairing, and Liming	Liming Drum	572	354.64
Fleshing	Fleshing Machine	780	483.6

Process	Machine	Electricity consumption per month (kwh)	Carbon Emission tCO2/month
Bating & Pickling	Liming Drum	572	354.64
Chrome Tanning	Blue Drum	780	483.6
Samming	Samming Machine	572	354.64
Splitting	Splitting Machine	3536	2192.32
Shaving	Shaving Machine	8528	5287.36
Neutralisation, Retanning & Fatliquoring	Tannery Drum	780	483.6
Dyeing	Tannery Drum	780	483.6
Setting	Setting Machine	572	354.64
Staking	Staking Machine	572	354.64
Final Finishing (Pressing)	Hydraulic Press	520	322.4
Trimming	Trimming Machine	130	80.6
Total			**11590.28**

Electricity use is highly concentrated in mechanical thickness-control stages, where hides are cut and refined. The shaving machine is the largest energy consumer, using 8,528 kWh per month, or 341.12 kWh per ton, which accounts for about 46% of total electricity use. The splitting machine is the second largest, consuming 3,536 kWh per month, or 141.44 kWh per ton, representing around 19% of total use. Together, these two machines account for nearly 65% of total electricity consumption per ton, making them key targets for energy-efficiency improvements, better maintenance, and optimized operating schedules.

Other processes consume moderate amounts of electricity. Drum-based wet operations such as fleshing, chrome tanning, retanning/fat liquoring, and dyeing each use about 31.2 kWh per ton. Soaking and liming, bating and pickling, samming, setting, and staking each consume around 22.88 kWh per ton. Final pressing requires about 20.8 kWh per ton, while trimming has the lowest demand at approximately 5.2 kWh per ton.

Overall, energy use in tannery operations is dominated by mechanical finishing stages, while wet chemical processes contribute smaller but consistent loads. This distribution highlights strong opportunities for targeted efficiency and renewable energy interventions in high-consumption equipment.

4.2 Light Engineering Sector: Energy Use and Carbon Emission

Based on recorded machine data and a production level of 15 tons per month, total electricity consumption at the factory is approximately 10,237.5 kWh per month, which equals 682.5 kWh per ton of product. Energy use is concentrated in a few major machines, reflecting the mechanical nature of production.

Shaping (flanging and bending) is the largest energy consumer, using about 7,020 kWh per month, or 468 kWh per ton, due to multiple presses operating for long hours. Mechanical crimping consumes around 2,340 kWh per month, equivalent to 156 kWh per ton. Shearing and cutting uses comparatively less electricity, at about 877.5 kWh per month, or 58.5 kWh per ton.

Table 3: Energy Use and Carbon Emission of a Light Engineering Factory

Process	Process Machine	Electricity consumption per month (kwh)	Carbon Emission tCO2/month
Shearing and cutting	50 ton pressing machine	877.5	544.05
Shaping (Flanging, Bending)	30 ton pressing machine	7020	4352.4
Mechanical Crimping	30 ton pressing machine	2340	1450.8
	Total		**6347.25**

This energy pattern reflects broader trends in the light engineering sector, where electric motors and presses dominate energy use and thermal energy demand is minimal. Most factories rely on older machinery, operate on an order-by-order basis, and face limited access to modern technology and finance.

Despite these constraints, the sector plays a major role in employment generation, import substitution, and low-carbon manufacturing. It produces mainly recyclable solid waste and creates minimal environmental pollution. Overall, the hinge factory represents a low-emission, electricity-intensive production model, where improvements in machine efficiency, better production planning, and rooftop solar systems can significantly reduce electricity costs and carbon intensity while supporting sustainable sector growth.

4.3 Plastics Manufacturing Sector: Energy Use and Carbon Emission

Electricity is the main energy source for all major machines in plastics manufacturing. Based on recorded machine data and a production level of around 10 tons per month, total electricity consumption is approximately 980 kWh per ton of plastic produced.

Energy use is strongly concentrated in the core processing stages. The injection molding machine is the largest electricity consumer, using about 3,900 kWh per month, or 390 kWh per ton, because it operates for up to 20 hours per day. The chiller system is the second-largest energy user, consuming around 5,850 kWh per month, equal to 585 kWh per ton, as it runs continuously to control mold temperature.

Resin preparation uses relatively little electricity, about 47.76 kWh per month, or 4.78 kWh per ton, and has a minor impact on overall energy use. Other supporting activities contribute only small amounts to total consumption.

Table 4: Energy Use and Carbon Emission of a Plastic Manufacturing Factory

Process	Process Machine	Electricity consumption per month (kwh)	Carbon Emission tCO2/month
Resin Preparation	Mixer Machine	47.76	29.61244
Feeding into hopper, Plasticizing (melting + mixing), Injection into Mold	Injection Molding Machine	3900	2418
Cooling & Solidification	Chiller system	5850	3627
	Total		**6074.61**

Overall, electricity demand in plastics factories is dominated by melting, molding, and cooling operations. This makes injection molding and chilling systems the main targets for energy efficiency measures, improved operating schedules, and rooftop solar integration. Strengthening these areas can significantly reduce production costs and carbon emissions while supporting sustainable growth of the plastics manufacturing sector.

4.4 Packaging Sector: Energy Use and Carbon Emission

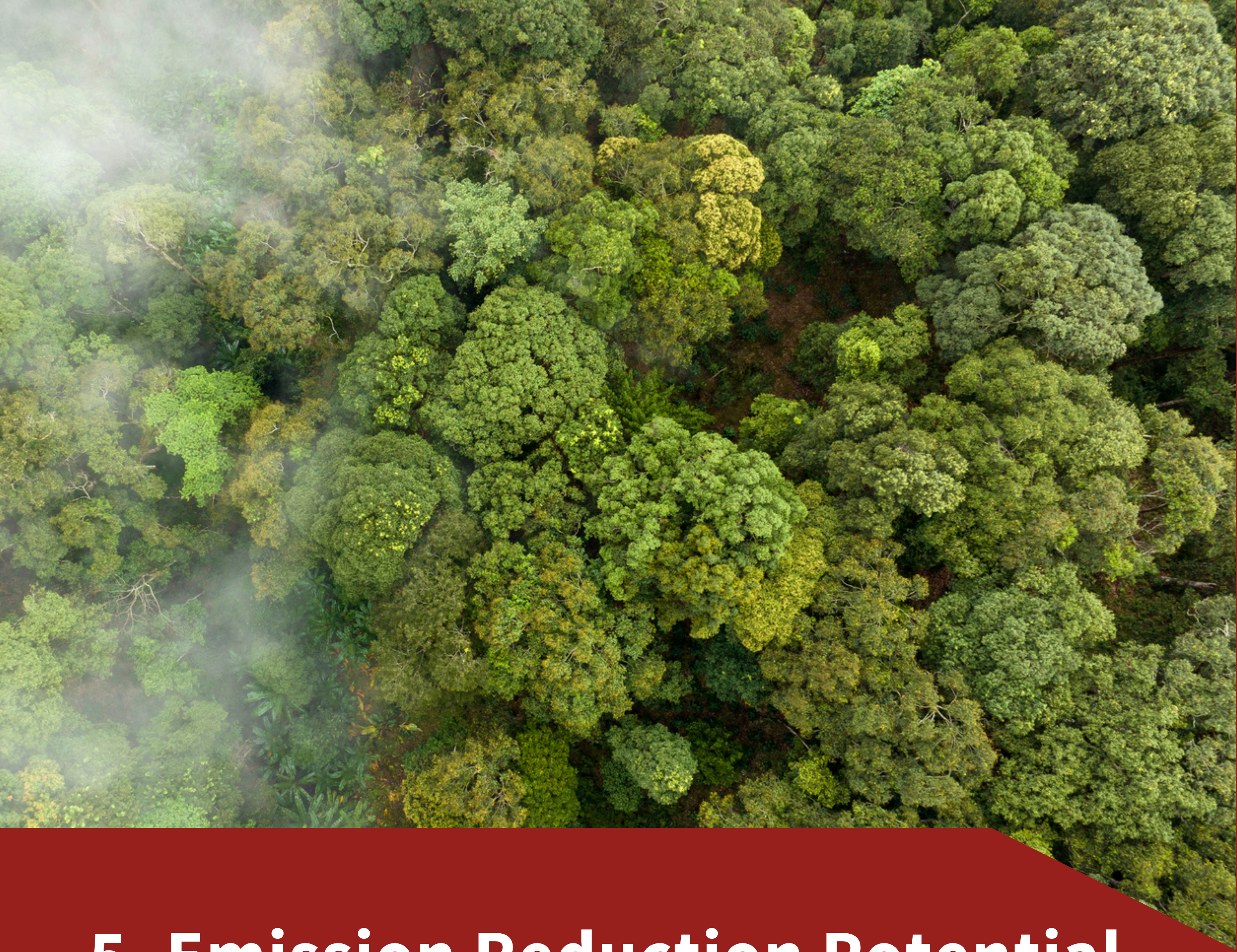
All major production equipment in packaging factories runs on electricity. Based on collected data and a production level of 20 tons per month, total electricity consumption is about 8,658 kWh per month, equivalent to 432.9 kWh per ton of packaging produced.

Energy use is mainly concentrated in the printing stage, which is the most power-intensive part of the process. Printing machines consume around 5,616 kWh per month, or 280.8 kWh per ton, accounting for more than half of total electricity use due to high motor capacity and long operating hours.
Surface treatment and laminating use relatively little electricity, about 624 kWh per month, or 31.2 kWh per ton. Cutting and die-cutting consume around 1,248 kWh per month, or 62.4 kWh per ton, while folding and gluing require about 1,170 kWh per month, or 58.5 kWh per ton.

Table 5: Energy Use and Carbon Emission of Plastic Packaging Factory

Process	Process Machines	Electricity consumption per month (kwh)	Carbon Emission tCO2/month
Printing	Offset Printing Machine	5616	3481.92
Laminating & Coating	Corona treatment Machine	624	386.88
Cutting & Die-Cutting	Die-Cutting Machine	1248	773.76
Folding & Gluing	Folder-Gluer Machine	1170	725.4
Total		**8658**	**5367.96**

Overall, energy demand in packaging factories is dominated by printing and finishing operations. Since production relies almost entirely on electricity and generates recyclable waste, the sector has strong potential for energy efficiency improvements, better machine scheduling, and rooftop solar adoption. Improving energy performance in printing and folding stages will be key to reducing production costs and carbon emissions while maintaining product quality.



5. Emission Reduction Potential

5.1 Technical and Process based Emission Reduction Potential by Sector

Technical reduction potential refers to the maximum achievable emission reduction through currently available technologies, improved operational practices, and process optimization, assuming no major structural changes in production volume. Since the assessed factories are primarily electricity-driven, emission reduction potential is directly linked to reductions in grid electricity demand, using the applied grid emission factor of 0.62 tCO_2e per MWh.

A cross-cutting finding across all sectors is that a large share of industrial electricity demand is driven by motor systems. Global evidence shows that electric motors and motor systems represent a major share of electricity consumption, and that new and existing technologies can typically reduce motor-system energy demand by about 20 to 30 percent with feasible payback periods (IEA 4E). In addition, variable speed drives can deliver significant savings where loads vary over time, with typical savings reported in the range of 15 to 40 percent in variable-load applications, and higher savings possible in appropriate pump and fan systems. (Energy Institute).

Baseline reference for technical potential assessment

The technical reduction potential is interpreted against the monthly electricity and emission baselines developed for representative process lines/factories in each sector:

Table 6: Baseline Reference for Technical Potential Assessment

Sector	Baseline electricity use (kWh/month)	Baseline emissions (tCO_2e/month)	Dominant electricity loads (share of total)
SME Scale Local Tannery	18,694	11590.28	Shaving 45.6%, Splitting 18.9% (combined ~64.5%)
Light engineering	10,237.50	6074.61	Shaping presses ~68.6%
Plastics	9,797.80	5367.96	Chiller ~59.7%, Injection molding ~39.8%
Packaging	8,658	6347.25	Offset printing ~64.9%

5.1.1 SME Scale Local Tannery Sector

The SME scale local tannery electricity demand is concentrated in mechanical thickness-control and finishing equipment, particularly shaving and splitting operations, which together account for approximately two-thirds of total electricity consumption in the observed factories. This concentration indicates that the largest emission reduction potential lies in improving the efficiency of high-load mechanical equipment.

From a technical perspective, the main decarbonization pathway involves replacing inefficient motor-driven systems with high-efficiency IE3 or IE4 motors combined with variable frequency drive (VFD) control, which are widely used in modern European leather processing plants. These technologies reduce electrical losses in motor systems and allow machine speed to adjust to actual production requirements, thereby lowering electricity consumption without affecting production capacity. Additional improvements in machine design and mechanical condition, such as better transmission alignment and reduced friction losses, can further enhance energy efficiency. At the process level, internationally recognized Best Available Techniques (BAT) for the tanning industry recommend operational improvements that reduce energy demand during wet processing and drying preparation. Key measures include optimizing mechanical dewatering (samming) to remove more water before drying and using short float tanning processes, which reduce hot water demand and drum rotation time during wet processing.rIn addition to energy efficiency improvements, waste management offers an important opportunity for emission reduction in tannery operations. Leather processing generates significant quantities of organic waste, including fleshing waste, trimmings, sludge from effluent treatment plants, and chromium-containing residues. When improperly managed, these wastes can contribute to methane emissions and increase the energy requirements of wastewater treatment.

Several internationally used waste management technologies can reduce emissions while maintaining production capacity:

- Anaerobic digestion of tannery organic waste (such as fleshing and sludge) to produce biogas, which can be used for heat or electricity generation within the facility.
- Solid waste valorization, where collagen-rich leather waste is converted into biogas, biofertilizer, or industrial by-products such as gelatin and protein hydrolysates.
- Chrome recovery and reuse systems, which reduce chemical consumption and lower wastewater treatment energy demand.
- Improved segregation of solid waste streams, allowing organic waste to be treated separately from hazardous waste and enabling energy recovery options.

5.1.2 Light Engineering Sector

The light engineering baseline is characterized by electrically driven mechanical production with minimal thermal energy demand and low direct emissions. Energy consumption is highly concentrated in shaping operations, where multiple presses operate for long hours and account for nearly 70 percent of electricity demand in the surveyed factories.

Given that production depends largely on motor-driven mechanical work, emission reduction potential is primarily associated with improving the efficiency of press systems and motor-driven equipment. Internationally, servo press technology is widely adopted in advanced manufacturing sectors such as automotive component production. Servo presses replace conventional mechanical or hydraulic presses by using digitally controlled servo motors that consume energy only when force is required, significantly reducing electricity consumption during idle or partial-load operation.

In addition, upgrading standard efficiency motors to premium efficiency IE3 or IE4 motors, together with improved drive and control systems, can reduce motor losses. Retrofitting suitable applications with variable speed drives allows motors to operate according to load demand rather than at constant speed, reducing idle electricity use.

Process optimization measures further enhance these technical improvements without affecting production capacity. These include batch-based production scheduling, idle shutdown of presses and auxiliary equipment, preventive maintenance to reduce mechanical losses, and operator training to improve load management and machine operation efficiency.

5.1.3 Plastics Manufacturing Sector

Among the analyzed sectors, plastics manufacturing shows the strongest decarbonization potential due to the dominance of two energy-intensive systems: injection molding and cooling or chilling operations. The chiller accounts for approximately 59.7 percent of electricity use, while injection molding machines account for about 39.8 percent.

A key technological pathway for emission reduction is the modernization of injection molding power systems. Many SMEs operate conventional hydraulic injection molding machines with fixed-displacement pumps, which consume electricity continuously regardless of actual load. International best practice in plastics manufacturing has increasingly shifted toward servo-hydraulic or all-electric injection molding machines, which use electronically controlled motors to deliver energy only when needed.

Empirical studies demonstrate that replacing conventional hydraulic systems with advanced electro-hydraulic power unit designs can reduce injection molding machine energy consumption by 47 percent to 87 percent, depending on the configuration of servo motors and variable-speed drives.

Cooling systems also offer significant opportunities for efficiency improvement. Technical upgrading of chillers through variable-speed compressor technology allows cooling capacity to adjust dynamically to process demand. Industry best-practice guidance indicates that variable-speed chillers can reduce annual energy consumption by up to 30 percent under real operating conditions.

Process optimization measures further reduce electricity demand without affecting production capacity. These include cycle-time optimization, chiller setpoint adjustment, maintenance and insulation of chilled water circulation systems, and reducing defect rates through improved process parameter control.

5.1.4 Packaging Sector

Electricity demand in the packaging sector is dominated by the printing stage. In the baseline assessment, offset printing accounts for approximately 64.9 percent of total electricity consumption, followed by die-cutting and folding or gluing operations.

Technical emission reduction potential in this sector primarily arises from improving the efficiency of printing and auxiliary motor systems. Modern printing facilities increasingly adopt LED-UV curing technology in place of conventional UV curing systems. LED-UV curing consumes significantly less electricity and generates less heat, allowing faster startup times and reduced standby energy use.

Additional technical improvements include upgrading printing press motor systems to high-efficiency motors combined with variable speed drives, which allow motors to operate according to production load and reduce idle electricity consumption.

Process optimization measures are also important because a significant portion of electricity use in printing operations occurs during setup, stoppages, and non-productive running time. Key operational improvements include improved job sequencing to reduce stop-start frequency, reducing reprints through better calibration and setup procedures, implementing standby and shutdown protocols, and routine maintenance of printing and finishing equipment.

Table 7: Sector Wise Technical and Process based Emission Reduction Potential

Sector	Existing High-Emission Technology	Low-Emission Technology (Used Globally)	Process Optimization Technique	Reduction Potential (%)	Estimated Emission Reduction (tCO_2e/month)
SME scale local Tannery	Conventional shaving machine with standard motor	IE3/IE4 high-efficiency motor shaving machines with Variable Frequency Drive (VFD) used in modern EU tanning plants	Mechanical dewatering (advanced samming) before drying to reduce drying energy demand	10-15%	1.16-1.74
	Conventional splitting machine	Energy-efficient splitting machines with servo motor control used in Italian and German leather plants	Short-float tanning technology (reduces water and drum rotation time)	8-10%	0.93-1.16
	Conventional tanning drum control	Automated drum control systems with efficient motors	Optimized drum loading and cycle time management	5-8%	0.58-0.93
Total Emission Reduction				**19-33%**	**2.23–3.77**
Light Engineering	Conventional hydraulic/mechanical press	Servo press systems widely used in automotive and precision manufacturing industries	Batch production scheduling and idle shutdown automation	10-15%	0.64-0.95
	Standard efficiency electric motors	IE3/IE4 premium efficiency motors (IEA high-efficiency motor standard)	Preventive maintenance and lubrication management for machining equipment	6-10%	0.38-0.64

Sector	Existing High-Emission Technology	Low-Emission Technology (Used Globally)	Process Optimization Technique	Reduction Potential (%)	Estimated Emission Reduction (tCO$_2$e/month)
	Manual machining control	Computer Numerical Control (CNC) machining systems with energy-optimized control	Machine standby power control and smart power management	5-8%	0.32-0.51
	Total Emission Reduction			**19-31%**	**1.21-1.99**
Plastic Manufacturing	Hydraulic injection molding machine	Servo-hydraulic or all-electric injection molding machines widely used in Japan and Europe	Optimized mold temperature and reduced idle heating cycles	20-35%	1.21-2.12
	Constant-speed industrial chiller	Variable-speed inverter chillers used in modern plastic manufacturing plants	Cooling system temperature optimization and heat recovery	10-15%	0.61-0.91
	Conventional air compressor	Energy-efficient inverter compressors	Compressed air leakage control and pressure optimization	5-8%	0.30-0.48
	Total Emission Reduction			**33-49%**	**1.97-2.97**
Packaging / Printing	Conventional UV curing system	LED-UV curing technology used in modern offset printing presses	Optimized print job sequencing to reduce machine startup losses	8-12%	0.43-0.64
	Conventional printing motor drive	High-efficiency motor with VFD control	Automated standby shutdown of printing equipment	5-8%	0.27-0.43
	Manual process setup	Digital printing process automation systems	Calibration optimization to reduce reprints and material waste	4-6%	0.21-0.32
	Total Emission Reduction			**15-28%**	**0.78-1.50**

5.2 Solar PV-Based Emission Reduction Potential

Solar photovoltaic deployment across BSCIC industrial estates represents the largest structural emission reduction opportunity identified in this study. Since all assessed SME sectors are predominantly electricity-driven, replacing fossil fuel-based grid electricity with on-site solar generation directly reduces indirect carbon emissions.

Using the national grid emission factor of 0.62 tCO_2e per MWh, each unit of solar electricity generated displaces an equivalent number of grid-based emissions.

To assess large-scale feasibility, two land-use scenarios were analyzed across major BSCIC zones:

- **Scenario 1:** 10 percent of total estate area allocated to solar PV
- **Scenario 2:** 20 percent of total estate area allocated to solar PV

The installed capacity and annual electricity generation under both scenarios are summarized below.

Table 8: Potential of Scaling up Solar System (Rooftop + Open Suitable Space) in BSCIC Industrial Estates

Division	BSCIC Zone Area (acres) (Rooftop + Open Suitable Space)	10% of space for potential solar power system		20% of space for potential solar power system	
		Potential Installed capacity- MW (Mega Watt)	Potential Electricity Generation- MWh (Mega Watt hour) per year	Potential Installed capacity (MW)	Potential Electricity Generation (MWh) per year
Khulna	173.38	4.95	7232.42	9.91	14464.85
Chattogram	339.71	9.71	14170.76	19.41	28341.52
Dhaka	665.23	19.01	27749.59	38.01	55499.19
Barisal	221.02	6.31	9219.69	12.63	18439.38
Rangpur	147.37	4.21	6147.43	8.42	12294.87
Rajshahi	323.89	9.25	13510.84	18.51	27021.68
Sylhet	118.38	3.38	4938.14	6.76	9876.27
Total	**1988.98**	**57**	**82968.88**	**114**	**165937.76**

Using the grid emission factor of 0.62 tCO_2e per MWh, the total annual emission reduction potential can be estimated.

Scenario 1: 10% Rooftop + Open Suitable Space Allocation (57 MW)

Annual solar generation: 82,968.88 MWh
Estimated annual emission reduction:
82,968.88 × 0.62 = 51,440.71 tCO_2e per year
Investment Needed: 285 Crore BDT (23.25 million USD)

Scenario 2: 20% Rooftop + Open Suitable Space Allocation (114 MW)

Annual solar generation: 165,937.76 MWh
Estimated annual emission reduction:
165,937.76 × 0.62 = 102,881.41 tCO_2e per year
Investment Needed: 570 Crore BDT (46.33 million USD)

This indicates that even allocating only 10 percent of total BSCIC zone area to solar PV could offset more than 51,000 tons of CO_2 annually, while a 20 percent allocation could exceed 100,000 tons of CO_2 reduction per year.

Dhaka zone alone demonstrates the highest potential due to its large estate area, contributing approximately:

- 27,749.59 MWh annually under 10% allocation
- 55,499.19 MWh annually under 20% allocation

The impact of solar deployment varies by sector:

- Plastics and tannery sectors, which show high electricity intensity per ton, would benefit most from solar integration.
- Light engineering and packaging sectors, although less energy intensive, could significantly reduce operational costs through rooftop solar.

Since all studied sectors are electricity-driven with limited thermal fuel dependency, solar PV integration directly reduces their carbon intensity without requiring process redesign.

Strategic Implications

Solar deployment within BSCIC estates provides multiple co-benefits:

1. Direct reduction of indirect emissions from grid electricity
2. Reduced exposure to rising electricity tariffs
3. Improved competitiveness in carbon-sensitive export markets
4. Enhanced eligibility for renewable energy finance and climate funds
5. Alignment with national renewable energy and NDC targets

Cluster-based solar deployment also allows shared infrastructure models, including:

- Centralized ground-mounted solar parks
- Rooftop solar aggregation models
- Hybrid net-metering systems

Compared to machine-level efficiency improvements, solar integration offers the largest absolute emission reduction potential at cluster scale. When combined with the 15-30 percent technical and process efficiency improvements identified earlier, BSCIC industrial estates could achieve a substantial reduction in electricity-based carbon emissions.

5.2.1 Cost Benefit Analysis of Installing Solar PV at the BSCIC Industrial Estate

To assess the financial feasibility of rooftop solar adoption in BSCIC industrial estates, a 20 kW on-grid rooftop solar system under the CAPEX model is analyzed. This system represents a typical small-scale installation suitable for SMEs with available rooftop space and consistent electricity demand. The analysis considers total investment cost, annual electricity generation, savings from reduced grid consumption, and key financial indicators over the project lifetime. By evaluating parameters such as payback period, net present value, and return on investment, this assessment provides a clear understanding of the economic viability of solar PV for SME adoption. The detailed cost structure and financial performance indicators are presented in the following table.

5.2.1.1 20KW On-Grid Rooftop Solar Project Description (CAPEX):

The 20 kW CAPEX system requires an approximate investment of Tk 1,373,900, covering key components such as 32 solar panels (620W each), inverters, mounting structures, and EPC charges. It occupies around 1,250 sq.ft of rooftop space and generates approximately 79 units of electricity per day, resulting in an annual electricity value of about Tk 346,020 at a commercial tariff of Tk 12 per unit. This configuration reflects a practical and scalable solution for SMEs, demonstrating both technical feasibility and cost-effectiveness. The detailed cost structure and system specifications are presented in the following table.

Table 9: Financial Performance Indicators for 20 kW On-Grid Rooftop Solar (CAPEX Model)

20KW On-Grid Rooftop Solar				
Instrument	**Capacity**	**Quantity**	**Per Unit Cost (TK)**	**Total Cost (TK)**
Solar Panel	620 Watt	32	12,400	396,000
On-Grid Inverter	20KW	2 (Lifetime 12 years)	145,000	290,000
Cable & Accessories	-	-	10	198,400
Mounting Structure (best one)	-	-	8	158,720
Survey & Design	-	-	-	10,000
Transportation	-	-	-	16,000
Installation	-	-	-	30,000
EPC Charges	-	-	25% of total cost	274,780
Total Cost				**1,373,900**
Area Required	1250 sq.ft	-	-	-
Capacity Factor	5 hrs a day	79.00 Unit	-	-
Per Unit Commercial Bill	12 Tk	-	-	-
Gross value of generated electricity	346,020 TK	Per year	-	-

The 25-year financial evaluation of the 20 kW on-grid rooftop solar system under the CAPEX model demonstrates strong economic viability for SMEs in Bangladesh. With a total investment of Tk 1,373,900 and annual net cash flow of approximately Tk 325,411 in the first year, the system achieves a simple payback period of about 4.2 years, while the discounted payback period at a 10 percent discount rate is around five years. Over the 25-year project life, the present value of total benefits is estimated at Tk 2.89 million, generating a positive Net Present Value of approximately Tk 1.52 million.

Table 10: Cost Benefit Analysis Result for 20 kW On-Grid Rooftop Solar (CAPEX Model)

Component	Formula / Basis	Calculation	Result	Interpretation
Net Cash Flow (Year 1)	Annual Savings – O&M	346,020 – 20,609	Tk 325,411	Net financial benefit in the first year
Cash Flow Trend	0.5% annual module degradation	Gradual decline in generation	-	Slight reduction in output each year
Simple Payback Period	CAPEX / Net Annual Cash Flow	1,373,900 / 325,411	4.2 years	Investment recovered in approximately 4.2 years
Discounted Payback Period	10% discount rate applied	Discounted cash flow method	≈ 5 years	Payback considering time value of money
Present Value of Benefits	25-year discounted savings	-	Tk 2,895,000	Total present value of lifetime benefits
Initial Investment	Total CAPEX	-	Tk 1,373,900	Upfront capital expenditure
Net Present Value (NPV)	PV Benefits – CAPEX	2,895,000 – 1,373,900	Tk 1,521,100	Positive NPV confirms financial viability
Internal Rate of Return (IRR)	IRR where NPV = 0	-	≈ 23%	Significantly higher than prevailing lending rates
Cost Benefit Ratio (BCR)	PV Benefits / PV Costs	2,895,000 / 1,373,900	2.11	Benefits are more than twice the investment cost

The 25-year financial evaluation of the 20 kW on-grid rooftop solar system under the CAPEX model demonstrates strong economic viability for SMEs in Bangladesh. With a total investment of Tk 1,373,900 and annual net cash flow of approximately Tk 325,411 in the first year, the system achieves a simple payback period of about 4.2 years, while the discounted payback period at a 10 percent discount rate is around five years. Over the 25-year project life, the present value of total benefits is estimated at Tk 2.89 million, generating a positive Net Present Value of approximately Tk 1.52 million. The Internal Rate of Return is about 23 percent, which is substantially higher than prevailing commercial lending rates, indicating attractive investment performance. Furthermore, the Cost Benefit Ratio of 2.11 confirms that the project generates more than double the economic value relative to its cost. Even after accounting for annual module degradation and operation and maintenance expenses, the system remains financially robust, making rooftop solar a viable and strategic investment option for industrial SMEs under BSCIC clusters.

5.2.1.2 20 kW On-Grid Rooftop Solar Project Description (OPEX Model)

For the OPEX model, the economics change completely. The SME does not buy the system. A third-party developer installs, owns, operates, and maintains the rooftop solar plant, and the SME simply purchases the generated electricity under a long-term power purchase arrangement. That means the customer-side story is no longer about recovering CAPEX. It is about bill reduction with zero upfront investment.

The analysis below uses following assumption:

- Grid/commercial tariff: Tk 12 per unit
- OPEX/PPA solar tariff: Tk 9.60 per unit
- This implies a 20% discount to the existing commercial tariff
- Generation remains the same as your CAPEX case: 79 units/day, or 28,835 units/year

5.2.1.3 Financial Performance Indicators for 20 kW On-Grid Rooftop Solar (OPEX Model)

To reduce the financial burden of upfront investment, the OPEX (or PPA-based) model is assessed for the same 20 kW on-grid rooftop solar system. Under this model, the entire system is developer-financed, meaning SMEs incur zero initial capital cost while purchasing electricity at a lower tariff.

Table 11: Financial Performance Indicators for 20 kW On-Grid Rooftop Solar (OPEX Model)

Instrument	Capacity	Quantity	Per Unit Cost (Tk)	Total Cost (Tk)
Solar Panel	620 Watt	32	Developer-financed	0 (for SME)
On-Grid Inverter	20 kW	2	Developer-financed	0 (for SME)
Cable & Accessories	-	-	Developer-financed	0 (for SME)
Mounting Structure	-	-	Developer-financed	0 (for SME)
Survey & Design	-	-	Developer-financed	0 (for SME)
Transportation	-	-	Developer-financed	0 (for SME)
Installation	-	-	Developer-financed	0 (for SME)
EPC Charges	-	-	Developer-financed	0 (for SME)
	Total Initial Cost to SME			**0**

The system generates approximately 28,835 kWh annually, equivalent to a market value of Tk 346,020 per year at the prevailing grid tariff of Tk 12 per unit. Instead, the SME pays the developer at a reduced rate of Tk 9.60 per unit, resulting in an annual payment of Tk 276,816 and immediate savings of around Tk 69,204 per year. This model demonstrates a low-risk and accessible pathway for SMEs to adopt solar energy without capital constraints, as detailed in the following table.

Table 12: Cost Benefit Analysis Result for 20 kW On-Grid Rooftop Solar (OPEX Model)

Item	Value
Area Required	1,250 sq.ft
Capacity Factor	5 hrs a day
Daily Energy Generation	79 units
Commercial Grid Tariff	Tk 12/unit
Solar OPEX/PPA Tariff	Tk 9.60/unit
Annual Gross Value of Generated Electricity(at grid tariff)	Tk 346,020
Annual Payment to Solar Developer	Tk 276,816
Annual Gross Savings to SME	**Tk 69,204**

The annual generation is 28,835 kWh, worth Tk 346,020/year at the commercial tariff. At an OPEX tariff of Tk 9.60/unit, the SME pays Tk 276,816/year to the developer, generating an immediate first-year saving of Tk 69,204/year.

5.2.1.4 Customer-Side Financial Indicators for 20 kW Solar (OPEX Model)

Further evaluating the economic benefits from the SME perspective, customer-side financial indicators under the OPEX model are analyzed over a 25-year period. Since there is no upfront investment, SMEs start benefiting immediately through reduced electricity costs. In the first year alone, the system generates savings of approximately Tk 69,204, with continued positive cash flow over time despite minor reductions due to module degradation. The total present value of benefits is estimated at Tk 3.03 million, compared with a lifetime cost of Tk 2.42 million, resulting in a net economic gain of Tk 605,419. The cost-benefit ratio of 1.25 confirms that savings exceed payments, making this model financially attractive and low-risk for SMEs. The detailed financial indicators are presented in the following table.

Table 13: Customer-Side Financial Indicators for 20 kW Solar (OPEX Model)

Component	Formula / Basis	Calculation	Result	Interpretation
Net Cash Flow (Year 1)	Avoided Grid Cost – PPA Payment	346,020 – 276,816	Tk 69,204	Immediate annual bill saving in the first year

Component	Formula / Basis	Calculation	Result	Interpretation
Cash Flow Trend	0.5% annual module degradation	Gradual decline in energy output	-	Slight reduction in annual savings over time
Simple Payback Period	Initial Investment / Annual Savings	0 / 69,204	Immediate / Not Applicable	No upfront capital to recover
Discounted Payback Period	Discounted cash flow method	No upfront investment	Immediate / Not Applicable	Positive cash flow starts from year 1
Present Value of Benefits	Discounted avoided grid purchases over 25 years	-	Tk 3,027,097	Lifetime value of electricity offset
Present Value of OPEX Cost	Discounted PPA payments over 25 years	-	Tk 2,421,678	Lifetime present cost of purchasing solar power
Net Present Value (NPV)	PV Benefits – PV OPEX Cost	3,027,097 – 2,421,678	Tk 605,419	Positive lifetime economic gain to SME
Internal Rate of Return (IRR)	Not meaningful with zero upfront equity by SME	-	N/A	IRR is not useful from the customer perspective here
Cost Benefit Ratio (BCR)	PV Benefits / PV OPEX Cost	3,027,097 / 2,421,678	1.25	Benefits exceed payments by 25%

5.2.1.5 Analytical Interpretation

The 20 kW on-grid rooftop solar system under the OPEX model is financially attractive for SMEs, primarily due to its zero upfront investment. The system is fully financed and maintained by a developer, while the SME purchases electricity at a lower tariff (Tk 9.60/unit) compared with the grid rate (Tk 12/unit), generating first-year savings of Tk 69,204 and immediate positive cash flow.

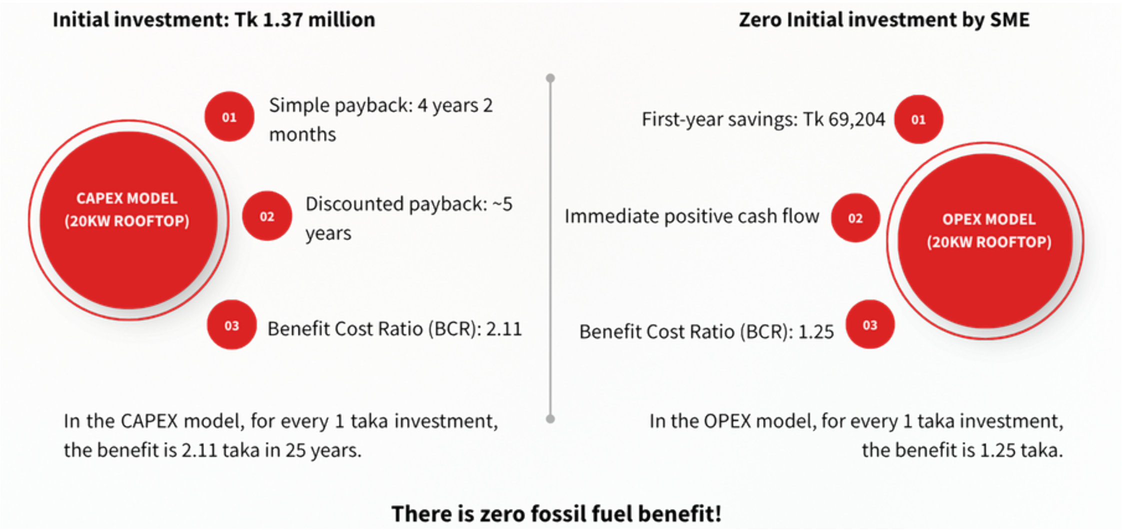


Figure 9: Cost-Benefit Analysis of Solar PV Installation

Over a 25-year period, the present value of avoided grid cost is Tk 3.03 million, against Tk 2.42 million in payments, resulting in a positive NPV of Tk 605,419 and a BCR of 1.25. Although returns are lower than the CAPEX model, this reflects a tradeoff where part of the value is shared with the developer.

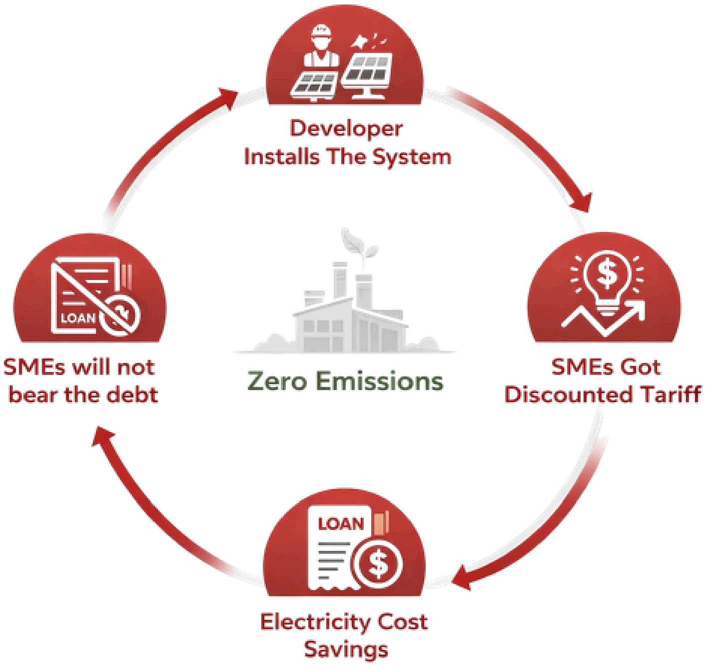


Figure 10: The OPEX Solar Power

From a practical SME perspective, the OPEX model may be more scalable in BSCIC clusters where firms face capital constraints, limited access to affordable finance, or reluctance to commit large upfront investment. The CAPEX model produces stronger returns for firms that can invest, but the OPEX model offers instant savings, no upfront burden, outsourced maintenance, and lower adoption friction, making it a highly suitable pathway for broader solar uptake among industrial SMEs.

6. Barriers and Constraints to Emission Reduction

Despite significant technical potential, emission reduction in BSCIC SMEs faces multiple structural, financial, technological, and institutional barriers.

Technology is not the only constraint to emission reduction in BSCIC SMEs, but data, finance, governance and regulatory gaps are also present. The factories lack a factory level carbon accounting system, and data on energy consumption is usually incomplete or non-transparent. BSCIC-wide emission registry is not provided and most of the estates do not have 24-hour profile data, which complicates grid planning and integration of renewables. Such information lapses complicate the planning to develop right baselines or raise funds. Lack of finances is also a concern with high-cost machines and solar systems being energy efficient and a lack of long-term and low-interest loans is a challenge. The loan size of small size is usually not appealing to institutions such as IDCOL and SMEs are thought to be high-risk borrowers thus the owners tend to give more priority on working capital rather than an efficiency upgrade.

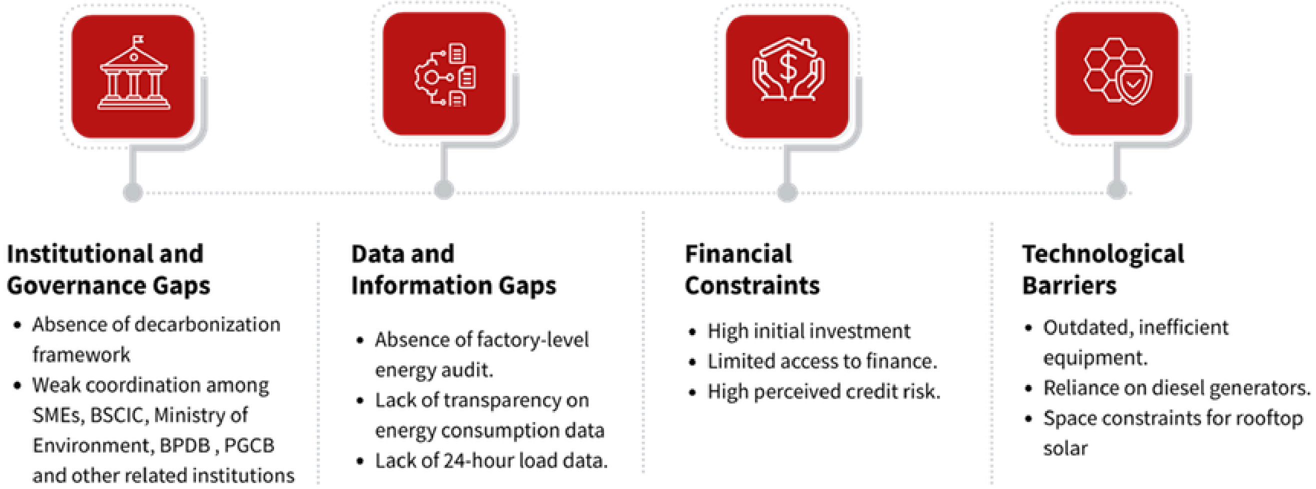


Figure 11: Barriers and Constrains of emission reduction in BSCIC-SMEs

The constraint of technology further slows down. The production equipment, boilers, and many factories are using old motors, and during power outages, they continue to use diesel generators. There is a lack of technical expertise regarding energy management and the space facilities within crowded estates do not allow rooftop solar constructions. Nobody has a BSCIC-specific decarbonization framework at the institutional level, and the centralized solutions are not possible due to fragmented ownership or rented plots, energy audits are not mandatory. There are environmental and waste management regulations, which are often poorly enforced to make improvements less motivational.

The adoption of renewable energy is also restricted by grid and policy conditions. The power system is built with centralized generation in mind, and net metering, wheeling charges, and other control mechanisms make it less possible to make distributed solar viable. SCADA-type monitoring systems are uncommon on the SME level, which suppresses the energy visibility. Moreover, most SMEs are in the short-term survival mode, not long-term efficiency, not subject to much pressure on export-driven carbon compliance, and unaware of the financial benefits of energy efficiency. All these barriers combined indicate that new technology is not the only way emission reduction will be reached in BSCIC clusters, it will be necessary to have coordinated policy, funding, and technical assistance.

6.1 SME Decarbonization as the Foundation of Bangladesh’s Energy Sovereignty

Bangladesh is not facing an energy crisis. It is facing a structural contradiction. On paper, the country has achieved near-universal electricity access. In reality, SMEs operate under extreme load shedding sometimes, unstable supply, and rising input costs. This contradiction defines the failure of the current energy model. Access without reliability is not development; it is stagnation disguised as progress. The global evidence is already settled. In India, rooftop solar adoption among SMEs has demonstrated 30-50% reduction in electricity costs, fundamentally improving cost structures and competitiveness (ET Edge Insights -).

In Vietnam, Direct Power Purchase Agreements (DPPA) are enabling factories to directly procure renewable energy, not as a climate gesture, but as a strategic necessity to remain embedded in global supply chains (World Resources Institute). Germany has moved even further, building localized energy systems that provide price shock resilience and decentralized energy trading. China, through aggressive investment in battery storage, is not merely reducing costs, it is engineering energy autonomy at scale. These are not isolated case studies. They are signals of a structural shift in how industrial economies are reorganizing themselves around energy.

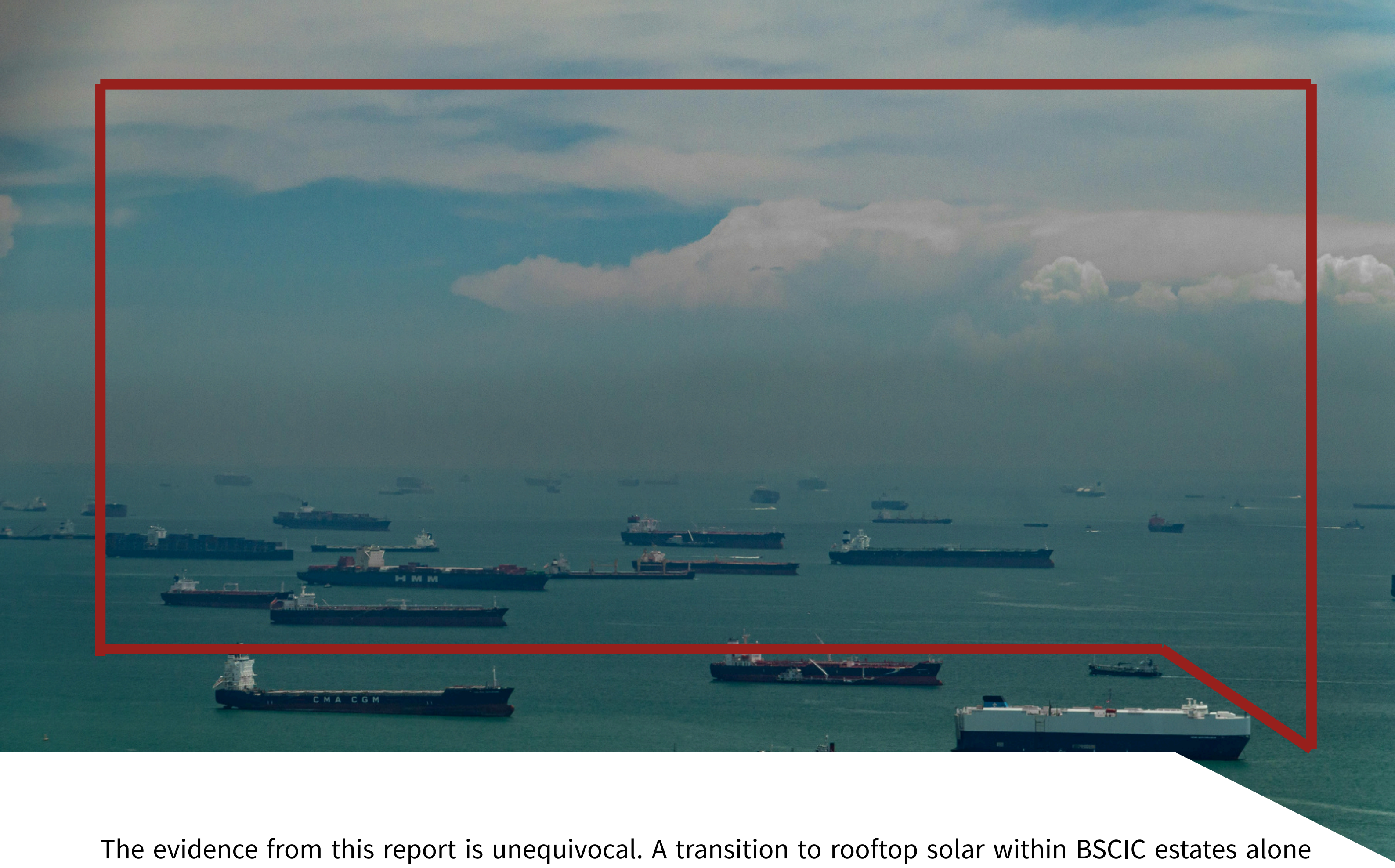
Table 14: Comparative Summary: Economic & Energy Performance (2025–2026)

Country	Primary RE Driver	Economic Benefit	Energy Benefit
China	Massive investment in battery storage (up 69% in 2025)	Cost reduction through transition from coal-fired thermal power	Storage-driven energy Autonomy/Sovereignty
India	Rooftop Solar / KUSUM	30-50% Cost Reduction	Decentralized Grid Relief
Germany	Onshore Wind / Solar	Price Shock Resilience	Localized Energy Trading
Vietnam	DPPA / Rooftop PV	Export Market Compliance	Reduced Grid Peak Load

Bangladesh, however, remains trapped in a fossil-dependent, import-driven energy paradigm that is now actively eroding its own economic base. The consequences are measurable and severe. Air pollution alone is reducing life expectancy by over five years and costing approximately 5% of GDP through lost productivity and health burdens.

At the same time, the global trade architecture is shifting. With the EU's Carbon Border Adjustment Mechanism, carbon is no longer invisible in trade flows. SMEs, which supply critical inputs like buttons, zippers, leather components, and light engineering goods, are now directly exposed. If SMEs do not decarbonize, Bangladesh's export engine, particularly garments, will face systemic risk. The issue is no longer whether to decarbonize. The issue is whether Bangladesh intends to remain competitive in a carbon-constrained global economy.

This is where the structural importance of SMEs becomes unavoidable. CMSMEs constitute 90% of industrial units, 80% of industrial employment, and contribute 45% to manufacturing value added. Yet they contribute only 25% to GDP, significantly below peer economies like Indonesia (59%), Vietnam (45%), and Cambodia (58%). (FREIHEIT,2024) This gap is not a coincidence. It is a reflection of structural inefficiencies, with energy being the most critical constraint. SMEs in Bangladesh are growing at approximately 6% annually, but this growth is constrained by high energy costs, unreliable supply, and technological stagnation. If Bangladesh is serious about increasing SME contribution to GDP to 32% and beyond, then energy transition is not optional. It is the single most powerful lever available.



The evidence from this report is unequivocal. A transition to rooftop solar within BSCIC estates alone can generate 57 MW with just 10% space allocation, and up to 114 MW with just 10% space allocation. Scaling this across EPZs and industrial clusters reveals a far more radical possibility: a “crash program” capable of delivering 3,000 to 5,000 MW within a single year. This fundamentally challenges the current policy timeline of achieving 20% renewable energy by 2030. The constraint is not land, as often cited. It is the failure to recognize that Bangladesh’s industrial rooftops are an unutilized energy infrastructure waiting to be activated.

The economic logic is equally compelling. Energy costs for SMEs often constitute 10-20% of operational expenditure. Reducing this by even 20% translates directly into lower production costs, improved margins, and enhanced export competitiveness. In sectors such as leather, plastics, and light engineering, this cost reduction cascades through the value chain, lowering export prices and increasing global competitiveness. The transition, therefore, is not about energy alone. It is about reconfiguring Bangladesh’s industrial cost structure.

Yet, the real bottleneck is neither technology nor economics. It is institutional design. Financing is often presented as the primary barrier, but this is a misdiagnosis. Bangladesh does not lack capital; it lacks mechanisms to deploy capital at scale. Instead of using limited public funds to directly build capacity, the state must shift toward catalytic instruments. Duty drawback mechanisms, already proven in the garment sector, can be repurposed for renewable energy imports, effectively reducing capital costs at scale. A modest carbon tax on international transport flows could mobilize a significant amount annually, creating a self-sustaining financing pool without imposing new burdens on domestic industries. The question is not where the money will come from. The question is whether policy will allow money to flow where it is needed.

At the microeconomic level, adoption will depend on incentive architecture. Progressive electricity tariffs for high-consumption users, integrated financing models embedded within consumer loans, and alignment with municipal incentives such as reduced holding taxes can create a self-reinforcing adoption cycle. The failure of rooftop solar in Bangladesh is not due to lack of awareness. It is due to lack of integration. When energy savings are not embedded into billing systems, regulatory approvals, and financial products, adoption remains fragmented. When they are, adoption becomes inevitable.

Central to this transition is the emergence of the ESCO-driven OPEX model. Evidence from global markets shows that SMEs prefer models where upfront capital expenditure is eliminated. Under an OPEX structure, SMEs pay for electricity as a service, often at rates lower than grid tariffs. This aligns incentives across developers, financiers, and users. In Bangladesh, the immediate savings potential of approximately 70,000 BDT per SME under such models is not insignificant. It represents liquidity, resilience, and survival. However, the ESCO ecosystem in Bangladesh remains underdeveloped. The regulatory framework may exist on paper, but the market is functionally absent. Without deliberate state intervention to create, de-risk, and scale ESCOs, the OPEX model will remain theoretical.

The transition must also be understood through the lens of employment and structural change. The promise of creating one crore jobs cannot be fulfilled through traditional industrial expansion alone. Automation is already reducing labor demand in the garment sector. The future of employment lies in decentralized, SME-driven ecosystems. Transitioning 1.3 million diesel pumps, scaling rooftop solar, and building localized operation and maintenance networks can create new categories of skilled employment. A just energy transition is not merely about reducing emissions. It is about redistributing economic opportunity.

Ultimately, the question is not about renewable energy. It is about sovereignty. Bangladesh's current energy model is import-dependent, price-volatile, and externally exposed. True energy security cannot be achieved under such conditions. Energy sovereignty, built on solar and wind, offers a fundamentally different trajectory. It is decentralized, locally controlled, and immune to global supply shocks. The Russia-Ukraine crisis exposed the vulnerabilities of import-dependent systems. Bangladesh missed that opportunity due to governance failures and systemic inefficiencies. The current moment presents a second chance.

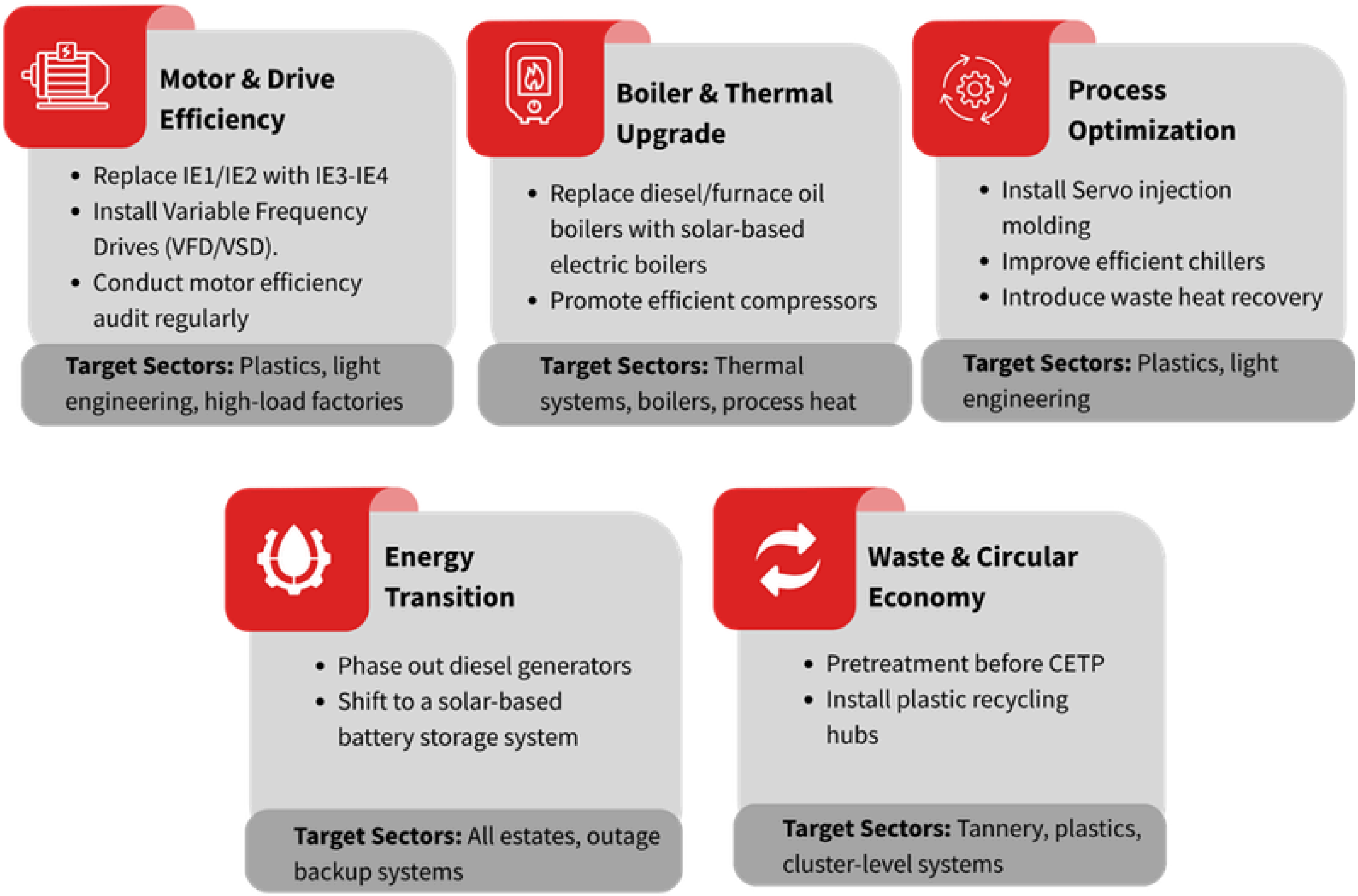
Energy is the lifeline of the economy. If energy remains externally controlled, the economy remains externally vulnerable. If energy becomes locally generated and controlled, the economy becomes sovereign. The transition to SME-led renewable energy is not a sectoral reform. It is the foundation of a new economic architecture. The evidence is clear. The opportunity is immediate. The only variable that remains uncertain is whether Bangladesh will act with the urgency that this moment demands.

7 Decarbonization Pathways:

7.1 Technological

The technological pathway for decarbonization in BSCIC SME clusters requires a transition from fragmented efficiency measures to an integrated energy management approach. Emission reductions are primarily achievable through improvements in electrical and thermal energy systems, particularly in energy-intensive sectors such as plastics, light engineering, and tannery. However, the impact of such interventions depends not only on technology adoption but also on operational efficiency and system optimization.

A significant share of energy loss in SMEs arises from inefficient production practices, including outdated machinery, poor load management, and idle operation. Addressing these inefficiencies offers immediate, low-cost mitigation opportunities. At the same time, the gradual electrification of processes and the transition away from diesel-based backup systems toward grid-connected and solar-integrated solutions are critical for reducing both emissions and long-term energy costs (where a diesel generator costs about 30 BDT per unit, whereas solar with battery storage costs around 14 BDT per unit).



Motor & Drive Efficiency

- Replace IE1/IE2 with IE3-IE4
- Install Variable Frequency Drives (VFD/VSD).
- Conduct motor efficiency audit regularly

Target Sectors: Plastics, light engineering, high-load factories

Boiler & Thermal Upgrade

- Replace diesel/furnace oil boilers with solar-based electric boilers
- Promote efficient compressors

Target Sectors: Thermal systems, boilers, process heat

Process Optimization

- Install Servo injection molding
- Improve efficient chillers
- Introduce waste heat recovery

Target Sectors: Plastics, light engineering

Energy Transition

- Phase out diesel generators
- Shift to a solar-based battery storage system

Target Sectors: All estates, outage backup systems

Waste & Circular Economy

- Pretreatment before CETP
- Install plastic recycling hubs

Target Sectors: Tannery, plastics, cluster-level systems

Figure 12: Technological Pathways

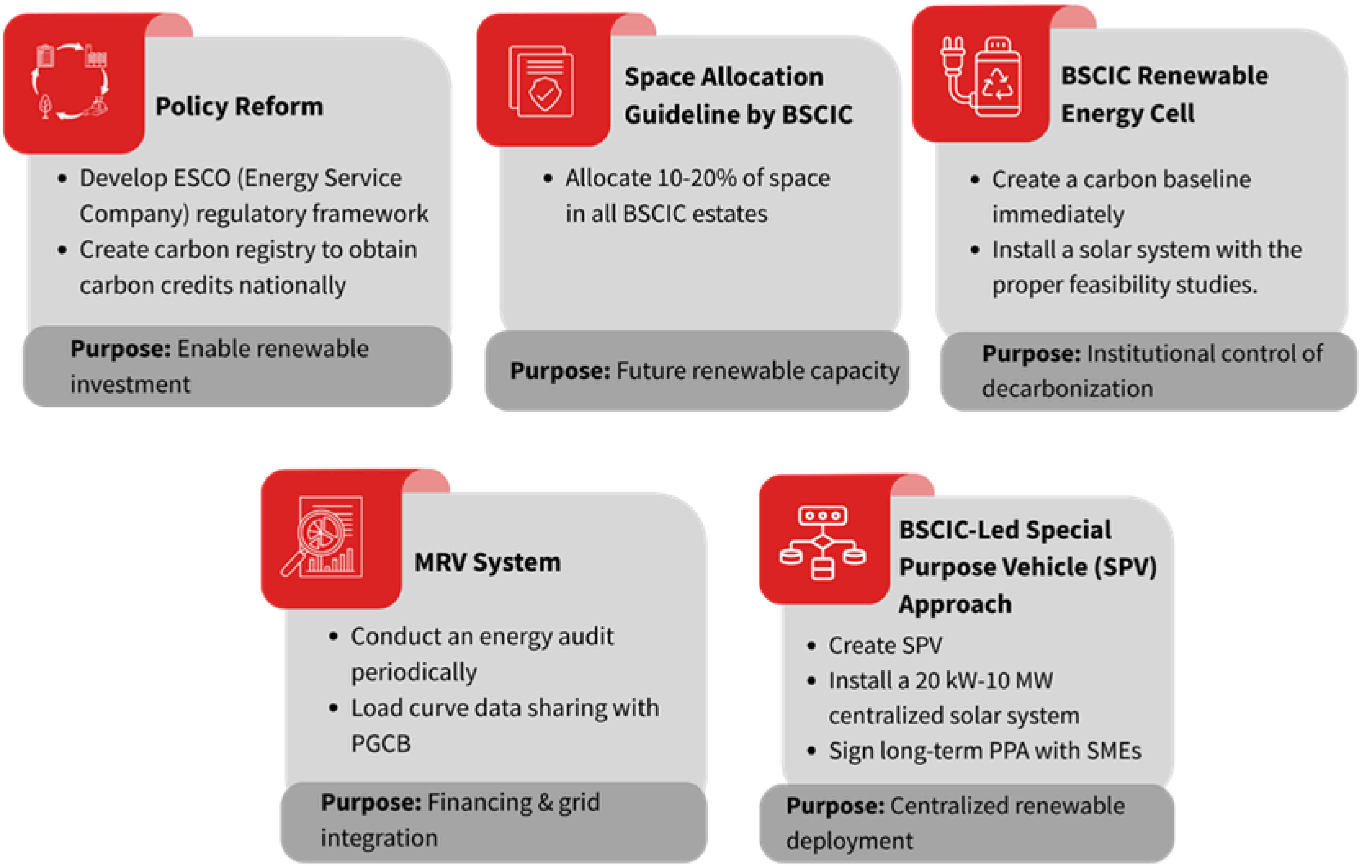
In parallel, the integration of circular economy practices at the cluster level can reduce material intensity and associated indirect emissions. Overall, the technological pathway should be understood as a combined shift toward energy efficiency, electrification, and resource optimization, aligned with sector-specific energy use patterns.

7.2 Structural and Governance Reform

The effectiveness of technological interventions is contingent upon the presence of a robust institutional and governance framework. In the current context, the absence of a dedicated coordinating mechanism within BSCIC limits the scalability and coherence of decarbonization efforts. Establishing a centralized institutional structure is therefore essential to oversee energy planning, data management, financing coordination, and sector prioritization.

Given the financial constraints of individual SMEs, aggregated investment models are necessary to enable access to large-scale renewable energy solutions. Cluster-level approaches can reduce investment risks and improve bankability, particularly for solar deployment and energy infrastructure.

Furthermore, the lack of standardized data and monitoring systems remains a critical barrier. Strengthening energy auditing, reporting, and centralized carbon tracking mechanisms is essential for evidence-based planning, financing eligibility, and future participation in carbon markets.



Policy Reform

- Develop ESCO (Energy Service Company) regulatory framework
- Create carbon registry to obtain carbon credits nationally

Purpose: Enable renewable investment

Space Allocation Guideline by BSCIC

- Allocate 10-20% of space in all BSCIC estates

Purpose: Future renewable capacity

BSCIC Renewable Energy Cell

- Create a carbon baseline immediately
- Install a solar system with the proper feasibility studies.

Purpose: Institutional control of decarbonization

MRV System

- Conduct an energy audit periodically
- Load curve data sharing with PGCB

Purpose: Financing & grid integration

BSCIC-Led Special Purpose Vehicle (SPV) Approach

- Create SPV
- Install a 20 kW-10 MW centralized solar system
- Sign long-term PPA with SMEs

Purpose: Centralized renewable deployment

Figure 13: Structural and Governance Reform

Policy and regulatory alignment is equally important to facilitate the transition. Existing limitations in net metering, energy sharing, and service-based energy models constrain the adoption of innovative solutions. Addressing these gaps will be key to mobilizing private investment and accelerating the low-carbon transition.

7.3 Just Energy Financing

A major barrier to decarbonization of SMEs under BSCIC is the lack of accessible and inclusive financing mechanisms. Existing financing systems, particularly from IDCOL and commercial banks, are largely designed for large-scale projects, making them unsuitable for SMEs. The loan process is often complex, time-consuming, and highly documentation-driven, while SMEs also face difficulties due to the absence of localized banking support within industrial estates. Moreover, there are no tailored financial products specifically designed for SME energy transition, and banks perceive SMEs as high-risk borrowers, further limiting access to credit. To address these challenges, financing systems must be restructured to become more SME-friendly by simplifying and standardizing loan procedures, deploying banking agents at the estate level, and introducing flexible renewable energy loan products with smaller ticket sizes. A cluster-based financing approach can reduce perceived risk by enabling collective collateral mechanisms, while a one-stop digital platform can streamline application, tracking, and disbursement processes.

In particular, IDCOL should expand its financing scope beyond large projects and introduce dedicated small-scale loans (e.g., 10–50 lakh) that allow direct SME participation through simplified cluster-based models. At the strategic level, BSCIC should engage with Bangladesh Bank to advocate for a dedicated SME renewable energy financing window, promote concessional interest rates, and explore partial credit guarantee mechanisms to unlock private sector lending.

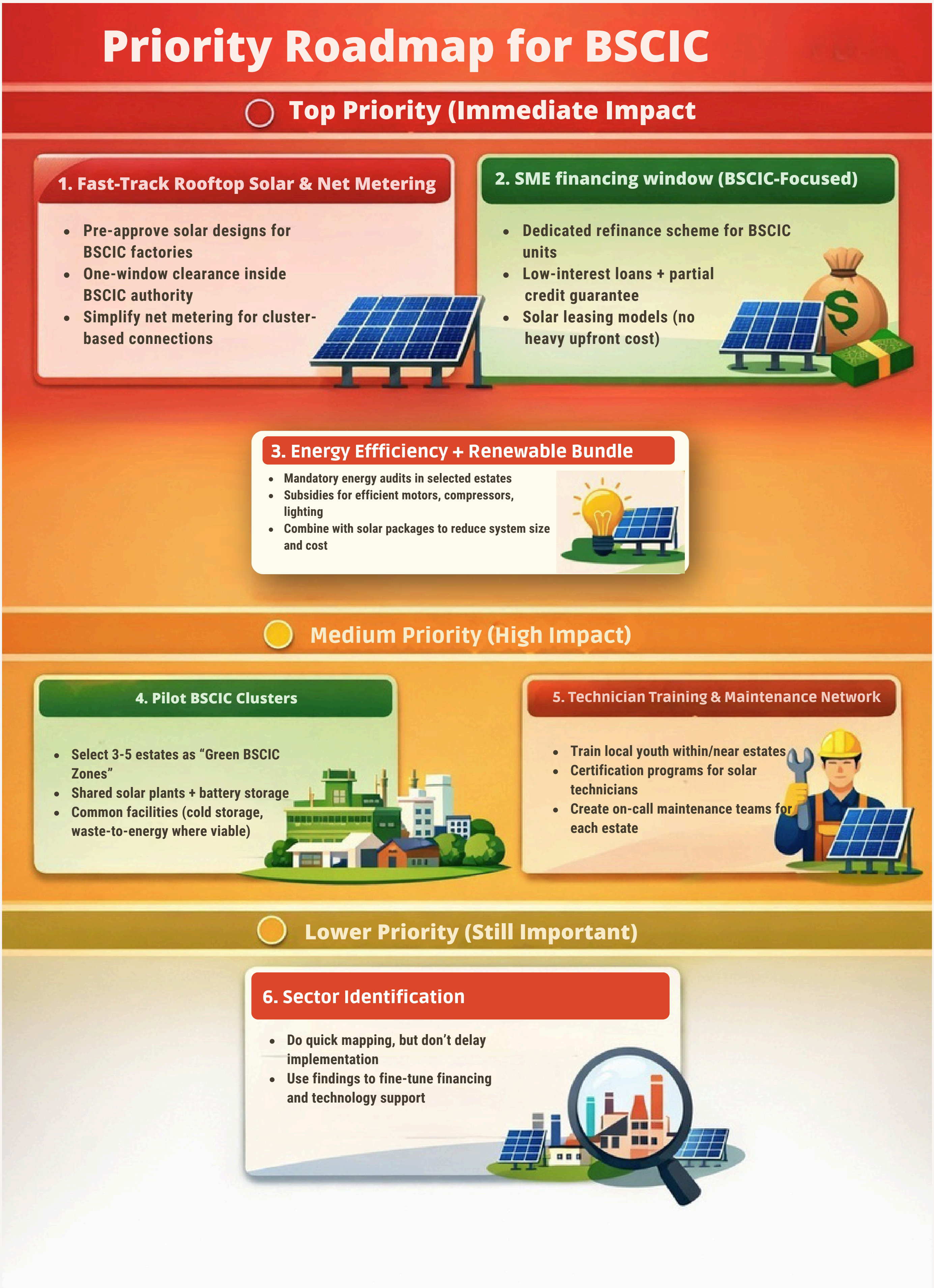
Table 15: Customer-Side Financial Indicators for 20 kW Solar (OPEX Model)

For IDCOL and other Commercial Banks	Loan process is complicated and takes too long	Make the process simple, fast, and standardized
	Absence of localized systems for SMEs	Place banking agents inside BSCIC estates
	No Investment products made for energy transition in SME.	Design flexible and SME-friendly renewable energy loans
	Banks see SMEs as risky due to perceived high credit risk	Create microfinance using cluster based collateral system
	Application process is manual and scattered	One-stop system for SMEs to apply, track, and access financing
For IDCOL	Financing is only designed for large projects (1 MW+),	Introduce small loans (10–50 lakh) specially for SMEs
	SMEs cannot apply directly, need aggregation	Create easy cluster-based financing for BSCIC estates

Together, these measures can enable a more inclusive, efficient, and scalable financing ecosystem for SME decarbonization.

8 Recommendation

Based on the findings from the emission baseline, techno-economic analysis, and financing models, it is clear that decarbonization of SMEs under BSCIC is both achievable and financially viable. Solar PV adoption and energy efficiency improvements offer immediate cost savings and emission reductions, while financing and implementation barriers remain the key challenges. Therefore, priority should now focus on practical, scalable actions that can accelerate adoption and ensure long-term sustainability across BSCIC industrial estates.



Priority Roadmap for BSCIC

○ Top Priority (Immediate Impact

1. Fast-Track Rooftop Solar & Net Metering

- Pre-approve solar designs for BSCIC factories
- One-window clearance inside BSCIC authority
- Simplify net metering for cluster-based connections

2. SME financing window (BSCIC-Focused)

- Dedicated refinance scheme for BSCIC units
- Low-interest loans + partial credit guarantee
- Solar leasing models (no heavy upfront cost)

3. Energy Effficiency + Renewable Bundle

- Mandatory energy audits in selected estates
- Subsidies for efficient motors, compressors, lighting
- Combine with solar packages to reduce system size and cost

● Medium Priority (High Impact)

4. Pilot BSCIC Clusters

- Select 3-5 estates as “Green BSCIC Zones”
- Shared solar plants + battery storage
- Common facilities (cold storage, waste-to-energy where viable)

5. Technician Training & Maintenance Network

- Train local youth within/near estates
- Certification programs for solar technicians
- Create on-call maintenance teams for each estate

● Lower Priority (Still Important)

6. Sector Identification

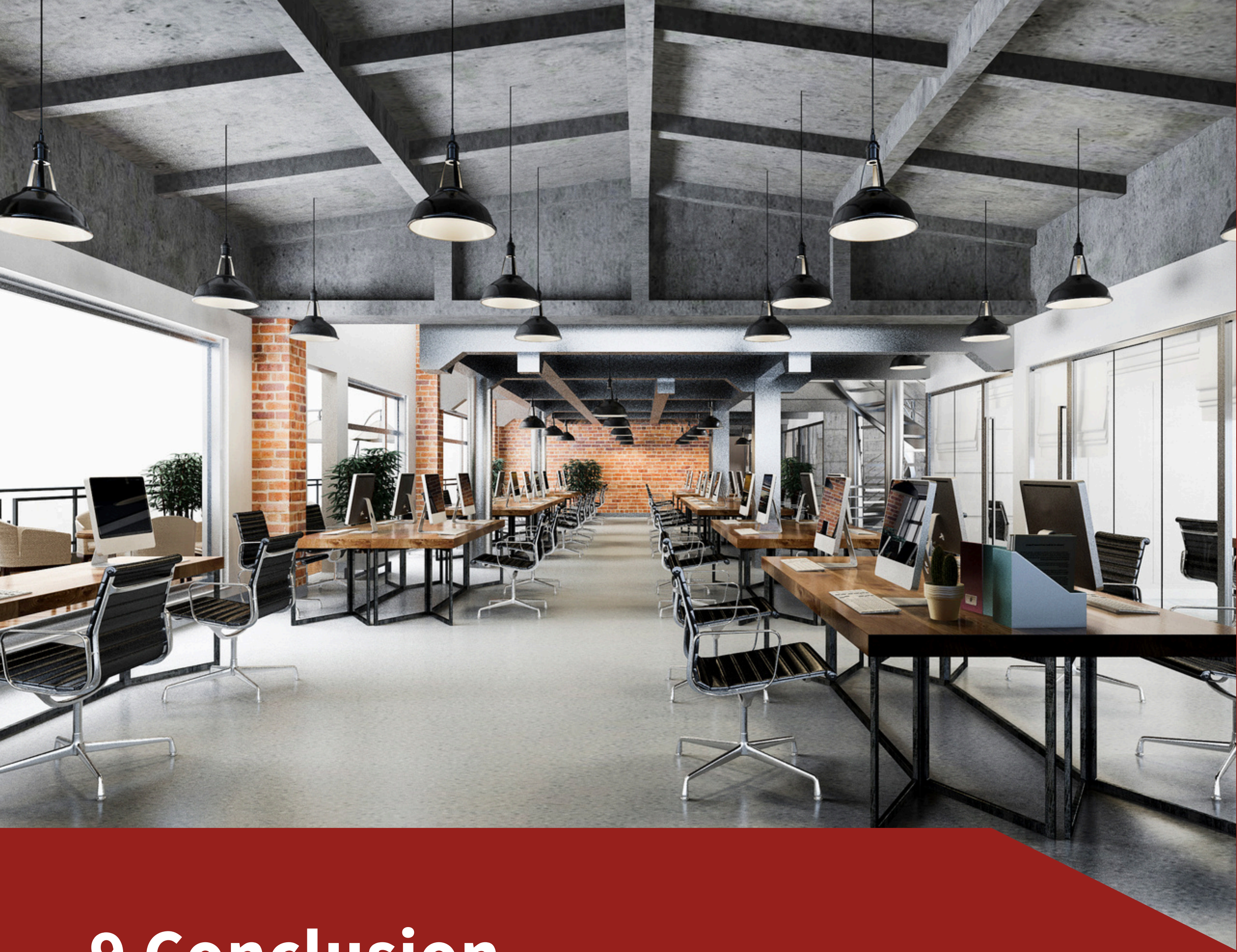
- Do quick mapping, but don’t delay implementation
- Use findings to fine-tune financing and technology support

Figure 14: Priority Roadmap for BSCIC

Public stakeholders play a critical role in enabling SME decarbonization by creating a supportive policy, financial, and regulatory environment. To accelerate this transition, governments and related institutions should introduce targeted capital subsidies for solar adoption and energy-efficient machinery, along with tax rebates to reduce the cost burden of clean technology investments.Reducing import duties on green technologies and offering export incentives for low-carbon products can further accelerate adoption and improve competitiveness. Such fiscal and policy tools are globally recognized as key drivers for scaling renewable energy and industrial decarbonization

Figure 15: Recommendations for Related Public Stakeholders

For detailed recommendations, see annex



9 Conclusion

This research aimed to study whether it is possible to achieve meaningful decarbonization of small and medium industries under the control of BSCIC without interrupting production and imposing extra financial pressure on the owners of factories. The results indicate that SMEs are individually small, but a large portion of industrial electricity consumption and hence they have a significant contribution to the emission profile in Bangladesh. The analysis of the base line assessment in the tannery, light engineering, plastics, and packaging industries reveals that most of the emissions are because of the use of electricity as a driving force in carrying out mechanical processes, especially motor system, press, injection molding, chiller, printing equipment. Since these loads are concentrated within limited high consumption machines, efficiency enhancement can be targeted in a few machines to achieve a measurable decrease in emission without lowering production. Frequently, the cost of electricity may be reduced through upgrading motors and better process control as well as reducing idle running, which is significant to the SMEs, having limited capital. It implies that decarbonization in SME clusters cannot be regarded merely as a compulsory measure but as an economic prospect that could enhance competitiveness, stabilize the cost of operations, and provide stable employment in industrial estates over the long term.

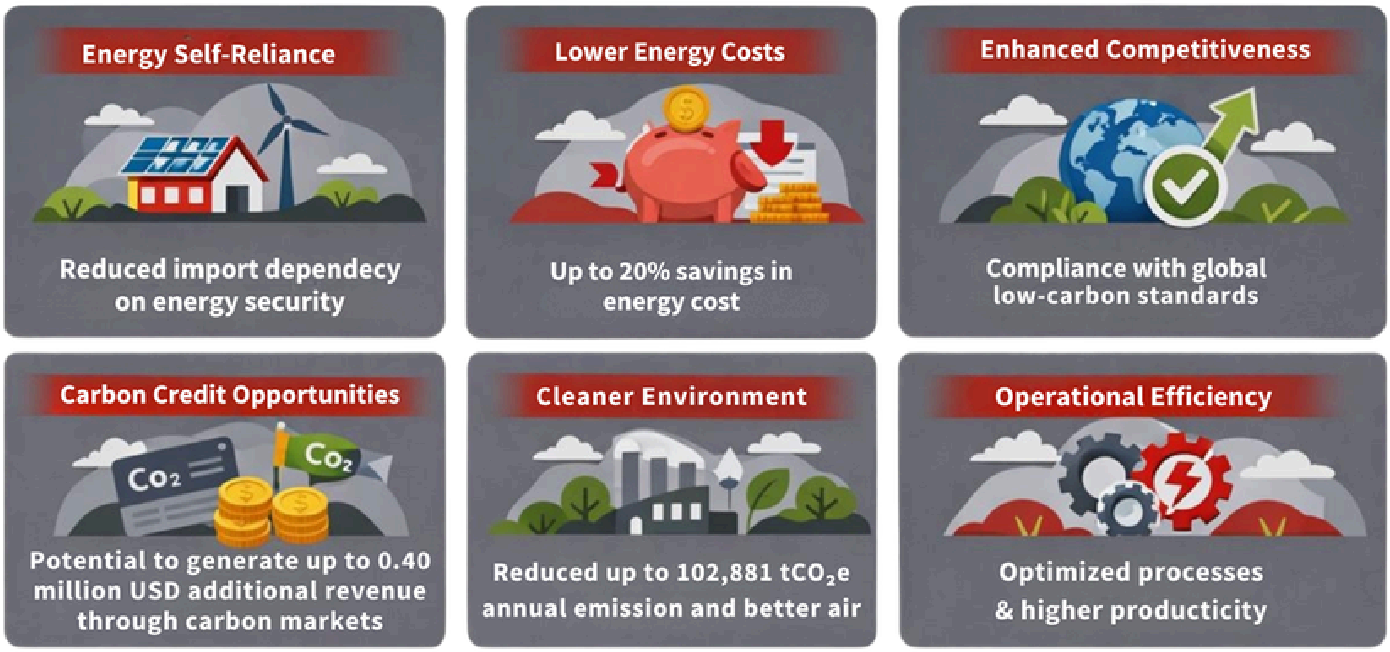


Figure 16: Projected Outcomes of Nature Smart Industrial Transition

It is also revealed in the study that the greatest structural emission reduction potential is in substituting fossil-fuel-based grid electricity with renewable energy, especially solar PV on an estate level. Partial solar implementation in the areas of BSCIC will be able to compensate for substantial quantities of indirect emissions and cushion factories against escalating electricity costs. Technical potential, however, will not guarantee transition only. According to the field assessment, SMEs are characterized by several impediments such as inaccessibility to accessible energy data, inaccessibility to low-cost finance, the presence of archaic machinery and absence of integrated planning at the estate level. The individual factories will not be willing to invest in the low-carbon technologies unless they are financially favorable and supported by the institutions. Thus, further development will be based on cluster-based solutions, including shared solar systems, aggregated financing, obligatory energy audits, and a special mechanism of green transition within BSCIC. When these measures are put in place, decarbonization of SME can develop into an option that will help minimize emissions, reduce the cost of production, and enhance the competitiveness of the industrial sector in Bangladesh and serve the national climate pledges.

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Annex

1. Existing strategies to access renewable energy finance from financial agencies

Accessing Nature Smart Finance from (IDCOL)

Aggregate demand, do not apply individually
IDCOL will not finance small SMEs separately. BSCIC must combine demand at estate level

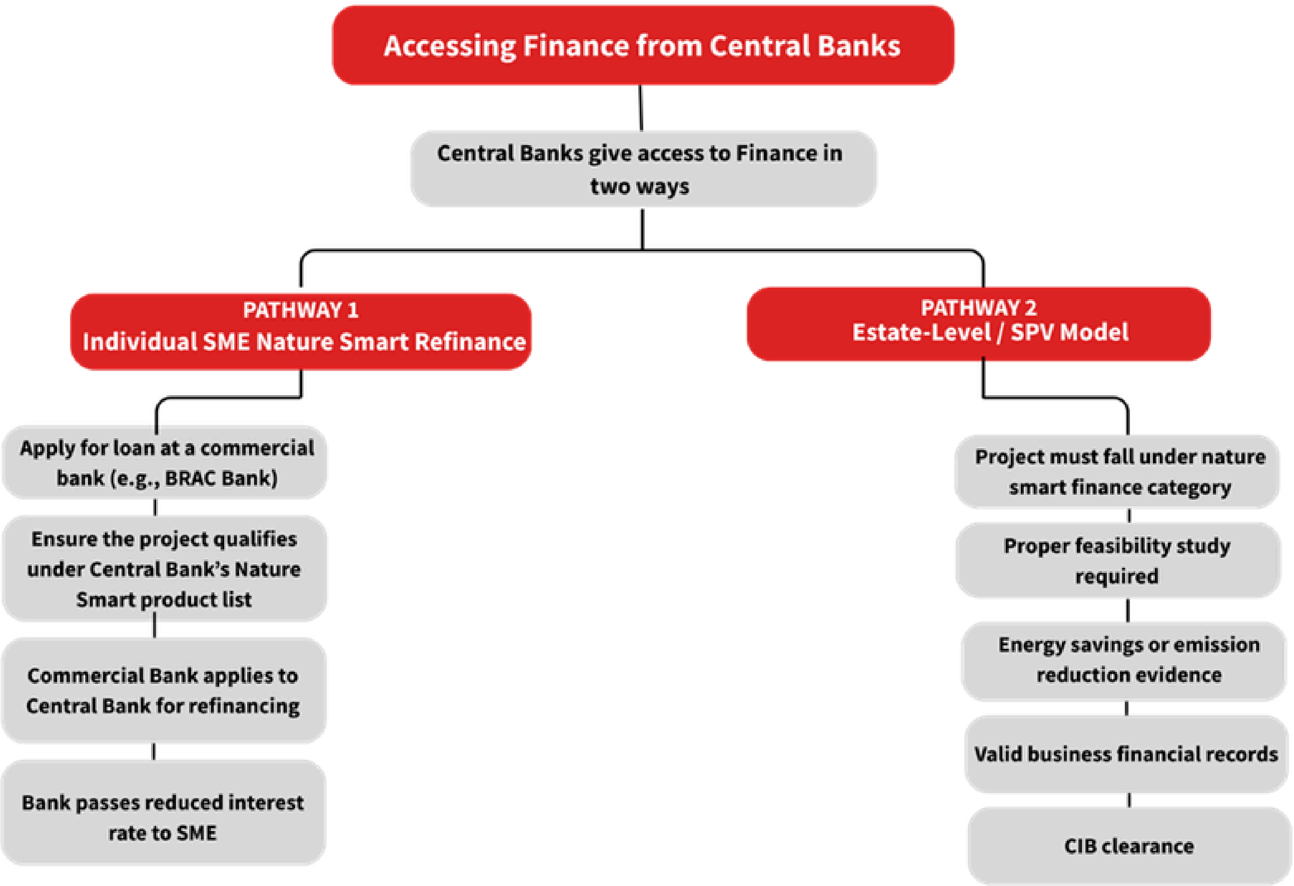
Form an SPV (Special Purpose Vehicle)
Create a single legal entity under BSCIC to own and manage the solar project

Ensure scale (minimum ~1 MW)
Combine rooftops or allocate common land to reach viable project size

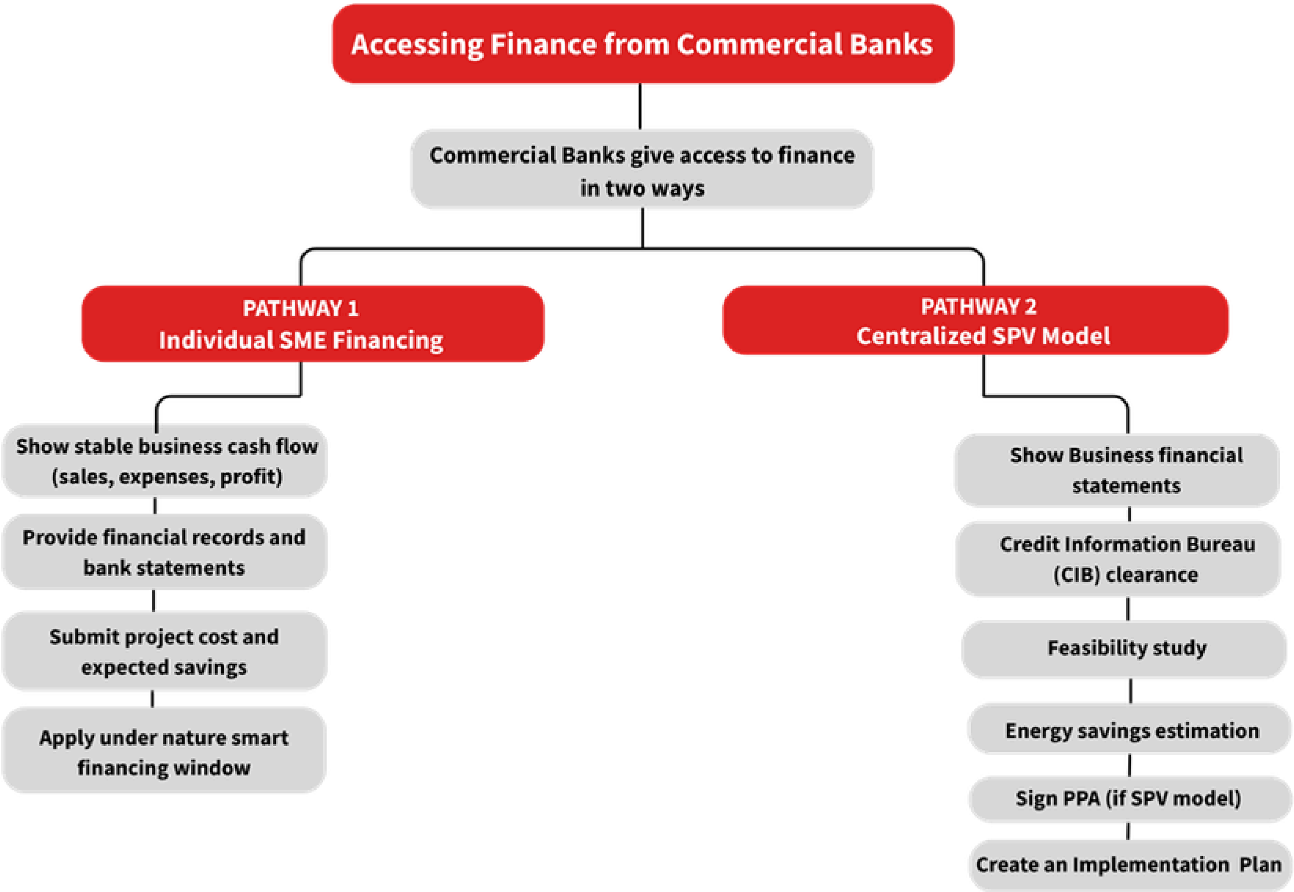
Prepare a bankable feasibility study
Include energy data, load profile, financial model, and repayment plan

Submit structured proposal to IDCOL

2. Existing Financing Structure of Central Banks



3. Existing Financing Structure of Commercial Banks



4. Detailed Recommendation

Priority Order for BSCIC

- Fast-track rooftop solar & net metering
- Green SME financing (BSCIC-focused)
- Energy efficiency + renewable bundle
- Pilot BSCIC clusters
- Technician training & maintenance network
- Sector identification (supporting step, not leading)

Top Priority (Immediate impact)

1. Approve fast-track rooftop solar & net metering

This is the quickest win for BSCIC estates.

- Most factories already have usable rooftop space
- Reduces load shedding impact immediately
- Cuts electricity bills for SMEs

Action:

- Pre-approve solar designs for BSCIC factories
- One-window clearance inside BSCIC authority
- Simplify net metering for cluster-based connections

2. Launch a targeted SME financing window (BSCIC-focused)

Finance is the biggest barrier for BSCIC entrepreneurs.

Action:

- Dedicated refinance scheme for BSCIC units
- Low-interest loans + partial credit guarantee
- Solar leasing models (no heavy upfront cost)

3. Bundle energy efficiency with renewable adoption

Many BSCIC factories waste energy due to outdated equipment.

Action:

- Mandatory energy audits in selected estates
- Subsidies for efficient motors, compressors, lighting
- Combine with solar packages to reduce system size and cost

Medium Priority (High impact but slightly slower)

4. Set up pilot green industrial clusters (inside BSCIC estates)

BSCIC is already cluster-based-this is a natural fit.

Action:

- Select 3–5 estates as “Green BSCIC Zones”
- Shared solar plants + battery storage
- Common facilities (cold storage, waste-to-energy where viable)

5. Train technicians & build local maintenance networks

Without maintenance, systems fail and trust is lost.

Action:

- Train local youth within/near estates
- Certification programs for solar technicians
- Create on-call maintenance teams for estate

Lower Priority (But still important)

6. Identify top energy-stressed SME sectors
This is useful, but for BSCIC:

Many estates already host known energy-intensive sectors (light engineering, food processing, plastics, textiles)

Action:

- Do quick mapping, but don’t delay implementation
- Use findings to fine-tune financing and technology support

Intervention Area	Key Actions	Lead Institutions	Expected Outcome
Immediate (0-12 Months)			
Institutional Setup	Establish BSCIC Green Cell	BSCIC	Dedicated institutional unit to coordinate decarbonization initiatives
Pilot Selection	Select one pilot industrial estate	BSCIC	Identification of pilot site for renewable energy deployment
Energy Assessment	Conduct detailed energy audits of top 20% high-energy-consuming units	BSCIC, UNIDO and other Energy Auditors	Identification of priority efficiency interventions
Data Collection	Collect 24-hour load profile data	BSCIC, Distribution Utilities	Reliable electricity demand data for solar planning
Industrial Categorization	Categorize industries by emission intensity	BSCIC, DoE	Sector prioritization for decarbonization measures
Renewable Feasibility	Conduct technical feasibility study for 1 MW centralized solar	BSCIC, Solar Consultants	Bankable solar project concept
Financial Engagement	Initiate discussions with IDCOL, Bangladesh Bank, and BRAC Bank	BSCIC	Identification of financing pathways
Institutional Structuring	Draft SPV structure legally	BSCIC, Legal Advisors	Legal framework for centralized renewable investment
Short-Term (1-3 Years)			
Renewable Energy Deployment	Form BSCIC Green SPV	BSCIC	Institutional vehicle for solar project development
Power Purchase Agreements	Sign aggregated PPAs with SMEs	BSCIC, SMEs	Guaranteed demand for solar electricity
Financing Mobilization	Secure IDCOL financing	BSCIC, IDCOL	Capital mobilization for solar investment
Solar Installation	Implement 1–3 MW solar pilot	SPV, Solar Developers	Operational renewable energy supply

Intervention Area	Key Actions	Lead Institutions	Expected Outcome
Energy Efficiency Programs	Introduce refinancing schemes for IE3 motors, VFDs, and boiler upgrades	Bangladesh Bank, Commercial Banks	Improved industrial energy efficiency
Monitoring Infrastructure	Develop central monitoring and carbon database	BSCIC	Improved energy and emission tracking
Regulatory Reform	Advocate virtual net metering and sanctioned load reform	BSCIC, Power Division	Improved regulatory environment
Stakeholder Engagement	Conduct stakeholder consultation forum	BSCIC, Industry Associations	Increased industry participation
Long-Term (3-10 Years)			
Solar Scaling	Scale solar aggregation across multiple estates	BSCIC, SPV	Large-scale renewable deployment
Capacity Expansion	Expand solar capacity to 5–10 MW per estate where feasible	BSCIC, Solar Developers	Increased clean electricity supply
Storage Integration	Introduce battery storage as costs decline	SPV, Technology Providers	Improved grid stability and reliability
Carbon Markets	Develop carbon credit participation mechanism	BSCIC, DoE	Access to carbon finance
Smart Grid Systems	Integrate SCADA-enabled smart inverter systems	Utilities, BSCIC	Improved grid management
Land Planning Reform	Mandate solar land allocation in new BSCIC estates	BSCIC, Ministry of Industries	Renewable-ready industrial estates
Export Compliance	Develop export-linked green compliance standards	Government, Industry Associations	Improved competitiveness in global markets
National Alignment	Align SME decarbonization with Vision 2041 clean energy targets	Government of Bangladesh	Long-term low-carbon industrial transformation

5. Table: List of KII

Background of the informant	Informant	Designation	Interview date
Government Official	A	Deputy Director	9/10/2025
	B	Executive Engineer (In. Ch.)	9/11/2025
	C	PR Officer and Industrial Estate Coordinator	27/11/2025
	D	Project Director	9/10/2025
	E	Deputy Manager (Cluster Development)	21/10/2025
	F	Deputy General Manager (Training and Capacity Building, Planning, Monitoring and Evaluation)	24/1/2026
	G	Executive Engineer	15/01/2026
Academician	H	Professor and Dean of Engineering	26/01/2026
Financial Institution	I	Senior Assistant Vice President, ICS Program	19/02/2026
	J	Head of Sustainable Finance	1/3/2026
Private Sectors	K	National Project Coordinator	5/3/2026
	L	Director	11/3/2026
	M	Senior Vice President	6/1/2025
	N	CEO	20/02/2025

6. Survey Questionnaire

Decarbonization Pathways for SME's under BSCIC

Section 1: Factory Information

Factory Name

Location

☐ Keraniganj Industrial Estate
☐ Savar Industrial Estate
☐ Tongi Industrial Estate

Sector

☐ Tannery
☐ Light Engineering
☐ Plastics Manufacturing
☐ Packaging Industries

Year of Establishment

Plot Size

Section 2: Industrial Process & Production

Working Days per month

What are the main products manufactured?

Monthly input of raw materials (tons)

What is your average monthly production quantity? (tons)

List the main production steps

Section 3: Energy Usage

What is the source of electricity?

○ Fossil Fuels
○ In house Renewable Energy

What is the RE type?

If you do not have RE system, please mention the reasons.

Average monthly electricity consumption (kwh)

Section 4: Technological Advancement

What are the machineries used in the production system?

Have you updated any machineries in last 5 years?

○ Yes
○ No

If yes, how many?

Have you received any technical support from these organizations?

☐ BSCIC
☐ SME Foundation
☐ NGO
☐ Vendors
☐ Others

Section 5: Workers, Labour & Skills

Do the factory have any Occupational Health and Safety maintenance system?

○ Yes
○ No

What are the OHS procedures used here?

☐ Security Surveillance
☐ Use Equipment, Machines, and Tools as Intended
☐ Wear Personal Protective Equipment (PPE)
☐ Implement Comprehensive Training Programs
☐ Inspect Your Facility Regularly
☐ Others

Please Mention the reason

____

Are workers provided with safety equipment?

○ Yes
○ No

What kind of safety equipment are provided for the workers?

☐ Personal Protective Equipment (PPE)
☐ Fire Safety Equipment
☐ First Aid Equipment
☐ Electrical Safety Equipment
☐ Others

If No, please mention the reason

____

Has any training been provided on new machines or technologies?

○ Yes
○ No

If Yes, how many workers received training tied to specific machines/roles?

____

If No, please mention the reason

____

Section 6: Rights & Social Protection

Is there any record of workplace accident in the factory?

○ Yes
○ No

What kind of accidents?

☐ Slips and Falls
☐ Ear Damage from Excess Noise
☐ Injuries From Machinery
☐ Falling Objects
☐ Fatigue and Dehydration
☐ Others

What type of measure is taken to prevent accidents?

☐ Hazard Identification
☐ Awareness Training
☐ Incident Monitoring
☐ Others

Women worker employed

○ Yes
○ No

Are they being paid equally?

☐ Yes
☐ No

If No, please, mention the reason

Are vulnerable or informal workers included in safety and wage protection?

○ Yes
○ No

If No, please mention the reason

Does the company allow workers to submit complaints?

○ Yes
○ No

If No, please mention the reason

Section 7: Environment & Waste Management

What type of waste is mainly generated from the production?

☐ Solid Waste
☐ Liquid Waste
☐ Both

Are the solid wastes categorised into recyclable-hazardous-organic categories?

☐ Yes
☐ No

How are they being managed?

☐ Assessing Current Waste Streams

☐ Conduct comprehensive waste audit
☐ Recycling and Reusing Materials
☐ Develop clear policies and procedures
☐ Reusing Packaging Materials
☐ Others

How liquid waste/effluent is treated before disposal?

○ No treatment
○ Segretion
○ ETP
○ Characterization
○ Disposal
○ Recycle and Reuse

Section 8: Adaptation & Resilience

What are the shock that disrupted the factory in the last 12 months?

○ Heatwave
○ Power Outage

○ Water Shortage
○ Supply Disruption
○ Others

Is there backup system for power?

○ Yes
○ No

What are the backup system used in that case?

☐ Diesel Generator
☐ Natural Gas Generator

☐ Others

If No, please mention the reason

Are workers informed about emergency or disaster procedures?

○ Yes
○ No

If No, please mention the reason

____

Section 9: Finance & Capacity

Does the factory have capacity to invest in renewable energy?

○ Yes
○ No
○ I don't know

If No, what are the main barrier for access to finance for implementing RE?

○ High Interest
○ Uncertain development cost
○ Paperwork
○ Lack of awareness
○ Lack of Long-term Financing

Are you interested in solar or renewable transition financing?

○ Yes
○ No

Section 10: Future Decarbonization Intent

What should be the decarbonization intent for your factory?

○ Technology Upgradation
○ Switch to Renewable energy
○ Use of low-carbon raw materials
○ Recycling
○ No plan till now
○ Others

In which area do the factory interested in training or technical assistance for decarbonization?

○ Energy Efficiency
○ Waste Management
○ Renewable Energy Transition
○ Others

CHANGE initiative

Decarbonization Pathways for SMEs
under Bangladesh Small and Cottage
Industries Corporation (BSCIC)