

Final Project Report

From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy in Cambodia and Pakistan

Table of Contents

Acknowledgements	2
1. Executive Summary	3
2. Background and Project Objectives	4
3. Project Implementation.....	5
3.1. Overview of Implementation Approach by UNEP-IETC	5
3.2. Coordination Mechanisms and Stakeholder Engagement	5
3.3. LCA Training Session (Online, December 2024)	5
3.4. Project Meeting on Feasibility Study (Osaka, January 2025)	6
3.5. Project Completion Meeting (Phnom Penh, March 2025)	7
4. Feasibility Study Findings	8
4.1. Cambodia.....	8
4.1.1. Assessment of Plastic Waste Types and Volumes	8
4.1.2. Technology Options and LCA Results	8
4.1.3. Proposed SME Recycling Models	9
4.1.4. Challenges and Recommendations.....	9
4.2. Pakistan.....	10
4.2.1. Assessment of Plastic Waste Types and Volumes	10
4.2.2. Technology Options and LCA Results	10
4.2.3. Proposed SME Recycling Models	11
4.2.4. Challenges and Recommendations.....	11
6. Lessons Learned and Recommendations for Phase 2	13
7. Conclusion	16
Annexes	17

Acknowledgements

The United Nations Environment Programme – International Environmental Technology Centre (UNEP-IETC) gratefully acknowledges the generous financial support of the Ministry of Foreign Affairs of Japan through its Japan Supplementary Budget (MOFA-JSB), which made this project possible. The project *“From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy”* was implemented with the aim of promoting inclusive, sustainable plastic recycling systems driven by small and medium enterprises in Cambodia and Pakistan.

We express our sincere appreciation to the national governments of Cambodia and Pakistan for their collaboration, leadership, and continued commitment to circular economy and plastic pollution reduction. In particular, we acknowledge the Ministry of Environment of Cambodia and the Ministry of Climate Change of Pakistan for their strategic guidance and support throughout the project.

Special thanks are extended to UNOPS, Living Indus Initiative, and the Sustainable Development Policy Institute (SDPI), whose coordination, technical expertise, and policy engagement played a critical role in delivering the project’s outcomes. Their contributions were vital in facilitating stakeholder consultations, field data collection, and the development of country-specific feasibility studies and recommendations.

In Cambodia, we also extend our appreciation to The Environmental Education and Recycling Organization (COMPOSTED) for its local knowledge, operational insight, and support in stakeholder coordination and data validation. Their contribution enriched the study’s contextual understanding and helped shape practical recommendations aligned with on-the-ground realities. We are also grateful to the municipal authorities, national consultants, and SME operators in both countries who contributed to the research, co-developed recycling business models, and provided real-world insights from the perspective of small-scale recyclers and entrepreneurs. The engagement of informal sector representatives further strengthened the inclusiveness and practical orientation of the proposed recycling systems.

We acknowledge the valuable contributions of international experts who supported the project through peer review, Life Cycle Assessment (LCA) training, business model refinement, and technical advice. Their input ensured methodological robustness and alignment with global best practices.

We thank our partners at Institute for Global Environmental Strategies (IGES) and the Global Environment Centre (GEC), as well as UNEP colleagues from regional and headquarters offices, for their efforts in knowledge sharing, capacity development, and technical coordination.

Finally, we extend our sincere appreciation to all participants in the LCA training session, the Osaka Project Meeting, and the Phnom Penh Project Completion Meeting. Their active participation and constructive dialogue ensured the success of the project and laid the foundation for future scaling of SME-led plastic recycling initiatives under Phase 2 in Pakistan and beyond.

This project was made possible through the collective dedication of all partners and individuals working toward a more sustainable and inclusive plastic circular economy in Asia.

1. Executive Summary

The project “*From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy*” was launched by the United Nations Environment Programme – International Environmental Technology Centre (UNEP-IETC), with financial support from the Ministry of Foreign Affairs of Japan through its Japan Supplementary Budget (MOFA-JSB). Recognizing the pressing need to reduce plastic pollution and promote resource circulation in developing countries, the project aimed to strengthen the capacity of small and medium enterprises (SMEs) as key actors in the plastic recycling value chain. It focused on two pilot countries—Cambodia and Pakistan—where the potential to build inclusive, locally adapted plastic recycling models is high, but where enabling conditions and technical knowledge are still evolving.

The project was designed around three interlinked pillars:

- (1) building technical capacity and life cycle understanding among key stakeholders,
- (2) fostering multi-stakeholder collaboration and information sharing, and
- (3) conducting detailed feasibility studies to explore viable and sustainable SME-led plastic recycling business models.

Key milestones included:

- A **Life Cycle Assessment (LCA) training workshop** conducted online in December 2024, which introduced LCA methodologies to national stakeholders and demonstrated how environmental impact assessments can guide the selection of suitable recycling technologies and operations.
- A **Project Meeting in Osaka** held in January 2025, bringing together policymakers, researchers, and UN partners to share initial findings, discuss synergies between the two countries, and identify common enablers and barriers.
- A **Project Completion Meeting** in March 2025, which provided a platform to present and validate final feasibility study results, refine policy and investment recommendations, and identify directions for future work.

The **Feasibility Study in Cambodia** assessed types and volumes of recyclable plastic waste, evaluated appropriate recycling technologies using LCA, and proposed SME-scale business models tailored to the local waste stream, market potential, and regulatory framework. The study underscored the importance of supporting SMEs with affordable technologies, technical training, and market access, while also strengthening policy coordination.

Similarly, the **Feasibility Study in Pakistan** provided a detailed picture of plastic waste generation and recycling opportunities in urban and peri-urban contexts. It highlighted SME potential to scale mechanical and semi-mechanical recycling processes using locally available technology. The analysis also emphasized gaps in enabling infrastructure, access to finance, and awareness of environmental standards, while recommending targeted interventions to enhance SME competitiveness.

Overall, the project generated implementable insights, practical tools, and a shared platform for collaboration among stakeholders from both countries. The results have been consolidated into final country reports and a set of strategic recommendations, which are expected to inform future technical cooperation and national action plans.

Importantly, the project laid the groundwork for **Phase 2**, to be implemented in Pakistan with support from the JSB 2024 allocation. Building on the lessons and models developed under this project, Phase 2 will deepen engagement with SMEs, strengthen institutional support, and foster investment partnerships to accelerate a circular plastic economy in Pakistan.

This project demonstrates UNEP’s continued commitment to inclusive and science-based waste management solutions. By positioning SMEs as active drivers of change, it contributes not only to sustainable development and environmental protection, but also to local economic empowerment and innovation in the waste sector.

2. Background and Project Objectives

The growing global production and consumption of plastics, coupled with insufficient collection and recycling infrastructure, has led to an escalating plastic pollution crisis. This is particularly acute in developing countries, where informal and semi-formal systems often dominate waste management, and where small and medium enterprises (SMEs) operate under limited policy, technical, and financial support. Despite their limitations, SMEs hold significant potential to drive innovation and local action in plastic recycling, offering flexible, community-embedded solutions that can reduce environmental leakage, generate livelihoods, and contribute to the transition toward a circular economy.

Recognizing the dual challenge of plastic waste and the need to empower local actors, UNEP-IETC, with financial support from the Ministry of Foreign Affairs of Japan under the Japan Supplementary Budget (MOFA-JSB), initiated the project titled *“From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy.”* The project focused on two pilot countries—**Cambodia** and **Pakistan**—selected for their active but under-supported SME sectors, growing plastic consumption, and strong policy interest in circular economy pathways.

The project sought to bridge the gap between local recycling practices and global environmental goals by building evidence-based, scalable models for SME involvement in plastic recycling. It was designed around the principle that SMEs can play a catalytic role in enhancing recycling rates and circularity—provided they are equipped with the right tools, knowledge, and enabling conditions.

Project Objectives:

- **To identify and analyze plastic waste streams in Cambodia and Pakistan** that offer potential for recycling by SMEs, using data-driven methodologies and on-the-ground assessments;
- **To evaluate and recommend appropriate recycling technologies** suitable for SMEs, with a strong emphasis on environmental soundness and operational feasibility, supported by Life Cycle Assessment (LCA);
- **To build national capacities through targeted training workshops and stakeholder meetings**, with a specific focus on LCA as a decision-making tool for technology selection and system optimization;
- **To develop feasible business models and operational scenarios** for SME-led recycling enterprises in both countries, taking into account local policy frameworks, market realities, and informal sector integration;
- **To promote stakeholder engagement and knowledge exchange** across countries and sectors through a structured series of online and in-person project meetings, thereby strengthening the foundation for regional cooperation and replication;
- **To generate strategic recommendations and a roadmap** for scaling up pilot findings, laying the groundwork for follow-up interventions—including Phase 2 implementation in Pakistan under MOFA-JSB 2024 funding.

The project also aligns with UNEP’s broader objectives under the Medium-Term Strategy (MTS), including promoting inclusive green economy transitions, supporting circular economy practices, and enhancing environmental governance through integrated waste management approaches.

By leveraging scientific tools, such as LCA, and combining them with practical SME-oriented implementation planning, the project aimed to demonstrate that sustainable plastic waste recycling is both technically achievable and economically viable at the local level—particularly when supported by strong partnerships, enabling policies, and targeted investment.

3. Project Implementation

3.1. Overview of Implementation Approach by UNEP-IETC

The implementation of the project *“From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy”* was spearheaded by the United Nations Environment Programme – International Environmental Technology Centre (UNEP-IETC), in close collaboration with national and local partners in Cambodia and Pakistan. As part of UNEP-IETC’s core mandate to promote holistic and environmentally sound waste management technologies, the project adopted a structured yet flexible approach that integrated technical assessments, multi-stakeholder engagement, and cross-country learning. The design allowed for iterative development, where activities were adjusted in real-time based on local feedback and evolving findings.

The implementation was guided by a dual-track structure. The first track focused on strengthening national technical capacity through targeted training and expert engagement, while the second concentrated on developing in-depth feasibility studies to assess the potential for small and medium-sized enterprises (SMEs) to play a leading role in plastic waste recycling. This dual approach ensured that the technical insights were grounded in national contexts, while the feasibility studies remained aligned with UNEP’s broader goals of supporting inclusive, evidence-based policy and circular economy practices.

UNEP-IETC served as the central coordinator for all project activities, working directly with consultants and institutional counterparts in both countries. In Cambodia, the project engaged with the Ministry of Environment, urban waste authorities, and national academic and technical institutions. In Pakistan, it collaborated closely with the Sustainable Development Policy Institute (SDPI), the Ministry of Climate Change, and key provincial stakeholders. Consultants in both countries were contracted to conduct localized assessments and business model development under UNEP-IETC’s technical guidance, while periodic virtual and in-person meetings allowed for joint reflection and strategy refinement.

3.2. Coordination Mechanisms and Stakeholder Engagement

From the early stages of project design to its final phase, UNEP-IETC placed strong emphasis on multi-stakeholder coordination and participatory engagement. The complexity of plastic waste recycling, especially when involving the informal sector and SME actors, demanded a nuanced and inclusive approach that recognized the importance of local experience, national policy direction, and regional coherence.

Stakeholder engagement activities were woven into each component of the project. In Cambodia and Pakistan, government ministries were consulted to ensure the feasibility studies aligned with national waste management and circular economy strategies. Local authorities and technical agencies were invited to provide ground-level data, share practical experiences, and participate in training. SMEs, often underrepresented in traditional planning processes, were given a platform to share their operational realities and discuss the support required for scaling up.

In addition to national consultations, UNEP-IETC facilitated joint sessions and comparative dialogues that enabled stakeholders from both countries to learn from one another’s challenges and innovations. These interactions not only improved the quality and relevance of the feasibility studies but also fostered a sense of shared purpose across the region. The sustained engagement helped strengthen relationships between UNEP and local partners, while positioning the project as a model for inclusive environmental programming.

3.3. LCA Training Session (Online, December 2024)

As part of its commitment to capacity development, UNEP-IETC organized an online training session in December 2024 on the use of Life Cycle Assessment (LCA) for plastic waste recycling. This session was a pivotal component of the project’s technical assistance activities,

aimed at equipping stakeholders in Cambodia and Pakistan with the knowledge and analytical tools needed to evaluate environmental performance across the recycling value chain. The training session was attended by a broad mix of participants, including officials from ministries of environment, local consultants engaged in the project, private sector actors involved in recycling, and development partners supporting plastic waste management. The session was structured to provide both theoretical and applied knowledge, beginning with an introduction to the LCA framework and then moving into its practical application in the context of plastic recycling.

A significant portion of the training was dedicated to explaining how LCA can be used to compare the environmental impacts of different recycling technologies, including mechanical, semi-mechanical, and informal recycling processes. Participants were introduced to concepts such as functional units, system boundaries, inventory data, and impact assessment categories such as greenhouse gas emissions, energy consumption, and resource use. The training also illustrated how LCA outputs can support technology selection, policy formulation, and investment planning, particularly for small-scale operations like those run by SMEs.

Importantly, the session created a common understanding of LCA methodology across the two countries and built the foundation for harmonized application in the upcoming feasibility studies. The interactive format of the session, including real-time questions, case discussions, and data interpretation exercises, ensured that the concepts were well understood and practically applicable. Participants expressed strong interest in continuing LCA-based assessments and integrating them into national planning and project evaluation processes.

3.4. Project Meeting on Feasibility Study (Osaka, January 2025)

The Project Meeting on Feasibility Study was convened on 23 January 2025 at the UNEP-IETC headquarters in Osaka, Japan. This in-person meeting served as a key coordination milestone in the project's timeline, providing an opportunity for cross-country exchange, mid-term review, and in-depth discussion of preliminary findings from the feasibility studies in Cambodia and Pakistan. Participants included UNEP staff, national consultants from both countries, representatives from the Japanese Ministry of Foreign Affairs, members of the UNDP Cambodia team, and key collaborators from IGES and the Global Environment Centre. The meeting was structured around a series of technical presentations, open discussions, and synthesis dialogues.

The Cambodian team shared early findings on waste characterization, highlighting the composition and quantities of plastic waste streams such as LDPE, PET, and PP. They discussed their approach to mapping existing recycling practices and the development of tailored SME business models based on operational realities in urban and semi-urban settings. The presentation also emphasized the role of informal collectors and aggregators in shaping feedstock availability for SME recyclers.

The Pakistani team, meanwhile, presented results from stakeholder mapping in Lahore and surrounding regions, identifying clusters of informal and formal recycling activity and opportunities to upgrade SMEs through targeted technical and financial interventions. They outlined possible SME models for scaling mechanical recycling, especially for PET and HDPE, and shared preliminary LCA results to assess the comparative environmental benefits of these approaches.

The discussions during the meeting were wide-ranging and insightful. Key issues raised included the need to contextualize recycling technologies within national policy frameworks, address gaps in financial access and technical training, and consider gender and social equity dimensions in SME operations. The meeting also included a session on UNEP-IETC's broader regional work on circular economy and discussed potential synergies with other ongoing initiatives. By the close of the meeting, participants had reached a consensus on the importance of continuing to support SMEs as agents of circular economy transformation. The feedback

collected informed the final adjustments to the feasibility studies and set the stage for their validation and dissemination.

3.5. Project Completion Meeting (Phnom Penh, March 2025)

The Project Completion Meeting for Cambodia was held in person in Phnom Penh in March 2025, marking the successful conclusion of project activities under the MOFA-JSB 2023 funding cycle. This meeting was convened exclusively for the Cambodia component of the project, as the Pakistan component is being extended into a second phase under MOFA-JSB 2024 funding, with implementation continuing through FY2024–2025. The Cambodia project activities, by contrast, were completed within FY2023, making this meeting a formal closing and knowledge-sharing event.

The meeting brought together key stakeholders in person, including representatives from the Ministry of Environment, national consultants, local authorities, and other development partners. UNEP-IETC staff joined the meeting remotely, providing technical inputs and facilitating discussion through virtual participation.

During the meeting, the Cambodian team presented the final results of the feasibility study on SME-led plastic recycling. The presentation covered the characterization of plastic waste streams, including LDPE and PET, assessment of existing recycling practices, and recommendations for introducing or upgrading SME-operated recycling facilities. Particular attention was given to the application of Life Cycle Assessment (LCA), which provided valuable insight into the environmental benefits and trade-offs of different recycling technologies. The findings suggested that small-scale mechanical recycling, when designed for material quality and energy efficiency, offers a viable path toward environmentally sustainable and economically feasible recycling operations.

Participants discussed key enabling conditions necessary to operationalize the proposed SME models. These included improved feedstock collection systems, access to low-cost and appropriate recycling technologies, workforce training, and simplified regulatory procedures. The role of the informal sector was also discussed, with recommendations to integrate informal collectors and aggregators into formal SME supply chains to ensure input continuity and social inclusion.

The meeting served not only as a closing event but also as a platform for stakeholders to validate recommendations and express interest in piloting selected SME models in priority locations. The Ministry of Environment expressed its appreciation for UNEP's technical support and welcomed future collaboration to implement policy and investment strategies that support circular economy initiatives at the local level.

The Project Completion Meeting in Phnom Penh symbolized the successful culmination of UNEP-IETC's technical cooperation in Cambodia under the JSB 2023 project. It reinforced national ownership of the project results and provided a strong foundation for continued engagement on SME development and sustainable plastic recycling in Cambodia.

4. Feasibility Study Findings

4.1. Cambodia

4.1.1. Assessment of Plastic Waste Types and Volumes

The feasibility study in Cambodia began with a detailed characterization of plastic waste generation, composition, and collection dynamics. Urban areas such as Phnom Penh emerged as hotspots for plastic waste generation, driven by rapid urbanization and increased consumption of packaged goods. The study identified four key plastic types with relevance to SME-scale recycling: low-density polyethylene (LDPE), polyethylene terephthalate (PET), polypropylene (PP), and high-density polyethylene (HDPE). LDPE and PET were the most prominent in terms of both volume and market interest, especially among informal collectors and small-scale aggregators. The availability of these plastic types was evaluated through interviews with waste collectors, secondary data analysis, and field observation. Informal collection networks were found to be the primary recovery mechanism, especially for LDPE and PET. However, the lack of material sorting and quality control posed challenges for consistent recycling operations.

The table below summarizes the findings of this assessment:

Table 1. Plastic Waste Streams in Cambodia

Plastic Type	Common Sources	Collection Method	Availability (Est. tons/year)	Recyclability Potential
LDPE	Plastic bags, films	Informal sector	6,000	High
PET	Beverage bottles	Informal + bins	4,500	High
PP	Food containers	Informal sector	3,000	Moderate
HDPE	Detergent bottles	Mixed	2,500	Moderate

These quantities suggest that there is sufficient volume to support small-scale recycling operations, particularly for LDPE and PET. However, seasonal fluctuations and inconsistent feedstock quality remain key concerns for SME recyclers.

4.1.2. Technology Options and LCA Results

To determine the most environmentally and economically viable recycling technologies for SMEs, the project conducted a Life Cycle Assessment (LCA) of selected mechanical recycling processes for PET and LDPE. The LCA model incorporated factors such as energy consumption, greenhouse gas emissions, and water use, tailored to Cambodia's electricity grid mix and market structure.

For PET, bottle-to-flake production using manual and semi-mechanical systems showed high environmental benefits, with substantial reductions in greenhouse gas emissions and relatively low energy intensity. For LDPE, film-to-pellet recycling was deemed moderately beneficial, provided the input quality was well-managed.

The table below presents the summarized LCA results:

Table 2. LCA Summary for Recycling Technologies in Cambodia

Material	Recycling Tech	Energy Use (kWh/ton)	GHG Emissions Reduction (kg CO ₂ e/ton)	Water Use (liters/ton)	Overall LCA Rating
PET	Bottle-to-flake	420	1,200	200	High benefit
LDPE	Film-to-pellet	510	950	300	Moderate benefit

These results underscored the importance of using clean and sorted input materials, minimizing energy consumption through equipment selection, and ensuring efficient water usage. The study recommended modular, energy-efficient technologies that could be locally operated and maintained by SMEs.

4.1.3. Proposed SME Recycling Models

Based on the waste flow and technology assessments, the study developed business model scenarios for SME-led plastic recycling, focusing on PET flake production and LDPE pelletizing. These models were designed with practical implementation in mind, balancing capital investment requirements, operational needs, and financial viability.

Each model included specifications for processing capacity, equipment needs, input-output ratios, and estimated financial metrics. The PET model focused on bottle-to-flake production for domestic and export markets, while the LDPE model targeted the production of low-grade pellets suitable for local film and construction product manufacturers.

Table 3. SME Business Model Summary in Cambodia

Material	Scale	Estimated Capacity (tons/day)	Initial Investment (USD)	Monthly OPEX (USD)	Estimated Monthly Revenue (USD)	Payback Period (months)	Jobs Created (per unit)	Main Product
PET	Small	1.0	20,000–30,000	1,500–2,000	2,000–3,500	12	5	PET flakes
LDPE	Micro to Small	0.5	15,000–25,000	1,000–1,500	1,200–2,000	14	3	LDPE pellets

The models demonstrated that, under realistic assumptions, SMEs could achieve a return on investment within one to two years, particularly when feedstock supply and product demand are stable. Opportunities were also identified for aggregating multiple SME units under cooperatives or municipal partnerships to improve scale and efficiency.

4.1.4. Challenges and Recommendations

Despite the promising potential of SME-based plastic recycling, the study identified a number of structural and operational challenges. Financing remains the most pressing issue. SMEs in Cambodia often lack access to affordable credit, and financial institutions typically view recycling businesses as high-risk. This hampers their ability to invest in new machinery or expand operations.

Technology access is another barrier. Many recycling facilities rely on second-hand or improvised equipment, which reduces efficiency and increases environmental impacts. Maintenance capacity and technical know-how are also limited, with few local service providers available to support machine repairs or upgrades.

Regulatory uncertainty further complicates SME operations. Licensing procedures can be inconsistent across jurisdictions, and few incentives exist for SMEs to formalize or invest in environmental compliance. Moreover, informal waste pickers—despite playing a crucial role in feedstock collection—are not integrated into formal business planning or policy frameworks. To address these challenges, the study recommended a coordinated policy and financing strategy that includes:

- Establishing public or donor-backed soft loan schemes for SME equipment investment;
- Providing technical training and maintenance support hubs for small recyclers;
- Simplifying business registration and environmental compliance procedures for recycling SMEs;
- Strengthening municipal-SME partnerships for feedstock supply and site development;

- Introducing pilot public procurement schemes to support demand for recycled-content products.

With these interventions, Cambodia can enable its SME sector to play a transformative role in the transition to a circular plastic economy, supporting job creation, pollution reduction, and local innovation in the waste sector.

4.2. Pakistan

4.2.1. Assessment of Plastic Waste Types and Volumes

The feasibility study in Pakistan focused primarily on urban areas such as Lahore and its surroundings, where plastic consumption and waste generation are particularly high. These areas also host a wide range of informal recycling activities, as well as small-scale enterprises engaged in sorting, cleaning, and reprocessing plastic materials. The assessment revealed that a diverse range of plastic waste types is present in the municipal waste stream, with polyethylene terephthalate (PET), high-density polyethylene (HDPE), polypropylene (PP), and low-density polyethylene (LDPE) being the most prominent.

Informal waste pickers and traders form the backbone of plastic waste recovery in Pakistan. They collect materials from households, commercial establishments, and dumpsites and sell them to middlemen or small-scale recyclers. However, the absence of structured coordination, along with seasonal variations in plastic availability and quality, creates uncertainty in the supply chain—particularly for SMEs who rely on consistent feedstock for operational stability.

The table below summarizes the plastic waste streams identified in the study, including their sources, collection mechanisms, and estimated recyclability:

Table 4. Plastic Waste Streams in Pakistan

Plastic Type	Common Sources	Collection Method	Availability (Est. tons/year)	Recyclability Potential
PET	Beverage bottles	Informal sector	8,000	High
HDPE	Detergent containers	Informal + traders	6,500	High
PP	Food packaging	Informal sector	4,000	Moderate
LDPE	Plastic bags	Mixed	3,500	Moderate

This waste composition indicates a viable foundation for SME-level recycling enterprises, especially if reliable sourcing arrangements and material quality improvements are established.

4.2.2. Technology Options and LCA Results

To assess the environmental viability of plastic recycling technologies suited for SMEs in Pakistan, the study applied a simplified Life Cycle Assessment (LCA) methodology to two dominant recycling routes: PET bottle-to-flake and HDPE container-to-pellet. These routes are widely used in informal and small-scale operations across urban centres.

The LCA accounted for energy use, greenhouse gas emissions (GHG) reduction potential, and water consumption. It drew on operational data collected from pilot sites, machinery vendors, and international benchmarks, calibrated to Pakistan's local context. PET recycling emerged as more environmentally beneficial in terms of GHG savings and lower water use, while HDPE recycling demonstrated strength in handling more heterogeneous waste and maintaining consistent pellet output.

Table 5. LCA Summary for Recycling Technologies in Pakistan

Material	Recycling Tech	Energy Use (kWh/ton)	GHG Emissions Reduction (kg CO ₂ e/ton)	Water Use (liters/ton)	Overall LCA Rating
PET	Bottle-to-flake	450	1,100	220	High benefit

HDPE	Container-to-pellet	530	880	310	Moderate benefit
------	---------------------	-----	-----	-----	------------------

These results supported the selection of mechanical recycling technologies that are both modular and adaptable to SME needs, especially those which allow for gradual upgrading or scaling as business capacity grows.

4.2.3. Proposed SME Recycling Models

Based on waste availability, market demand, and LCA results, the feasibility study proposed two SME recycling business models for Pakistan. The first focuses on PET bottle-to-flake production; the second targets HDPE container-to-pellet processing. Each model considers local sourcing, workforce availability, expected output, and potential market linkages.

The PET model is structured around purchasing bottles from informal traders, cleaning and shredding them into flakes, and selling to textile manufacturers or regional recyclers. With a processing capacity of 1 ton/day, this model targets small enterprise operators and cooperatives. The HDPE model involves reprocessing used detergent and chemical containers into uniform pellets, mainly for use in the manufacturing of plastic piping and household goods.

Table 6. SME Business Model Summary in Pakistan

Material	Scale	Estimated Capacity (tons/day)	Initial Investment (USD)	Monthly OPEX (USD)	Estimated Monthly Revenue (USD)	Payback Period (months)	Jobs Created (per unit)	Main Product
PET	Small	1.0	18,000–25,000	1,200–1,700	2,100–3,200	12	6	PET flakes
HDPE	Small	0.75	18,000–25,000	1,000–1,500	1,800–1,500	14	5	HDPE pellets

The models show promising returns with relatively short payback periods (12–14 months) under stable input and market conditions. Their successful implementation would depend on securing low-cost credit, reliable electricity, and feedstock availability through informal sector partnerships or municipal support.

4.2.4. Challenges and Recommendations

The feasibility study identified several systemic barriers hindering the expansion of SME-led plastic recycling in Pakistan. Chief among them is the fragmented nature of the waste management ecosystem, where informal sector actors operate outside formal policy and financial systems. This fragmentation undermines consistent feedstock access, operational predictability, and potential partnerships with local governments.

Financial constraints are a major bottleneck. Few banks or microfinance institutions extend loans to recycling SMEs, citing a lack of credit history, business formalization, or perceived risk. As a result, most SMEs rely on personal savings or informal borrowing, which limits their growth and ability to adopt more efficient technologies.

Technical capacity gaps further restrict the sector. Many SME operators lack access to machinery manuals, quality standards, and preventive maintenance protocols, resulting in lower product quality and frequent breakdowns. There is also a lack of structured training opportunities in waste processing, safety, and business management.

To unlock the potential of SMEs in plastic recycling, the study recommended the following actions:

- Develop SME financing schemes backed by public funds or impact investors, including low-interest loans and lease-to-own programs for machinery;
- Promote formal registration of recycling SMEs and offer compliance support, including streamlined licensing and documentation services;

- Establish municipal-level recycling hubs or clusters with shared infrastructure and services (e.g., electricity, water, sorting bays);
- Integrate technical training into national vocational education schemes and partner with technical institutes to provide short courses for SME workers;
- Create digital platforms to connect SMEs with upstream waste collectors and downstream product buyers;
- Provide policy incentives for SMEs to participate in city-level waste service contracts, pilot schemes, or EPR-related projects.

By implementing these recommendations, Pakistan can enable its dynamic SME sector to serve as a cornerstone of the country's circular economy transition, while generating employment, reducing pollution, and enhancing environmental resilience at the local level.

5. Key Results and Achievements

The project *"From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy"* achieved notable outcomes in its efforts to empower SMEs in Cambodia and Pakistan to take a leading role in local plastic recycling systems. Implemented by UNEP-IETC with support from the Ministry of Foreign Affairs of Japan under its Japan Supplementary Budget (MOFA-JSB), the project demonstrated the feasibility of SME-led recycling models through integrated research, stakeholder consultation, and practical design of business and policy solutions.

A central achievement of the project was the completion of two comprehensive feasibility studies—one each for Cambodia and Pakistan. These studies provided a deep analysis of local plastic waste streams, existing recycling infrastructure, stakeholder dynamics, and market readiness. In Cambodia, the studies identified LDPE and PET as the most abundant and recyclable plastic types, whereas in Pakistan, PET and HDPE emerged as priority materials with the highest potential for recovery and reuse through SME-scale operations. The studies also examined the role of informal actors and emphasized the importance of integrating them into formal recycling frameworks. The final outputs included a set of operational, policy, and investment recommendations tailored to each country's unique conditions.

Another key outcome was the integration of LCA into the technology evaluation process. This was the first time that LCA was systematically applied to compare SME-relevant plastic recycling options in both countries. The LCA models showed that mechanical recycling systems—particularly PET bottle-to-flake and LDPE film-to-pellet—provide substantial reductions in greenhouse gas emissions, energy use, and environmental impact when compared to conventional disposal methods such as landfilling or open burning. In Pakistan, LCA results confirmed the environmental soundness of HDPE pellet production from post-consumer containers. These assessments allowed the project teams and stakeholders to select recycling pathways not only based on operational feasibility and cost but also on their environmental performance.

The development of practical, context-specific SME business models was another major accomplishment of the project. In Cambodia, the proposed models focused on small, modular systems for recycling LDPE and PET, with emphasis on low energy use, ease of maintenance, and adaptability to informal sector linkages. In Pakistan, two detailed SME models were created for PET flake and HDPE pellet production. These included operational layouts, equipment specifications, capital and operating costs, and estimated financial returns. For example, a PET flake production facility in Pakistan was projected to operate at one ton per day, require a capital investment of USD 18,000 to 25,000, and generate monthly revenues of USD 2,100 to 3,200 with a payback period of around 12 months. Each facility was estimated to create five to six local jobs. These models not only highlighted the viability of SME-scale recycling but also pointed to opportunities for scaling through coordinated support in finance, policy, and market development.

Capacity building formed another cornerstone of the project's success. In December 2024, UNEP-IETC delivered a regional online training session on Life Cycle Assessment, which brought together government officials, technical consultants, SMEs, and other partners from Cambodia and Pakistan. The training introduced the principles of LCA and provided guidance on how it can inform recycling system design, technology selection, and policy-making. This knowledge transfer helped strengthen the capacity of national stakeholders and enabled them to engage more effectively in subsequent project activities, including the feasibility studies and business model refinement.

The project also created strong platforms for stakeholder engagement and cross-country learning. Three major events anchored this process: the online LCA training session in December 2024, the in-person project meeting held at UNEP-IETC in Osaka in January 2025, and the project completion meeting for Cambodia, held in Phnom Penh in March 2025. These meetings enabled direct interaction between policy officials, technical experts, private sector actors, and development partners. They also allowed participants from Cambodia and Pakistan to exchange ideas and identify common challenges and opportunities in advancing circular economy approaches to plastic waste.

Importantly, the project laid the groundwork for further action, particularly in Pakistan. Based on the success of the initial feasibility phase, UNEP-IETC secured additional funding through MOFA-JSB 2024 to launch a second phase focused on piloting SME business models, enhancing city-level implementation, and deepening national policy integration. This Phase 2 initiative will build on the findings of the feasibility study and continue to strengthen the enabling environment for SME-led recycling initiatives. In Cambodia, while project activities have formally concluded, the outputs provide a model that could inform regional replication and adaptation in other ASEAN countries exploring similar circular economy pathways.

Overall, the project demonstrated how technical assessment, policy dialogue, and local business modelling can converge to support inclusive and environmentally sound plastic recycling. The results offer governments and partners a credible framework for scaling up SME participation in the circular economy while delivering social, environmental, and economic benefits. These achievements provide a strong foundation for ongoing engagement and implementation in the years ahead.

6. Lessons Learned and Recommendations for Phase 2

The implementation of the project across Cambodia and Pakistan offered valuable insights into the practicalities, challenges, and opportunities of developing SME-led plastic recycling systems within a circular economy framework. These lessons not only informed the final feasibility studies but also provided strategic direction for scaling up efforts—particularly in the context of Pakistan's Phase 2 implementation under MOFA-JSB 2024 funding. The following key lessons and recommendations emerged from the project.

One of the most consistent lessons from both countries was the importance of grounding technical solutions in local realities. The availability and type of plastic waste, informal sector dynamics, electricity access, and land use constraints vary widely between—and even within—countries. Standardized business models or technology recommendations are often not fit-for-purpose without local customization. Therefore, feasibility studies that include detailed field research, stakeholder interviews, and scenario modelling are essential to guide practical implementation.

Another critical takeaway was the need to strengthen and formalize the role of informal sector actors. Informal waste pickers and aggregators form the backbone of plastic waste recovery in both Cambodia and Pakistan, but they operate without formal recognition, protections, or access to capital. Integrating these actors into formal SME operations—whether as suppliers, employees,

or partners—enhances feedstock reliability and promotes inclusive economic development. Future project phases should emphasize mechanisms for integrating informal actors, including incentives, formal supply agreements, and support for cooperative models. Access to finance was consistently identified as a major barrier for SME growth. In both countries, recycling SMEs are typically undercapitalized, relying on self-financing, small-scale savings, or informal loans. Commercial banks often consider waste recycling too risky, and financial products tailored to the realities of waste SMEs are almost non-existent. This underscores the need for blended finance instruments—such as public-backed loan guarantees, subsidized interest rates, or leasing schemes—that can reduce risk for investors while enabling SMEs to upgrade their equipment and facilities. In Phase 2 of the project in Pakistan, partnerships with microfinance institutions and green investment platforms should be prioritized to bridge this financing gap.

The project also highlighted a need for greater technical support and training. Many SMEs operate using outdated or second-hand machinery with limited awareness of maintenance protocols, safety procedures, or quality assurance. As a result, production efficiency and product consistency suffer, undermining market competitiveness. Technical training should therefore be embedded into future implementation efforts. This could include hands-on training, access to repair services, and development of equipment maintenance manuals in local languages. Partnerships with vocational institutes, engineering schools, or private service providers could ensure continued technical assistance beyond the project's lifecycle.

From a policy perspective, both countries demonstrated a general alignment with circular economy objectives, but challenges remain in translating national strategies into local-level support for SMEs. Regulatory processes are often unclear or inconsistent, and environmental compliance can be burdensome for small operators. In Phase 2, efforts should be made to work with municipal governments to simplify permitting, reduce regulatory bottlenecks, and integrate SME recyclers into local waste management strategies—including public-private partnerships or participation in Extended Producer Responsibility (EPR) schemes.

The project also emphasized the value of coordinated stakeholder engagement. In both countries, engagement with ministries, municipalities, private sector actors, and civil society helped ensure project ownership and built momentum for future implementation. The cross-country meetings and LCA training sessions further promoted shared learning and encouraged harmonized approaches. For Phase 2, these partnerships should be deepened, with a particular focus on aligning national circular economy targets with city-level waste reduction and recycling goals.

In practical terms, the development of an SME-led plastic recycling system in a local city in Pakistan—such as Lahore, Faisalabad, or Karachi—would involve identifying specific geographic clusters with high plastic waste generation and existing informal recovery activity. A pilot site could be selected through consultation with municipal authorities, followed by a localized feasibility scoping to assess material availability, land access, and potential SME partners. Working closely with city officials, informal aggregators, and financing institutions, a group of small enterprises could then be supported to establish modular recycling operations (e.g., PET flake or HDPE pellet production). These operations would receive technical guidance, financial assistance, and regulatory facilitation to ensure compliance and market integration. Municipalities could help by securing collection agreements, ensuring input flow, and promoting the use of recycled products through procurement or awareness campaigns.

To implement such a system effectively, the following step-wise process is recommended:

1. **Site Selection and Scoping:** Identify a city or district with high plastic waste generation and stakeholder willingness. Conduct baseline studies to map plastic flow, informal actor presence, and SME potential.

2. **Stakeholder Engagement and Partnerships:** Establish a local coordination group including city authorities, waste collectors, recyclers, SMEs, and technical institutions. Define roles and collaboration frameworks.
3. **Business Model Customization:** Adapt the national SME business models to the selected site's realities, including investment levels, material types, and infrastructure conditions.
4. **Access to Finance:** Mobilize financing through partnerships with microfinance institutions, government schemes, or donor support. Provide training in business planning and financial literacy.
5. **Technology Setup and Training:** Procure or upgrade recycling equipment. Conduct technical training on machinery operation, safety, maintenance, and product quality standards.
6. **Operational Launch:** Facilitate regulatory compliance (permits, waste licenses), initiate input contracts (e.g. from informal sector or municipal sources), and commence operations with support from project partners.
7. **Monitoring and Support:** Provide follow-up technical assistance, ensure product quality control, and support marketing of recycled products. Document results and feed lessons into broader policy and financing frameworks.
8. **Scale-Up and Replication:** Evaluate performance and design replication pathways to other districts or provinces, supported by national policy instruments and investment mobilization.

By taking a structured, city-focused approach that builds on the feasibility study's insights and aligns with local needs, Phase 2 of the project in Pakistan has the potential to demonstrate a replicable and scalable model of SME-led plastic recycling that is inclusive, efficient, and circular by design.

7. Conclusion

The project *“From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy”* has demonstrated that small and medium enterprises can serve as powerful engines for advancing inclusive and sustainable plastic waste management. By building on locally available materials, informal recovery systems, and market-driven business models, SMEs are uniquely positioned to deliver circular solutions that generate environmental, economic, and social benefits at the community level.

Through comprehensive feasibility studies in Cambodia and Pakistan, this project has identified viable recycling technologies, developed implementable SME business models, and outlined enabling conditions necessary for success—ranging from financial access and technical training to regulatory streamlining and informal sector integration. The use of Life Cycle Assessment (LCA) further strengthened the environmental credibility of proposed solutions, reinforcing the importance of data-driven planning in circular economy strategies.

The successful delivery of this project also highlights the value of multi-stakeholder collaboration. By convening policymakers, technical experts, recycling practitioners, and informal actors, UNEP-IETC and its partners were able to co-create practical roadmaps grounded in field realities. These roadmaps now serve not only as guides for local implementation, but also as models for replication and scale-up across the region.

With Phase 2 of the project now set to proceed in Pakistan under the MOFA-JSB 2024 funding, the foundation laid through this first phase will be critical. The next stage will move beyond feasibility to action—supporting pilot projects, mobilizing investment, and deepening partnerships to accelerate the transition toward a circular plastic economy led by SMEs. UNEP-IETC remains committed to supporting countries in transforming waste challenges into opportunities through innovation, inclusiveness, and environmental responsibility. The outcomes of this project reaffirm our shared vision: that a zero-waste future is not only necessary, but achievable—when anchored in local entrepreneurship, informed policy, and shared global commitment.

Annexes

The following annexes provide detailed documentation, data, and supporting materials referenced throughout the main body of this report. These resources are intended to complement the findings, provide transparency for the analysis, and support future implementation or replication of SME-led plastic recycling initiatives.

Annex 1: Project Proposal Document

- *Title:* From Waste to Wealth: Small and Medium Enterprises-led Plastic Recycling for a Circular Economy
- *Reference:* MOFA-JSB 2023 Project Proposal
- Summary of project rationale, objectives, methodology, and expected outcomes, as approved by the Government of Japan and UNEP-IETC.

Annex 2: Summary Report of Online LCA Training (December 2024)

- Description of the agenda, list of participants, training modules covered, and key takeaways.
- Training materials and sample LCA outputs used during the session.

Annex 3: Report of the Project Meeting on Feasibility Study on Plastic Recycling Towards a Circular Future in Cambodia and Pakistan (Osaka, February 2025)

- Meeting agenda, presentation summaries, country updates, and conclusions from technical discussions.
- Participant list, and minutes of discussions.

Annex 4: Project Completion Meeting Report (Phnom Penh, March 2025 – Cambodia)

- Final meeting proceedings, validation of Cambodia's feasibility study, and strategic recommendations discussed.
- Reflections from the Ministry of Environment and national stakeholders.

Annex 5: Final Feasibility Study – Cambodia with the LCA Full Report

- Full report containing waste characterization data, LCA results, SME business models, and implementation roadmaps.
- Data tables, maps, and model financial scenarios.

Annex 6: Final Feasibility Study – Pakistan with the LCA Full Report

- Comprehensive analysis of plastic waste streams, informal sector dynamics, LCA modelling, and business model design.
- Recommendations for Phase 2 implementation and stakeholder roles.