

Advancing Styrofoam Waste Recycling Management within the Framework of a Green Economy At UD Tiga Putra

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Abstract

The increasing accumulation of Styrofoam waste has become a serious environmental concern due to its non-biodegradable properties and the lack of effective disposal and recycling pathways. Micro- and small-scale enterprises play a strategic role in addressing this issue at the local level, including UD Tiga Putra in Gresik, Indonesia, which is actively involved in Styrofoam waste processing. Before the implementation of this community engagement program, the enterprise encountered several operational challenges, such as the use of outdated processing equipment, limited production capacity, and inadequate managerial and occupational safety practices. In particular, the existing Styrofoam melting machine, with a capacity of 150 kg per day, frequently experienced technical failures and resulted in recycled products of inconsistent quality. To address these constraints, a community partnership program was developed by integrating technological upgrading, occupational health and safety improvement, and managerial capacity strengthening. A newly designed appropriate-technology Styrofoam melting machine with a capacity of 300 kg per day was introduced, leading to a substantial increase in production efficiency and operational stability. This technological enhancement was complemented by structured training on workplace safety, including the proper use of fire extinguishers and personal protective equipment, as well as mentoring on systematic financial record-keeping practices. The program outcomes indicate improved operational reliability, enhanced safety awareness among workers, and greater financial transparency. Overall, the findings demonstrate that an integrated, community-based approach can effectively enhance the resilience and competitiveness of small recycling enterprises while supporting circular economy initiatives and sustainable local economic development.

INTRODUCTION

Expanded polystyrene (EPS), widely referred to as Styrofoam, is extensively used in food packaging, protective casings for electronic products, and various single-use

applications because of its low production cost, low density, and favorable thermal insulation characteristics. Despite these advantages, the widespread utilization of EPS has raised serious environmental concerns due to its resistance to natural decomposition. Traditional waste management practices, including landfilling and incineration, have been increasingly recognized as unsustainable, as they contribute to long-term soil and groundwater pollution, greenhouse gas emissions, and the release of hazardous substances. As a result, growing attention has been given to alternative recycling approaches that emphasize sustainability and value recovery. Among these, chemical recycling techniques such as pyrolysis and depolymerization have gained considerable interest as effective pathways for converting Styrofoam waste into styrene monomers, which serve as key raw materials for the production of new polystyrene. In addition to significantly reducing waste volume, these recycling strategies are closely aligned with circular economy principles by promoting resource efficiency and material reuse. Fitriasari et al., (2025) reported, based on a combined techno-economic evaluation and life-cycle assessment, that the recovery of styrene from EPS waste can achieve a substantial reduction in global warming potential—up to 89%—while still ensuring economically competitive product costs. In a related study, Holtkamp et al., (2024) showed that chemical recycling routes for EPS exhibit superior environmental performance compared with incineration, although the overall efficiency of these processes is highly sensitive to operational parameters and processing conditions.

Recent technological advancements have significantly strengthened the prospects of chemical recycling for expanded polystyrene (EPS). Lei et al., (2025) emphasized that the application of catalysts, advanced oxidation techniques, and optimized pyrolysis parameters plays a crucial role in improving both product yield and quality. Furthermore, Singh et al., (2025) demonstrated that closed-loop depolymerization processes allow for the efficient recovery of styrene from EPS without the use of additional solvents, offering a more environmentally sustainable recycling route. In addition, Li et al., (2025) proposed a threshold-temperature pyrolysis approach that effectively lowers energy consumption while enhancing product selectivity. Collectively, these innovations indicate a clear shift in research focus from mere technical viability toward the integration of environmental and economic sustainability considerations. Recent literature consistently highlights that chemical recycling pathways provide a promising solution for reducing Styrofoam waste while enabling the recovery of valuable materials. However, studies that comprehensively evaluate sustainability by simultaneously considering environmental impacts and economic performance remain relatively scarce. Addressing this gap is crucial for supporting the large-scale industrial adoption of EPS recycling technologies and for facilitating the broader transition toward a circular economy.

Conventional waste management approaches, including open dumping, incineration, and landfilling, are insufficient in addressing the environmental impacts associated with Styrofoam waste. Incineration poses risks through the emission of hazardous pollutants, whereas landfilling merely transfers the problem to long-term soil and groundwater contamination (Mahmudi et al., 2017). Moreover, although certain recycling applications have achieved improvements in dimensional stability and water absorption properties, significant challenges remain in meeting national compressive strength requirements, such as those specified in SNI 03-0691-1996. In parallel, community-based initiatives, including eco-paving programs, have demonstrated the potential of utilizing Styrofoam and other plastic wastes as alternative construction materials, thereby contributing to environmental protection while generating local economic value (Royani et al., 2025). Technological progress has also been reflected in the development of specialized recycling equipment. For example, extrusion-based Styrofoam recycling machine prototypes have shown promising results in producing reusable plastic

feedstock through optimized thermal and flow control during processing (Mahmudi et al., 2017). Additionally, alternative machine configurations employing heating-belt systems have been introduced to improve melting efficiency and reduce emissions during recycling operations (Mulyanto et al., 2020). Collectively, these advancements highlight the feasibility of integrating Styrofoam waste into circular economy frameworks when supported by appropriate technological solutions.

Fire-related hazards continue to represent a significant concern in both industrial and community settings in Indonesia. The effective use of fire extinguishers (APAR) is a critical measure for preventing minor fire incidents from developing into major emergencies; however, its effectiveness is strongly influenced by users' knowledge and practical competence (Firdayanti et al., 2024). Evidence from industrial environments, such as CV. Soka Mandiri, indicates that structured APAR training programs can substantially enhance workers' preparedness, as reflected by measurable improvements in post-training knowledge levels (Regina Berliana Rachmadona et al., 2024). Similarly, community-based initiatives implemented in Desa Sandik, West Lombok, have demonstrated that systematic training combined with simulation exercises effectively increases participants' awareness and practical skills in responding to fire emergencies (Wiryajati et al., 2025). These findings underscore the importance of continuous and well-structured APAR training as a fundamental element of occupational safety and community resilience, although maintaining long-term awareness and consistent application remains a challenge. Micro, Small, and Medium Enterprises (MSMEs) constitute a major pillar of Indonesia's economy, yet many continue to face limitations in financial management practices. Common issues include inadequate bookkeeping, the commingling of personal and business finances, and low accounting literacy, which collectively hinder performance evaluation and access to external financing (Cindy Oktavian Indah Rahmadhani, 2024; Magdalena & Yohanson, 2022). Previous studies have shown that targeted training and mentoring programs, including the adoption of digital tools such as Lamikro, can significantly improve financial literacy, promote systematic record-keeping, and enhance financial transparency (Sugiarto & Budiantara, 2024). Therefore, strengthening bookkeeping capabilities remains a critical prerequisite for supporting the sustainable growth and long-term viability of MSMEs (Mahmud et al., 2024; Zakiyyah, 2021).

The primary aim of this community engagement program is to enhance the operational capability and long-term sustainability of micro-enterprises involved in Styrofoam waste processing. To achieve this objective, the program focuses on improving production efficiency through the design and implementation of an appropriate technology-based Styrofoam melting machine with an optimized daily capacity. In parallel, the program seeks to strengthen occupational health and safety practices by equipping workers with essential knowledge and practical skills in fire prevention, particularly regarding the proper use of portable fire extinguishers (APAR) and the consistent application of personal protective equipment, thereby reducing the likelihood of workplace accidents during production activities. In addition, business management capacity is reinforced through training and mentoring in basic financial record-keeping, enabling partner enterprises to establish systematic and transparent financial administration that supports long-term sustainability. The anticipated outcomes of this initiative extend beyond technical and managerial improvements. The increase in production capacity resulting from the introduction of the Styrofoam melting machine is expected to improve operational efficiency and generate higher economic value from recycled materials. Moreover, the integration of occupational safety training is intended to promote a safety-oriented culture, enhancing workers' preparedness in emergency situations. At the same time, the adoption of structured bookkeeping practices is expected to improve financial transparency and

accountability, facilitate access to external funding, and support business continuity. Collectively, these efforts aim to empower partner enterprises to operate more effectively, sustainably, and responsibly while contributing to local economic development and environmental conservation.

IMPLEMENTATION METHOD

Based on a community development-oriented approach, the methodological design of this program was structured into several sequential stages, including an initial site assessment, community engagement and socialization, the development of an action plan, systematic program implementation, and a comprehensive monitoring and evaluation process, as summarized in Table 1.

Table 1. Community Partnership Empowerment (PKM) Implementation Method

Activity	Problem	Solution	Indicator Achievement
Production Aspects	The production process relied on a Styrofoam melting machine with a capacity of 150 kg per day; however, frequent mechanical malfunctions, limited throughput, and uneven heat distribution reduced its ability to meet market demand and resulted in inconsistent, brownish product quality.	Production capacity was enhanced through the design and implementation of an appropriate-technology Styrofoam melting machine with an optimized capacity of 300 kg per day.	The introduction of the appropriate-technology melting machine led to a 100% increase in production capacity, from 150 kg/day to 300 kg/day, accompanied by improved process stability and product quality.
Management Aspects	Occupational safety practices among workers were insufficient, and UD Tiga Putra had not yet established systematic and structured financial record-keeping practices.	Employees' knowledge and skills were strengthened through training in occupational health and safety (OHS) and mentoring in basic business financial documentation.	Observable improvements were achieved in employees' understanding of safe and healthy production practices, along with increased awareness and consistency in maintaining systematic financial records for small business operations.

RESULT and DISCUSSION

This section outlines the outcomes of the community service program and discusses their implications with respect to the identified challenges and the objectives that were established.

1. Site Survey Activities

The site survey was conducted through a direct visit to UD Tiga Putra, a Styrofoam waste processing enterprise located in Beton Village, RT 11 RW 04, Menganti District, Gresik Regency. This activity aimed to obtain a comprehensive understanding of the operational challenges faced by the enterprise, as illustrated in Figure 1.



Figure 1. Implementation of the Site Survey in the Community Service Program.

2. Implementation of the Socialization Activity within the Community Partnership Empowerment Program.

The socialization activity was conducted to communicate the objectives of the Community Partnership Empowerment (PKM) program initiated by the Universitas Wijaya Putra (UWP) team to the partner enterprise. During this stage, the PKM team collaborated closely with the owner of UD Tiga Putra, as depicted in Figure 2.



Figure 2. Socialization Activity of the UWP Team with Partner UD Tiga Putra.

3. Preparation of the Work Plan for the Community Partnership Empowerment (PKM) Initiative.

Following the identification of the partner's primary challenges, the UWP PKM team developed a structured work plan. This stage involved the formulation of proposed solutions aimed at enhancing production capacity and improving business management practices in Styrofoam waste processing, in line with green economy principles. The work plan was designed to facilitate collaborative coordination between the UWP PKM team and the partner, enabling both parties to establish an agreed-upon schedule of activities.

4. Implementation of the Work Program within the Community Partnership Empowerment (PKM) Project.

Implementation of the Community Partnership Empowerment (PKM) Work Program :

a. Training and Mentoring on the Operation of the Appropriate Technology Styrofoam Melting Machine.

The existing Styrofoam melting process relied on a machine with a capacity of 150 kg per day, which frequently experienced operational failures, was unable to meet market demand, and produced recycled materials with a brownish appearance due to uneven heat distribution. To address these limitations, a new Appropriate Technology-based Styrofoam Melting Machine with an increased capacity of 300 kg per day was designed and implemented, as shown in Figure 3. The Styrofoam melting process represents one of the practical approaches for processing polystyrene-based plastic waste. Initially, used Styrofoam is collected and cleaned to remove impurities and non-plastic components before being fed into the melting machine. During processing, controlled heat is applied, causing the lightweight and porous structure of Styrofoam to collapse and significantly reduce in volume. As heating continues, the low-density material melts and transitions into a denser phase. Proper temperature regulation is crucial, as uneven heat distribution can lead to discoloration and a decline in the quality of the recycled product. The melting process yields a viscous polystyrene material that solidifies into dense forms upon cooling. These solidified products can subsequently be reused as raw materials in various applications, including frame production, household plastic goods, and recycled construction materials. Consequently, the Styrofoam melting process not only reduces the volume of non-biodegradable waste but also supports material recovery and reuse in accordance with green economy principles.



Figure 3. Training and Mentoring on the Operation of the Appropriate Technology Styrofoam Melting Machine.

b. Capacity Building through Occupational Health and Safety (OHS) Training for Employees at UD Tiga Putra.

Occupational Health and Safety (OHS) training was implemented as an integral component of the community partnership empowerment program to enhance employees' knowledge, skills, and awareness in maintaining safe and healthy working conditions. The training emphasized the correct use of fire extinguishers (APAR), incorporating both

demonstrations and practical exercises to ensure proper operation, effective response during fire incidents, and routine inspection procedures to maintain equipment readiness. In addition, employees were introduced to the appropriate use of personal protective equipment, including gloves, masks, and safety footwear, which play a vital role in reducing occupational risks associated with the Styrofoam melting process. This initiative not only strengthened employees' technical competence in occupational safety practices but also fostered the development of a safety-conscious work culture that supports sustainable business operations. The implementation of the OHS training activities is presented in Figure 4.



Figure 4. Capacity Building through Occupational Health and Safety (OHS) Training.

c. Training and Mentoring on systematic financial documentation practice for Small Enterprises.

Training and mentoring activities focused on financial documentation practices were conducted with employees of UD Tiga Putra as the primary participants. The program highlighted the importance of systematic and well-organized financial administration as a foundation for business sustainability. The training sessions covered essential topics, including the recording of daily financial transactions, the separation of personal and business finances, the preparation of simplified financial statements—such as cash flow reports, profit and loss statements, and asset records—and the proper documentation of transaction evidence. Beyond theoretical instruction, hands-on mentoring was provided to assist participants in developing daily cash books, maintaining regular records of income and expenditures, and preparing simplified financial reports to support more informed decision-making. This initiative aimed not only to promote consistent financial record-keeping and improve transparency, but also to strengthen the capacity of small enterprises to access future financing opportunities. The implementation of these training and mentoring activities is illustrated in Figure 5.



Figure 5. Training and Mentoring on systematic financial documentation practice.

d. Monitoring and Evaluation of the Community Partnership Empowerment (PKM) Program Implementation.

Monitoring and evaluation of the Community Partnership Empowerment (PKM) program were conducted through a series of systematic activities. Direct field observations were undertaken to verify that program implementation was consistent with the agreed work plan. In addition, the PKM team carried out interviews and discussions with the owner and employees of UD Tiga Putra to obtain feedback regarding the program’s benefits, challenges, and long-term sustainability. The effectiveness of the training and mentoring components was also evaluated, particularly in relation to employees’ ability to operate the appropriate-technology melting machine, their awareness and application of Occupational Health and Safety (OHS) practices, and their consistency in maintaining financial records. Program performance was assessed by comparing conditions before and after implementation, including the increase in production capacity from 150 kg/day to 300 kg/day, as shown in Figure 6, as well as improvements in employees’ understanding of OHS practices and systematic financial documentation, as illustrated in Figure 7. The results of the monitoring and evaluation process were subsequently compiled into a structured report, which serves both as a basis for future program improvement and as a form of academic accountability.

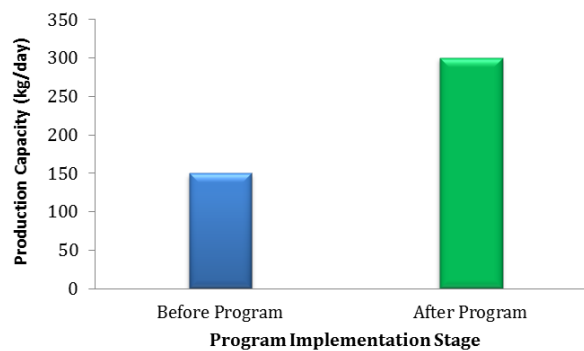


Figure 6. Improvement in the Production Capacity of UD Tiga Putra.

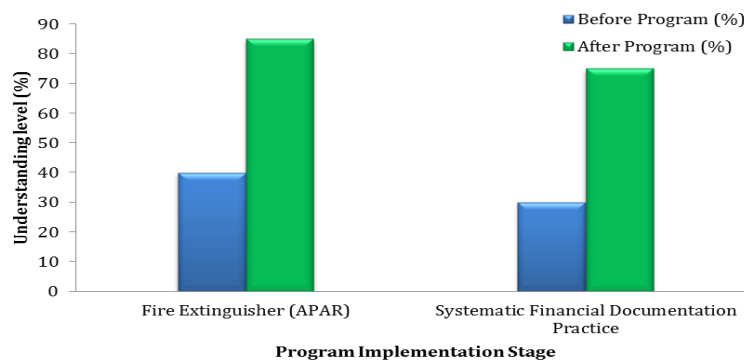


Figure 7. Employee Understanding Level at UD Tiga Putra.

CONCLUSION

The implementation of the community partnership program at UD Tiga Putra demonstrated measurable progress in strengthening small-scale Styrofoam waste recycling activities. The adoption of an appropriate-technology melting machine successfully increased production capacity to 300 kg per day, resulting in improved operational efficiency as well as more consistent recycled product quality. In parallel, occupational health and safety training enhanced workers’ awareness and contributed to the

development of a safety-oriented working environment, while mentoring in financial documentation practices supported more systematic and transparent business management. These combined outcomes highlight the effectiveness of the program in simultaneously addressing technical and managerial challenges, thereby fostering a more sustainable and competitive enterprise framework. Nevertheless, certain limitations remain, particularly with regard to maintaining long-term consistency in safety practices and ensuring routine maintenance of the newly implemented equipment to prevent potential operational disruptions. Future efforts to replicate and scale this program across other micro and small enterprises could significantly strengthen the application of green economy principles, contribute to environmental protection, and enhance the resilience of local economies.

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