

## Enhancing the Management and Recycling Capacity of Styrofoam Waste Through a Green Economy Approach

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### Abstract

*Styrofoam waste poses a serious environmental challenge due to its non-biodegradable nature and the lack of sustainable disposal solutions. Conventional methods such as landfilling and incineration often lead to secondary problems, including soil contamination and harmful emissions. This community partnership program was conducted at UD Tiga Putra, a micro-enterprise in Gresik, Indonesia, which previously relied on a 150 kg/day Styrofoam melting machine prone to frequent breakdowns and inconsistent product quality. To address these issues, an appropriate-technology Styrofoam melting machine with a capacity of 300 kg/day was introduced, effectively doubling production capacity (from 150 to 300 kg/day) and improving product uniformity. In addition, structured occupational health and safety (OHS) training was provided to 12 employees, covering fire extinguisher (APAR) usage, personal protective equipment, and workplace safety practices. Financial mentoring was also delivered, emphasizing systematic bookkeeping, separation of personal and business finances, and preparation of transparent reports. Evaluation using pre- and post-training assessments and direct observation showed significant improvements: OHS awareness scores increased by 20%, financial documentation accuracy improved, and operational disruptions decreased. Overall, the integration of technological innovation, safety training, and financial management mentoring not only strengthened the resilience and sustainability of UD Tiga Putra but also offers a replicable model for empowering other micro-enterprises in line with circular economy principles.*

*Keywords: styrofoam recycling, micro-enterprise, community partnership, circular economy, sustainability*

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### 1. Introduction

Expanded polystyrene (EPS), commonly known as Styrofoam, is widely employed in food packaging, protective materials for electronic devices, and other disposable products due to its low cost, lightweight structure, and excellent thermal insulation properties. However, its extensive use has created significant environmental concerns because of its

extremely slow degradation in nature. Conventional disposal methods such as landfilling and incineration have proven unsustainable, leading to long-term soil contamination, greenhouse gas emissions, and the release of toxic compounds. Consequently, increasing attention has been directed toward more sustainable and value-added recycling strategies, particularly chemical recycling. In recent years, chemical recycling of Styrofoam through pyrolysis

and depolymerization has emerged as a promising approach to recover styrene monomer, the primary feedstock for new polystyrene production. This method not only reduces the volume of waste but also aligns with the principles of the circular economy [1]. Fitriasari et al., [2] demonstrated through techno-economic analysis and life cycle assessment that styrene recovery from EPS can reduce global warming potential by up to 89% while maintaining competitive product pricing. Similarly, Holtkamp et al., [3] confirmed that chemical recycling of EPS outperforms incineration in terms of environmental performance, although the efficiency strongly depends on operating conditions.

Technical innovations have further advanced the potential of EPS chemical recycling. Lei et al., [4] highlighted the role of catalysts, advanced oxidation processes, and optimization of pyrolysis conditions in enhancing product yield and quality. These developments reflect a clear research trend that extends beyond technical feasibility to incorporate environmental and economic sustainability. Singh et al., [5] reported that closed-loop depolymerization enables the recovery of styrene from EPS without additional solvents, representing a more environmentally benign pathway. Overall, recent studies underscore that Styrofoam recycling through chemical pathways offers a viable solution for mitigating plastic waste while recovering valuable resources. Nevertheless, comprehensive sustainability assessments that simultaneously integrate environmental and economic dimensions remain limited. Addressing this research gap is essential for guiding the industrial implementation of EPS recycling technologies and supporting the broader transition toward a circular economy.

Conventional disposal practices such as open dumping, incineration, and landfilling have proven inadequate in mitigating these impacts. Incineration can release harmful emissions, while landfilling only shifts the problem to long-term soil and groundwater contamination. Prototypes of extrusion-based Styrofoam recycling machines have shown promise in producing reusable plastic feedstock by optimizing heating and flow rates during processing [6]. However, despite improvements in dimensional stability and water absorption, challenges remain in meeting national compressive strength standards (SNI 03-0691-1996). Parallel community-driven initiatives, such as eco-paving projects, illustrate how Styrofoam and other plastic waste can be repurposed into building materials, supporting both environmental sustainability and local economic benefits [7]. Other machine designs, such as those utilizing heating belts, have been developed to enhance melting efficiency and reduce emissions during recycling operations [8]. These efforts demonstrate the potential for Styrofoam waste to be

integrated into circular economy frameworks when supported by appropriate technological solutions.

Fire hazards remain a critical issue in both industrial and community contexts in Indonesia. The proper use of fire extinguishers (APAR) is essential for preventing small fires from escalating, yet its effectiveness depends on user knowledge and skills [9]. In industrial settings such as CV. Soka Mandiri, where flammable materials are frequently used, APAR training has been shown to significantly improve workers' preparedness, with post-training evaluations indicating notable knowledge gains [10]. Likewise, community-based programs in Desa Sandik, West Lombok, demonstrated that structured APAR training and simulations effectively increased residents' awareness and practical capabilities in handling fire emergencies [11]. These cases highlight that systematic APAR training is a vital component of occupational safety and community resilience, though sustaining awareness and ensuring consistent implementation remain key challenges. Micro, Small, and Medium Enterprises (MSMEs) are key drivers of Indonesia's economy, yet many still struggle with weak financial recording practices. Business owners often mix personal and business funds and lack proper bookkeeping, limiting their ability to evaluate performance and access financing [12], [13]. Limited accounting literacy reduces the quality of financial reports and hampers decision-making [14], [15]. Training and mentoring, including the use of applications such as Lamikro, have proven effective in improving financial literacy, separating personal and business finances, and producing more transparent reports [16]. Strengthening bookkeeping skills is therefore essential to ensure the growth and sustainability of MSMEs.

Therefore, this community partnership program was specifically designed to respond to the technical, safety, and managerial challenges encountered by UD Tiga Putra as a local micro-enterprise engaged in Styrofoam waste processing. The first objective was to enhance production efficiency through the introduction of an appropriate-technology Styrofoam melting machine with a larger capacity of 300 kg/day, replacing the previous 150 kg/day unit that frequently experienced breakdowns and produced inconsistent results. The second objective focused on improving occupational health and safety (OHS) practices by providing structured training to employees, including hands-on demonstrations in the use of fire extinguishers (APAR), the application of personal protective equipment, and the development of a workplace safety culture to reduce fire hazards and accidents. The third objective aimed to strengthen the business management aspect by mentoring simple and systematic bookkeeping practices, encouraging the separation of personal and business finances, and improving financial

transparency to support long-term sustainability and potential access to external financing. These three interventions were expected not only to solve the pressing local problems faced by UD Tiga Putra but also to create measurable improvements, such as doubling production capacity, increasing OHS awareness, and enhancing the quality of financial documentation. Furthermore, the integration of technology, safety, and management components positioned the program as a replicable model that can be adopted by other micro- and small-scale enterprises. In this way, the initiative contributes to the implementation of circular economy principles, supports local economic resilience, and strengthens

community-based environmental preservation efforts, contributing both to economic development and environmental preservation.

**2. Community Service Methods**

Grounded in a community development approach, the methodological framework of this program comprised several stages, namely preliminary site surveys, community socialization, the formulation of work plans, systematic program implementation, and a comprehensive evaluation process, as illustrated in Table 1.

Table 1. Community Partnership Empowerment (PKM) Implementation Method

Activity	Problem Identified	Solution / Program	Method of Implementation	Indicator of Achievement
Production Aspect	The partner relied on a 150 kg/day Styrofoam melting machine that frequently broke down, had limited capacity, and produced low-quality products.	Designed and introduced an appropriate-technology Styrofoam melting machine with a 300 kg/day capacity.	Technical training and mentoring on machine operation, accompanied by demonstration and practice.	Production capacity doubled from 150 kg/day to 300 kg/day; improved product uniformity.
Occupational Health and Safety (OHS) Aspect	Lack of awareness and skills in OHS practices; employees had never received structured training in fire prevention and PPE use.	Conducted structured OHS training for 12 employees focusing on APAR use, PPE application, and safe work culture.	Lectures, discussions, and practical simulations (fire extinguisher drills, PPE use).	OHS awareness score increased by ±20%; employees demonstrated proper use of APAR and PPE during practice.
Management Aspect	Financial records were not systematic; business and personal finances were mixed; lack of transparent reporting.	Training and mentoring in simple bookkeeping, including transaction recording, cash flow, profit-loss reports, and separation of funds.	Combination of lectures, case studies, and hands-on practice in preparing financial records.	Daily transaction book established; transparent financial reports prepared; increased accuracy of documentation.
Evaluation	No systematic monitoring of improvements before.	Assessed effectiveness of the program through comparison before and after intervention.	Pre- and post-tests, direct observation, and interviews with the owner and employees.	Verified improvements in production capacity, OHS awareness, and financial documentation practices.

**3. Result And Discussion**

This section presents the results of the community service program, followed by a discussion of their implications in relation to the identified problems and targeted objectives.

**3.1 Site Survey Activities**

The site survey involved a direct visit to UD Tiga Putra, a styrofoam waste melting enterprise located in Beton Village, RT 11 RW 04, Menganti District, Gresik Regency. This stage was intended to provide a clearer understanding of the challenges experienced by UD Tiga Putra, which are further illustrated in Figure 1.



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

**3.2 Implementation of the Socialization Activity within the Community Partnership Empowerment Program.**

The socialization activity aimed to introduce the objectives of the Community Partnership Empowerment (PKM) program initiated by the Universitas Wijaya Putra (UWP) team to the partner. In this stage, the PKM UWP team received assistance from the owner of UD Tiga Putra, as illustrated in Figure 2.



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

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

After identifying the key challenges faced by the partner, the UWP PKM team proceeded with the formulation of a work plan. This process involved proposing solutions centered on strengthening production capacity and business management of styrofoam waste melting, aligned with the principles of a green economy. The preparation of the work plan was intended to assist the UWP PKM team and the partner in collaboratively setting a mutually agreed activity schedule

### 3.4 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 melting process depends on a 150 kg/day capacity machine that often malfunctions, fails to meet market demand, and produces brownish products as a result of uneven heat distribution. To overcome these shortcomings, a new Appropriate Technology Styrofoam Melting Machine with a higher capacity of 300 kg per day was developed, as further demonstrated in Figure 3. The styrofoam melting process is one of the methods for processing polystyrene-based plastic waste. In the initial stage, used styrofoam is collected, cleaned from impurities or non-plastic materials, and then fed into a melting machine. The machine applies heat to the styrofoam, causing its lightweight and porous structure to shrink significantly in volume. During heating, the low-density styrofoam melts and transforms into a denser form. Temperature control is essential, as uneven heat distribution may result in brownish products and reduce the quality of the recycled material. The melting process produces a viscous polystyrene liquid, which solidifies into dense lumps upon cooling. These products can be reused as raw materials in various industries, such as frame manufacturing, household plastic goods, or recycled construction materials. Thus, the styrofoam melting process not only serves to reduce the volume of non-biodegradable waste but also contributes to the reutilization of plastic waste in line with the principles of the green economy.



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 carried out as part of the community partnership empowerment program to improve employees' knowledge, skills, and awareness in maintaining a safe and healthy workplace. The training placed particular emphasis on the proper use of fire extinguishers (APAR), including demonstrations and hands-on practice on how to operate the equipment correctly, respond effectively in fire emergencies, and conduct routine inspections to ensure readiness. Furthermore, employees were introduced to the use of additional protective equipment such as gloves, masks, and safety shoes, which are critical in minimizing risks associated with the styrofoam melting process. This initiative not only enhanced the employees' technical competencies in occupational safety but also encouraged the development of a safety-oriented culture that supports sustainable business practices. The implementation of the training activities is illustrated in Figure 4.

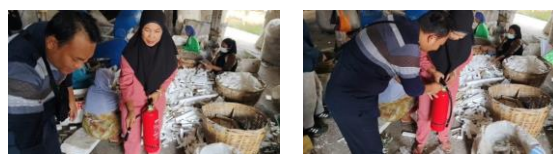


Figure 4. Capacity Building through Occupational Health and Safety (OHS) Training.

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

The training and mentoring activities on financial documentation practice for small enterprises involved employees of UD Tiga Putra as participants. The program emphasized the importance of systematic and organized financial administration to support business sustainability. The sessions addressed key topics, including the recording of daily transactions, the separation of business and personal finances, the preparation of simplified financial reports (cash flow statements, profit and loss accounts, and asset records), as well



as the proper documentation of transaction evidence. In addition to theoretical instruction, practical mentoring was conducted to guide UD Tiga Putra employees in developing daily cash books, maintaining routine records of income and expenses, and preparing simplified financial statements to strengthen decision-making processes. This initiative was designed not only to instill consistent financial documentation practices and enhance transparency, but also to improve the capacity of small enterprises to access future funding opportunities. The implementation of this training and mentoring activity 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 carried out through several key activities. Direct field observations were conducted to ensure that the implementation of the program aligned with the jointly agreed work plan. The PKM team also engaged in interviews and discussions with the owner and employees of UD Tiga Putra to gather feedback on the program’s benefits, challenges, and sustainability. Furthermore, the outcomes of training and mentoring activities were assessed, particularly regarding the employees’ ability to operate the appropriate technology melting machine, their awareness and practice of Occupational Health and Safety (OHS), and their consistency in maintaining financial records. Performance indicators were measured by comparing conditions before and after the program, such as the increase in production capacity from 150 kg/day to 300 kg/day, as illustrated in Figure 6, and the enhancement of employee understanding in both OHS practices and systematic financial documentation, as demonstrated in Figure 7. The findings from monitoring and evaluation were then compiled into a structured report, serving as a basis for future improvements and as an academic accountability measure

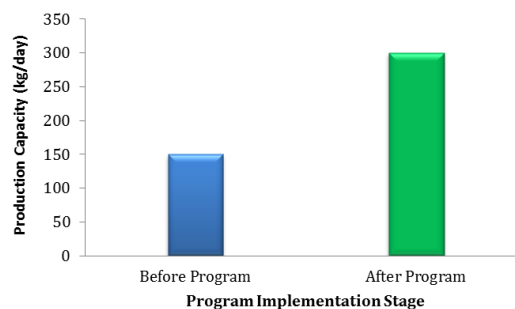


Figure 6. Improvement in the Production Capacity of UD Tiga Putra.

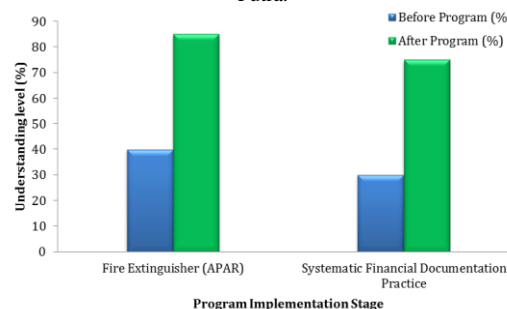


Figure 7. Employee Understanding Level at UD Tiga Putra.

The community service program at UD Tiga Putra demonstrated tangible improvements in production, safety, and management capacity. The introduction of an appropriate-technology Styrofoam melting machine with a capacity of 300 kg/day effectively doubled production output compared to the previous 150 kg/day unit. This increase not only improved efficiency but also produced more uniform recycled products, reducing the incidence of defects caused by uneven heating. In the area of occupational health and safety (OHS), training was delivered to 12 employees through a combination of lectures, discussions, and practical simulations. Pre- and post-test assessments showed a 20% increase in participants’ awareness and understanding of fire prevention, proper use of fire extinguishers (APAR), and consistent application of personal protective equipment. Observations confirmed that workers were able to demonstrate correct procedures during fire drills and displayed greater attentiveness to workplace hazards.

Financial management mentoring also resulted in measurable progress. Employees were guided to maintain daily transaction records, separate personal and business finances, and prepare simplified reports such as cash flow and profit–loss statements. As a result, UD Tiga Putra produced systematic and transparent financial documentation for the first time, which enhanced accountability and provided a stronger foundation for future access to external financing. Several factors contributed to the success of this program, including strong partner commitment, practical training methods, and the integration of technology with managerial support. Nevertheless, challenges remained in ensuring

consistent application of safety practices and in maintaining the newly introduced machine to avoid future breakdowns. For long-term sustainability, periodic refresher training in OHS and regular monitoring of financial records are recommended. Moreover, the experience gained from this partnership provides a replicable model for other micro-enterprises in the recycling sector, thereby amplifying the impact of circular economy practices at the community level.

#### 4. Conclusion

The community partnership program at UD Tiga Putra successfully strengthened the capacity of a small-scale Styrofoam recycling enterprise. The introduction of an appropriate-technology melting machine doubled production capacity from 150 kg/day to 300 kg/day and improved the quality of recycled products by reducing defects caused by uneven heating. Structured occupational health and safety (OHS) training, attended by 12 employees, increased awareness and preparedness by 20%, as confirmed through pre- and post-test evaluations and direct observations. Financial mentoring enabled the enterprise to establish systematic bookkeeping practices, separate personal and business finances, and prepare transparent reports, which enhanced accountability and provided a stronger basis for accessing external financing.

Several factors contributed to the success of the program, including strong commitment from the partner, the use of practical training methods, and the integration of technological, safety, and managerial improvements. However, challenges remained in ensuring the consistency of OHS practices and in maintaining the newly introduced machine to prevent future operational disruptions. For long-term sustainability, periodic refresher training and regular machine maintenance are recommended. This program not only addressed the pressing local problems of UD Tiga Putra but also offered a replicable model for other micro-and small-scale enterprises engaged in recycling activities. By integrating appropriate technology, occupational safety, and financial accountability, the program demonstrated how micro-enterprises can adopt circular economy principles to enhance local economic resilience while contributing to environmental preservation.

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