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Educational Program on Converting Plastic Waste into Alternative Fuel Using Pyrolysis and Triboelectric Nanogenerators (TENG) for Community Leaders in Kasomalang Kulon Tourism Village, Subang Regency

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Abstract: *This Community Service (CS) initiative was executed collaboratively by faculty members from five universities—Universitas Pamulang, Universitas Presiden, Universitas Trisakti, Universitas Pembangunan Jaya, and Universitas Borobudur—in Kasomalang Kulon Tourism Village, Subang Regency, West Java, on April 17, 2026. This initiative aimed to instruct village leaders, as prospective catalysts for change in waste management and renewable energy, on the technique for converting plastic trash into pyrolysis-derived alternative fuel and the Triboelectric Nanogenerator (TENG) energy harvesting technology. This activity addresses the critical issues of plastic waste pollution and the exhaustion of fossil fuel reserves. Annually, almost 8 million tonnes of plastic waste infiltrate the oceans, yet merely 9% of all plastic ever manufactured is effectively recycled. The collaborative effort encompassed Electrical Engineering, Computer Systems, Petroleum Engineering, Information Systems, Product Design, and Agrotechnology. The instructional techniques employed comprised lectures and conversations. The activity's results indicated that participants acquired a thorough comprehension of pyrolysis mechanisms, the principles of TENG energy conversion, and its possible applications at the village level. Despite the absence of direct implementation, the cadres shown significant motivation to facilitate technology adoption inside their communities. This PKM model demonstrates that interdisciplinary collaboration across universities is effective in providing innovative technological education to rural populations.*

1. INTRODUCTION

The rapid growth of modern civilization has brought serious impacts on global environmental conditions (Darwati Susilastuti et al., 2024; Dicky Adi Pratama et al., 2023; Meidya Buana et al., 2025; Satiawati et al., 2024). Since 1950, global plastic production has reached a total of 8.3 billion metric tonnes, with only 9% being effectively recycled, 12% incinerated, and 79% sent to landfill or released into the natural environment (Geyer et al., 2026). Plastic waste entering the ocean is estimated to reach 4.8 to 12.7 million tons per year, threatening marine ecosystems and the global food chain (Jambeck et al., 2015). Conversely, global solid waste generation is projected to rise from 2.3 billion tonnes in 2023 to 3.8 billion tonnes in 2050, with South Asia and East Asia being the main contributors.

The challenge of managing plastic waste in Indonesia is becoming increasingly acute due to a lack of waste treatment infrastructure (Lukman et al., n.d., 2025) in rural areas and the still low public understanding of sustainable processing technologies (Dhokhikah & Trihadiningrum, 2012). Law Number 18 of 2008 concerning Waste Management has mandated systematic waste reduction and handling, but its implementation at the village level still faces many challenges, especially in terms of human resource capacity and technology mastery.

Pyrolysis technology (Lukman Medriavin Silalahi et al., 2025; Safrizal et al., 2024) merupakan cara yang efektif untuk mengatasi masalah sampah plastik (Ranudinata et al., 2026; Uddin et al., 2023) while also producing alternative energy. Pyrolysis is a process involving the thermal degradation of plastic polymers at high temperatures (300–900°C) in an oxygen-free environment, yielding pyrolysis oil, gas and solid residue (char) as its main products (Anuar Sharuddin et al., 2016). This process has the advantage of being able to convert 70–80% of plastic waste into liquid oil with a high calorific value comparable to conventional diesel fuel (Miandad et al., 2016). In pyrolysis plants that use the principle of fractional distillation, plastic is heated in a reactor using methane gas as a heat source, producing polymer vapour which is then condensed into an alternative fuel(Panda et al., 2010).

In addition to pyrolysis, the Triboelectric Nanogenerator (TENG) serves as a complementary technology relevant to innovations in the use of renewable energy (Darudiato & Widjaja, 2022; Silalahi et al., 2024; Widjaja et al., 2025). TENG was first discovered by Fan, Tian, and Wang in 2012 based on the principles of the triboelectric effect and electrostatic induction, which allow the direct conversion of mechanical energy into electrical energy (Fan et al., 2012). Since its discovery, TENG technology (Asmaidin & Budy Santoso, 2026; Budy Santoso et al., 2025; Siregar et al., 2025) has experienced rapid development with various applications ranging from self-powered sensors, human motion energy harvesting, to wave energy generation (Wang, 2020; Wang et al., 2015). The capability of TENG (Budiyanto et al., 2024; Hayadi Hamuda et al., 2026; Simanjuntak, Haidi, et al., 2024; Simanjuntak, Heryanto, et al., 2024) to harvest low-frequency mechanical energy, including from human footsteps, makes it highly relevant for applications in tourist village environments (Niu et al., 2015).

Kasomalang Kulon Tourism Village, West Java, is an area with high potential for nature tourism, featuring the flagship destination Cimutan Water Tourism, but it still faces problems with unstructured plastic waste. The presence of village cadres who understand waste processing technology is a strategic key in encouraging changes in community behavior. On this basis, this CS is designed as a technology education activity for village cadres, carried out collaboratively by lecturers from five universities with multidisciplinary backgrounds.

The objectives of this PKM are:

a. To provide education to village cadres about pyrolysis technology for processing plastic waste into alternative fuels.
b. To introduce the working principles of TENG as renewable energy harvesting technology.
c. To build cross-disciplinary understanding about the potential and challenges of technology adoption at the village level.
d. To inspire cadres to become agents of change in waste management and renewable energy.

2. METHODS

Location and Time of Implementation

The PKM activities were carried out in Kasomalang Kulon Tourism Village, Kasomalang District, Subang Regency, West Java Province, on April 17, 2026. This location was chosen because it has significant natural tourism potential, especially the Cimutan Water Tourism area, but still faces issues with unstructured plastic waste management and lacks cadres with technological knowledge.

Activity Methods

The method is participatory education with technology demonstration approach. This approach allows participant not only to receive information passively but also to interact directly with the materials and technology prototypes being demonstrated. The activities are carried out in 4 stages:

Figure 1. Preparation stage.

Figure 2. Workshop activity poster.

a. Preparation Stage: Figure 1 shows the coordination between teams of lecturers from five universities, the preparation of a multidisciplinary education module, the preparation of a small-scale pyrolysis technology demonstration prototype, as well as an initial survey of waste management conditions at the location.

b. Initial Data Collection Stage: Identification of plastic waste management problems through field observations and brief interviews with village officials and local community leaders, as well as a literature review on pyrolysis technology and TENG as shown in Figure 2, which is the result of waste identification in the form of a poster.

Figure 3. Workshop activity.

Figure 4. Lecturers and Cadres of Kasomalang Kulon Tourism Village.

c. Education Implementation Stage: delivery of material by a multidisciplinary lecturer team covering the principles of pyrolysis, plastic processing machine design, TENG working principles, waste management information systems, recycled product design, and the agrotechnology impact of plastic waste management; followed by a prototype demonstration session and a Q&A discussion as shown in Figure 3.

d. Evaluation and Follow-Up Stage: reflective discussion with participants to identify the understanding achieved, measure technology adoption motivation, and plan follow-up steps that can be carried out independently by the cadres.

The participants of the activity are village cadres from the young generation of Kasomalang Kulon Tourism Village who were selected by the village officials. The success of the education is measured through interactive discussions and the participants' ability to explain back the technology concepts that have been delivered at the end of the session, as shown in figure 4.

3. RESULTS AND DISCUSSION

Profile of the Multidisciplinary Collaboration of the Service Team

The main advantage is represents cross-study program synergy. Hayadi Hamuda (Computer Systems Study Program, Universitas Pamulang) contributes to the control system and prototyping machine computation. Ir. Lukman Medriavin Silalahi (Electrical Engineering, Universitas Presiden) strengthens the material on energy conversion systems and principles of TENG. Dr., Ir. Listiana Satiawati (Petroleum Engineering, Universitas Trisakti) presents aspects of pyrolysis process engineering, the characteristics of the produced fuel fractions, and the quality standards of pyrolysis oil based on petroleum science. Dr. Yunus Widjaja (Information Systems, Universitas Pembangunan Jaya) provides a perspective on the digitization of waste data management. Teddy Mohamad Darajat (Product Design, Universitas

Pembangunan Jaya) contributes to design aspects of ergonomic machines and visual communication of educational materials. Ir. Sumihar M.L. Tobing and Ir. Aditiameri (Agrotechnology, Universitas Borobudur) present the impact of plastic waste management on agricultural soil conditions and agro-ecosystems in tourist village areas.

Educational Material: Principles and Mechanisms of Pyrolysis Technology

The main material presented is the technology of machines that process plastic waste into alternative fuels through the principles of pyrolysis and fractional distillation. Pyrolysis is a thermochemical process that breaks down the polymer chains of plastic at high temperatures in the absence of oxygen, producing products such as liquid oil, gas, and char (Anuar Sharuddin et al., 2016). Village cadres are educated on the working principle of the pyrolysis reactor, where plastic is heated using methane gas as a heat source until it surpasses the melting point of the plastic. The melted plastic then transforms into polymer vapor, which is channeled through a cooling pipe so that condensation occurs, producing alternative liquid fuel (Panda et al., 2010).

The addition of a sterilization process in the machine design aims to produce clearer fuel, while the addition of a condenser functions to accelerate the condensation of polymer vapor. Catalytic pyrolysis technology is even capable of converting 70–80% of plastic waste into high-quality liquid oil with a calorific value of 38–45.86 MJ/kg, characteristics comparable to conventional diesel fuel (Miandad et al., 2016). (Bridgwater, 2012) emphasises that optimising process parameters such as temperature, heating rate and residence time is crucial to ensuring the quality and yield of pyrolysis products.

Village cadres also received information that similar technology has been successfully piloted at the Banaran TPS with the guidance of the Conservation Development Agency of Universitas Negeri Semarang (UNNES) to manage plastic waste on campus. This concrete example strengthened the participants' belief that community-scale pyrolysis technology is feasible to be developed at the village level.

Educational Material: TENG Technology as an Alternative Energy Harvester

In addition to pyrolysis, village cadres received education regarding the Triboelectric Nanogenerator (TENG) as a complementary technology within the renewable energy ecosystem. TENG was first demonstrated by (Fan et al., 2012), which proved that contact between two different triboelectric materials produces surface electrical charges that can be harvested as electrical energy. The principle of operation combines the triboelectric effect and electrostatic induction: when two materials come into contact and then separate, a charge transfer occurs, which triggers an electron flow in the external circuit (Wang, 2013).

The development of TENG technology is progressing rapidly, characterised by four main operating modes: vertical contact-separation mode, lateral sliding mode, single-electrode mode, and self-contained triboelectric layer mode (Wang et al., 2015). (Niu et al., 2015) developed a comprehensive theoretical framework for TENG systems, proving that TENG energy conversion efficiency can reach more than 85% under optimal conditions. This also reviews various applications of TENG as self-powered sensors that do not require external batteries, highly relevant for environmental monitoring applications in tourist village areas.

In a demonstration presented to the cadres, three rectangular TENGs (3 cm × 8 cm) stacked were able to harvest energy from footsteps and generate enough power to light up 76 LED modules. The same TENGs can be integrated with an Arduino microcontroller as a distance and speed sensor, illustrating the potential of renewable energy-based IoT applications that do not require conventional batteries (Wang, 2020).

Response and Enthusiasm of Village Cadres

During the education session, the village cadres showed high enthusiasm and actively participated in the Q and A. The questions raised reflected a developing understanding, including the types of plastic most efficient for processing through pyrolysis, the estimated capacity and cost of building a village-scale machine, as well as the operational safety procedures of the pyrolysis reactor. Regarding TENG, participants inquired about the potential integration of TENG into the village tourism route for an energy-saving lighting system, which demonstrates the participants' ability to connect the educational material with the context of the village's real needs as shown in Figure 5.

The cadres also identified the potential sources of plastic raw materials available in the village, especially from packaging waste of agricultural products and tourist waste in the Cimutan Water Tourism area. The awareness of the value chain of waste processing into energy that is beginning to form in the minds of the participants is an indicator of the success of this education. Implicitly, this finding confirms the relevance of the issues raised by (Dhokhikah & Trihadiningrum, 2012) that waste management in Indonesian cities and villages still requires systematic educational and appropriate technology interventions.

This educational activity has not yet reached the stage of direct technology implementation in the village. However, the education stage is an important investment that cannot be skipped, considering that the adoption of technology in rural communities requires a process of thorough understanding internalization before implementation. The formation of cadres who understand technology is the main prerequisite for successful adoption in the field.

Figure 5. Response from village cadres.

Contribution of Cross-Departmental Synergy

The multidisciplinary collaboration model provides a richness of perspectives that cannot be offered by a single field of study alone. The Electrical Engineering perspective ensures the accuracy of explanations regarding energy conversion systems and TENG circuits. Petroleum Engineering provides a strong scientific foundation on the characteristics of pyrolysis oil fractions and their comparison with fossil fuels. Information Systems opens insights into data management digitization for waste that can be implemented in villages. Product Design helps participants visualize the tangible form of an ergonomic machine. Agrotechnology offers a perspective on the positive impact of proper plastic management on soil fertility, water source quality, and agricultural productivity around the tourist village area.

The effectiveness of this collaboration is in line with the spirit of the three pillars of higher education, as stipulated in Law No. 18 of 2008 on Waste Management, which encourages the active involvement of various stakeholders, including higher education institutions, in achieving holistic and sustainable waste management. This collaboration embodies the principles of SDG 7 (affordable and clean energy), SDG 12 (responsible consumption and production), and SDG 17 (partnerships for the goals).

4. CONCLUSION

The conclusion of this CS activity produced a collaborative CS activity on pyrolysis technology education and TENG for the cadres of Kasomalang Kulon Tourism Village, successfully held on April 17, 2026, by seven lecturers from five universities. The education presented covers the principles of pyrolysis processing of plastic into alternative fuel, the mechanism of TENG energy conversion, as well as the potential application of both technologies at the tourism village level. Furthermore, the multidisciplinary collaboration involving six fields of study Electrical Engineering, Computer Systems, Petroleum Engineering, Information Systems, Product Design, and Agrotechnology—proved effective in producing an educational approach that is comprehensive, layered, and easily understood by rural communities. Each field provides complementary perspectives. Although the activities have not yet reached the stage of direct technology implementation, the formation of cadres who understand pyrolysis technology and TENG is a strategic investment in building the readiness of village communities for technology adoption in the future. The cadres show high enthusiasm and motivation to become agents of change in waste management and renewable energy in their communities. Suggestions for development at this education stage need to be continued with an implementation assistance program, namely the construction of a village-scale pyrolysis machine prototype, operational trials, and evaluation of the quality of the fuel produced. Support from the local government of Subang Regency as well as the local Environmental Agency is highly needed to facilitate the licensing process and the procurement of equipment. Furthermore, the universities involved are advised to continue collaboration in the form of joint applied research, focusing on optimizing the design of small-scale pyrolysis machines suitable for the plastic waste capacity of tourist villages, as well as exploring the integration of TENG with energy-efficient tourist lighting systems. Finally, village cadres who have undergone education need to be facilitated with advanced training modules based on practice and access to networks of renewable energy technology managers, so that the knowledge acquired can develop and be applied concretely in the tourist village environment.

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