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Community Empowerment through Agricultural Waste-Based Bio-Briquette Production for Renewable Energy

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Abstract

This community service program aimed to empower residents of Attangsalo Village, Ma'rang Subdistrict, Pangkep Regency, to convert locally abundant rice husk and pomelo peel waste into bio-briquettes as an alternative renewable energy source. The program was implemented through four stages: preliminary field assessment, community education, hands-on training, and program evaluation. A distinctive feature of this initiative was the integration of two underutilized agricultural wastes into a community-based renewable energy solution, promoting both waste valorization and environmental sustainability. Program effectiveness was evaluated using pre-test and post-test questionnaires, direct observation, and participant interviews. The average knowledge score increased from 49% in the pre-test to 100% in the post-test, while more than 90% of participants successfully produced functional bio-briquettes independently following the training. Participants also demonstrated improved technical skills and expressed strong interest in adopting the technology for household use and small-scale enterprises. Overall, the program enhanced community capacity in agricultural waste management, promoted renewable energy awareness, and created opportunities for sustainable local economic development through bio-briquette production.

Introduction

Energy plays a vital role in supporting economic growth, household activities, and community welfare. However, the increasing demand for energy is accompanied by the continuous depletion of fossil fuel reserves and rising fuel prices, creating an urgent need for affordable, sustainable, and environmentally

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friendly alternative energy(Chusniyah et al., 2023; Nainggolan et al., 2023). Among the various renewable energy resources, biomass has attracted considerable attention because it is abundant, renewable, low in sulfur emissions, and capable of converting agricultural residues into valuable energy products while reducing environmental pollution (Ali et al., 2024; Nadiyya et al., 2022; Shahzad et al., 2024).

In addition to providing alternative energy, community-based biomass utilization contributes to broader sustainable development by supporting the principles of the circular economy, reducing environmental burdens associated with agricultural waste, and creating new livelihood opportunities for rural households. The conversion of agricultural residues into value-added bioenergy products not only minimizes waste disposal and open burning practices but also generates economic benefits through the production of marketable renewable energy products. Consequently, integrating agricultural waste management with community empowerment initiatives represents a practical pathway for improving environmental quality, strengthening local resilience, and fostering inclusive rural development aligned with global sustainability objectives (Khanna et al., 2024).

One promising approach to biomass utilization is the production of bio-briquettes from agricultural residues. Bio-briquettes are solid biofuels produced by compressing carbonized biomass with suitable binders, offering advantages such as high energy density, ease of transportation and storage, and relatively low emissions during combustion (Prasetyoko et al., 2020). The quality of bio-briquettes is influenced by several factors, including the characteristics of the raw materials, particle size, carbonization process, binder composition, and compression pressure (Amin et al., 2023; Asfar et al., 2022). Recent studies have further demonstrated that biomass briquettes contribute to renewable energy development while supporting sustainable agricultural waste management and circular economy initiatives (Ali et al., 2024; Rashif et al., 2025; Roman & Grzegorzewska, 2024).

Rice husk and pomelo peel represent two locally abundant agricultural residues with considerable potential as bio-briquette feedstocks because of their high lignocellulosic content, particularly cellulose, hemicellulose, and lignin, which are important components for producing durable and energy-efficient briquettes (Dahdah et al., 2020). Pangkep Regency is one of the largest agricultural production areas in South Sulawesi, generating substantial quantities of both rice husk and pomelo peel waste. In 2024, rice production reached approximately 111,980 tons of dry milled grain, resulting in a significant amount of rice husk

waste (BPS Pangkep, 2024). Likewise, Pangkep is the leading producer of pomelo in South Sulawesi, with annual production exceeding 27,500 tons) (Marhawati, 2019), while more than half of each fruit consists of peel that is generally discarded as waste. Improper disposal or open burning of these residues contributes to environmental pollution, unpleasant odors, and greenhouse gas emissions, while simultaneously wasting valuable biomass resources (Abdussamad et al., 2024; Widiya et al., 2024).

The successful adoption of renewable energy technologies in rural communities depends not only on the availability of suitable biomass resources but also on the active participation and capacity of local communities. Community empowerment approaches that integrate participatory education, practical training, and continuous mentoring have been widely recognized as effective strategies for enhancing technical knowledge, strengthening local ownership, and promoting the long-term sustainability of renewable energy initiatives. By involving community members throughout the planning, implementation, and evaluation processes, technology transfer becomes more relevant to local needs and increases the likelihood of continued adoption beyond the duration of the program. Moreover, collaborative learning encourages communities to identify locally available resources and develop context-specific solutions that simultaneously address environmental and socioeconomic challenges (Shi et al., 2024).

Despite the abundance of these agricultural residues, their utilization at the community level remains very limited. Existing waste management practices in Ma'rang Subdistrict primarily involve disposal or open burning, whereas community empowerment activities have generally focused on environmental awareness rather than providing practical skills for converting agricultural waste into value-added renewable energy products. Moreover, previous initiatives have rarely integrated rice husk and pomelo peel into a single community-based bio-briquette production system. Consequently, local communities have not fully benefited from the economic and environmental potential of these readily available biomass resources. This implementation gap highlights the need for participatory community empowerment programs that combine technology transfer, practical training, and agricultural waste utilization to support sustainable rural development.

The novelty of this community service program lies in integrating two locally abundant agricultural wastes—rice husk and pomelo peel—into a community-based renewable energy initiative through participatory education,

hands-on training, and continuous mentoring. Beyond introducing an environmentally friendly bio-briquette production technique, the program emphasizes community capacity building, promotes agricultural waste valorization, and encourages the development of small-scale renewable energy enterprises that support the principles of the circular economy.

Therefore, this community service program aimed to empower residents of Ma'rang Subdistrict, Pangkep Regency, through technology transfer and participatory training on the utilization of rice husk and pomelo peel waste for bio-briquette production. Specifically, the program sought to improve community knowledge and technical skills in agricultural waste management, promote renewable energy utilization, and encourage the development of community-based economic activities through sustainable bio-briquette production.

Methods

This community service program was conducted on 2 August 2025 at the Secretariat Hall of the Geographical Indication Protection Society (MPIG), Attangsalo Village, Ma'rang Subdistrict, Pangkep Regency, South Sulawesi, Indonesia. The study area was purposively selected because it is one of the major production centers for rice and pomelo, generating substantial quantities of rice husk and pomelo peel waste with considerable potential for conversion into bio-briquettes.

A total of 20 participants were purposively recruited, comprising members of the Pelita Desa Farmer Group, the Sipadecengie Farmer Group, and local community representatives. These participants were selected because they are directly involved in rice and pomelo production and therefore represent the primary beneficiaries of agricultural waste management and renewable energy development initiatives in the village. Their active participation was considered essential to ensure the applicability and sustainability of the community empowerment program. The community service program adopted a participatory community empowerment approach, emphasizing active involvement of local communities throughout the planning, implementation, and evaluation processes. This approach is widely recognized as an effective strategy for enhancing community capacity through collaborative learning and technology transfer.

Training activities were designed based on the principles of Experiential Learning Theory, which emphasizes that practical knowledge and technical skills are most effectively acquired through direct experience, reflection, and active participation (Kolb, 1984). Accordingly, participants were encouraged to learn

through demonstrations, guided practice, group discussions, and independent hands-on activities. This approach was expected to improve participants' understanding while strengthening their confidence in independently producing bio-briquettes after the program. The implementation consisted of four sequential stages: Preliminary monitoring and field observation; Community education and awareness; Hands-on bio-briquette production training; Program evaluation.

Preliminary monitoring and field observation

Preliminary monitoring was conducted approximately one month before program implementation to establish collaboration between the community service team, farmer groups, and local stakeholders. This stage included three main activities: (1) Field surveys to identify the availability of agricultural biomass resources and assess community needs; (2) Coordination meetings with farmer group leaders and the MPIG Secretariat regarding program implementation; (3) Identification and mapping of prospective participants representing the target community. The information collected during this stage was used to determine the training materials and implementation strategy according to local conditions.

Community education and Hands-on Training

The educational component aimed to improve community awareness regarding agricultural waste management and the potential utilization of rice husk and pomelo peel as renewable energy resources. Educational sessions were delivered through interactive lectures, discussions, visual presentations, and question-and-answer sessions.

Following the educational session, participants completed a pre-test questionnaire to assess their initial understanding of agricultural waste utilization and bio-briquette production. After completion of the educational activities and practical training, participants completed the same questionnaire as a post-test to evaluate knowledge improvement. The practical training focused on the production of simple bio-briquettes using rice husk and dried pomelo peel. Participants performed every production stage directly under the supervision of the service team, including: (1) drying raw materials; (2) carbonization; (3) grinding charcoal into powder; (4) mixing biomass with tapioca starch as a binder; (5) molding; (5) final drying.

The training employed learning-by-doing and demonstration methods to facilitate skill acquisition. Each participant received an illustrated practical guidebook containing detailed instructions for each production step, enabling

participants to independently reproduce the bio-briquette manufacturing process after the training.

Program evaluation

Program effectiveness was evaluated using a combination of pre-test and post-test questionnaires, direct observation, participant interviews, and evaluation forms. The questionnaire consisted of six indicators assessing participants' knowledge regarding: (1) agricultural waste management; (2) biomass energy; (3) bio-briquette production; (4) renewable energy utilization; (5) environmental benefits; (6) willingness to adopt bio-briquette technology.

Each correct response received a score of one point, while incorrect responses received zero points. Scores were subsequently converted into percentages to compare participants' knowledge before and after the intervention. At the end of the program, participants completed an evaluation form regarding the quality of the educational materials, guidebook, practical training, and overall implementation. Short interviews were also conducted to obtain qualitative feedback regarding participants' experiences, perceived benefits, and future intentions to utilize bio-briquette technology within their households and farmer groups.

Prior to participation, all respondents received an explanation regarding the objectives of the program and voluntarily agreed to participate in the questionnaires and interviews. All responses were treated confidentially and analyzed anonymously solely for educational evaluation and scientific publication purposes. The roadmap for community service activities is shown in Figure 1.

Figure 1. Flowchart illustrating the four stages of the community service program, including preliminary monitoring, community education, hands-on training, and program evaluation.

Results and Discussion

This community service activity focuses on utilizing rice husks and orange peels as raw materials for making bio-briquettes, with the aim of reducing the community's dependence on firewood and LPG. Based on initial observations, Ma'rang District has abundant potential for rice husk waste from rice milling activities, as well as pomelo peel waste from agricultural activities and household fruit processing industries. This potential has not been optimally utilized, and most of it is simply discarded or burned, causing environmental problems.

Initial monitoring and observation of the Ma'rang sub-district

Initial monitoring was conducted on 2 July 2025 in Attangsalo Village, Ma'rang Subdistrict, Pangkep Regency, through field observations, interviews with representatives of the Geographical Indication Protection Society (MPIG), and discussions with local farmer groups. This preliminary assessment identified two active farmer organizations—the Pelita Desa Farmer Group and the Sipadecengie Farmer Group—as the primary community partners because of their direct involvement in rice and pomelo cultivation. The monitoring also confirmed the abundant availability of rice husk generated from local rice milling activities and pomelo peel produced from household consumption and commercial orchards. Despite their considerable biomass potential, both agricultural residues were generally discarded or openly burned, resulting in environmental pollution while leaving their economic value largely untapped.

The initial assessment further revealed that community members had limited knowledge of converting agricultural residues into renewable energy products. Existing waste management practices primarily focused on disposal rather than value-added utilization, indicating a clear need for practical technology transfer and community-based capacity building. These findings support the implementation of bio-briquette production as an appropriate technology capable of addressing both agricultural waste management and rural energy challenges simultaneously.

Similar observations have been reported in previous community service programs, where abundant agricultural biomass remained underutilized because communities lacked technical knowledge and practical skills for processing biomass into renewable energy products. Community-based training combined with technology transfer has been shown to improve local participation, encourage the adoption of environmentally friendly technologies, and increase the

utilization of agricultural residues as alternative energy resources (Ali et al., 2024; Waziri et al., 2024). Therefore, the findings from the preliminary monitoring are consistent with previous studies demonstrating that community empowerment constitutes an essential prerequisite for successful biomass utilization.

The monitoring results also served as the basis for designing the educational materials, practical guidebook, and hands-on training activities implemented in this program. The guidebook was specifically developed to provide participants with clear, step-by-step instructions that could be easily followed during and after the training. According to Experiential Learning Theory (Kolb, 1984), practical experience combined with guided reflection facilitates deeper understanding and long-term skill retention. Consequently, integrating demonstrations, direct practice, and written instructional materials was expected to improve participants' confidence and competence in independently producing bio-briquettes.

From a sustainability perspective, the abundant availability of rice husk and pomelo peel in Ma'rang Subdistrict provides favorable conditions for the continued production of bio-briquettes beyond the duration of this community service program. The technology utilizes locally available raw materials, requires relatively simple equipment, and can potentially be adopted by farmer groups or household-scale enterprises. In addition to reducing agricultural waste accumulation and open burning practices, community-based bio-briquette production may contribute to renewable energy adoption while creating additional income-generating opportunities for rural communities. Nevertheless, several challenges remain, including maintaining consistent product quality, ensuring market acceptance, and providing continued technical assistance to support long-term commercialization and program sustainability.

Education and Socialization to the Community

The educational and awareness-raising activity was conducted on August 2, 2025, at 8:00 AM at the MPIG Secretariat Hall, Attangsalo Village, Ma'rang Sub-district, Pangkep Regency. The program was attended by 20 participants representing two local farmer groups, namely “Pelita Desa” and “Sipadecengie”, who were actively involved in agricultural production and generated rice husk and pomelo peel waste as part of their farming activities. The educational session was designed to increase participants' awareness of the environmental impacts associated with improper agricultural waste disposal while introducing the potential of converting locally available biomass into value-added bio-briquettes as an alternative renewable energy source.

Figure 2. Education and Socialization to the Community: (a) Presentation of material by the team leader; (b) Participants fill out pre-test and post-test questionnaires

As illustrated in Figure 2a, the educational session was delivered through an interactive presentation led by the community service team. The presentation introduced participants to the environmental problems associated with agricultural waste disposal, the characteristics of rice husk and pomelo peel as potential biomass resources, and the principles of bio-briquette production as an alternative renewable energy source. Participants were encouraged to actively engage in discussions by sharing their experiences with agricultural waste management and asking questions regarding the proposed technology. Subsequently, as shown in Figure 2b, participants completed pre-test and post-test questionnaires before and after the educational session. These questionnaires served as an evaluation tool to measure changes in participants' knowledge and awareness regarding agricultural waste utilization and bio-briquette production following the community education program.

The activity began with a pre-test, which revealed that only 49% of participants had adequate knowledge regarding the production process and potential benefits of bio-briquettes, indicating limited awareness of agricultural waste utilization as a renewable energy source. This finding reflects the common situation in many rural communities, where agricultural residues are frequently disposed of or openly burned because of limited access to appropriate technologies, technical information, and practical training opportunities. Following the educational session, which combined interactive presentations, discussions, and opportunities for participants to ask questions, the post-test

showed a substantial improvement, with the average score increasing from 49% to 100%. Furthermore, all participants (100%) expressed their willingness to learn and independently produce bio-briquettes. These findings indicate that the educational strategy effectively enhanced participants' understanding while simultaneously increasing their motivation to adopt environmentally friendly technologies. The considerable improvement in knowledge also demonstrates that participatory learning can serve as an effective mechanism for transferring appropriate technology, enabling rural communities to recognize both the environmental and economic value of agricultural waste and encouraging the adoption of renewable energy practices at the household level.

Table 1. Participants' pre-test and post-test responses regarding agricultural waste management and bio-briquette production (n = 20).

No	Indicators	% Farmer Responses			
		Pre-Test		Post-Test	
		Yes	No	Yes	No
1	Are you aware of the presence of rice husk waste in your neighborhood?	100	0	100	0
2	Are you aware that pomelo peels can be used as a biomass energy source?	10	90	100	0
3	Are you familiar with the concept of biobriquettes as an alternative fuel?	15	85	100	0
4	Do you agree that biobriquettes can help reduce dependence on firewood or LPG?	15	85	100	0
5	Are you interested in using biobriquettes made from rice husk and pomelo peel waste?	10	90	100	0
6	Do you agree that utilizing agricultural waste as biobriquettes can help reduce environmental pollution?	10	90	100	0
	Pre-Test Score	**49**			
	Post-Test Score	**100**			

Note: The overall pre-test and post-test scores represent the average percentage of positive ("Yes") responses across the six questionnaire indicators completed by all participants (n = 20). The overall score was calculated by averaging the percentage of affirmative responses for each indicator before and after the educational intervention.

As presented in Table 1, participants' knowledge of agricultural waste utilization and bio-briquette production improved substantially following the educational session. Before the intervention, the average affirmative response across the six indicators was only 49%, indicating limited awareness of the potential use of rice husk and pomelo peel as renewable energy resources. After the education and discussion sessions, affirmative responses increased to 100% for all indicators, demonstrating a marked improvement in participants' understanding. These findings indicate that the educational approach effectively enhanced participants' knowledge and readiness to adopt bio-briquette technology. Similar improvements in community knowledge have been reported in previous biomass-based community empowerment programs, where participatory education and practical demonstrations significantly increased technology adoption and environmental awareness (Frinaldi et al., 2025; Waziri et al., 2024).

The significant improvement in participants' knowledge demonstrates that participatory learning is an effective approach for facilitating technology adoption in community-based renewable energy programs. Unlike conventional extension activities that primarily rely on one-way information delivery, participatory education enables community members to actively engage in problem identification, practical demonstrations, and collaborative learning. This approach not only enhances participants' technical competence but also strengthens their confidence to independently apply and disseminate the acquired knowledge within their communities. The findings of this program are consistent with previous studies indicating that agricultural extension and participatory learning play an essential role in promoting sustainable innovation adoption and supporting community-based circular bioeconomy initiatives in rural areas (Yanfika et al., 2024).

Community Training and Technology Demonstration

The community training session introduced the bio-briquette production process through an instructional demonstration supported by visual presentations, finished bio-briquette samples, and raw materials, including rice husk and pomelo peel (Figure 3). Rather than conducting full-scale on-site

production, the team facilitator explained each stage of the manufacturing process in a step-by-step manner to ensure that participants clearly understood the complete production workflow before attempting independent production. This approach allowed participants to observe the characteristics of the raw materials, the intermediate products, and the final bio-briquettes while actively engaging in discussions and asking questions regarding the production procedure.

Figure 3. The instructional demonstration illustrating the sequential stages of bio-briquette production from rice husk and pomelo peel used during the technology demonstration session.

As illustrated in Figure 3, the instructional demonstration presented the complete workflow of bio-briquette production from rice husk and pomelo peel through seven sequential stages. These stages comprised: (1) drying the rice husk and pomelo peel to reduce their moisture content; (2) obtaining the properly dried raw materials, which were ready for further processing; (3) carbonization of the dried biomass using a controlled combustion process to produce charcoal; (4) obtaining the resulting charcoal after carbonization, followed by grinding it into a fine powder; (5) mixing the charcoal powder with tapioca starch and water to produce a homogeneous briquette mixture; (6) molding and compressing the mixture into briquette shapes using a briquette mold; and (7) drying the molded bio-briquettes under sunlight or at a low oven temperature until they reached sufficient hardness for storage and utilization. During the technology demonstration, each stage was explained in detail to familiarize participants with the required raw materials, equipment, and processing techniques, enabling them

to understand the complete production sequence before independently applying the technology in their respective communities.

To support independent learning after the community service program, participants were provided with an illustrated guidebook describing each production stage in detail. The guidebook served as a practical reference that participants could use when producing bio-briquettes independently at home. During the discussion session, participants expressed positive responses toward the instructional materials and indicated that the combination of visual demonstrations, finished product samples, and the guidebook made the production process easier to understand. This finding suggests that technology transfer through instructional media can effectively improve community readiness to adopt biomass-based renewable energy technologies, particularly in areas where direct practical training is constrained by time, facilities, or logistical considerations.

Beyond improving participants' technical skills, the utilization of rice husk and pomelo peel for bio-briquette production provides important environmental and economic benefits. Converting agricultural residues into renewable energy products reduces the volume of biomass waste that would otherwise be openly burned or discarded, thereby contributing to lower greenhouse gas emissions and improved environmental quality. Furthermore, biomass briquettes have the potential to generate additional household income through small-scale production while simultaneously reducing dependence on conventional fossil fuels. These findings reinforce the important role of agricultural waste valorization in promoting renewable energy development, resource efficiency, and circular economy practices within rural communities (Roman & Grzegorzewska, 2024).

Activity Evaluation

The training evaluation showed a significant improvement in participants' skills. As many as 90% were able to complete all stages of the training without significant errors, while 85% stated that they were confident in producing independently based on interviews and direct discussions. Feedback showed that the guidebook and live demonstrations were very helpful in the learning process. Participants also suggested further training related to packaging techniques and marketing strategies to make the products more marketable.

The long-term sustainability of community-based bio-briquette production depends on continued institutional support, regular technical mentoring, and collaboration among universities, local governments, and

community organizations. Establishing community production groups and facilitating market access for bio-briquette products may further strengthen the economic viability of this initiative while ensuring the continuity of renewable energy utilization at the household level. In addition, integrating community empowerment with biomass-based renewable energy development contributes to achieving broader sustainable development objectives by improving environmental stewardship, enhancing local resilience, and encouraging more efficient utilization of agricultural resources. These outcomes demonstrate that community service programs can serve as an effective bridge between scientific innovation and practical community development (Li et al., 2024).

Conclusion

This community service program successfully enhanced the knowledge and practical skills of community members in Attangsalo Village, Ma'rang Subdistrict, in utilizing rice husk and pomelo peel waste to produce bio-briquettes as an alternative renewable energy source. Beyond improving technical capacity, the program demonstrated that participatory training and technology transfer can effectively promote agricultural waste valorization, increase community awareness of renewable energy, and support sustainable rural development. The approach also provides a practical model that can be replicated in other agricultural communities with similar biomass resources. To ensure long-term sustainability, continued collaboration among local governments, community organizations, agricultural extension services, and farmer groups is recommended, particularly in supporting product quality improvement, business development, and wider adoption of bio-briquette technology.

Building upon these findings, future research should focus on optimizing the physical and chemical properties of the bio-briquettes. Specifically, experimental studies are needed to evaluate the effects of varying mixing ratios (rice husk to pomelo peel) and different binder types on calorific value, combustion efficiency, compressive strength, and emissions profiles (e.g., proximate and ultimate analysis). Additionally, further studies should conduct a comprehensive techno-economic assessment and life cycle assessment (LCA) to determine the commercial viability, environmental footprint, and market scalability of small-scale community-based bio-briquette production. Finally, investigating socio-economic factors influencing long-term local adoption and formal supply chain integration will provide valuable insights for scaling up this technology in broader rural contexts.

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