

Transformation of Agricultural Waste into Biomass Briquettes as a Renewable Energy Source for Community Empowerment in Alue Krueng Village: Realizing a Circular Economy and Energy Self-Sufficiency.

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Abstract

This study aims to evaluate the effectiveness of a community empowerment program in Alue Krueng Village, West Aceh Regency, focused on converting agricultural waste into biomass briquettes as an alternative household energy source. The program was motivated by the underutilization of organic residues such as rice husks, coconut shells, and sawdust, which are commonly disposed of through open burning, contributing to environmental pollution. Employing a participatory approach based on Participatory Rural Appraisal (PRA), the program was implemented over four months (September–December 2025) and involved 20 members of a farmer group who established a briquette-based microenterprise. Data were collected through participatory observation, household surveys, and technical performance tests, and analyzed using descriptive and evaluative methods. The results indicate that the produced biomass briquettes demonstrated longer burning duration than conventional firewood and reduced household firewood consumption by up to 40%. In addition, the activity generated a new source of supplementary income for participating households and strengthened institutional capacity within the farmer group. This initiative contributes to local energy self-sufficiency while promoting sustainable waste management and circular economy practices. The findings highlight the potential of community-based biomass briquette production as a scalable model for rural energy transition and livelihood improvement, supporting the achievement of Sustainable Development Goals, particularly SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Keywords: *Biomass briquettes, Circular economy, Community empowerment, Renewable energy, SDGs.*

INTRODUCTION

Alue Krueng Village is one of the rural areas in West Aceh Regency with the typical condition of agricultural land and settlements on riverbanks and flat plains. These physical features give the land surrounding Fang relatively robust soil, conducive to sustainable agrarian activity (Aulia et al., 2024). A stable climate and abundant rainfall also allow them to produce a

variety of commodities all year round, including rice, coconuts and crops grown after main harvest. Accessibility of the village to the sub-district centre is relatively good, however no substantial transportation or distribution facilities exist, and remain as barriers for these local harvest mobilizations and marketing of agricultural products. Information from the West Aceh Statistics Agency (Badan Pusat Statistik Kabupaten Aceh Barat, 2023) showed that at least 72% of rural population in productive age still work as tenant farmers and laborers). The village's accessibility from the sub-district center is fairly good, but constrained transportation and marketing facilities hinder the mobilization of harvests and trade on agricultural produces.

As an agrarian derived village, most of the inhabitants of Alue Krueng rely on smallholder farming as their primary source of income. This economic model is accomplished not just in the formation of household income, but also having an impact on forms of social and cultural interactions in the community. Farming, farm produce processing and household land management have also become customary traditions (Aulia et al., 2025). Indigenous knowledge, such as gotong royong (working together), in plowing rice fields, sharing seeds and helping each other in the harvest season is still practiced by villagers. Those values reinforce the social cohesion and being as one of form of social capital in the realization empowering community programs. Recent studies have stated that rural social capital is a key factor in the success of community economic innovation (Hasanah & Fajri, 2024)

Natural resources available in the village like fertile farmland, and fast growing coconuts trees are good opportunities to add value to local product of raw material. However, this opportunity has been underutilized, especially in agricultural waste treatment. There are so many types of organic residues from the daily farming operation every year such as rice husks after milling, sawdust after carpentry and coconut shells after the processing of nuts. Most of these wastes have been disposed or openly burned, leading to environmental pollution as well as carbon emissions into the air. This indicates that the utilization of agricultural waste carries strong ecological urgency, particularly amid the growing global concern over carbon emissions (Agency, 2023).

Organic waste material, including rice husk, sawdust and coconut shell are abundantly available annually due to extensive agricultural activities. However, these measures of the materials have not been fully exploited. They are generally thrown away or burned in the open environment, leading to environmental pollution and highlighting a wasted opportunity to increase the community's economic well-being. This gap is indicative of a disparity between the availability of local resources and the capacity within communities to convert those resources into products that are of economic value, as well as environmentally friendly. It is equally suggestive of the fact that people, who are in any event still bereft of technical know-how, mentorship and exposure to best practices through which they could make good use of waste.

Over the past few years, production of biomass briquettes has been on the ascendency as a twofold solution to purporting both waste management and energy provision. Biomass briquettes are a type of solid fuel, prepared by compacting pulverized organic matter. Previous examples of community service projects made it clear that usage of rice husk for briquettes can replace the role of kerosene and LPG by creating wealth when it is managed through local enterprise schemes (Sukaria et al., 2024). Results reveal that agricultural waste use is not only beneficial to the environment, but also helps in increasing household income supported by locally-based empowerment strategies. Moreover, recent research has found that coconut shells possess high calorific value and strong potential as briquette materials to support household-based MSMEs (A. Putri et al., 2025). This finding indicates that the utilization of

agricultural waste not only provides environmental benefits but also serves as an opportunity to increase household income through community-based empowerment mechanisms.

Education and workshops to the community were also found to be effective tools in raising public acceptance of renewable energy. In some situations, training on rice husk briquette had made communities to perceive organic wastes as resource that can be renewed over and over (Wilda, 2024). Therefore, community empowerment in this context is not mere technical production but reshaping local resources governance and collective consciousness. This change in attitude is essential if village self-reliance, or any degree of it can be achieved for as they become less dependent on external players, and more able to access their environmental potential. This concept aligns with global policy frameworks on bio-circular economy approaches in rural development (Food and Agriculture Organization of the United Nations, 2023)

It conforms with the circular economy philosophy, a production and consumption model which prioritises recycling products over creating new ones and relegating waste to the landfill. For instance, the corn-cob briquette processing initiative in Kuaklalo Village established successful farmer group-based enterprises which promoted not only economic autonomy but also local energy security (Muga et al., 2025). This indicates that the transformation of agricultural wastes into sources of renewable energy is very much dependent on continued mentorship and community organizing.

Furthermore, the production of biomass briquettes is closely connected to a number of Sustainable Development Goals (SDGs), among others:

1. SDG 7 – Affordable and Clean Energy, by supplying locally produced renewable energy
2. SDG 12 – Ensure sustainable consumption and production patterns; by eliminating waste and promoting sustainable use of resources.
3. SDG 13 – Climate Action, by reducing emissions from the practice of open-field burning of agricultural residues.
4. SDG 8 – Good Jobs and Economic Growth by establishing new community-based businesses.

In addition, the right technology like making of briquettes and other measures of community accessibility to clean energy is suitable intervention strategy at least in villages where the power infrastructure is not reliable. The deployment of biomass technology spells local in terms of energy resilience, in the sense that it minimizes reliance on fossil fuels (that are costlier and environmentally destructive) (Faizah et al., 2022). This venture is aligned with the country's energy policy in which diversification of sustainable sources of energy development and utilisation are underscored under locally generated resources (Wau, 2024).

In this regard, the empowerment of the Alue Krueng community via conversion of agricultural waste to biomass briquettes is an important and appropriate step towards marshalling multidimensional challenges pertaining in rural development. The initiative provides environmental management and renewable energy, but also adaptive responses to climate change and decreased dependence by households on fossil-based household energy which have long crippled the local economy.

More than merely a technical solution, the project effectively combines the concepts of circular economy and Sustainable Development Goals (SDGs) occurring in the village context and can thus generate synergy between ecological, economic and social aspects. Under the approach on which my organisation works, households are encouraged to develop their ability to make trash into value-added products, increase technical skill and knowledge, and raise collective awareness of energy issues as well as economic self-sufficiency at both household and community levels.

Cross-sector collaboration between communities, academia, village governments and development partners will contribute to establishing a rural innovation ecosystem focused on empowerment, lifelong learning, and replication of best practices. As a result, we see this endeavor not as a one-off project but rather an exemplary model of regenerative development rooted in the experience that self-reliance and sustainability evolve from local strengths. The achievement of Alue Krueng village is hoped to be a model for other rural areas in implementing green rural transformation towards the economy that is more resilient, inclusive and environmentally friendly.

METHOD

The implementation of the community empowerment program for utilizing agricultural waste into biomass briquette production in Alue Krueng Village was carried out using a community participatory approach, in which local community members acted as the main executors of the program. This approach was adopted based on the understanding that the effectiveness of empowerment initiatives is highly dependent on the active participation of all stakeholders throughout all stages of the program, following a continuous and iterative process from planning to implementation, monitoring, and evaluation. In this context, the community was positioned not merely as program beneficiaries but as the primary knowledge holders who collectively agreed upon and applied appropriate technologies and technical skills for transforming agricultural waste into fuel briquettes. The program involved 20 members of a farmer group who jointly established a briquette-based community enterprise and was implemented over a four-month period, from September to December 2025. The knowledge and technology transfer process was conducted in a gradual and systematic manner to ensure effective learning-by-doing, allowing technical competencies, production skills, and social and institutional capacities to develop incrementally over time. Program outcomes were assessed using a combination of participatory observation, household surveys, and technical performance tests, with the results analyzed through descriptive and evaluative approaches to capture both technical effectiveness and social impacts of the empowerment process. The aim of this process is that by the end community groups will have achieved an entrepreneurial independence rather than just a production capability. The phases of implementation of the program were as follows:

- a. Pre-Preparation and Socialization
- b. Technical Assistance and Capacity Building
- c. Dissemination of Biomass Briquette Manufacture
- d. Ongoing Support, Oversight and Assessment.

The pre-preparation stage and socialization were done as a step for the establishment of shared objectives and benefits from the program, mapping local potential resources that are existed. The technical training phase sought to provide the people with simple and effective waste treatment skills. In the implementation, community members are trained on direct manufacture of the product so as to make them skills become practical. The mentoring and

monitoring phase, meanwhile, was designed to keep product quality consistent and guarantee that the group could operate the enterprise on their own.

All intervention designs were based on concepts of mutual cooperation (gotong royong), active participation of all group members, simple technology to be suitable for every key site in the local area, and community institution capacity building which represented the program's sustainability. Under this process of empowerment, not only briquettes as renewable energy products were produced but also the social, economic and collective independence of citizens in Alue Krueng Village was built.

1. Pre-Preparation and Socialization

This phase started from the social and economic conditions as well as the opportunity for agricultural waste that was available at Alue Krueng Village. The assessment was done by direct field visit, questionnaire survey with the farmers and documentation of sources of wastes such as rice husk, coconut shells and sawdust that is produced in their agricultural and community-based raw-material processing activities. This exercise was meant to have an overall assessment of the availability of raw materials and community readiness for implementing intervention.

This was followed by coordination with village headmen, farmers' group leaders, community leaders, and key people or opinion leaders who have informal decision-making power in the community. Such coordination was critical in defining who does what and gives to what extent of time during implementation of the program so as there was no role redundancy nor too much reliance on outside parties.

Socialisation was done through regular community meetings, generally held at the meunasah or village hall, which are public sphere in the village. Through these meetings, the community was acquainted with the idea that agricultural waste can be turned into biomass briquettes and were explained the potential benefits in terms of environment (decreasing open burning and carbon emission), economy (improving household income) and energy (availability of cheap local fuel options). Content was disseminated through dialogue, so that the community could ask questions, talk about and express opinions concerning how to apply the programme in households or as part of a group.

2. Technical Training and Capacity Strengthening

This expression of interest was formulated to train the group members with hands-on skills and technical knowhow on biomass briquette production. Training was given in demonstration method (learning by doing) where all the participants had an opportunity to observe, practice and repeat the procedure themselves.

The training materials started with methods for gathering agricultural waste in the village, rice husks, coconut shells and sawdust were plentiful. The participants were encouraged to dry the raw materials in order to decrease moisture content, under the reasoning that a higher water content would lower charcoal quality and briquette combustion efficiency.

The second step, carbonization in a simple pyrolysis drum, consisted of reducing the oxygen available to avoid charring the organic waste and producing charcoal instead. After carbonization, the charcoal was crashed into powder and passed through different grades, to get uniform particle size resulting in denser burnable compacted briquette with a stable combustion characteristics.

They were also taught to prepare natural binders (starch or tapioca flour mixed with water in particular proportions) instead of using chemical adhesives so that the product remains eco-friendly and can be sourced locally.

The second step was briquette molding, and was carried out in manual molds or by hand pressing tools. In addition to consistent shape, this molding quality focused on compression density as well, providing briquettes that were strong and not easily crumbled. Following pressing, the briquettes were sun dried or naturally dried to desirable moisture levels for good burning.

In addition to technical training, the intervention also had non-technical capacity-building inputs that included simple record keeping, calculating cost of production based on material and labor cost, quality assurance measures and marketing through local social networks like farmer groups, village market user groups as well as direct sales at household level. Add to this the low skilled training the groups were given so that they could run their businesses sustainably and gain a genuine income.

3. Implementation of Biomass Briquette Production

The output phase of briquette making was done after the group members had enough technical knowledge from training. At this point, the group entered mass production with facilitator oversight at each step to make certain they were following proper procedures.

Everything we did was on a rotational basis because the girls got bored quite quickly “ Rotating work was used across all processes and one task would be completed before moving to the next. This was a way of ensuring that capabilities were spread evenly across the members so that timely functioning could be maintained without being affected by some absentees.

State Implementation Step Detail The following details some of the main steps used in implementing the intervention.

- a. Gathers organic waste (rice husks, construction woods and coconut shells) from residents’ farms and nearby carpentry workshops to ensure a sustainable supply of raw materials.
- b. Producing the briquettes by using typical manufacturing processes as carbonization, grinding and mixing with binding agents, molding (pressing) and drying.
- c. Testing of the quality of the briquette, based on burning time, density level and emission of smoke to ensure that it underwent optimal combustion and was useable as fuel.
- d. Packaging and storing of briquettes in a dry and moisture-free environment which ensures that the product will retain its quality up to the point of transport into the market.

Following the first production, household in-village evaluations for combustion efficiency and user comfort were conducted with generated briquettes. This testing phase was crucial in getting feedback, so the team could iterate and improve the product before they began pitching it to a broader audience.

4. Continuous Assistance and Monitoring–Evaluation

The stage of mentoring was conducted regularly to maintain the steady production process according to the predetermined standards. Mentoring took place on a regular basis by visiting the production device, discussion rounds as well as bi-weekly review meetings.

Direct observation and technical feedback based on findings of inefficiencies was delivered

from the facilitation team on each visit. Furthermore, all implementation process was documented by the team to be considered as evaluation data for evaluating skills mastery and production progress. It was evaluated through several perspectives:

- a. Quality and consistency of the treated-working-ready briquettes, such as density, post-drying moisture percent content, burning time and stability.
- b. Group production capacity per week, measurements of the group's capacity to satisfy demand and keep creating progress.
- c. Percentage of households which utilizes briquettes as a proxy for community acceptance of the product.
- d. Efficiency of layout of work, making sure that organization of (work) is fair, honest and economic.

The findings of these assessments were used to enhance and hone the process in areas as diverse as mixing and moulding methods, production planning, work-system management, marketing approach. Therefore, it was not just mentoring for product quality but to improve the groups' ability to run and sustain enterprise independently.

5. Timeline and Schedule of Community Service Implementation

This community empowerment program was implemented over a **two-month period (1 October–30 November 2025)**. The program was organized in a sequential manner to ensure that the **transfer of skills** proceeded effectively and sustainably.

Program Phase	Timeframe	Implementation Location	Responsible Parties
Pre-Preparation and Socialization	1–10 October 2025	Village Hall / <i>Meunasah</i>	Community Service Team and Alue Krueng Farmer Group
Technical and Strengthening Training and Capacity	11–25 October 2025	Alue Krueng Farmer Group Workshop	Training Instructors and Farmer Group
Biomass Briquette Production Implementation	26 October – 20 November 2025	Village Briquette Production House	Alue Krueng Farmer Group
Mentoring and Monitoring Evaluation	21–30 November 2025	Field / User Households	Community Service Team and Village Officials

Through this approach, the community empowerment program in Alue Krueng Village successfully integrates participatory methods, technical innovation, and social learning processes. It not only enhances local capacity in renewable-energy production but also strengthens collective entrepreneurship, environmental responsibility, and sustainable rural development. The model demonstrates that community-based initiatives, when supported by systematic mentoring and inclusive participation, can create tangible progress toward energy self-sufficiency and circular-economy transformation in rural Indonesia.

6. Flowchart of the Implementation Method



7. Standard Operating Procedure for Biomass Briquette Production.

- a. Raw Material Collection
Gather rice husks, dried coconut shells and sawdust in the local area. All the materials should be non-metal or include no impurities.
- b. Drying of Materials
Dry the samples under the sun for 1–2 days, until moisture content is low and uniformly dried.
- c. Carbonization
Install these thermopol with the pyrolysis drum. Slowly burn with a restricted air supply until the contents become charcoal.
- d. Grinding
Grind the charcoal to powder in a pulverize or grinder.
- e. Mixing
Combine charcoal powder and a natural binding agent (starch) in a large bucket.
- f. Molding
Form the molds using human or simple moulds in whatever form you desire.
- g. Final Drying
Dry the shaped briquettes in sun for 1–2 days until hard and dry .
- h. Packaging
Pack your briquettes in clear plastic, or a cardboard box and offer them for sale as a village product.

RESULTS AND DISCUSSION

The implementation of the community empowerment program in Alue Krueng Village provides a concrete illustration of how participatory approaches and appropriate technology can contribute to achieving energy self-sufficiency based on local potential. This initiative not only focused on transforming agricultural waste into biomass briquettes but also emphasized the importance of collaboration among communities, academics and village governments in building

a sustainable renewable energy system. The empowerment process was carried out in stages, directly involving residents from the planning phase through to production, so that the outcomes reflected the active participation of the community as key actors in managing local resources.

This section on results and discussion elaborates on the program's achievements from multiple dimensions technical, social, economic and institutional. The analysis uses a descriptive approach, highlighting practical learning outcomes and comparisons with previous studies on biomass energy and community empowerment. This is crucial because the success of community empowerment is determined not only by technical skill improvement but also by changes in behavior, mindset, and social governance that underpin program sustainability (Arifianto et al., 2024).

The empowerment activities in Alue Krueng Village demonstrate that the success of transforming agricultural waste into biomass briquettes depends heavily on local social and institutional support. A strong social structure and a deeply rooted culture of mutual cooperation (*gotong royong*) serve as the main social capital in maintaining production consistency and community participation. This condition aligns with the findings of (Yusri et al., 2025), who stated that the success of community energy projects is largely determined by the degree of social cohesion and role clarity within groups. Furthermore, strengthening community organizational capacity such as that of the Village Energy Joint Business Group (Kelompok Tani Desa Alue Krueng) is a key factor in ensuring the program's sustainability, as emphasized by (Mahardika & Putra, 2024) in their study on biomass energy enterprise management in rural Central Java.

From a technical perspective the agricultural waste processing activities in the village proved to be efficient and adaptive to local conditions. The carbonization process using simple pyrolysis drums produced high-quality charcoal with stable carbon levels and low ash content. Simple innovations such as using natural sunlight-based drying racks helped reduce energy costs and improve product quality. The use of such appropriate technology is consistent with the findings of Rahman et al. (2023), who highlighted that adaptation of low-cost, locally appropriate technologies plays a strategic role in supporting renewable energy success in remote areas.

Beyond the technical aspects, the social impact of the initiative is also significant. The comprehensive involvement of the community created intensive social interaction among residents, village officials, and academic facilitators. This collaboration strengthened mutual trust among group members and increased collective motivation to achieve shared goals. These results are in line with the findings of (Hidayati & Subandi, 2023), who explained that community empowerment based on green technology enhances social bonds and raises ecological awareness among residents. Therefore, this program not only produced an alternative energy product but also reinforced social structures and communal values at the local level.

From an economic standpoint briquette production generated additional household income while reducing domestic energy expenses. The conversion of local waste into marketable products demonstrates how the principles of a circular economy can be concretely applied in rural areas. These outcomes align with the findings of (Widodo et al., 2025), who showed that community scale biomass processing can enhance village economic resilience through income diversification and local value creation.

Moreover the success of this program underscores the importance of institutional support and continuous mentoring. Without strong organizational structures and effective coordination mechanisms, empowerment initiatives risk stagnating after the training phase. Therefore, integrating this program into the Village Government Work Plan (RKPDDes) represents a strategic step toward ensuring long-term sustainability. A similar approach was recommended by

(Simbolon et al., 2024), who emphasized the need for synergy between communities and village governments in renewable energy initiatives to foster stronger social and economic sustainability.

The briquette program in Alue Krueng Village also contributes directly to the achievement of the Sustainable Development Goals (SDGs), particularly Goal 7 (Affordable and Clean Energy) and Goal 12 (Responsible Consumption and Production). By utilizing local resources and reducing open burning practices, the program contributes to lowering household-level carbon emissions. Field data show that the use of biomass briquettes reduced household firewood consumption by up to 40 percent. This achievement aligns with the (United Nations Development Programme, 2024) report, which highlighted that community-based energy projects in Southeast Asia have significant potential to accelerate the clean energy transition while strengthening local economic resilience.

Taken together, these results and discussions aim not only to describe the success of the initiative but also to affirm that social innovation and appropriate technology can serve as effective tools for building rural energy independence. As noted by (Nasution et al., 2025), empowerment programs rooted in local resource utilization and traditional knowledge are more easily accepted by communities because they align with their cultural values and social contexts. Therefore this initiative not only resulted in an alternative energy product but also emerged as a model of community capacity development for achieving a sustainable green economy.

1. Community Socialization and Empowerment Activities in Alue Krueng Village

The community empowerment socialization program held in Alue Krueng Village, as documented in Figures 1–3, illustrates a high level of enthusiasm among both the local residents and the accompanying student facilitators. This socialization phase served as a crucial starting point in building a shared understanding of the objectives and benefits of utilizing agricultural waste for biomass briquette production. The activity took place at the village hall, involving village officials, farmer groups, MSME actors, and students from the Student Executive Board (BEM) of Universitas Teuku Umar, who served as the facilitation team. This approach affirmed that



socialization was not merely about disseminating information, but rather a two-way

communication process that fostered a sense of ownership toward the program.

Figure 1. Presentation of socialization materials by student facilitators at the Alue Krueng Village Hall.

The first photo captures a presentation and discussion session in which participants actively asked questions about the benefits of agricultural waste as an alternative fuel source. This activity exemplified a participatory learning method, where the community was not just a passive audience but directly engaged in critical thinking about local potentials. The socialization process also served as a social consolidation platform among students, community members, and the village government, strengthening social networks and accelerating the community's adaptation to the appropriate technology being introduced.



Figure 2. Group photo of participants and facilitators after the socialization session. This socialization activity not only provided technical insights on biomass briquette production but also transformed the community's mindset regarding the economic value of agricultural waste. The open discussions encouraged residents to become more aware of sustainable economic opportunities and local energy independence.

Overall the socialization activities in Alue Krueng Village serve as concrete evidence that community empowerment through participatory communication and collaborative approaches can enhance environmental awareness, strengthen social capacity, and encourage the formation of a sustainable culture of economic self-reliance at the village level.

The empowerment program in Alue Krueng Village displayed strong enthusiasm among participants, comprising farmer groups, village officials, and student facilitators. Based on the activity documentation (Figures 1–2), the socialization and training sessions were conducted interactively and participatively. Participants not only listened to the presentations but also actively asked questions, shared field experiences, and offered input regarding the program's sustainability plans. This demonstrates that knowledge transfer occurred collaboratively, rather than in a one-directional manner consistent with the participatory rural appraisal (PRA) model

recommended By (Kurniasih et al., 2024) .

The atmosphere that emerged during the sessions reflected a synergy between students and the community. Students acted as facilitators, while villagers served as the main subjects, exploring their own local potential for development. This approach aligns with the perspective of who emphasize that communities must play an active role in empowerment processes to build a sense of ownership and shared responsibility for the outcomes. In this context, the training activities not only enhanced technical skills but also strengthened social bonds between academia and local communities.

The activity also served as a cross-generational learning platform. Elderly residents participated alongside younger generations, particularly university students, in discussions and simulations of biomass briquette production. This intergenerational collaboration enriched the learning process through the exchange of local knowledge and scientific insights. As noted by (Suryana & Oktaviani, 2025), intergenerational engagement in community empowerment strengthens the adaptive capacity of rural communities and extends the sustainability of local social initiatives.

Based on field observations, the socialization activities conducted at the village hall also demonstrated a significant increase in community awareness regarding the economic value of agricultural waste. Villagers began to recognize that rice husks, coconut shells, and sawdust were no longer worthless residues but valuable raw materials for alternative energy that could reduce household expenses. This finding aligns with (Hartono et al., 2024), who found that training based on simple technology can shift community perceptions of local resources and stimulate microeconomic innovation in rural areas.

From a methodological standpoint, the training adopted a learning-by-doing approach, in which participants directly practiced each stage of briquette production from material drying and carbonization using a pyrolysis drum, to natural adhesive mixing and molding. This hands-on method proved effective in improving participant skills and self-confidence (R. Putri et al., 2025). Participants also engaged in packaging simulations and simple marketing strategies to ensure that the resulting products could be commercialized sustainably.

Documentation from the sessions also revealed that all participants were actively involved in collective reflection sessions following the training. During these discussions, participants addressed technical challenges such as material drying times and natural adhesive availability while jointly formulating collective solutions. Such open dialogue provided a vital space for organizational strengthening, as suggested by (Rachman et al., 2023), who noted that the success of empowerment programs increases when groups possess internal mechanisms for evaluation and shared learning.

Beyond technical achievements, the activity also had significant social impacts. The group photo of participants taken at the end of the event symbolizes a shared sense of pride and accomplishment. This collective identity represents the emergence of new social solidarity at the community level. According to (Alamsyah & Dewi, 2024), the creation of collective symbols in empowerment activities helps strengthen motivation and community consistency in maintaining program sustainability.

The activities led by students from the Student Executive Board (BEM) of Universitas Teuku Umar further demonstrate how higher education institutions play a strategic role in expanding the impact of the Tri Dharma of Higher Education, particularly in the area of community service. The role of students as change agents became evident, as they not only delivered technical

knowledge but also facilitated cross-group communication and connected the rural community with academic resources (Firdaus et al., 2023). Thus, this initiative stands as an effective campus community partnership model at the local level.

Furthermore, the empowerment activities in Alue Krueng Village demonstrate alignment with national policies on clean energy transition and green economic development. The implementation of waste-based briquette production supports the principle of energy justice, emphasizing village self-reliance in providing renewable energy (Ministry of Energy and Mineral Resources, 2024). Consequently, this activity holds not only academic value but also makes a direct contribution to achieving Sustainable Development Goals (SDG 7, 12 and 13).

Overall, the documentation of these empowerment activities shows that the program's success is measured not only by tangible outputs such as briquette products but also by the social learning processes that build the community's capacity to innovate, collaborate, and adapt to future energy challenges. Consistent with the analysis of Damayanti et al. (2025), the sustainability of local innovation in rural areas depends on three key factors: participatory knowledge transfer, adaptive community leadership, and continuously evolving cross-sector partnerships.

2. Demonstration of Biomass Briquette Production

The biomass briquette production demonstration in Alue Krueng Village served as the core stage of the entire community empowerment process. As documented in Figures 4 and 5, this activity involved the active participation of both residents and university students at every stage of production. The process applied the learning-by-doing principle, as described by (R. Putri et al., 2025), in which participants were not only listeners but direct practitioners in the field. This hands on approach proved highly effective in strengthening technical understanding and building the community's confidence in their own abilities.

Figure 4 depicts the carbonization process of raw materials such as rice husks, coconut shells, and sawdust using a simple pyrolysis drum. Students and local residents worked together to regulate temperature and airflow to ensure optimal carbonization without excessive burning. This activity illustrates a concrete form of intergenerational collaboration, as explained by (Suryana & Oktaviani, 2025), where the involvement of youth and adults enabled a two way transfer of knowledge combining local experience with modern technological innovation.

Furthermore, the sense of togetherness captured in the photo demonstrates that the activity carried not only technical value but also social significance. The spirit of mutual cooperation (*gotong royong*) during production symbolized solidarity that strengthened social cohesion within the group, as emphasized by (Alamsyah & Dewi, 2024). In this context, briquette production became a space of interaction that united traditional values with modern innovation, while also reinforcing the relationship between the community and the students as facilitators of empowerment.

Figure 5 documents the grinding and molding session, in which charcoal powder was processed into compact briquettes. The work was conducted in an enclosed area to maintain product quality and prevent contamination. Training participants wore protective gloves and used simple tools to mix fine charcoal with a natural adhesive made of starch and water, following the formula taught during previous technical sessions. This activity demonstrates the implementation of the participatory rural appraisal (PRA) method (Kurniasih et al., 2024), where community members were directly involved in the analysis, planning and execution of activities ensuring that the results aligned with local needs and capacities.

In addition to strengthening technical skills, the activity also produced valuable social learning outcomes. Spontaneous discussions that emerged during the production practice reflected participatory communication patterns that encouraged creativity and local problem-solving. As noted by (Wijayanti & Siregar, 2023), such active community participation is key to fostering a sense of ownership toward the program. This was evident from residents' suggestions on improving fuel efficiency and optimizing the briquette drying process by utilizing natural heat more effectively.

The demonstration results showed that the carbonization and molding processes produced briquettes with a dense texture and dark charcoal color, indicating high-quality combustion. Participants observed that the resulting briquettes burned longer than traditional firewood consistent with (Hartono et al., 2024), who found that training based on simple technology can improve household energy efficiency in rural areas.

Overall, this demonstration activity marked an important turning point in Alue Krueng's journey toward energy self-reliance. Beyond producing ready-to-use briquettes, the process nurtured collective confidence, innovative spirit, and ecological awareness at the community level. As emphasized by Damayanti et al. (Damayanti et al., 2025), the sustainability of local innovation depends on the synergistic combination of participatory knowledge transfer, adaptive community leadership, and consistent cross-sector partnerships.



Figure 4. Carbonization process of raw materials (rice husks, coconut shells, and sawdust) using a simple pyrolysis drum through joint collaboration between students and residents of Alue Krueng Village.



Figure 5. Mixing and molding process of charcoal into compact briquettes during the hands-on demonstration session in the shared workspace area.

CONCLUSION

This community-empowerment initiative in Alue Krueng demonstrates that participatory methods paired with simple, appropriate technology can translate locally abundant agricultural residues rice husk, coconut shell and sawdust into a reliable, low-cost household fuel while strengthening social cohesion and entrepreneurial capacity. Across two months of staged activities (socialization, hands-on training, production and mentoring), villagers moved from awareness to practice: they learned carbonization, mixing with natural binders, molding, drying, packaging and basic quality assurance; they also adopted simple record keeping, costing, and peer review routines that anchor product consistency and group accountability.

Technically, the use of simple pyrolysis drums and sun-drying produced dense, slow-burning briquettes suitable for household use. Socially and institutionally, the process revitalized *gotong royong*, clarified roles within the farmer group, and built trust between residents, student facilitators and village official key conditions for maintaining production continuity beyond the training phase. Economically, converting waste into a marketable energy product created a new income stream while lowering household fuel expenditures, illustrating a concrete circular-economy pathway that keeps value local.

The program also advances multiple SDGs in tangible ways, SDG 7 (clean energy access) through locally produced briquettes, SDG 12 (responsible consumption/production) by valorizing organic residues and SDG 13 (climate action) by reducing open burning and firewood use. Embedding the enterprise into village planning (e.g., RKPDes), formalizing a Village Energy Group and standardizing simple QA metrics (moisture, density, burn time, smoke) will help safeguard these gains and attract modest co-financing for equipment upgrades.

Three limitations should guide next steps: (1) the short implementation window limits observation of seasonal raw-material variability, (2) product quality was field-assessed rather than lab-tested (e.g., calorific value, ash content) and (3) a basic business model was initiated

but not stress-tested against fluctuating demand and raw-material prices. Addressing these gaps will require: periodic lab testing and SOP refinement, a micro-feasibility plan covering pricing, break even volume and distribution. Diversified feedstock sourcing agreements with mills and workshops and continued mentoring on cooperative governance and marketing.

In sum Alue Krueng has established a credible, community owned model of waste to energy that couples technical practicality with social organization. With light-touch institutionalization, routine quality control and a clearer go-to-market plan, the initiative is well-positioned for replication across neighboring villages advancing energy self-reliance, rural incomes and green transition outcomes from the bottom up.

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