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Educating Renewable Energy Innovation: Bio-Briquette Development from Plantation Waste in South Toapaya, Bintan Island

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Abstract— The increasing demand for energy and the continued reliance on fossil fuels in Indonesia present serious environmental and economic challenges. This community service project introduces an innovative solution by developing bio-briquettes from cassava peel waste in South Toapaya Village, Bintan Island. The program applies a Participatory Action Research (PAR) approach to engage the community in a hands-on learning experience, from problem identification to production and evaluation. Through interactive socialization and technical training, villagers—especially farmers and housewives—were educated on the benefits of converting plantation waste into renewable energy. The process involved drying, pyrolysis, mixing with natural adhesives, molding, and testing of the resulting briquettes. The produced bio-briquettes demonstrated effective burn duration up to 42 minutes with low smoke output, making them a viable alternative to firewood. This initiative not only reduced organic waste but also empowered the community to create economic value from local resources. While the project achieved its educational and technical goals, limitations included a lack of laboratory validation and small-scale outreach. The results show promising potential for broader implementation in rural energy innovation.

Keywords: Educating, New Renewable Energy, Bio-briquette, Cassava Bark Waste

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1. Introduction

The growth of global energy demand is increasing in line with population growth, transportation, and industrialization. According to the International Energy Agency (IEA), in 2022 world energy consumption increased by 2.3% compared to the previous year, with fossil fuels still dominating 81% of total global energy consumption [1].

In Indonesia, the household and small business sectors still rely heavily on the use of conventional energy sources based on natural resources such as petroleum, natural gas, coal, and firewood, which are included in the fossil energy group. The high dependence on fossil energy is a serious threat because these energy reserves are limited and their use produces carbon emissions that accelerate climate change [2]. Therefore, it is necessary to make efforts to find and develop alternative energies that are sourced from abundant natural potentials such as water, wind, sunlight and sunlight. In addition, alternative energy can also be created through the output of agricultural products, both in the form of cultivated crops, and those sourced from the rest of agricultural products (waste) which do have a fairly high sustainability value [3,4,5,6].

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South Toapaya Village on Bintan Island, Riau Islands is one example of a village whose community is highly dependent on fossil-based energy and firewood for daily needs. This dependence is exacerbated by fluctuations in supply and fuel prices that are often unstable, especially in the rainy season.

Geographically, South Toapaya Village is located in a lowland with an altitude between 5 to 50 meters above sea level. The village has a tropical climate with average temperatures ranging from 25°C - 32°C with high rainfall, especially in October to April. The fertile soil condition makes most of the village area used as plantation, forest, and agricultural land. The main commodities cultivated include cassava, oil palm, rubber, corn, and sweet potatoes [7]. Plantation products are mostly used for consumption or sale, while waste such as cassava peel waste, oil palm fronds, leaves, twigs, and plant remains are often left unmanaged. As a result, the waste accumulates so that it becomes a source of environmental pollution.

This organic waste problem requires a targeted solution so that it does not continue to become an ecological burden. Various leftover plantation products actually contain potential that can be used as raw materials to produce environmentally friendly products [2]. Through an approach based on appropriate technology and community empowerment, the waste can be converted into alternative energy, one of which is in the form of bio briquettes. Bio briquettes are solid fuels from organic materials that contain carbon, have a high calorific value, can burn for a long time, as a substitute fuel for gas and coal [8], [9], [10]. One of the agricultural by-products that can be used to produce bio-briquettes is cassava peel waste. Cassava peel contains a high concentration of carbohydrates, ranging from 72.49% to 85.99% of its total weight [11], potentially present as linamarin [12]. Due to this significant carbohydrate content, cassava peel is considered a promising candidate for use as an alternative energy source. In addition, properly managed cassava peel waste has the potential to become a high-value economic commodity [13].

However, the lack of public awareness of the potential use of plantation waste as an alternative energy source causes the waste to still not be utilized optimally. Education and active community involvement are key factors in encouraging the processing of organic waste into bio briquettes that are not only environmentally friendly, but also have high economic value [14]. Therefore, the purpose of this service activity is to educate the people of South Toapaya Village through the transfer of knowledge, insights, and awareness of the importance of using cassava peel waste as one of the alternative renewable fuels, namely bio-briquettes. The implementation of this service prioritizes practical education, demonstrations of making bio-briquettes, and socialization to increase public awareness about the benefits of local waste into bio-briquettes.

2. Method

This community service activity is carried out with a Participatory Action Research (PAR) approach. PAR is a method with an approach that involves various stakeholders in the process and actions to be implemented, so that there is a transfer of knowledge to stakeholders to find out the importance of the product manufacturing process and understand the steps to implement it [15]. The PAR approach was chosen to ensure that the community is not only a beneficiary, but also plays an active role in the process of identifying problems, planning, implementing, and evaluating activities [16], [17]. This method is considered effective in empowering and increasing the capacity of village communities to be able to manage plantation waste into bio briquettes independently and sustainably. There are 4 stages in this service activity, as shown in Figure 1 below:

2.1 Preliminary Stage

This stage carried out initial observation and participatory discussions with the people of South Toapaya Village to identify problems related to the need for alternative energy and plantation waste

management. The findings in the field then became the basis for conducting a literature review on the use of plantation waste as raw materials in the production of alternative energy, namely bio briquettes [18], [19]. Furthermore, a joint activity plan was formulated which included the selection of potential waste types as raw materials, bio briquette making techniques, and educational strategies that are in accordance with the conditions of the local community. Community involvement in the planning of community service activities increases the sense of ownership and sustainability of the program. This approach emphasizes the importance of joint surveys and deliberations before the implementation of waste treatment activities.

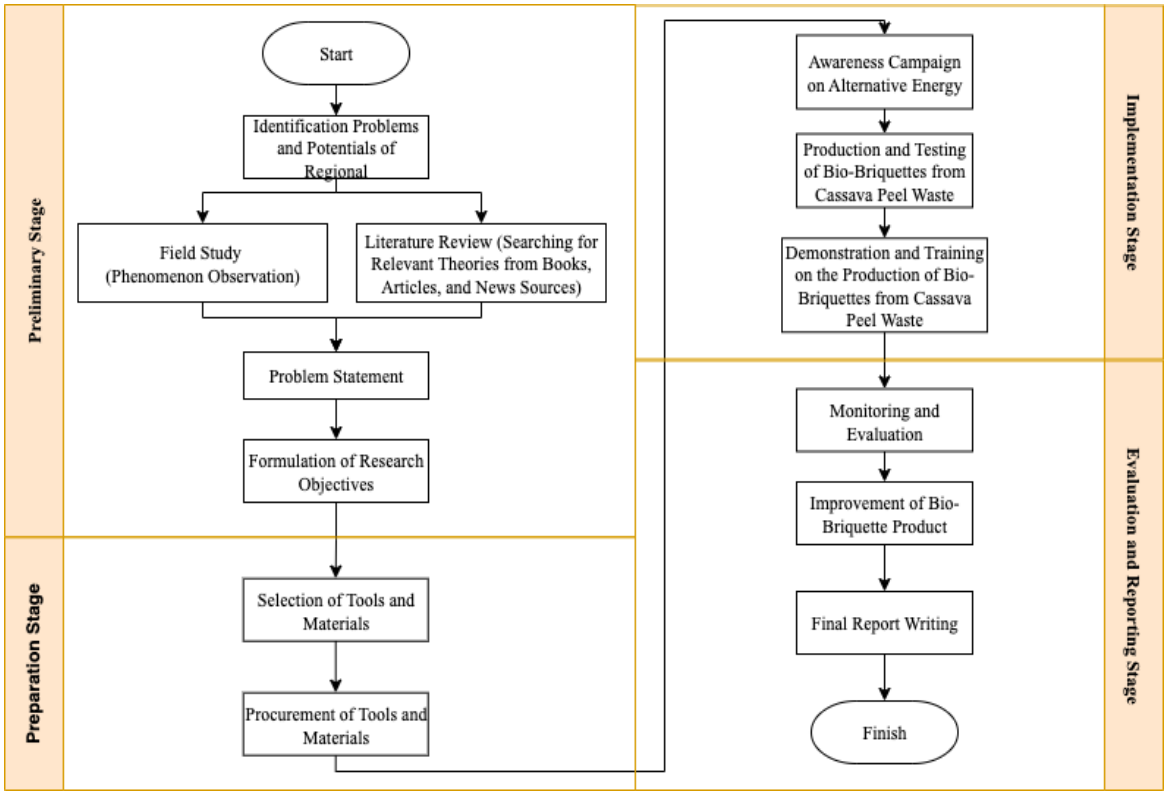


Figure 1. Flowchart

2.2 Preparation Stage

The preparation stage is carried out to ensure the smooth implementation of the service program. At this stage, the implementation team together with local partners carried out a number of activities that included technical planning, field coordination, and the procurement of tools and materials to support activities. One of the main focuses in the preparation stage is the determination of the types and specifications of tools and materials that will be used in the process of making and training bio briquettes. Furthermore, equipment and materials are purchased, both through local providers and online orders, taking into account ease of use, availability of spare parts, operational efficiency, and affordability. The tools and materials prepared can be seen in Table 1 below:

Table 1. Tools and Materials for Service Activities

Tool	Material
Plastic basin	Cassava Skin Race
Pot	Tapioca flour
Mortar	
Sieve	
Parallon Pipe	
Mold	
Scales	

Glove	
Mask	

2.3 Implementation Stage

The implementation stage is the core of community service activities which are carried out in a participatory manner by involving the people of South Toapaya Village as the main subject. At this stage, the program is carried out according to the plan that has been prepared in the preparation stage, with a focus on socialization, technical training, and direct assistance.

The implementation of the program began with socialization activities aimed at educating the community about the importance of using renewable energy and the potential use of agricultural waste, especially cassava peels, as an alternative fuel in the form of bio briquettes. This socialization was delivered interactively so that it was easy to understand by all circles of the community, including housewives and village youth groups. Furthermore, technical training on making briquettes was carried out, which was divided into several sessions, namely:

a. Introduction of raw materials: participants are invited to recognize the characteristics of cassava peel waste and other additives such as natural adhesives.
b. Waste treatment process: participants practice the stages of drying, cassava skin shredding, mixing of ingredients, forming dough, and printing briquettes using simple tools.
c. Drying and storage: participants were given an understanding of the importance of an optimal drying process to maintain the flammability of the briquettes and avoid mold or damage.

All activities are carried out with a *hands-on* approach (hands-on) so that participants gain concrete experience and can apply it independently after the program is completed. The implementation of the activity can be seen in Figure 2-8 below:



Figure 2. Field Observation



Figure 3. Socialization



Figure 4. Cassava peel waste



Figure 5. Drying



Figure 6. Milling



Figure 7. Filtering



Figure 8. Formation

2.4 Evaluation and Reporting Stage

The final stage is in the form of a joint evaluation between the service team and the community to assess the success of the program, identify the obstacles faced, and develop a follow-up plan. To ensure that the training results are in accordance with standards, direct assistance and monitoring are carried out, especially in terms of briquette quality (texture, strength, and burn time). The community is involved in simple tests such as combustion power tests and evaluation of the ease of use of bio briquettes produced. This observation aims to ensure that the products produced are in accordance with the needs of the community and are safe to use. After that, an activity report is written as proof that the activity has been carried out.

3. Result and Discussion

Community service activities with participatory action research (PAR) approach carried out in South Toapaya Village have succeeded in achieving a number of important achievements, both in terms of education, community involvement, and innovative products produced. In the field of sustainability studies, researchers utilize PAR approach collaborations to combine scientific knowledge with local, community-based insights, enabling marginalized groups to create effective, practical responses to sustainability challenges [20]. In addition, through the PAR method, researchers collaborate with and support communities in the processes of co-creating knowledge, seeking solutions, and making decisions [21], [22]. The result showed that the community showed high enthusiasm, as evidenced by their active involvement in question and answer sessions in socialization, technical discussions, as well as direct participation in briquette making practices. This activity not only introduced the concept of biomass-based renewable energy, but also succeeded in changing people's perspective on plantation waste which was previously considered worthless into a potential alternative energy source with economic value.

In practice, the team successfully produced bio-briquettes from cassava peel waste, which offer the advantage of a combustion efficiency lasting up to 42 minutes, along with good density and moisture content levels, making them suitable as a substitute for firewood at the household. Revealed that the most effective bio-briquette formulation consisted of 50 grams of cassava peel waste combined with 5% epidermis starch as a binding agent. This composition produced the highest heating value of 5337.83 cal/g and showed the lowest levels of moisture and ash. And also sing cassava skin as main ingredient for bio-briquette will help to reduce organic waste [23], [24], [25], [26]

The test products were also distributed to residents as pilot materials, to strengthen a direct understanding of their benefits and uses. Through this activity, the community gains basic skills in processing waste into solid fuel, including the stages of drying, combustion (pyrolysis), charcoal refining, mixing with natural adhesives (tapioca flour), printing, and packaging. This approach

strengthens the transfer of knowledge in an applicative manner, as well as fosters awareness of the importance of waste management and diversification of energy sources [27]. So through this activity, the process of converting cassava peel waste into bio-briquettes can serve as a solution to address cassava peel waste. This was also stated by researcher [11], [28].

4. Conclusion

These findings show that the processing of plantation waste into bio briquettes is a real opportunity in encouraging a renewable energy transition that can be widely implemented in various regions of Indonesia. Theoretically, the program proves that the PAR approach is effective in integrating education, training, and the implementation of renewable energy production at the community level. The community not only understands the concept of new and renewable energy, but is also able to utilize waste into the latest alternative energy by practicing and continuing production activities in a sustainable manner. Meanwhile, practically, this activity provides concrete solutions to the problem of plantation waste and community dependence on fossil fuels. The production of bio-briquettes in South Toapaya Village is able to reduce the volume of previously unmanaged organic waste, as well as provide a more economical fuel alternative for household needs. From the observation results, the use of bio-briquettes made from cassava peel waste is quite effective in producing heat energy with low smoke levels and a long burning time. This shows great potential in the development of local biomass-based energy. However, this study has some limitations. First, laboratory tests to measure the calorific value, moisture content, and emissions of bio-briquettes have not been carried out in detail so that the quality of the product is only tested based on functional observations in the field. Second, the scope of training is still limited to the household scale with a relatively small number of participants, so the evaluation of long-term social and economic impacts cannot be comprehensively measured. Third, the limitation of production equipment causes production capacity to be not optimal. However, further research is still needed that focuses on the scale of implementation of village communities and strengthening education programs so that the benefits can be felt directly and sustainably.

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