Sustainability Design on Use of Biomass Waste Gasification Technology for Small Industry of Palm Sugar in Sinarlaut Village

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Abstract. Sinarlaut Village is located in Agrabinta District, Cianjur Regency, West Java Province. The community is mainly farmers, and some people produce palm sugar from coconut tree sap. Farming activities produce various agricultural waste. One of them is an abundant rice husk. This research conducted an analysis focusing on the feasibility of implementing gasification technology in supporting small industry palm sugar. The study was conducted not only on the technical aspect but also on the multi-variable sustainability aspect. One business cooks around 60 liters of sap for 6-8 hours to produce approximately 20 kg of palm sugar daily. The community uses firewood to cook coconut tree sap. They need around 50 kg/day firewood equivalent to 197,400 kcal/day. Based on the calculations, 59,818 kg of rice husk is an alternative resource to replace wood as fuel for cooking sap by gasification technology. The evaluation shows disadvantages and gap problems in terms of social, operation and maintenance, readiness to use, waste, land availability, and safety standard that should be managed. To implement the technology diffusion, social engineering needs to be conducted in the community to build system sustainability. The challenge will be more substantial for the effort to implement gasification technology on mass scale.

1. Introduction
Sinarlaut Village is a part of the Agrabinta District, Cianjur Regency, West Java Province. The area of Sinarlaut is 22.22 km². Its population in 2015 is 4,339 people. The village has 750 hectares of agricultural land, 850 hectares of plantation, 50 hectares of the community forest. The village has 13 farmer groups and 18 rice milling services as well. The livestock population in Sinarlaut reaches 922 head of cattle, 48 head of buffalo, and 1,200 goats. There are also 50 small palm sugar industries and three industries in the wood sector [1-3].

There is a chance to develop the palm sugar business in Sinarlaut Village by implementing better appropriate technology and in more environmentally friendly fuel management. In the village, waste from the wood industry had not been utilized properly. The residue of wood processing in the form of small wood or powder were just thrown away. This industrial waste has the potential to be used as biomass fuel by using gasification technology. Gasification technology using biomass waste raw
material can be applied for the substitution of fuelwood in coconut sugar production and for reducing agricultural and wood industries waste that has not been utilized. Biomass gasifier performs well even if it only uses biomass waster from agricultural or plantation that is scattered in almost all areas in Sinarlaut Village. Some types of biomass waste usually only burned, such as rice husks, dried banana leaves, dried leaves, dried midribs, small twigs, and other types of agricultural waste, can be used to substitute the firewood for cooking sap through a tool called the biomass gasifier.

Changing the fuel from firewood to agricultural waste might reduce the daily operational costs of fuel. In terms of occupational health, substitution to the biomass gasifier can reduce or even eliminate the effects of smoke generation, which can interfere with the breathing of farm laborers. It should be an essential consideration because people work around the furnace for 6-8 hours per day. In comparison, in 2010, an estimated 2.6 to 4.4 million deaths were caused by poor indoor air quality due to cooking activities with solid fuels in developing countries [4].

Moreover, the use of biomass as a gasification fuel in the palm sugar business should be able to meet the sustainability criteria such as economic, social, and environment. Sustainability is crucial because a large number of technological constructions in developing countries did not function well according to the design time because of no sustainability assessment [5].

2. Material and method

2.1. Materials
Before the field survey was conducted, a questionnaire was prepared for an interview with several stakeholders, community, and small business entity in Sinarlaut Village. The field survey was conducted in August 2016 to find out the latest and actual conditions of the palm sugar business. Taking pictures and plotting some important locations inside and outside the village were also conducted to give a more extensive insight into the business entity in Sinarlaut Village.

2.2. Methodology
The methodology that was used in this research can be seen in the following diagram.

![Diagram of methodology](image-url)

**Figure 1.** Methodology of research
Biomass gasification is the process of converting biomass into gas fuels with particular calorific value [6]. This gasification gas is called synthetic gas (syngas). In the gasification process, gas purification is carried out by separating unwanted substances from syngas, such as ash, sulfur, and tar. So that the content of this syngas is cleaner when compared to the gas directly burning biomass. In general, the syngas content is in the form of carbon monoxide (CO) gas, carbon dioxide (CO2), methane (CH4), hydrogen, (H2), Nitrogen (N2), and others. The syngas can be used for diesel fuel and power plants. The gasification process can be grouped into four processes, namely drying, pyrolysis, oxidation, and reduction [7].

Technology construction needs to be well designed to fulfill the sustainability aspect. Sustainable development is defined as a comprehensive process to maintain harmony between the natural environment and the artificial environment, as well as creating living conditions that uphold human dignity while encouraging the creation of economic justice [8]. Technically, technology construction can be called sustainable or fulfill sustainability aspect if it is able to have an additional impact on several factors, such as, (1) access and quality of health, (2) community and institutional cohesion through participation, (3) the role of marginalized community groups, (4) unemployment and relative poverty, and (5) technical competence locally [9-11].

Besides, the process of achieving social sustainability must fulfill at least eight steps, namely, (1) ensuring the legality of land ownership, both positive and customary law, (2) involving local communities to actively participate until construction activities are completed, (3) preparing designs following the local wisdom, (4) utilizing sustainable energy sources at the local level (locally sustainable systems for energy) and in accordance with local thermal comfort, (5) ensuring using safety standards that are generally applicable locally, while still referring to international standards, (6) construction must be safely constructed by local communities, (7) using construction methods that can be easily understood by local communities, and (8) construction is built with sustainable and affordable materials at the local level (locally sustainable and affordable materials) [5].

3. Result and Discussion
Evaluation on technological sustainability requires data on current conditions from an economic standpoint (such as income structure, the existence of mediators, and the projected market for palm sugar products), social side (such as the level of education and community skills, the presence or absence of marginalized groups, the number of the workforce, and a map of influential figures or groups), as well as environment aspect (such as agriculture and plantation productivity to calculate biomass waste estimates, the number of respiratory health complaints from farmers or communities near production sites, and detailed mapping of biomass waste utilization).

Based on the interview results, the sap is taken twice a day, in the morning and evening. Farmer cooks 60 liters of sap that was obtained that morning and the afternoon before. The sap is boiled in one pan using a wood-burning stove. Besides firewood, the farmer also uses a waste of firewood to minimize the production cost. The price of firewood waste is IDR 1,000.00. The cooking process takes about 6-8 hours, and the final product is obtained in the form of palm sugar weighing 20-30 kg, with prices ranging from IDR 10,000 to IDR 12,000 per kg. Farmworkers sell the final product to traders in the Sinarlaut region. Table 1 shows the characteristics of the coconut sugar small industry in Sinarlaut Village.

| Variable                      | Notes               |
|-------------------------------|---------------------|
| Cooking duration              | 6-8 hours/day       |
| Raw materials requirement     | 60 liters/day       |
| Products (palm sugar)         | 20 kg /day          |
| Need of firewood              | 0.5 m³ - 1 m³ /day  |
| Price of firewood             | IDR 120,000 – IDR 150,000 / m³ |
| Need of firewood waste        | 50 kg /day          |
| Price of firewood waste       | IDR 1,000/kg        |
| Variable                      | Notes                                           |
|-------------------------------|------------------------------------------------|
| Price of palm sugar           | IDR 10,000 – IDR 12,000/kg                    |

Production equipment:
1. Stove
2. Pan
3. Palm sugar molds
4. Sap container

- Diameter: 1 m, depth: 1.5 m
- Diameter varies, height varies, made from bamboo, coconut shells, or plastic
- Capacity: 20 liters

To cook 60 liters of sap, the fuel need - e.g., for firewood waste - is 50 kg. The caloric value for Sengon firewood based on data is 3,948 kcal/kg [12], so the calorie needs per day are:

\[
\text{Needs of calories (kcal/day)} = \text{Need of fuel} \times \text{Calorific values (kcal/kg)}
\]

\[
\text{Need of calories (kcal/day)} = 50 \times 3,948 (\text{kcal/kg})
\]

\[
\text{Need of calories} = 197,400 \text{kcal/day}
\]

The characteristics of palm sugar business, especially regarding energy needs, are very compatible with the essential characteristics of energy products from biomass gasifiers. Figure 2 shows the biomass needs that have various specifications, potentially replacing wood fuel, which amounts to 1 m³/day or around IDR 120,000 per day. The potential of the agricultural, plantation and wood industry biomass waste can be calculated from the value of the ratio of waste to its products or commonly called RPR (residue to product ratio). RPR value can be used to calculate the potential of agricultural/plantation biomass waste, by multiplying it by the mass of the final product. Figure 2 shows the RPR of some agricultural and plantation products [11].

**Figure 2.** Average RPR of agricultural, plantation and wood industry waste products in Southeast Asia [11]

Based on [13], rice husk has a calorific value of 3,300 kcal/kg. Therefore, the rice husk needs for palm sugar production per day is calculated as follow:

\[
\text{Rice husk needs} \left(\frac{kg}{day}\right) = \frac{\text{Calories need} \left(\frac{kcal}{day}\right)}{\text{Calorific value of rice husk} \left(\frac{kcal}{kg}\right)}
\]

\[
\text{Rice husk needs} \left(\frac{kg}{day}\right) = \frac{197,400 \text{ kcal/day}}{3,300 \text{ kcal/kg}}
\]

\[
\text{Rice husk needs} = 59,818 \text{ kg/day}
\]
Sinarlaut Village has eight rice mills. For every 100 kg of milled unhusked rice will produce 65 kg of rice and 35 kg of rice husk (1/3 of dry unhusked rice). In the regular season, each rice mill will produce 10 kg of rice husk per day. However, during the harvest season, the husk reaches 70 kg per day. By using this resource, a demand of around 60 kg of rice husk per day can be fulfilled by waste supply from 6 different mills in Sinarlaut Village. This calculation is for one palm sugar business.

Besides, the biomass gasifier specification can also be developed into a "communal heat source", where one unit of biomass gasifier can be used together by several furnaces at once. The commonality of the heat source is in accordance with field conditions, where several farm laborers carry out their cooking activities communally in the same place.

The potential of palm sugar business to substitute fuels has several logical consequences, especially regarding the need for social engineering efforts so that technological sustainability can be assured to be met. In general, social engineering is needed to introduce new technology that will replace the existing technology that has been going on for a long time and has become an essential daily activity for many years. The technology diffusion method will be applied for technology substitution. Some general criteria for the process of the diffusion of gasifier technology are summarized in Table 2.

Table 2. Criteria and measurement of gasifier technology innovation

| Criteria         | Value                                                                 |
|------------------|----------------------------------------------------------------------|
| Relative advantage | Lower production cost                                                 |
| Compatibility    | Availability of supporting infrastructure: spare parts and fuel continuity |
| Simplicity       | Easiness of operation and maintenance                                 |
| Trialability     | Experience satisfaction of gasifier performance                       |
| Observability    | There is training, user manuals, and reliable instructors             |

Meanwhile, from the technical side, Table 3 illustrates some of the advantages and disadvantages of gasification technology from various aspects, which must be introduced to prospective beneficiaries.

Table 3. Ease and difficulty of gasification technology in terms of several aspects

| Aspect          | Advantages | Disadvantages                                                                 |
|-----------------|------------|-------------------------------------------------------------------------------|
| Cost            | Gasification machine manufacturing needs a capital cost                   |
| Fuel availability | Rice husk and sawdust available in a large quantity                      |
| Fuel cost       | Rice husk and sawdust cost cheaper than wood                             |
| Production cost | Production cost will be decreased due to the decrease in fuel cost      |
| Readiness to use| - Gasification technology for people in Sinarlaut village was not familiar. So it is needed to assist the community from the beginning until they can operate the gasification technology and fix related problems by themselves.  
- The community in Sinarlaut already feels the comfort of the existing system. Therefore, there could be resistance to gasification technology. |
| Aspect                          | Advantages                                                                 | Disadvantages                                                                 |
|--------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Health                         | The gasification process is environmentally friendly: it is clean and does not produce smoke as much as using existing technology. | Sinarlaut is located in a rural area with difficult access to reach the village. The community has not known the technology yet. Therefore, implementation of gasification machine will need more effort in assuring success in operation and maintenance. |
| Operability and Maintainability | Sinarlaut is located in a rural area with difficult access to reach the village. The community has not known the technology yet. Therefore, implementation of gasification machine will need more effort in assuring success in operation and maintenance. | Waste Gasification will also produce tar as its waste. |
| Land availability              | Need land to put the gasification machine                                    |                                                                             |

Table 4 shows a comparison between ideal and existing conditions currently available in Sinarlaut Village. It presents a gap for the implementation of the gasification technology.

**Table 4.** Comparison of ideal descriptions and existing conditions

| Variable                  | Ideal description                                                                 | Existing condition                                                                 | Gap                                                                 |
|---------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Land ownership            | Ensure the legality of land ownership, both positive and customary law            | Land is owned by individuals. There is no land issue in business development       |                                                                      |
| Local community’s participation | involving local communities to actively participate including in construction activities | The culture of mutual cooperation *(gotong royong)* is still embedded in the villagers |                                                                      |
| Design                    | prepare designs in accordance with local wisdom                                   | The current design can be applied in the village                                   |                                                                      |
| Local energy resource     | Utilize the locally sustainable systems for energy according to local thermal comfort | Local resources can be used for fuel                                               |                                                                      |
| Safety standard           | Ensure implementation of safety standards suitable to local conditions, while still referring to international standards. Construction must be safely built and operated by local communities | Gasification system suitable to local demand has not been tested nationally or internationally | There is a standard gap in implementing gasifier technology suitable to the village |
| Construction method       | Using construction methods that can be easily conducted by the local community    | The construction method is not complicated and can be carried out by the community |                                                                      |
| Material                  | Construction is built by using sustainable and affordable materials at the local level | Can be implemented in the village                                                  |                                                                      |
| Variable | Ideal description | Existing condition | Gap |
|----------|-------------------|--------------------|-----|
|          | (locally sustainable and affordable materials) |                    |     |

Table 2, 3 and 4 show multi-variable challenge in implementing the gasification technology in the village. Providing comprehensive solution needs cross-sectoral involvement of local stakeholders, such as (1) the role of village government and local community institutions at the village, hamlet or village level, as the initiator of the social movement, (2) the role of local industry, workshop, or machinery and equipment shops, as well as the nearest technical education institution to support spare parts and equipment maintenance, (3) industrial continuity or local activities that supply waste biomass as fuel, (4) the role of innovators in machinery and ergonomics sectors, and (5) the role of small and medium entrepreneurship (SMEs) to adopt gasifier technology. Diffusion of technology and encouragement so that the five roles can be realized can only be done if social engineering is carried out at the local level, which usually takes a long time to realize sustainable engineering design. The challenge will be more substantial for the effort to implement gasification technology on a mass scale.

4. Conclusion
The palm sugar business in Sinarlaut Village has the potential to be developed with the use of gasification technology. Gasification technology with biomass waste raw material can be utilized to replace fuelwood in the manufacture of palm sugar and to reduce waste from agricultural activities. By using gasification technology, rice husk is an alternative resource to be used to replace wood as fuel for cooking sap. The demand can be fulfilled, for instance, by waste supply from the rice mills in Sinarlaut Village.

However, the evaluation shows some disadvantages and gap problems in terms of social, operation and maintenance, readiness to use, waste, land availability, as well as safety standard that should be managed. To implement the technology diffusion, social engineering needs to be conducted in the community to build system sustainability. The challenge will be more definite for the effort to implement gasification technology on a mass scale.

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