Biogas Implementation as Waste Management Effort in Lembang Sub-district, West Bandung District

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Abstract. As the population and economic activities increase, energy demand will increase significantly too. In the near future, Indonesia will have more limitations on fossil fuel based energy. Therefore, sources of renewable energy have to be found. On the other hand, rural areas in Indonesia suffer from lack of energy supply. Therefore, energy resilient villages need to be created. Kampung Areng in Cibodas Village, Lembang sub-district is one of the locations declared as an energy resilient village. This study focused on Kampung Areng due to previous information and studies that have shown the farmers in this area are capable of generating renewable energy through conversion of animal waste using biogas digesters. Biogas adoption was also initiated due to the issue of Cikapundung river pollution. Some people pointed their finger at Kampung Areng as the upstream source of this pollution due to irresponsible handling of animal waste. Thus, the idea emerged that biogas digester adoption in this area could solve the waste management issue while providing an alternative energy source for the community. In this paper, the authors aimed to identify the benefit and impact of biogas adoption in Cibodas Village, particularly regarding waste management.

1. The first section in your paper

Energy is an important resource for economic development and improvement of living conditions. In the past, Indonesia has been an oil exporter with several production areas such as Balikpapan [1]. However, Indonesia has already been a net oil importer since 2004, which will likely continue in the future. From 1980 to 2010, Indonesia oil consumption has increased while its production has decreased. Since the year 2004, there has been an energy deficit and therefore Indonesia has started importing oil from other countries. If not managed carefully, this could become a threat to the energy security of Indonesia. In fact, Indonesia’s Agency for Assessment and Application of Technology has predicted that Indonesia could be a net importer for fossil energy [2]. Therefore, Indonesia has to utilize other sources of energy, for instance new and renewable energy (NRE).

The utilization of renewable energy resources could be an effective and efficient solution, not only for providing energy but also for reducing pollution and emissions [3]. One of the largest environmental problems in Indonesia is waste management. As one of the countries with the largest populations in Southeast Asia, about 220 million people, which has increased in the last decade, the amount of waste it produces has also increased. There are several factors that influence waste
management in Indonesia, such as regulations, capacity and dumpsite technology, low public awareness, lack of infrastructure, and low priority from local governments [4].

Indonesia has a target to achieve 23% renewable energy in the energy mix by 2025 [5], which is possible to achieve with the renewable energy potential of Indonesia. This is an ambitious target that needs involvement from various stakeholders. However, it is in contrast with the inequality of access to energy resources such as electricity, particularly for communities in rural areas. It has been shown that the electrification rate in Indonesia was 91.2% in 2016 [6] and the lower electrification rates are mostly found in eastern Indonesia. However, there are alternative resources in rural areas that can be utilized to generate renewable energy, such as biogas, biomass, and biofuel.

Biogas utilization has been done since 1895 in England using sewage treatment installations to provide street lighting [7]. Interest in biogas depends on the price and availability of fossil fuels. Interest was revived in 1973 by the mounting concern for environmental protection [8]. A number of studies [9][10] showed that Indonesia has great potential to utilize biogas in a feasible way. Subsequently, several biogas development projects were started in Indonesia. International and national organizations were involved in managing these projects with support from the government.

Indonesia has used biogas since the 1970s, and in 1981, biogas development projects have been implemented with funding from FAO in several provinces of Indonesia. Although there has been no significant effect in the last decades, the Indonesian government recently again has initiated several biogas projects. In Palembang, GoI built a biogas power plant using waste from dump sites. In other places, POME is the main material to generate biogas. In rural areas, biogas generators are managed by households or small communities. They usually use livestock manure as the resource. Several provinces use this kind of biogas technology, among which East Java, Central Java, East Nusa Tenggara and West Java.

Lembang subdistrict is one of the areas that have developed biogas utilization on a small scale for communities in rural areas. Lembang is located in West Java Province. In Cibodas village, more specifically Kampung Areng, in Lembang, the majority of the population are cattle farmers. Biogas is generated from cow manure as their source of energy due to the quite large number of small-scale cattle farms in this area. Small-scale cattle farms have a disadvantage in that it is difficult for them to handle the waste of cows wisely [11]. The development of biogas utilization in this area was also part of the problem of maintaining water quality in Cikapundung river, which passes Kampung Areng. Badly managed cow manure from the cattle farms is assumed to affect its water quality. This study focused on Kampung Areng in Lembang subdistrict because previous information and studies have shown that the farmers in this area are capable of generating renewable energy through conversion of animal waste using biogas digesters. This is supported by the fact that most households in Kampung Areng do cow farming and have enough manure to supply and support the development of biogas digesters. Biogas adoption was initiated also due to the issue of Cikapundung river pollution; some people pointed their fingers at Kampung Areng as an upstream source of pollution due to the irresponsible handling of animal waste. Thus, the idea emerged that biogas digester utilization in this area could solve the waste management issue while providing an alternative energy source for the communities. This study aimed to identify the benefits and impacts of biogas adoption in Cibodas village.

2. Methodology

This research used a mixed qualitative and quantitative approach. The region selected for the case study in this research was Lembang subdistrict, Kab. Bandung Barat, West Bandung regency. There are currently 775 biogas installations that have been built by Hivos and Yayasan Rumah Energi (YRE) in Lembang. Tools used were questionnaires, in-depth interviews and observation. Questionnaires were spread among 81 respondents from different neighborhoods: RW 07, RW 17, RW 05, RW 04, RW 02, RW 16, RW 10, RW 14 and RW 11; in-depth interviews were conducted with seven key informants, i.e. a neighborhood head (RW 07), a women’s group, an ex-leader of a farmer’s group, Energi Persada, a garbage bank manager, and the current treasurer of a farmer group. Observations
were done in cowsheds that have biogas reactors. Secondary data used are the list of reactor recipients from ESDM and the list of reactor recipients from the BIRU program.

For this study, data from 79 respondents were collected, from a total of 125 households that have a biodigester. Respondents had to be more than 17 years old, could understand the questions, and be the beneficiary or user of a biodigester.

The quantitative analysis used a descriptive analysis that explains the condition of the object of study for easier understanding. In addition, a content analysis was done to support the descriptive analysis to get a deeper understanding of biogas implementation in Lembang, particularly in Kampung Areng. A subsection

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3. Literature Study

3.1. Waste management in rural areas
Agriculture is usually the main livelihood in rural areas, particularly in developing countries. Waste from agriculture is often not managed well, particularly because of limited infrastructure. Agricultural activities usually produce organic waste such as animal manure, food processing waste, crop/plant waste, and other organic waste from agricultural industry. However, this waste could be a valuable resource if managed carefully.

One agricultural waste is animal manure produced daily by cattle. The large amount of animal manure has a negative impact on the environment if not managed properly. When treated poorly, animal manure can be a major source of air and water pollution [12], which often occurs in rural areas in developing countries. In developing countries, there are limitations in choosing management strategies for utilization of animal manure [13], such as:

- Public acceptance (nuisance or environmental concern)
- Acceptable integration into agriculture
- Quality control of residues being applied
- Logistics and organization
- Fulfillment of environmental regulations
- Economic viability
- Sustainability

Environmental factors are an important aspect in choosing strategies for animal waste management. Strategies for waste management that minimize water and air pollution, emission of ammonia and pathogens could provide solutions in handling animal manure [13]. Anaerobic digestion of animal manure is a method of managing this waste. This process usually produces two main products: a biogas that can be used as fuel for stoves or to generate electricity; a substrate that can be used as fertilizer.

3.2. Waste management in rural areas
Rural areas have many resources that can be developed for energy production. However, this potential relies on traditional methods, particularly in developing countries. In several areas, Indonesian communities still use firewood, which contributes to carbon emission and lack of energy efficiency. To unleash the renewable energy potential in rural areas is not an easy task. There are several problems that usually challenge the development of renewable energy, such as financial issues, coordination problems, awareness problems, and technological and knowledge problems.

The development of rural biogas utilization at household level comes with several benefits simultaneously, namely improving sanitation, enhancing ecology in rural areas, more efficient and effective energy production, decreasing greenhouse gas emission, and improving agricultural products.
Rural areas in developing countries usually have abundant biogas fermentation resources [14]. In addition, biogas is easy and simple to utilize. In the last decades, biogas utilization has grown quickly in many Asian, Latin America, and African countries, such as in China, Nepal, Thailand and Indonesia [7][14][15][16]. In China, the development of biogas for commercial use began in 1921 in Guangdong province, however its popularity increased when the Chinese government started to promote ‘biogas use by every rural family’ and facilitated seven million biodigesters [17].

Several types of biogas can be categorized based on its main substrate [18]:

- Natural fertilizer (cattle slurry, pig slurry, cattle manure, pig manure, chicken manure)
- Plants (maize silage, rye, grass silage)
- Products of agricultural industry (brewer grain, grain decoction, potato decoction, pomace)
- Other substrates (waste fittings, gastric contents)
- Grasses (mown grass)

In developing counties, most biodigesters in rural areas can be categorized into three major types, namely fixed dome digester, floating drum digester (telescoping digester), and plug flow digester (saued-bag or channel digester) [19][20]. Each of this type has advantages and disadvantages (Table 1). The design of biodigesters is varied based on aspects such as geographical location, availability of substrate, and climatic conditions [19]. For instance, the fixed dome model was developed in China and the floating drum model was developed in India.

Table 1. Advantages and disadvantages of three types of biodigester.

| Digester Type       | Advantages                                                                 | Disadvantages                                                                 |
|---------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Fixed dome digester | • Low initial cost <br>• Long useful lifespan <br>• No moving or rusting parts <br>• Compact basic design <br>• Less land required <br>• Low maintenance | • Requires high technical skill <br>• Difficult to repair in case of leakage <br>• Requires heavy construction materials <br>• Amount of gas produced is not immediately visible |
| Floating drum digester | • Simple and easy to understand operation <br>• Visible stored gas volume <br>• Constant gas pressure <br>• Relatively easy construction | • High material costs of extra steel drum <br>• Short lifespan because of steel drum corrosion <br>• High maintenance because of regular painting of drum |
| Plug flow digester  | • Low cost <br>• Ease of transportation <br>• Low construction sophistication <br>• Uncomplicated maintenance <br>• Less subject to climatic variations than fixed dome | • Relatively short lifespan <br>• High susceptibility to damage <br>• Low gas pressure <br>• Limited creation of local employment <br>• High impact on environment |
In Indonesia, several studies have shown the impact of renewable energy in rural areas. For example, biogas implementation in Boyolali district provided economic benefit for the communities as well as a clean environment and organic fertilizer for farmers [21]. In addition, biogas has an important role in providing energy to villages who have limited access [22]. Furthermore, in Sumba Island, renewable energy, i.e. biogas, provided a platform for increasing community resilience [23].

4. Study Context
Kampung Areng is located in Cibodas village, Lembang subdistrict, West Bandung district, at an altitude of 1260 meter above sea level. Cibodas village has 2,959 households and is divided into 17 small neighborhoods (rukun warga). Some small neighborhoods have a majority of residents working as dairy cattle farmers. The majority of biodigesters in Cibodas village are located in Kampung Areng (Figure 1). Most of the farmers use communal stalls, thus in one stall are cows with different owners. Below is a neighborhood level map of Cibodas village and the number of biodigesters installed in the area according to Yayasan Rumah Energi’s list of beneficiaries acquired in 2015.

![Figure 1. Map of Cibodas village](image)

Sources: Google Maps and Yayasan Rumah Energi beneficiary list, 2015

The utilization of biodigesters in Cibodas village began with the research of a college student for Student Creativity Week. This was continued with a project from Hivos, a non-goverment organization from the Netherlands. The project is called the Indonesia Domestic Biogas Program (IDBP) and started in 2009 in West Java province. Through collaboration with the Ministry of Energy and Mineral Resources and local partner Rumah Energi Foundation, IDBP – popularly called BIRU (Biogas Rumah) – was implemented in Cibodas village.
Above is a diagram of the biodigester mechanism that converts cow manure to energy in a fixed dome digester [24]. Biodigesters in Cibodas village are mostly of the fixed dome type as shown above. The majority of them have a size of about 4 or 6 m\(^2\). Most biodigesters are aid from the BIRU Program or the government of West Java province. The biodigesters from the government were granted free of charge. However, beneficiaries from the BIRU program pay for construction and services, although they receive an incentive as applied under the BIRU Program, i.e. the beneficiary or potential user can receive a subsidy of about 2 million IDR. Therefore, there are some limitations and differences in the services of each program in its implementation process.

Usually, biodigesters are located near a stall to make it easier to use. The biogas is connected to a house or stall. If the distance between the house and the biodigester is far, more pressure from the biodigester is required.

According to Mekar Saluyu, ex-farmer’s group head, from 2004 to 2009 the adoption of biogas in Kampung Areng proceeded relatively slowly. After Yayasan Rumah Energi intervened with their BIRU program at the end of 2009, people begin to have more interest in using biogas. YRE’s cooperation with KPSBU (Bandung Utara Milk Cooperation) also helped its distribution. Then, after biogas received widespread implementation, the West Java provincial government introduced the idea of Kampung Areng as an independent energy village and granted a total of 82 biogas units from 2011-2014. However, after the introduction of these programs, the interest in the community decreased and due to a lack of supervision and maintenance, many biodigesters broke down and were left unused. More recent adoption of biogas, after 2014, came from farmers who participated in the BIRU program.
5. Biogas as waste management

Biogas can provide environmental benefits, such as supplying a sustainable source of energy, soil enrichment, re-utilization and treatment of a variety of organic wastes, and minimization of environmental impacts of greenhouse gas emission, and even reduction of land use problems caused by organic waste disposal [15]. In Kampung Areng, the main benefit is waste management of cow manure. Due to the limited waste management infrastructure, sometimes cow manure is flushed into Cikapundung river, which is close to the area. Biodigesters can replace waste management services and even have other benefits for cattle farmers.

Implementation of biodigesters in Cibodas village is a potential solution in managing waste, specifically cow manure from dairy cattle farms. If managed correctly, cow manure can potentially be utilized for producing biogas for cooking and electricity, and even as fertilizer, as illustrated in table 1.

| Biodigester Capacity (m³) | Quantity (Unit) | Maximum input of digestor | Total volume of manure in biodigesters |
|--------------------------|-----------------|---------------------------|---------------------------------------|
| 4                        | 43              | 40                        | 1.720                                  |
| 6                        | 31              | 60                        | 1.860                                  |
| 8                        | 4               | 80                        | 320                                   |
| 12                       | 1               | 120                       | 120                                   |

Based on the capacity of a biodigester, effectively about 4020 kg of cow manure can be processed, about 81.21% of the total amount of cow manure produced by the cows (Table 2). However, this calculation is limited to the cows that are owned by the beneficiary of the biodigester. It is very likely that the amount of cow manure is higher than this calculation shows, because not all of the cattle farmers have a biodigester. In some cases we found that a cattle farmer who did not have a biodigester gave his cow manure to a neighbor who owned one. This calculation assumes that each cow produces about 15 kg of cow manure per day.
Table 3. Waste potentials of cows’ manure.

| Number of cows | Average amount of cow manure | Potential amount of cow manure processed by biodigesters | Amount of cow manure unprocessed by biodigesters |
|----------------|-----------------------------|----------------------------------------------------------|-----------------------------------------------|
| Value          | 330                         | 4.950                                                    | 4.020                                         | 930                                            |
| Unit           | Kg                          | Kg                                                       | Kg                                            |
| %              | 100                         | 81.21                                                   | 18.79                                         |

From Table 3, not all cow manure is processed due to the limited number of biodigesters. In addition, some biodigesters are not operational for various reasons. The majority of them because some parts of the biodigester are broken, such as the inset (figure 4) or the biogas pipe that connects the biodigester to a stove. Other reasons were because the cows were sold or the stove was broken, etc. Thus, the real biodigester capacity in processing cow manure is reduced; only about 73 % of total cow manure can be processed into biogas and bio-slurry.

Unprocessed cow manure can be a problem for the environment as it is a water and air pollutant. It can pollute the soil and the water of Cikapundung river near Kampung Areng that is used as water supply for Bandung city.

![Figure 4. Inlet of a biodigester with a broken mixer.](image)

Other than processing animal waste, biodigesters also have the additional benefit of slurry production. Bio-slurry can be processed further into items with added economic value such as fertilizer. In Cibodas usually bio-slurry is processed into wet fertilizer, dry fertilizer, liquid fertilizer, and medium for worm farming.

- **Dry fertilizer** is made using wet solid biogas dregs, which are then dried. This takes a long time because traditional methods are still used, which depend on the heat of the sun. After drying the texture of the fertilizer becomes slightly tenuous and lightweight so it is easier to transport and the price is slightly higher when sold compared to wet fertilizer. Dry organic fertilizer is sold at prices ranging from Rp. 10,000 to 15,000 per sack.
- **Wet fertilizer** is non-dried and can be directly used. It is used by vegetable farmers in the study sites and yields good results. The constraint is that the wet conditions make it difficult to transport to agricultural sites that are far from the road and can be steep. Because it is in a wet condition, this type of fertilizer has a lower price at Rp. 5000 per sack.
Liquid fertilizer is a liquid-like biogas dreg that comes out of the digester outlet and contains many nutrients that are good for plants but is still very under-utilized by the owners of digesters in Cibodas village, whereas in some other areas liquid organic fertilizer from digesters is successfully sold after screening to get rid of unnecessary by-products. This fertilizer can be applied directly to plants or diluted with water.

Worm farm medium, i.e. solid-state biogas dregs, is used for the cultivation of the earthworm species of lumbricus rubellus, from which worms and kascing (worm-based) fertilizers can be produced. From the process of worm maintenance using biogas dregs a worm harvest is obtained that can be sold directly to collectors. These worms have a high enough selling value of Rp. 25,000 per kilogram, while good quality kascing fertilizer is valued at Rp. 25,000 per sack weighing about 30 kg. Using these worms, the resulting fertilizer dries faster than naturally dried biogas dregs and obtains a crumbly and light texture, making it easier for farmers to transport and to apply on the farm. It yields higher prices compared to dried compost. The price is set at the level of the worm farmers, where buyers buy directly from the worm cultivators. However, despite the high prices, worm farmers who also work as farmers prefer to use kascing fertilizer to meet their own fertilizer needs, especially for feeding seeds, because it produces healthy and strong seeds.

Below is a table of how the questionnaire respondents process their slurry in the area of Cibodas village.

| Bio-slurry uses   | Yes | No  | % use |
|-------------------|-----|-----|-------|
| Dry fertilizer    | 37  | 42  | 46,84 |
| Wet fertilizer    | 15  | 64  | 18,99 |
| Liquid fertilizer | 3   | 76  | 3,80  |
|                   | 18  | 61  | 22,78 |

In Cibodas, dry fertilizer production is a popular way to process slurry. In the case of further processing of biogas dregs to get additional benefits that can increase the family income, 42 digester owners (53.2%) process it into dry organic fertilizer, 18 use it as a medium for kascing fertilizer, 15 use it as wet organic fertilizer and only 3 use it as liquid organic fertilizer. Meanwhile, there are only 18 (22.78%) who process their slurry as a worm farming medium.

There are some challenges in the implementation of biogas in Kampung Areng:

1. Not all of the bio-slurry is being used. Sometimes the farmer does not use the solid slurry because he does not have a farm field and the liquid slurry is thrown away into a ditch or near a neighbor’s field farm. This happens because of oversupply and limited demand of bio-slurry.
2. Some of the beneficiaries of the biogas project still use LPG, particularly for biodigesters with a smaller capacity (4 or 6 m³), because their stove can only be used for 1-2 hours on biogas.

3. There is no monitoring of the implementation of biodigesters, particularly from the government, so some of the biodigesters are not operational.

One of the clear impacts of these biogas programs is empowerment of the women in Kampung Areng. Kampung Areng’s Kelompok Karya Ibu has developed a business of worm farming with members consisting of mothers of farmers/ranchers, counting about 25 people. Group earnings are usually collected every two weeks from the members of the group, who collectively can produce about 100 kilograms of worms and 100 sacks (sacks) of kasaging fertilizer. This is done when there is a buyer of kasaging fertilizer who needs a large amount of fertilizer. Otherwise, they sell directly to farmers in need or to meet their own needs. However, this case is quite rare in Kampung Areng. In addition, the women in Kampung Areng also actively manage a waste bank. They have developed an organization that manages the waste in Kampung Areng so it can be sold.

6. Discussion

To maintain a small-scale biodigester and keep it working well is not easy. It requires cooperation between the user and the provider. There are many factors that can affect the user to no longer use a biodigester, such as broken parts, cows were sold, or the family moved to another place. The BIRU project tries to manage these issues through several strategies. They provide after-sales services in the form of maintenance and monitoring the biodigesters to ensure they work well. This helps the user to keep the biodigester in good condition and to process cow manure in producing biogas and bio-slurry. However, owners of biodigesters that were provided by the government do not have this support, so some of the biodigesters are no longer operational because parts are broken and the users do not have the capability to do the repairs. This is a problem for the development of biogas as waste management solution related to cow manure in rural areas. It needs to be addressed particularly by government agencies who provide biodigesters to cattle farmers, by monitoring the implementation and maintenance of this infrastructure.

Bio-slurry as by-product of biogas can have many benefits for a community. For instance, bio-slurry is a potent organic fertilizer. It could help farmers grow their plants using organic matter and provide a viable solution to nutrient depletion of many agricultural soils. Bio-slurry can boost agriculture and horticultural production. In Kampung Areng, cattle farmers use it for their plants in the field or use it as fertilizer for growing grass as food for their cows. In some cases, they use it in the forest to maintain the growth of grass. In addition, it can reduce the costs of cattle farmers who also have a field farm.

Biodigesters could be mandatory for cattle farmers in rural areas to process their cow manure, particularly farmers who have quite a large number of cattle. It would be best if the locations of the farmers are spread so they can each distribute and sell their bio-slurry in their own area. However, if the locations of stalls and biodigesters are agglomerated, the market system for bio-slurry needs to be developed. The excess bio-slurry needs to be distributed to other farmers, but this does not happen well. The popularity of bio-slurry as fertilizer for agriculture plants is still limited and is not insufficient to build interest of farmers to use it. Sometimes, the transport cost of bio-slurry is higher than the price of the product. If there is a market system for bio-slurry, it would give owners motivation to maintain their biodigester.

7. Conclusion

This paper shows the possibilities of biogas utilization, specifically biodigester utilization, as an infrastructure for waste management of cow manure in rural areas. Biodigesters can benefit cattle farmers by transforming cow manure to a source of energy and even fertilizer. Biogas in rural areas
can become an important solution in the reduction of waste (cow manure), as found in Kampung Areng, particularly for the neighborhoods close to the upstream of Cikapundung river.

There remain some challenges in the implementation of biogas digesters. Firstly, not all of the bio-slurry is used. Secondly, some of the beneficiaries of biogas projects still have to rely on LPG, particularly in the case of biodigesters with a smaller capacity (4 or 6 m³), because their stoves can only be used for 1-2 hours on biogas. Finally, there is no monitoring of the implementation of biodigesters, particularly those granted by the government, thus some biodigesters do not operate well.

Through collaboration between the government, INGO, unions and communities, farmers in Kampung Areng could gain benefits from utilizing biodigesters. However, in some households the biodigester is not working optimally after a number of years due to several issues, such as broken parts, not having enough cow manure (cows have been sold), and more user-friendly and easier sources of energy such as LPG. Based on this study, thee is a possibility to increase the capacity of biodigesters in Kampung Areng, Cibodas village. Maintenance and monitoring of implementation of biodigesters could optimize biogas utilization and creation of a market for bio-slurry can give farmers more motivation to use a biodigester.

References
[1] Tarigan AKM et al 2017 Balikpapan: Urban planning and development in anticipation of the post-oil industry era Cities 60(2017):246–59 A
[2] Fitriana I et al 2017 Indonesia Energy Outlook 2017 (Jakarta: Badan Pengkajian dan Penerapan Teknologi)
[3] Dincer I 2010 Renewable energy and sustainable development: a crucial review Renew Sustain Energy Rev 2000;4(2):157–75
[4] Meidiana C and Gamse T Development of Waste Management Practices in Indonesia Eur J Sci Res 40(2):199–210
[5] Pemerintah Republik Indonesia 2017 Rencana Umum Energi Nasional (Jakarta: Ministry of Energy and Mineral Resources of Indonesia)
[6] Perusahaan Listrik Negara 2017 Rencana Usaha Penyediaan Tenaga Listrik ( RUPTL ) Perusahaan Listrik Negara (Jakarta: Perusahaan Listrik Negara)
[7] Mengistu MG et al 2015 A review on biogas technology and its contributions to sustainable rural livelihood in Ethiopia Renew Sustain Energy Rev 48:306–16
[8] Deublein D and Steinhauser A 2008 Biogas from Waste and Renewable Resources (Weinheim: WILEY-VCH verlag GmbH & Co)
[9] Bajgain S 2011 Feasibility of Biogas in Sumba [Internet]. Hivos Org. 2011. Available from: https://hivos.org/sites/default/files/feasibility_of_biogas_in_sumba_.pdf
[10] van Ness WJ, Tumiwa F and Setyadi I 2009 Feasibility of a National Programme on Domestic Biogas in Indonesia: Final Report. SNV Netherl Organ Netherl
[11] Widodo TW and Hendriadi A 2005 Development of Biogas Processing for Small Scale Cattle Farm in Indonesia. Proc. Int. Semin. Biogas Technol Poverty Reduct Sustain Dev Beijing, 17-20 Oct 2005 (October):255–61
[12] Holm-Nielsen JB, Al Seadi T and Oleskowicz-Popiel P 2009 The future of anaerobic digestion and biogas utilization Bioreour Technol 100(22):5478–84
[13] Westerman PW and Bicudo JR 2005 Management considerations for organic waste use in agriculture Bioresour Technol 96(2):215–21
[14] Ni JQ and Nyns EJ 1996 New concept for the evaluation of rural biogas management in developing countries Energy Convers Manage 37(10):1525–34
[15] Aggarangsi P et al 2013 Overview of livestock biogas technology development and implementation in Thailand Energy Sustain Dev 17(4):371–7
[16] Cheng S et al Development and application of prefabricated biogas digesters in developing
[17] He PJ 2010 Anaerobic digestion: An intriguing long history in China Waste Manag 30(4):549–50
[18] Kazimierowicz J 2015 The Effect of Substrate on the Amount and Composition of Biogas in Agricultural Biogas Plant Pol Akad Nauk (III):809–18
[19] Rajendran K, Aslanzadeh S and Taherzadeh MJ 2012 Household biogas digesters-A review Energies 5(8):2911–42
[20] Plöchl M and Heiermann M 2006 Biogas Farming in Central and Northern Europe: A Strategy for Developing Countries Agric Eng Int VIII(8):1–15
[21] Hnyine ZT et al 2015 Analysing the economic benefits of rural biogas adoption in Selo Sub-District, Boyolali, Indonesia (Bandung: RDI)
[22] Sagala S et al 2015 Energy Resilient Village Potential In Boyolali, Indonesia (RDI Working Paper Series; Bandung: Indonesia)
[23] Al-faruq U et al 2016 Assessment of Renewable Energy Impact to Community Resilience in Sumba Island. In: Anwar H, editor. Masyarakat Tangguh Bencana
[24] Yayasan Rumah Energi. Tentang Bio-Slurry [Internet]. Biogas Rumah. Available from: http://www.biru.or.id/index.php/bio-slurry/