The potential and prospect of biomass as primary energy in Indonesia

A I D Lantasi*, Syafrudin2, Budiyono3

1Master program of Environmental Science, School of Postgraduate Studies, Diponegoro University
2Department of Environmental Engineering, Faculty of Engineering, Diponegoro University
3Department of Chemical Engineering, Faculty of Engineering, Diponegoro University

ayudyaaa@gmail.com

Abstract. Energy is one of the needs to support daily human activities. Without energy, various activities such as industry, health, and household will be disrupted. Total energy consumption in Indonesia in 2018 reached 875 million barrels of oil equivalent (BOE), which was dominated by fuel oil. It illustrates that national energy consumption is still dominated by primary energy sources originating from fossil fuels. Various previous studies have suggested the environmental and health impacts of air pollution from burning fossil fuels. This article will briefly discuss biomass as a primary energy source based on the results of literature studies. The discussion section will discuss the environmental impacts of biomass utilization based on several scientific studies and the form of biomass utilization in Indonesia that has been carried out. As a follow-up to several scientific facts, it is necessary to mix other primary energy from new and renewable energy sources.

1. Introduction
Based on the Energy outlook report in 2018, Indonesia’s energy consumption projection is still centered on fossil fuel in 2050, up to 40% of all types of energy resources. On the other hand, Indonesia has a target to reduce GHG emissions up to 29% and increase renewable energy utilization up to 23% of the overall energy source. For years, issues related to the availability of fossil fuel which is decreasing, are taken to account to find new energy resources that are more sustainable. One of the renewable energy sources is biomass from plants or animals. The abundance of biomass in Indonesia is 54% greater than in India but not utilized better than in India. It could be an opportunity to develop technology related to renewable energy from biomass [1–3]. This potential and problem need to be addressed to increase renewable energy in national energy sources.

As mentioned, fossil fuel usage needs to reduce and promote renewable energy more and biomass as alternatives for renewable energy. Biomass is one of the renewable energy sources whose availability is quite significant in Indonesia. Biomass which is widely used as fuel, is in the form of waste which has been utilized beforehand. Biomass is considered to have several advantages, namely that it can be renewed and is more guaranteed for its sustainability and sustainability. Apart from technology, in its development, one of the things that need to be considered is the environmental
impact arising from biomass as an energy source. One of the biomass that can be utilized is agricultural waste, especially crops [4, 5].

One example is the abundant production of rice crops. Rice husk makes up 23% of the total weight of rice plants. The abundant production of rice crops is not followed by proper utilization of its’ by-products [6, 7]. In Indonesia, most rice husk is used as growing media for plants, bricks, burned, or just being piled up. This potential biomass had a chance to support energy needs, but up until today, it is not being utilized properly. The proximate analysis shows that the lignocellulose structure is made up of rice husk [8]. This constituent material is one of the characteristics of a material that can produce high biogas and a barrier. Lignocellulose is the structure of plant cell walls which generally consists of lignin, cellulose, and hemicellulose. Hemicellulose and cellulose are polysaccharides consisting of sugar and glucose polymers, while lignin covers the hemicellulose structure, and cellulose has aromatic-phenolic solid bonds. The chemical structure is one of the obstacles to processing rice husks. Then one way to overcome this is by pre-treatment. It aims to break the complex chains in the lignocellulose structure to process the substrate more efficiently [5, 9, 10]. Apart from technology, in its development, one of the things that need to be considered is the environmental impact arising from the use of biomass as an energy source. Environmental impacts that need to be taken into account include land use and water consumption [11]. In addition, it is necessary to take into account the environmental impact of fuels derived from biomass [12, 13].

This paper will briefly review the primary energy from biomass. The discussion will lead to the characteristics and categorization of biomass as primary energy and its conversion to secondary energy. This paper will also briefly discuss the various existing biomass processing technologies and the impacts that may be caused by using biomass as an energy source. This paper will also present several issues related to biomass as an energy source, especially in Indonesia, and discuss them further based on several studies in international scientific journals. This paper is a mini-review from various international scientific journals conducted by the author.

2. Methodology
This article is compiled based on a scientific journal literature study with the keywords biomass, environmental impact (environmental impact), and energy in the last ten years (2011-2020). Scientific journals are selected from major international scientific journal publishers; namely, Elsevier and Springer were selected first through abstract analysis. In addition, there are also several research articles published as proceedings from international journals. Selected journal articles are articles that meet the criteria (1) discussing biomass energy conversion, (2) discussing the environmental impact of biomass energy use (3) Potential biomass energy production. Selected journal articles are used as references in writing this article. In addition, other data is obtained from the energy outlook report by the Agency for the Assessment and Application of Technology (BPPT) [4, 8].

3. Result and discussion

3.1. Biomass as primary energy
Primary energy is energy taken directly from nature. Primary energy has to be converted into secondary energy or usable products before used. Primary energy can be in the form of fossil fuels derived or biomass, solar energy, wind, water and nuclear. Biomass is a fuel that has long been used by humans since the use of firewood to generate heat through direct combustion [14]. This makes biomass one of the raw materials that can support the sustainability and sustainability of energy needs in the future. Biomass is an energy source that is harvested from waste products from various activities [15–17].

Biomass can be categorized into 3 types, namely primary, secondary and tertiary waste. In addition, biomass processing products as primary energy are categorized into 4 generations. Primary waste is generally the result of plantation and agricultural activities such as corn stalks, stalks, straw and leaves. Meanwhile, secondary waste is produced from food plant activities that have been
processed into products. Wood chips, coffee bean husks, rice husks, and palm shells. Tertiary waste is generated from the consumption of biomass by humans and / or animals. Tertiary waste that is commonly found is household waste which is then converted into sludge and / or waste water.

As technology develops, biomass can be obtained from agricultural and plantation waste [18–20], building and industrial waste [21] and household waste [22, 23]. Each biomass has different characteristics. Table 1 shows the chemical characteristics of each biomass. The differences in these characteristics will determine a more appropriate processing process to produce an optimum product.

| Biomass  | Cellulose | Hemicellulose | Lignin |
|----------|-----------|---------------|--------|
| Grass    | 25-40     | 35-50         | 10-30  |
| Wheat Straw | 39.2     | 26.1          | 21.1   |
| Rice Straw | 37.5-44  | 20.8-35       | 17-20  |
| Rice Husk | 24-30     | 20-29         | 17.7-19|
| Bagasse  | 45        | 20            | 30     |

Some biomass has a high lignocellulose content. This can be both an advantage and a hindrance. The chemical structure of the lignin bonds that surround cellulose and hemicellulose is a strong chain that can inhibit energy production [27]. This can be overcome by pre-treatment. The purpose of pre-treatment is to break the lignin structure in the biomass so that chemical processes can run more quickly (Figure 1). In studies [25, 28, 29] showed that by pre-treatment, biogas production can be increased compared to control. In different studies, SEM analysis showed that there was damage to the lignocellulose structure due to pre-treatment using NaOH [30].

### 3.2. Biofuel production process from biomass

![Lignocellulose structure illustration.](image)

Various kinds of technology are used and developed to utilize waste to produce bioenergy into many forms to support energy needs. These technologies and process options for biomass energy conversion
are carried out using the thermochemical and biochemical conversion [8, 14, 31]. Thermochemistry decompose biomass organic components using heat, whereas biochemical conversion uses microorganisms or enzymes. Thermochemical conversion includes pyrolysis, gasification, liquefaction, and combustion [31, 32] while biochemical conversion includes a choice of three processes known as anaerobic processes, fermentation and photo-biological reactions.

Thermochemical conversion involves a process with high temperatures that causes the breaking of chemical bonds and the re-formation of organic matter into bio-char, synthesis gas and bio-oil which is highly oxygenated. It is very important to know the properties and quantity of feedstock, the desired energy type, and the right project aspects to have the right conversion technology. Based on previous studies, thermal conversion technology received extra attention to its ability to supply high demands of energy, low water usage and short processing time. It’s process also independent of environmental conditions therefore, it is important to understand various thermochemical process to evaluate their potential [14].

Biochemical conversion includes the use of specific bacterial to convert biomass or waste into desired type of energy through anaerobic digestion, fermentation and photo-biological that produce various type of biofuels. Biochemical conversion often used in a smaller scale due to it dependency of the environment. Furthermore, biochemical conversion are widely used in rural are in Indonesia to support household needs in the kitchen [14, 33–35].

3.3. Biomass in Indonesia: potential and problems

Indonesia is considered as one of the countries with considerable biomass potential. The potential for biomass which is large enough to be used as primary energy faces various obstacles in the field. Based on data [36], Central Java’s rice production in 2018 reached 9 million tons of dry un-hulled rice, but the utilization of this biomass waste has not been widely used. Research [37] shows that Indonesia has a biomass potential from forests of 132 Peta Joules. In addition, biodiesel from palm oil is a potential alternative fuel to replace diesel for electricity generation in Indonesia [17]. However, policies and strategies for utilizing biomass as an energy source in Indonesia are no better than in India [38]. Research shows that local air pollution in Southeast Asia is dominated by biomass burning (48%). This figure has a value almost 2 times compared to air pollution caused by human activities and transportation of pollutants between regions/transboundary emissions [16]. Although the study did not explain the causes of biomass burning; whether natural or man-made, but this needs attention in order to improve environmental management. Burning of biomass, especially by humans, can be prevented if biomass can be used, one of which is the raw material for primary and secondary energy.

![Figure 2. Indonesia's primary energy mix [3, 39, 47].](image-url)
On the other hand, biomass technology is abandoned because it requires sufficiently up-to-date technology so that fossil energy such as coal, oil and natural gas are deemed cheaper [14]. This is in line with the Indonesia Energy Outlook report for 2018. The primary energy mix in Indonesia in 2018 still shows the dominance of the use of fossil fuels. Although there was an increase in the NRE mix compared to the primary energy mix in 2014 [39] (Figure 2), the data does not focus on the use of biomass as a primary energy source. In general, the projection of Indonesia's energy mix shows a decrease in the use of petroleum as primary energy and an increase in the NRE mix with a projection of 20% in 2030. Meanwhile, new coal has not changed too much. However, the 20% projection is below the Indonesian government's target of 23% in 2025. If things go as projected, not only will the energy mix target not be achieved, but the target for reducing air / greenhouse gas emissions cannot be achieved, namely by not more than 29% [40].

Another problem in utilizing biomass as a primary energy source is its impact on the environment. Various studies have shown that biomass is more environmentally friendly than other primary energy sources that come from fossil energy sources. However, some things that cannot be ruled out are environmental changes due to biomass such as changes in forest land cover to plantation / agricultural land, water use for the biomass conversion process, loss of animal habitat due to reduced forest area, etc. The ecological value that might be sacrificed due to the utilization of biomass is one of the dilemmas behind the environmental friendly and sustainable label which is put on the primary energy source from biomass.

One type of biomass that is widely used in Indonesia is livestock manure. The conversion of livestock manure to produce energy is generally through anaerobic processes which then produce several gases, one of which is methane gas [19, 41]. Generally, this program takes place in rural areas where the community owns livestock such as cows or buffaloes. Manure from livestock is used to harvest methane gas and use it as fuel for kitchen needs. The presence of the BIRU reactor can almost replace LPG and reduce the use of firewood. In addition, the presence of biogas can reduce the average financial expenditure on energy by 45% or about 3.5% of the total expenditure of each household in the study area [42].

The results of another study [43] also show a similar thing. In general, the level of biogas technology adoption among smallholders in the study area (Yogyakarta) is related to economic characteristics and access to biogas technology installation capital. In this study, it is known that biogas technology tends to be adopted by small farmers who have a formal educational background. In addition, farmers who have more livestock also tend to adopt biogas technology. In addition, the presence of biogas can reduce the use of firewood. Previously, each household used at least 115 MJ/day of energy for cooking activities with 80% using firewood. If a household decides to adopt biogas technology, that household can contribute to reducing 80% of its energy use from firewood for cooking. These changes can also have an impact on habits, especially for women. The adoption of this biogas technology is also able to reduce methane and nitrogen emissions, which are greenhouse gases, into the atmosphere. So that indirectly, the farming community in the study area can contribute to environmental improvement. However, what needs to be improved based on the results of the two studies is the use of bio-slurry from the reactor. Its use needs to be expanded and adapted to the needs of the location.

3.4. Environmental impacts
Environmental impacts will always exist as a consequence of human activities. Environmental impact analysis of an activity is an effort to manage the environment. Knowing the environmental impacts at the planning stage will describe the environmental impacts that may occur in the future and choose other scenarios that have a smaller impact but still support the planned activities. Utilization of biomass as an energy source is also inseparable from environmental risks that may arise. Based on [44] several environmental impacts that may occur as a result of biomass utilization are Large scale utilization of land and water resources, soil erosion, high water runoff, the loss of soil nutrition and
natural wildlife and biodiversity. Those are possible considering that a lot of biomass is produced from agricultural and plantation activities. However, impacts such as land use due to agricultural and plantation activities can be reduced if the biomass used is a by-product / waste. So that the purpose of planting biomass is not only intended to be harvested as a primary energy source, but its use as a primary energy source is one way out to reduce waste generation [14, 45].

Research [46] on biomass processing under different scenarios, AD (anaerobic digestion) has the lowest EIBP (environmental impact of biomass processing) for most feedstock, and has the lowest lower EIBP limit, implying that AD is possibly maintain an advantageous impact to the environment. Increasing carbon conversion and transferring elemental endpoints to less hazardous forms are the two main approaches to reducing EIBP. The energy conversion efficiency and EIBP are not always strongly correlated. This could be implied that the biomass combustion process should be considered separately from the environmental impacts. However, this does not cover the fact that biomass processing has a lower environmental impact in terms of carbon conversion. In a different study it was stated that the use of biodiesel from palm oil is estimated to be able to reduce cumulative emissions by 12.1% sulphur dioxide, 2.2% particulate matter, 0.6% carbon monoxide, 0.2% VOC and 0.1% nitrogen oxide. This figure is estimated to reduce the cost of externalities by up to USD32.5 billion [17]. In addition, the impact of climate change due to the use of biofuels as fuel has a lower value than fossil fuels. The research was conducted with a Life Cycle Assessment (LCA) model approach where LCA GHG emission from biofuels has a greater value than fossil fuels. Although research is considered uncertain because it is built based on a model, the use of biofuel / biomass as a fuel certainly has advantages because of its availability and renewable nature [12].

4. Conclusion

Biomass is one of the primary energy sources which is considered more environmentally friendly and easily renewable compared to fossil primary energy sources. The potential for biomass is quite large and its availability is very abundant, especially in Indonesia. However, their utilization in Indonesia is still low. In addition, biomass technology is considered to require quite up-to-date technology so that fossil energy such as coal, oil and natural gas is considered cheaper. Another thing that must be considered when utilizing biomass as an energy source, both primary and secondary, is its impact on the environment. Various studies have shown that the use of biomass as an energy source has positive environmental impacts. However, technical criteria for biomass utilization remain an important concern so that the resulting environmental impact remains minimal. Until now, the most widely applied biomass conversion in Indonesia is biogas. The program, which is carried out in rural areas, is able to reduce the use of firewood and help the farming community financially and indirectly contribute to environmental improvement. Various studies related to the environmental impact of biomass utilization are still needed to find out more about the possible environmental impacts of biomass utilization.

References

[1] Fotidis I A, Laranjeiro T F V C and Angelidaki I 2016 J Clean Prod 127 610–617
[2] Patowary D and Baruah D C 2018 Ind Crops Prod 124 735–746
[3] BBPT: Indonesia Energy Outlook 2018 Outlook Energi Indonesia 2018: energi berkelanjutan untuk transportasi darat
[4] Ge X, Xu F and Li Y 2016 Bioresour Technol 205 239–249
[5] Mothe S and Polisetty V R 2020 Environ Sci Pollut Res.
[6] Lim J S, Abdul Manan Z, Wan Alwi S R et al 2012 Renew Sustain Energy Rev 16 3084–3094
[7] Chitawo M L and Chimphango A F A 2017 Renew Sustain Energy Rev 75 58–67
[8] Abaide E R, Tres M V, Zabot G L et al 2019 Biomass and Bioenergy 120 240–256
[9] Xin L, Guo Z, Xiao X, et al 2019 Environ Sci Pollut Res 26 19434–19444
[10] Matin H H A and Hadiyanto 2018 E3S Web Conf 31
[11] Panigrahi S and Dubey B K 2019 Renew Energy 143 779–797
[12] Liu W, Xu J, Xie X, et al 2020 J Clean Prod 267 122061
[13] Mancini E, Arzoumanidis I and Raggi A 2019 J Clean Prod 214 927–938
[14] Lee S Y, Sankaran R, Chew K W, et al 2019 BMC Energy 1 1–22
[15] Permadi D A and Kim O N T 2013 Atmos Environ 78 250–258
[16] Yin S, Wang X, Zhang X, et al 2019 Environ Pollut 254 112949
[17] Indrawan N, Thapa S, Rahman S F et al 2017 Environ Technol Innov 7 110–127
[18] Avicenna, Mel M, Ihsan SI, et al 2015 Procedia Chem 14 91–100
[19] Dahunsi S O, Osueke C O, Olayanju T M A et al 2019 Bioresour Technol 283 229–241
[20] Elsoragaby S, Yahya A, Mahadi M R et al 2019 Energy 173 1285–1303
[21] Faisal M, Machdar I, Mulana F, et al 2014 Asian J Chem 26 6601–6604
[22] Xu Q, Qin J and Ko J H 2019 J Clean Prod 222 446–454
[23] Malinauskaite J, Jouhara H, Czajczyńska D et al 2017 Energy 141 2013–2044
[24] Huang Y-F and Lo S-L Utilization of rice hull and straw (AACC International Press)
[25] Dai B L, Guo X J, Yuan D H, et al 2018 Waste and Biomass Valorization 9 1503–1512
[26] Kumari D, Singh R 2018 Renew Sustain Energy Rev 90 877–891
[27] Chaturvedi V and Verma P 2013 J Biotech 3 415–431
[28] Nugraha W D, Syafrudin, Keumala C F, Hawali A M H and Budiyono 2018 E3S Web Conf. 31
[29] Syafrudin, Dwi N W, Hawali A M H, et al 2017 MATEC Web Conf; 101
[30] Syafrudin, Dwi N W, Annisa P S, et al 2020 E3S Web Conf; 202
[31] Bööner S, Devisscher T, Suljada T, et al 2019 Biomass and Bioenergy 122 457–465
[32] Ozturk M, Saba N, Altay V, et al 2017 Renew Sustain Energy Rev 79 1285–1302
[33] Scarlat N, Dallemagne J F and Fahl F 2018 Renew Energy 129 457–472
[34] Banja M, Jégard M, Motola V, et al 2019 Biomass and Bioenergy 128 105313
[35] Walter B d O S V, Leoneti A B, Magrini Caldo G M, et al 2011 Biomass and Bioenergy; 35 2608–2618
[36] BPS 2018 Luas Panen dan Produksi Padi di Jawa Tengah 2018, https://yogyakarta.bps.go.id/pressrelease/2018/11/01/893/luas-panen-dan-produksi-padi-di-d-i--yogyakarta-2018.html
[37] Simangunsong B C H, Sitranggang V J, Manurung E G T, et al 2017 For Policy Econ 81 10–17
[38] Singh R and Setiawan A D 2013 Renew Sustain Energy Rev 22 332–345
[39] Sugianto Y and Managi S 2016 Energy Policy 98 187–198
[40] Kementerian Lingkungan Hidup dan Kehutanan (KLHK) Update Komitmen Target Penurunan Emisi Indonesia 18 Februari 2020; 1
[41] Ali G, Bashir M K, Ali H, et al 2016 Renew Sustain Energy Rev 61 25–29
[42] Bedi A S, Sparrow R and Tasciotti L 2017 Energy Econ 68 66–76
[43] Ahmad R S P R, Liu Z and Lund M 2017 Renew Sustain Energy Rev 74 1371–1378
[44] Sayed E T, Wilberforce T, Elsaid K, et al 2020 Sci Total Environ 140808
[45] Khalil M, Berawi MA, Heryanto R, et al 2019 Renew Sustain Energy Rev 105 323–331
[46] Tao J, Hou L, et al 2020 J Clean Prod 261 121217
[47] BPPT 2020 Indonesia Energy Outlook 2020 - Special Edition Dampak Pandemi COVID-19 terhadap Sektor Energi di Indonesia Diterbitkan (Pusat Pengkajian Industri Proses dan Energi (PPIPE) Badan Pengkajian dan Penerapan Teknologi (BPPT))