Analysis of potency and development of renewable energy based on agricultural biomass waste in Jambi province

W H Devita¹, A M Fauzi¹ and Y A Purwanto²

¹Department of Agroindustrial Technology, Bogor Agricultural University, Indonesia
²Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia

E-mail: wildaharliadevita@gmail.com

Abstract. Indonesia has the big potency of biomass. The source of biomass energy is scattered all over the country. The big potential in concentrated scale is on the island of Sumatera. Jambi province which is located in Sumatra Island has the potency of biomass energy due to a huge area for estate crop and agriculture. The Indonesian government had issued several policies which put a higher priority on the utilization of renewable energy. This study aimed to identify the conditions and distribution of biomass waste potential in Jambi province. The potential biomass waste in Jambi province was 27,407,183 tons per year which dominated of oil palm residue (46.16%), rice husk and straw (3.52%), replanting rubberwood (50.32%). The total power generated from biomass waste was 129 GWhₑ per year which is consisted of palm oil residue (56 GWhₑ per year), rice husk and straw (3.22 GWhₑ per year), rubberwood (70.56 GWhₑ per year). Based on the potential of biomass waste, then the province of Jambi could obtain supplies of renewable energy from waste biomass with electricity generated amount to 32.34 GWhₑ per year.

1. Introduction

Indonesia today is currently facing energy problems. Indonesian energy condition that occurs due to the growth in energy consumption that has not been matched by sufficient energy supply, the increased of energy consumption by an average of 3.46% per year [1]. Energy supply crises that have been facing by Indonesia has pushed the government to issue a policy on the utilization of renewable energy to meet energy needs. One of the policies that have issued attached to the Presidential Decree No. 2 of 2015 on the National Medium Term Development Plan (RPJMN) 2015-2019. The policy is explicitly state that the issue of 2015-2019 science and technology development strategy was the increase of science and technology capacity of the ability to give a real contribution to the competitiveness of the production sector, sustainability and utilization of natural resources, and the preparation of Indonesian society to meet the advanced and modern global life. Furthermore, the research focused on the mandated areas of Long-Term Development Plan (RPJPN) 2005-2025, which is new and renewable energy as it mentioned in the regulation.

Biomass is a renewable resource, and the energy from it called renewable energy [2]. The most suitable biomass as energy resources is biomass with the low economic value. An ideal type of biomass to be utilized is biomass that has lost the primary product. Currently, biomass potential in Indonesia that can be used for energy generation is available in a waste of agricultural, plantation, forest and livestock [3]. Biomass for energy has the highest value because it’s characteristics. Some of
the characteristics are renewable and sustainable, can be stored, replaced, and transported, high of availability, and carbon neutral. Biomass from waste (agricultural, plantation, forest and livestock) and garbage waste can be an environmentally friendly source of energy because biomass is derived from non-fossil organic materials that produced non-pollutants CO₂ from it burning results [2].

Jambi province has the biggest biomass potential sources in some area. The potential sources came from agricultural, plantation, forest, livestock and municipal waste. Each region in Jambi province produces biomass from waste by palm oil, coconut, rice, cassava, maize, rubber, cow liquid waste, municipal waste, pulp, industrial forest, and wood industry. The information from data that accessed through the website from Directorate General of Estate Crops (Ditjenbun) and Central Agency of Statistics (BPS) of Jambi province. It is known that solid waste from plantation and processing industry of palm oil, rubber and rice milling waste have the most potential biomass source to be developed into energy generation. In 2014, Jambi province had a palm oil plantation area fixed a total of 692,967 ha, and the agricultural area had a rice harvesting fixed a total of 145,990 ha [4, 5]. Rubber plantation area fixed a total of 664,704 ha in 2015 [12].

Renewable energy development potency in Jambi province is quite large to produce energy from biomass, hence the objectives of this study were to identify the potential condition and distribution of agricultural solid waste biomass that can be utilized in each region. As is known the land area that has the highest value in Jambi province are palm oil with total production by 1,773,735 tons per year, rice by 664,720 tons per year and rubber by 328,581 tons per year [4, 5, 12]. The identification result of the potential condition and agricultural waste distribution are expected to be used as information for utilization in renewable energy development.

1.1. Production and total area of crops

Palm oil production increased the amount to 774,116 tons from 2006 to 2015. The increase in palm oil production by an average of 8.78% per year in eight times increased within ten years. At the same period, an increase occurred average palm oil area total 8.89%, i.e. 46,437 ha in seven times. The highest increase of palm oil production occurred in 2012, with an increase 459,449 tons also corresponded to 32.22% of the production total 1,426,081 tons. The highest increase in palm oil area totals up to 29.23%. Despite production decreased 7.21% in 2013 and area total decreased average 2.55% in 2010 and 2013, palm oil production tends to increase. The production changes more clearly are shown in figure 1.

![Figure 1. Trend of palm oil production and plantation area in 2006-2015.](source: [11, 12, 14, 18, 19])
From the results rice production data, known 2005 to 2015 the change annually. Rice production decreased the amount to 38,149 tons (6.58%) from 2005 to 2015. Changes in production were averaged 5.90% per year with an average increase of 5.55% from 579,635 tons to 541,486 tons in five times increased within ten years. The highest increase of production amount occurred in 2009 by 63,243 tons, corresponded to 10.87% of the total production 581,704 tons in 2008. At the same time of production changes, total rice area decreased the amount to 32,727 ha (21.12%) from 2005 to 2015. The lowest production decreased down to 18.54% in 2015. Annually an average change 7,343 ha (5.03%) with an average increase up to 5.10% from 154,941 ha to 122,214 ha in four times increased. The production changes more clearly are shown in figure 2.

![Figure 2](image1.png)

**Figure 2.** Trend of rice production and rice harvesting area in 2005-2015. Source: [5, 12, 14, 15, 16, 17]

The total increase in production and a rubber plantation area from 2006 to 2015 by 22% and 24%. Amount of production increase and plantation area is 62,318 tons and 131,455 ha. Increased production of the total production of 266,263 tons in 2006 and the total production of 328,581 tons in

![Figure 3](image2.png)

**Figure 3.** Trend of rubber production and rubber plantation area in 2006-2015. Source: [12]
2015. While the increase in rubber plantation area of the total area of 533.249 ha in 2006 and 664.704 ha in 2015. The average number of changes in rubber production each year is 2.40% with production value average is 6.92 tons and an average number of changes in rubber plantation area per year is 2.63% with plantations area value average is 131.455 ha in seven times increased. An increased average amount of rubber production is 3.28% meanwhile plantations area 3.48%. The production changes more clearly are shown in figure 3.

1.2. Waste biomass potency for a renewable energy source

The biomass potency of palm oil is produced by during activity in the palm oil processing industry and oil palm plantation. The waste composition of biomass production solid waste during palm oil processing industry activity are 5-7% shell, 11-12% fiber, 20-23% empty fruit bunch (EFB) of fresh fruit bunch (FFB) and biomass production from palm frond during activity in oil palm plantation is 8.4 ton/ha per year [8]. During harvest, harvested paddy is cut off, and the biomass from husk 8.4 % and 58% straw are produced during rice mill activity [8]. While biomass from rubberwood is produced during replanting activity in rubber plantation 21.8 ton/ha per year [9].

| Waste          | Calorific value (kcal/kg) |
|----------------|---------------------------|
| Shell          | 4105-4802                 |
| Fiber          | 2637-4554                 |
| EFB            | 4492                      |
| Frond          | 3757                      |
| Rubberwood     | 4400                      |
| Husk           | 3350                      |
| Straw          | 2800                      |

Source: [7, 8]

The direct combustion process is the most convenient and conventional in the thermal conversion technology of biomass. Biomass is burned directly without any material process. Using additional generators to obtain electricity. This method is mostly using in factories that use waste as fuel [6]. The efficiency of biomass energy is approximately 20-25 percent to generate electricity [13].

2. Methodology

This study consists of a literature study and secondary data collection. Secondary data collection based on Ministry of Agriculture’s data that is obtained by Directorate General of Estate Crops (Ditjenbun) database and Central Agency of Statistics (BPS) database of Jambi province. The statistics that were collected is the area of oil palm plantation, rubber plantation area, palm oil production, and rice harvest area. The waste biomass calculated from the statistic data. Descriptive analysis was used to explain and describe the condition and potential agricultural waste biomass of plantation and palm oil processing, rubber and rice mill. Descriptive analysis used tabulation to providing the detailed explanation. Forecasting method was used to estimate the availability of production and total area to produce the biomass from waste to generate power of thermal and electricity to 2025. The technique used in this method was time series analysis, mathematical equation by double exponential smoothing. Data analysis of biomass waste potency in Jambi Province was carried out to identify the potency, location of waste biomass for a renewable energy source.
3. Result and discussion

3.1. Potential of agricultural waste biomass

Agricultural waste biomass potential that has calculated are a shell, fiber, EFB, frond, husk, straw, and rubberwood with waste total volume 27,407,183 tons per year. As based on table 2, the rubberwood waste biomass obtained from replanting activity in rubber plantations was 13,790,997 tons also corresponded to 50.32% of the agricultural waste production total volume. The calculated rubber waste biomass is rubberwood of replanting. Rubber trees in plantations are replanted 3-4% per year and produce an average rubberwood of 35 m\(^3\) per year or 21.5 ton/ha per year [9]. Palm oil waste biomass production was 12,651,965 or 46.16%, then 3.52% waste biomass by rice. Among the seven kinds of waste, rubberwood was the highest value with power reaching 70,559 MWh\(_{th}\) (54.55%) then followed by frond 40.83%, straw 2.12%, EFB 1.25%, fiber 0.53%, husk 0.37%, and the smallest by shell 0.69%, from the power total potency up to 129,351 MWh\(_{th}\) and 32,339 MWh\(_{e}\).

Table 2. The annual average of agricultural waste potency in Jambi province 2015

| Production | Volume (ton) | Waste (ton) | Thermal (MWh\(_{th}\)) | Electrical (MWh\(_{e}\)) |
|------------|-------------|-------------|------------------------|------------------------|
| Palm oil   | 1,439,359   | Shell 86,362 | 447 112                |
|            |             | Fiber 165,526 | 692 173                |
|            |             | EFB 309,462  | 1,616 404              |
|            |             | Frond 12,090,615 | 52,820 13,205         |
| Rice       | 609,899     | Husk 121,980  | 475 119                |
|            |             | Straw 842,241 | 2,742 686              |
| Rubber     | 641,442     | Rubberwood 13,790,997 | 70,559 17,640         |

Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 17, 18, 19]

The potency calculation result detailed of waste biomass by Regency/city in Jambi province can be seen in table 2. From table 2 is known, a waste biomass obtained from Merangin regency is the area that has the highest biomass production value. The biomass production value was 3,356,5748 tons or 16.75% of the total volume of agricultural waste biomass potential with power total potency up to 105,438 MW\(_{th}\) and 26,361 MW\(_{e}\). Second place of the highest biomass production value is Sarolangun regency with biomass production value 3,214,597 tons. Followed continuity Batanghari regency 3,036,193 tons, Tebo regency 2,867,981 tons, Bungo regency 2,770,642 tons, Muaro Jambi Regency 2,495,561 tons, Tanjung Jabung Barat 1,422,126 tons, Tanjung Jabung Timur 568,678 tons, Kerinci regency 240,149 tons and the lowest biomass production value are Sungai Penuh regency 62,811 tons and Jambi city 6,429 tons. Sungai Penuh regency and Jambi city are areas that have the lowest potential value caused the area did not have oil palm and rubber plantations and effected to waste biomass production total.

3.2. Projection Biomass Production as Renewable Energy Source

From forecasting results, the increased trend of palm oil, rice, and rubber production several years to come was estimated. Estimation result shows that there will be an increase in agriculture production 2,814,153 ton in 2025. Increase in production will be related to the increased area, therefore Jambi province will continue to produce biomass as a source of renewable energy materials. Each agricultural production increased graphics more clearly are shown in figure 4, 5, and 6. The potential production waste from palm plantations and industry, rice mills and rubber in the future is huge. Based on table 4, it is known that the estimated amount of agricultural waste biomass production from palm plantations and industry, rice mills and rubber, annually from 2016-2025 in Jambi province.
Table 3. The annual average of agricultural waste in Jambi province 2006-2015 by regency/city

| Regency/City          | Production Waste biomass (ton) | Thermal (MWh<sub>th</sub>) | Electrical (MWh<sub>e</sub>) |
|-----------------------|--------------------------------|-----------------------------|------------------------------|
| Batanghari            | Palm oil                        |                             |                              |
|                       | Shell                           | 12.654                      | 66                           | 16                           |
|                       | Fiber                           | 24.254                      | 101                          | 25                           |
|                       | EFB                             | 45.344                      | 237                          | 59                           |
|                       | Frond                           | 668.925                     | 4,091                        | 1,023                        |
|                       | Rice                            | 7234                        | 28                           | 7                            |
|                       | Husk                            | 49,950                      | 163                          | 41                           |
|                       | Straw                           | 2,227,832                   | 11,398                       | 2,850                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 3,036,193                   | 16,084                       | 4,021                        |
|                       | Total                           |                               |                              |                              |
| Muaro Jambi           | Palm oil                        | 18.323                      | 95                           | 24                           |
|                       | Shell                           | 35.136                      | 147                          | 37                           |
|                       | Fiber                           | 65.869                      | 343                          | 86                           |
|                       | EFB                             | 1,030,982                   | 6,306                        | 1,576                        |
|                       | Frond                           | 7941                        | 31                           | 8                            |
|                       | Rice                            | 54,828                      | 179                          | 45                           |
|                       | Husk                            | 1,282,653                   | 6,562                        | 1,641                        |
|                       | Straw                           | 2,495,561                   | 13,663                       | 3,417                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 9.994                       | 52                           | 13                           |
|                       | Palm oil                        | 24.154                      | 80                           | 20                           |
|                       | Fiber                           | 35.810                      | 187                          | 47                           |
|                       | EFB                             | 568.075                     | 3,475                        | 869                          |
|                       | Frond                           | 8020                        | 31                           | 8                            |
|                       | Rice                            | 55.374                      | 180                          | 45                           |
|                       | Husk                            | 2,074,215                   | 10,612                       | 2,653                        |
|                       | Straw                           | 2,770,642                   | 14,617                       | 3,655                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 2,867,981                   | 14,952                       | 3,737                        |
|                       | Total                           |                               |                              |                              |
| Tebo                 | Palm oil                        | 6.871                       | 36                           | 9                            |
|                       | Shell                           | 13.170                      | 55                           | 14                           |
|                       | Fiber                           | 24.623                      | 129                          | 32                           |
|                       | EFB                             | 374.222                     | 2,289                        | 572                          |
|                       | Frond                           | 6299                        | 25                           | 6                            |
|                       | Rice                            | 43.495                      | 142                          | 35                           |
|                       | Husk                            | 2,399,301                   | 12,276                       | 3,069                        |
|                       | Straw                           | 2,877,041                   | 14,952                       | 3,737                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 10.575                      | 55                           | 14                           |
|                       | Palm oil                        | 20.269                      | 85                           | 21                           |
|                       | Fiber                           | 37.894                      | 198                          | 49                           |
|                       | EFB                             | 466.187                     | 2,851                        | 713                          |
|                       | Frond                           | 13.502                      | 53                           | 13                           |
|                       | Rice                            | 3.214,597                   | 15,277                       | 3,319                        |
|                       | Husk                            | 2,955,110                   | 16,755                       | 4,189                        |
|                       | Straw                           | 77168                       | 251                          | 62                           |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 7,872,542                   | 5,400                        | 1,350                        |
|                       | Total                           |                               |                              |                              |
| Sarolangun            | Palm oil                        | 8.456                       | 44                           | 11                           |
|                       | Shell                           | 16.207                      | 68                           | 17                           |
|                       | Fiber                           | 30.300                      | 158                          | 40                           |
|                       | EFB                             | 476.180                     | 2,913                        | 728                          |
|                       | Frond                           | 11,176                      | 44                           | 11                           |
|                       | Rice                            | 77168                       | 251                          | 62                           |
|                       | Husk                            | 2,955,110                   | 15,277                       | 3,319                        |
|                       | Straw                           | 7,872,542                   | 5,400                        | 1,350                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 3,138,764                   | 17,437                       | 4,359                        |
|                       | Total                           |                               |                              |                              |
| Tanjung Jabung Barat  | Palm oil                        | 17,282                      | 89                           | 22                           |
|                       | Shell                           | 33.123                      | 138                          | 35                           |
|                       | Fiber                           | 61.925                      | 323                          | 81                           |
|                       | EFB                             | 882.942                     | 5,400                        | 1,350                        |
|                       | Frond                           | 13.584                      | 53                           | 13                           |
|                       | Rice                            | 93,795                      | 305                          | 76                           |
|                       | Husk                            | 319,475                     | 1,635                        | 409                          |
|                       | Straw                           | 1,422,126                   | 7,943                        | 1,986                        |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 1,422,126                   | 7,943                        | 1,986                        |
|                       | Total                           |                               |                              |                              |
| Tanjung Jabung Timur  | Palm oil                        | 2,198                       | 11                           | 3                            |
|                       | Shell                           | 4,212                       | 18                           | 4                            |
|                       | Fiber                           | 7,875                       | 41                           | 10                           |
|                       | EFB                             | 257,103                     | 1,573                        | 393                          |
|                       | Frond                           | 186.16                      | 73                           | 18                           |
|                       | Rice                            | 128,539                     | 419                          | 105                          |
|                       | Husk                            | 150,135                     | 768                          | 192                          |
|                       | Straw                           | 568,678                     | 2,903                        | 725                          |
|                       | Rubber                          |                               |                              |                              |
|                       | Rubberwood                      | 2,401,149                   | 853                          | 213                          |
|                       | Total                           |                               |                              |                              |
| Sungal Penuh          | Rice                            | 7946                        | 31                           | 8                            |
|                       | Husk                            | 54,865                      | 179                          | 45                           |
|                       | Straw                           | 62,811                      | 210                          | 53                           |
|                       | Total                           |                               |                              |                              |
| Jambi                | Rice                            | 813                         | 3                            | 1                            |
|                       | Straw                           | 5,616                       | 18                           | 5                            |
|                       | Total                           | 6,429                       | 21                           | 6                            |
|                       | Total                           | 20,041,915                  | 105,438                      | 26,361                        |
Figure 4. Palm oil production projected graphics in 2006-2025. Source: Processed secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

Figure 5. Rice production projected graphics in 2005-2025. Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]
Figure 6. Rubber production projected graphics in 2006-2025.
Source: Processed from secondary data [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

Table 4. Estimated production of biomass from agricultural waste in 2016-2025.

| Year | Palm oil (ton) | Rice (ton) | Rubber (ton) |
|------|----------------|------------|--------------|
|      | Shell | Fiber | EFB | Frond | Husk | Straw | Rubberwood |
| 2016 | 119,111 | 228,297 | 426,816 | 6,300,609 | 135,753 | 937,341 | 16,126,559 |
| 2017 | 124,638 | 238,889 | 446,619 | 6,566,439 | 137,802 | 951,493 | 17,487,356 |
| 2018 | 130,164 | 249,481 | 466,422 | 6,832,269 | 139,852 | 965,643 | 18,167,756 |
| 2019 | 135,691 | 260,074 | 486,225 | 7,098,100 | 141,901 | 979,795 | 18,848,154 |
| 2020 | 141,217 | 270,666 | 506,028 | 7,363,930 | 143,951 | 993,947 | 19,528,560 |
| 2021 | 146,744 | 281,258 | 525,831 | 7,629,763 | 146,001 | 1,008,099 | 20,208,958 |
| 2022 | 152,270 | 291,851 | 545,634 | 7,895,593 | 148,050 | 1,022,251 | 20,889,357 |
| 2023 | 157,796 | 302,443 | 565,437 | 8,161,423 | 150,100 | 1,036,403 | 21,569,756 |
| 2024 | 163,323 | 313,035 | 585,240 | 8,427,253 | 152,149 | 1,050,555 | 22,250,155 |
| 2025 | 168,849 | 323,628 | 605,043 | 8,693,084 | 154,199 | 1,064,707 | 22,930,556 |

Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

Table 5. Estimated waste biomass potency for a renewable energy source in 2016-2025.

| Year | Palm oil (MWh)<sub>ha</sub> | Rice (MWh)<sub>ha</sub> | Rubber (MWh)<sub>ha</sub> |
|------|-----------------------------|--------------------------|---------------------------|
|      | Shell | Fiber | EFB | Frond | Husk | Straw | Rubberwood |
| 2016 | 617 | 954 | 2,229 | 27,525 | 529 | 3,052 | 82,509 |
| 2017 | 645 | 999 | 2,333 | 28,686 | 537 | 3,098 | 85,990 |
| 2018 | 674 | 1043 | 2,436 | 29,848 | 545 | 3,144 | 89,471 |
| 2019 | 703 | 1087 | 2,540 | 31,099 | 553 | 3,190 | 92,952 |
| 2020 | 731 | 1132 | 2,643 | 32,170 | 561 | 3,236 | 96,433 |
| 2021 | 760 | 1176 | 2,747 | 33,332 | 569 | 3,282 | 99,914 |
| 2022 | 789 | 1220 | 2,850 | 34,493 | 577 | 3,328 | 103,395 |
| 2023 | 817 | 1264 | 2,953 | 35,654 | 585 | 3,374 | 106,877 |
| 2024 | 846 | 1309 | 3,057 | 36,816 | 593 | 3,420 | 110,358 |
| 2025 | 874 | 1353 | 3,160 | 37,977 | 601 | 3,467 | 113,839 |

Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]
Table 6. Estimated waste biomass potency for electricity in 2016-2025

| Year | Palm oil (MWhₑ) | Rice (MWhₑ) | Rubber (MWhₑ) |
|------|-----------------|-------------|---------------|
|      | Shell | Fiber | EFB | Frond | Husk | Straw | Rubberwood |
| 2016 | 154   | 239   | 557 | 6,881 | 132  | 763   | 20,627     |
| 2017 | 161   | 250   | 583 | 7,172 | 134  | 774   | 21,497     |
| 2018 | 169   | 261   | 609 | 7,462 | 136  | 786   | 22,368     |
| 2019 | 176   | 272   | 635 | 7,752 | 138  | 798   | 23,288     |
| 2020 | 183   | 283   | 661 | 8,043 | 140  | 809   | 24,108     |
| 2021 | 190   | 294   | 687 | 8,333 | 142  | 821   | 24,979     |
| 2022 | 197   | 305   | 713 | 8,623 | 144  | 832   | 25,849     |
| 2023 | 204   | 316   | 738 | 8,914 | 146  | 844   | 26,719     |
| 2024 | 211   | 327   | 764 | 9,204 | 148  | 855   | 27,589     |
| 2025 | 219   | 338   | 790 | 9,494 | 150  | 867   | 28,460     |

Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

Results of analysis on biomass potency show that there is going trend in raw material for renewable energy. Based on table 5 and 6, it is known that the estimated amount of thermal and electrical annually from 2016-2025 will increase every years.

Conclusion

Waste that has the highest potential to be developed into a source of renewable energy raw materials from waste biomass in Jambi province is replanting rubberwood which has 68.81% biomass production percentage of waste biomass potential in Jambi province. There are 11 areas in Jambi province consist of 10 regencies and 1 city that have potential to be developed into a source of renewable energy. The highest percentage of waste biomass potential is Merangin regency. The total raw materials from potential waste in Jambi province consisted of: Merangin (16.75%), Sarolangun (16.04%) Batanghari (15.15%), Tebo (14.31%), Bungo (13.82%), Muaro Jambi (12.45%), Tanjung Jabung Barat (7.10%), Tanjung Jabung Timur (2.84%), Kerinci (1.20%), Sungai Penuh (0.31%), and Jambi city (0.03%).

References
[1] BPPT 2015 Indonesia Energy Outlook 2015, ed A Sugiyono et al. (Jakarta: Center for Energy Resources Development Technology) p 11
[2] Yokoyama S 2008 Asian Biomass Handbook, ed S Yokoyama et al. (Jakarta: The Japan Institute of Energy) p 16
[3] Hermawati W 2014 Biomass Conversion for Alternative Energy in Indonesia: A Review of Resources, Technology, Management, and Policy, ed H Abimanyu and S Hendarana (Jakarta: LIPI Press) p 14
[4] Ditjenbun 2015 Tree Crop Estate Statistics of Indonesia 2014-2016, ed M E Subiyantoro et al. (Jakarta: Directorate General of Estate Crops) pp 18-51
[5] BPS 2016 Jambi in Figures 2016, ed Division of Data Processing Integration and Statistical Dissemination (Jambi: Statistic of Jambi Province) pp 325-327
[6] Kong GT 2002 Biomass Conversion for Alternative Energy in Indonesia: A Review of Resources, Technology, Management, and Policy, ed H Abimanyu and S Hendarana (Jakarta: LIPI Press) pp 88-89
[7] Budiarto R and Agung A 2009 Potential of Energy from Palm Oil Mill Waste (Malang: Brawijaya University) p 6
[8] Tajali A 2015 Guide to Assessing Biomass Potential as an Alternative Energy Source in Indonesia (Jakarta: Penabulu Alliance) pp 7-11
Sudrajat R 2004 *The Potential of Biomass Energy Resources in Indonesia for the Possible Development of Clean Technology Process (CTP)* (Jakarta: Center for Energy Resources Development Technology)

Directorate General of New Renewable Energy and Energy Conservation Ministry of Energy and Mineral Resources 2013 *Map of Biomass Resources in Indonesia 2012-2013* (Jakarta: Directorate General of New Renewable Energy and Energy Conservation)

Ditjenbun 2016 *Tree Crop Estate Statistics of Indonesia 2015-2017*, ed W K Zuraina et al. (Jakarta: Secretariate of Directorate General of Estate Crops) p 21

BPS 2017 *Plantation Crop Production by Regency/City* (Jambi: Statistic of Jambi Province)

BERC 2009 *Biomass Energy: Efficiency, Scale, and Sustainability* (Montpelier: Biomass Energy Resource Center) p 1

BPS 2016 *Agricultural Surveys: Rice Production of Jambi Province 2015* (Jambi: Statistic of Jambi Province) pp 14-49

BPS 2010 *Jambi in Figures 2010*, ed Division of Data Processing Integration and Statistical Dissemination (Jambi: Statistic of Jambi Province) p 303

BPS 2012 *Jambi in Figures 2011*, ed Regional Account and Statistical Analysis Division (Jambi: Statistic of Jambi Province) p 303

BPS 2012 *Jambi in Figures 2012*, ed Division of Data Processing Integration and Statistical Dissemination (Jambi: Statistic of Jambi Province) p 303

Ditjenbun 2014 *Tree Crop Estate Statistics of Indonesia 2013-2015*, ed I Y Soependi et al. (Jakarta: Directorate General of Estate Crops) pp 21-51

Ditjenbun 2013 *Tree Crop Estate Statistics of Indonesia 2012-2014*, ed B S Juga et al. (Jakarta: Directorate General of Estate Crops) pp 21-51