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

W H Devita[1], A M Fauzi[1] and Y A Purwanto[2]

[1] Department of Agroindustrial Technology, Bogor Agricultural University, Indonesia
[2] Department 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 GWh_{th} per year which is consisted of palm oil residue (56 GWh_{th} per year), rice husk and straw (3.22 GWh_{th} per year), rubberwood (70.56 GWh_{th} 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 GWh_e 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 CO_2 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.

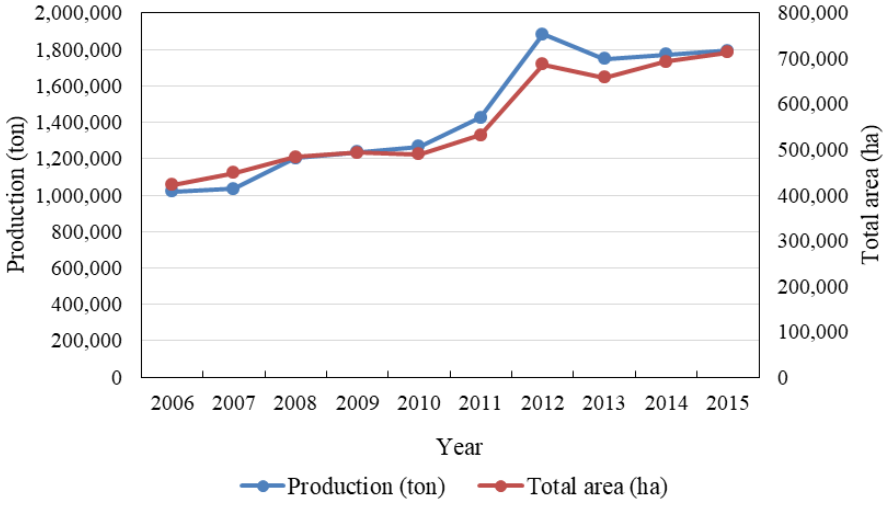

Figure 1. Trend of palm oil production and plantation area in 2006-2015.
Source: [11, 12, 14, 18, 19]

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.

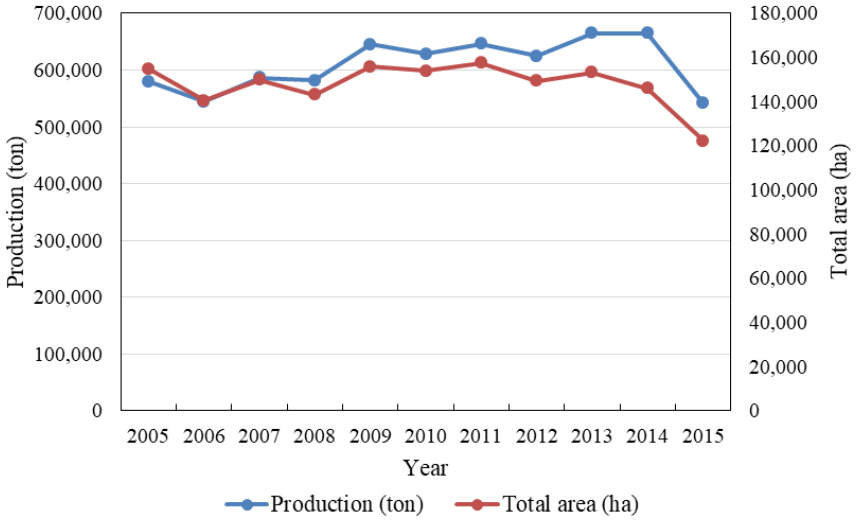

Figure 2. Trend of rice production and rice harvesting area in 2005-2015.
Source: [5, 12, 14, 15, 16, 17]

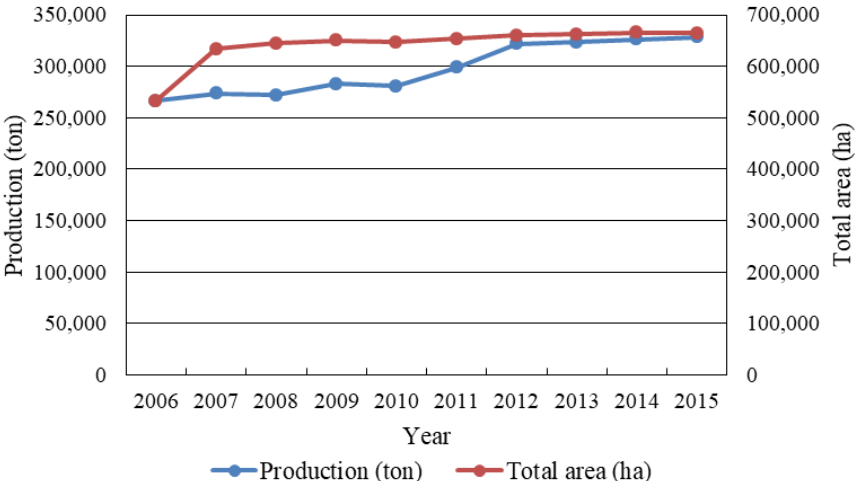

Figure 3. Trend of rubber production and rubber plantation area in 2006-2015.
Source: [12]

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

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 6.924 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].

Table 1. The calorific value of potential waste

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
Rice	609,899	Frond	12,090,615	52,820	13,205
		Husk	121,980	475	119
		Straw	842,241	2,742	686
	Area (ha)				
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 MWhth and 26,361 MWhe. 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_{th})	Electrical (MWh_e)
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	Husk	7234	28	7
		Straw	49,950	163	41
	Rubber	Rubberwood	2,227,832	11,398	2,850
Total			3,036,193	16,084	4,021
Muaro Jambi	Palm oil	Shell	18,332	95	24
		Fiber	35,136	147	37
		EFB	65,689	343	86
		Frond	1,030,982	6,306	1,576
	Rice	Husk	7941	31	8
		Straw	54,828	179	45
	Rubber	Rubberwood	1,282,653	6,562	1,641
Total			2,495,561	13,663	3,417
Bungo	Palm oil	Shell	9,994	52	13
		Fiber	19,154	80	20
		EFB	35,810	187	47
		Frond	568,075	3,475	869
	Rice	Husk	8020	31	8
		Straw	55,374	180	45
	Rubber	Rubberwood	2,074,215	10,612	2,653
Total			2,770,642	14,617	3,655
Tebo	Palm oil	Shell	6,871	36	9
		Fiber	13,170	55	14
		EFB	24,623	129	32
		Frond	374,222	2,289	572
	Rice	Husk	6299	25	6
		Straw	43,495	142	35
	Rubber	Rubberwood	2,399,301	12,276	3,069
Total			2,867,981	14,952	3,737
Merangin	Palm oil	Shell	10,575	55	14
		Fiber	20,269	85	21
		EFB	37,894	198	49
		Frond	466,187	2,851	713
	Rice	Husk	13502	53	13
		Straw	93,230	304	76
	Rubber	Rubberwood	2,715,091	13,891	3,473
Total			3,356,748	17,437	4,359
Sarolangun	Palm oil	Shell	8,456	44	11
		Fiber	16,207	68	17
		EFB	30,300	158	40
		Frond	476,180	2,913	728
	Rice	Husk	11176	44	11
		Straw	77,168	251	63
	Rubber	Rubberwood	2,595,110	13,277	3,319
Total			3,214,597	16,755	4,189
Tanjung Jabung Barat	Palm oil	Shell	17,282	89	22
		Fiber	33,123	138	35
		EFB	61,925	323	81
		Frond	882,942	5,400	1,350
	Rice	Husk	13584	53	13
		Straw	93,795	305	76
	Rubber	Rubberwood	319,475	1,635	409
Total			1,422,126	7,943	1,986
Tanjung Jabung Timur	Palm oil	Shell	2,198	11	3
		Fiber	4,212	18	4
		EFB	7,875	41	10
		Frond	257,103	1,573	393
	Rice	Husk	18616	73	18
		Straw	128,539	419	105
	Rubber	Rubberwood	150,135	768	192
Total			568,678	2,903	725
Kerinci	Palm oil	Shell	1	0.003	0.001
		Fiber	1	0.005	0.001
		EFB	2	0.012	0.003
		Frond	646	4	1
	Rice	Husk	26848	105	26
		Straw	185,380	604	151
	Rubber	Rubberwood	27,271	140	35
Total			240,149	853	213
Sungai Penuh	Rice	Husk	7946	31	8
		Straw	54,865	179	45
Total			62,811	210	53
Jambi	Rice	Husk	813	3	1
		Straw	5,616	18	5
Total			6,429	21	6
Total			20,041,915	105,438	26,361

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

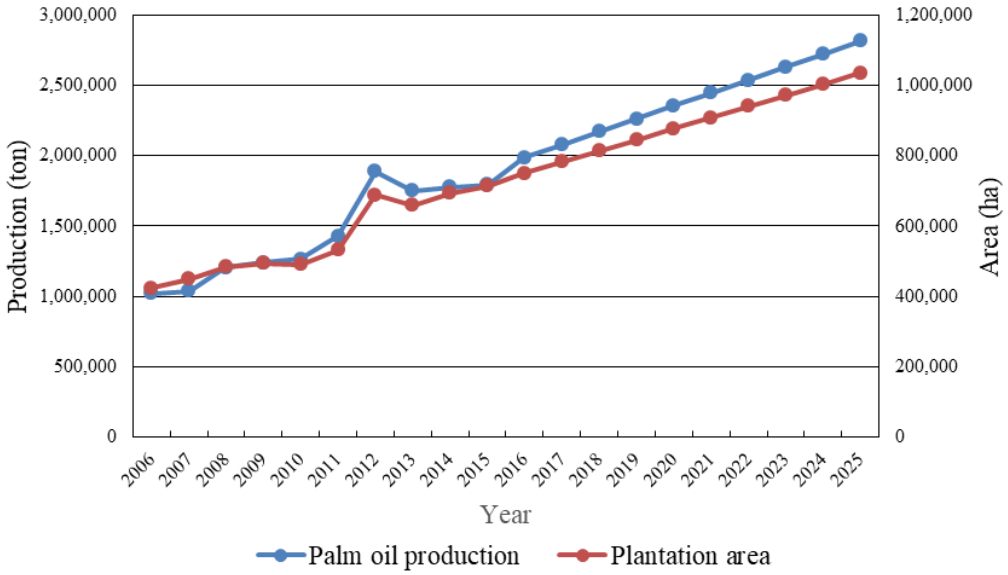

Figure 4. Palm oil production projected graphics in 2006-2025.
Source: Processed secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

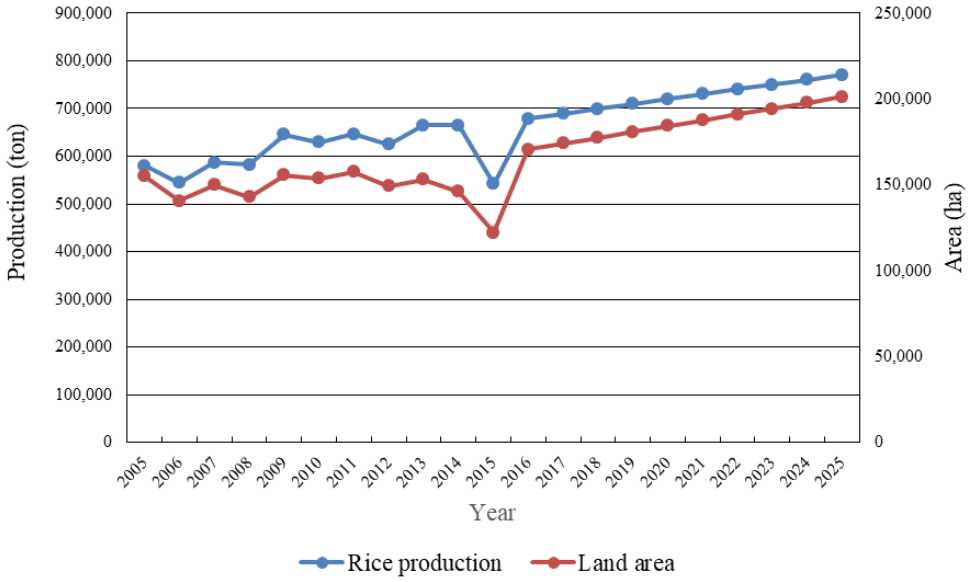

Figure 5. Rice production projected graphics in 2005-2025.
Source: Processed from secondary data based on [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

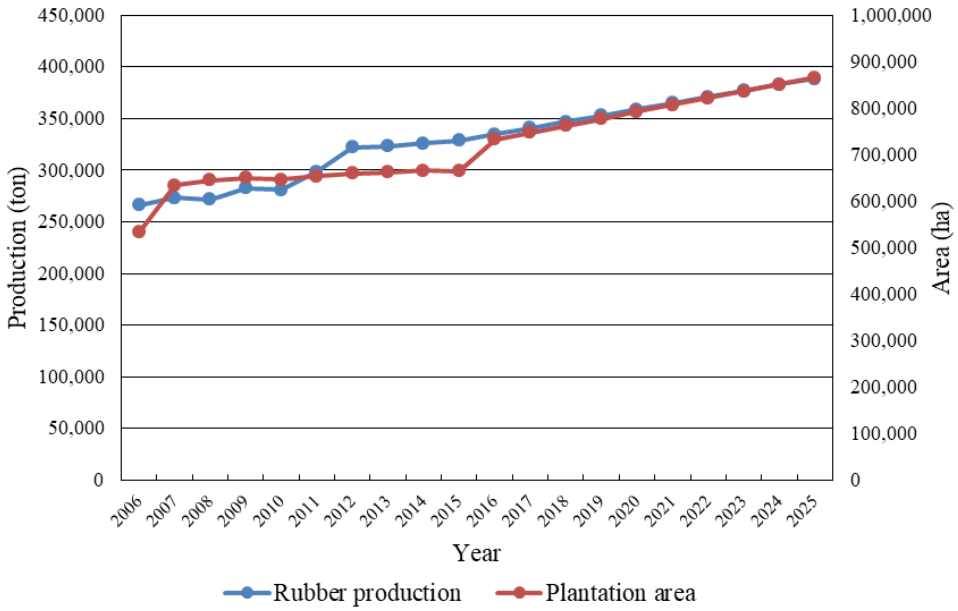

Figure 6. Rubber production projected graphics in 2006-2025.
Source: Processed from secondary data [4, 5, 11, 12, 14, 15, 16, 17, 18, 19]

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	16,806,957
2018	130,164	249,481	466,422	6,832,269	139,852	965,643	17,487,356
2019	135,691	260,074	486,225	7,098,100	141,901	979,795	18,167,755
2020	141,217	270,666	506,028	7,363,930	143,951	993,947	18,848,154
2021	146,744	281,258	525,831	7,629,763	146,001	1,008,099	19,528,560
2022	152,270	291,851	545,634	7,895,593	148,050	1,022,251	20,208,958
2023	157,796	302,443	565,437	8,161,423	150,100	1,036,403	20,889,357
2024	163,323	313,035	585,240	8,427,253	152,149	1,050,555	21,569,756
2025	168,849	323,628	605,043	8,693,084	154,199	1,064,707	22,250,155

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_{th})				Rice (MWh_{th})		Rubber (MWh_{th})
	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	31,009	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 (MWh_e)				Rice (MWh_e)		Rubber (MWh_e)
	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	23,238
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%).

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