

Assessment of agricultural biomass potential to electricity generation in Riau Province

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Abstract : Utilization of biomass as a source of electrical power is one potential solution that can be developed in order to increase of the electrification ratio and to Achieve the national energy security. However, now it is still difficult, to Determine the amount of potential energy that can be used as an alternative power generation. Therefore, as a preliminary step to assess the feasibility of biomass development as a power generation source, an analysis of potential resources are required, especially from some of the main commodities, both of residues of agriculture and plantation. This study aims to assessing the potential of biomass-based supply from unutilized resources that can be Obtained from the residues of agricultural and plantations sectors, such as rice straw and rice husk; Dry straw and chaff of rice; corn stalks and cobs; stalks of cassava; and fiber, shell, empty fruit Bunches, kernels and liquid wastes in the palm oil factories. More research is focused on the theoretical energy potential measurements using a statistical approach which has been developed by Biomass Energy Europe (BEE). Results of the assessment has been done and showed that the total theoretical biomass energy that can be produced is equal to 77,466,754.8 GJ year⁻¹. Theoretically, this potential is equivalent to generate electricity of year 21,518,542.8 MWh⁻¹.

1. Introduction

National electricity consumption in the period of 2000-2012 continued to increase with an average growth rate of 6.2% per year. It was lower than coal (9.9%) and LPG (13.5%). It also led to the national electrification ratio still at the value of 75.8% in 2012. Higher value of other ASEAN countries such as Singapore (100%), Malaysia (99.4%), Philippines (89.7%), and Vietnam (97.6%) showing that electrification rate of Indonesia is still low [1].

Furthermore, in electricity supply of year 2012, the power plants owned by the Indonesian State Electricity Company still dominated with a share of over 73% (32.9 GW), power plants owned by Independent Power Producer (IPP) in the range of 17% (7.4 GW), and the rest is met by power plants owned by Private Power Utility (PPU), power plant of non-fossil Operating Permit, and rental power plants with a share of the range of 10% (4.5 GW) [1].

Meanwhile, especially in the province of Riau, the electrification ratio has reached 77.56%. However, in some districts, seven regencies / cities in Riau province have lower electrification ratio than the national average [2]. Certainly, it should be considered, especially by local government, in order to overcome problems of the growing demand for electricity in the future.

To address the problems of the demand for electricity which continues to increase, it is necessary to utilize various alternative sources. An alternative source is through the utilization of the remaining agricultural products, plantation or residual forest products such as biomass.

Currently, biomass has been the most important source of energy in every region of the world [3]. Biomass has the potential to be one of the main energy source in the future, and the modernization of bioenergy systems suggested as an important contributor in the development of sustainable energy in the future, especially for sustainable development in industrialized countries and in developing countries [4]. As a result, there will be mobilization of the provision of biomass on a large scale as an effort to fulfill the energy needs in each region [5].

Biomass is the term for any organic material derived from plants (including algae, trees, and plants). Biomass is produced by green plants that converts sunlight into plant material through photosynthesis. Biomass resource can be considered as an organic material, in which the solar energy stored in chemical bonds. When the bonds between adjacent carbon, hydrogen and oxygen molecules are broken by digestion, combustion, or decomposition, then it releases their stored chemical energy [6]. Exploiting the potential of biomass as a source of electrical energy has started to be developed in some countries in the world. Such as in China, with the potential of available biomass, allowing them to generate electrical energy with a capacity of 30 GW [7]. Similarly, in the EU, even the demand of biomass raw material exceeds the supply capability can be provided for the needs of power plants [8]. Biomass basically can be divided into three major groups, wood biomass, non-wood biomass and secondary fuels [9]. On the other hand, Biomass Energy Europe divides biomass into four categories: (1) forest biomass and waste, (2) energy crops, (3) agricultural waste, and (4) organic waste [10].

Efforts to address the problems of the community energy requirements continue to be implemented by the provincial government. Start with drafting the rules and policy of regional energy management, consolidation of cross-sectors, the budget provision that is sufficient for the construction of various center of electrical energy generation, and foster cooperation with various industry parties in and outside the country to jointly develop technologies supplying alternative energy in accordance with the potential which exists.

Basically, the potential of new and renewable energy, especially biomass energy in the province of Riau are available in large enough quantities. Sources of potential energy are from agricultural products waste, forest products waste, industrial waste, and urban sewage coming from households. One of agricultural potentials to be utilized as an alternative energy source in the province of Riau is palm oil.

However, the underlying issue is the level of the overall potential of the various sources of biomass energy in Riau Province that cannot be known certainly. Lack of availability of data, undeveloped knowledge and technology utilization of biomass energy, cause portions of the utilization of biomass energy for the effort to fulfill the energy needs of society and increase the portion of renewable energy in the national mixed energy is still quite low.

The lack of data on potential energy source causes doubts to investors in investing their capitals for alternative energy development efforts in the province of Riau. The complexity of the existing problems, could impede utilization development efforts of biomass energy in the province of Riau. Therefore, it is necessary to carry out assessment of the potential of biomass energy in the province of Riau as a first step. This study will be the baseline to determine the direction of policy on the use and development of biomass energy in the province of Riau.

The purpose and scope of this study include: 1) Obtain the value of biomass energy potentials from two main sources, from the rest of the agricultural products which are distinguished into two groups: *First*, the rest of the agricultural product of horticulture crops such as straw and rice husks, leftover corn cobs, and cassava stem. *Second*, biomass potential can also be measured from the waste products of oil palm plantations that are divided into empty fruit bunches of palm oil, palm shells, kernel fibers,

and liquid waste of POME (Palm Oil Mill Effluent). In this study, the biomass potential obtained is still a theoretical potential. 2) Obtain the value of the electricity that is a conversion of whole agricultural biomass energy. 3) Obtain the classification of agricultural biomass energy potential of any region in the province of Riau. Classification is divided into three levels, high, medium, and low potential.

2. Literature Review

According to the Biomass Energy Europe, there are five types of potential sources of biomass energy: theoretical, technical, economical, implementation, and sustainable implementation. Because this study is a preliminary study, the research focuses on the theoretical potential. Figure 1 shows an illustration of the first four potentials and are described in the following sections [10].

Theoretical potential is the maximum number of total land biomass that is theoretically available for bioenergy production with basic biophysical limits. The theoretical potential is usually expressed in Joules primary energy, which is the energy contained in the biomass raw material, and has not been processed. Primary energy is converted into secondary energy, such as electricity, liquid fuels, and gaseous fuels. In the case of crops and forest biomass, theoretical potential describes the maximum productivity under theoretical optimal management by considering constraints such as soil conditions, temperature, solar radiation, and precipitation.

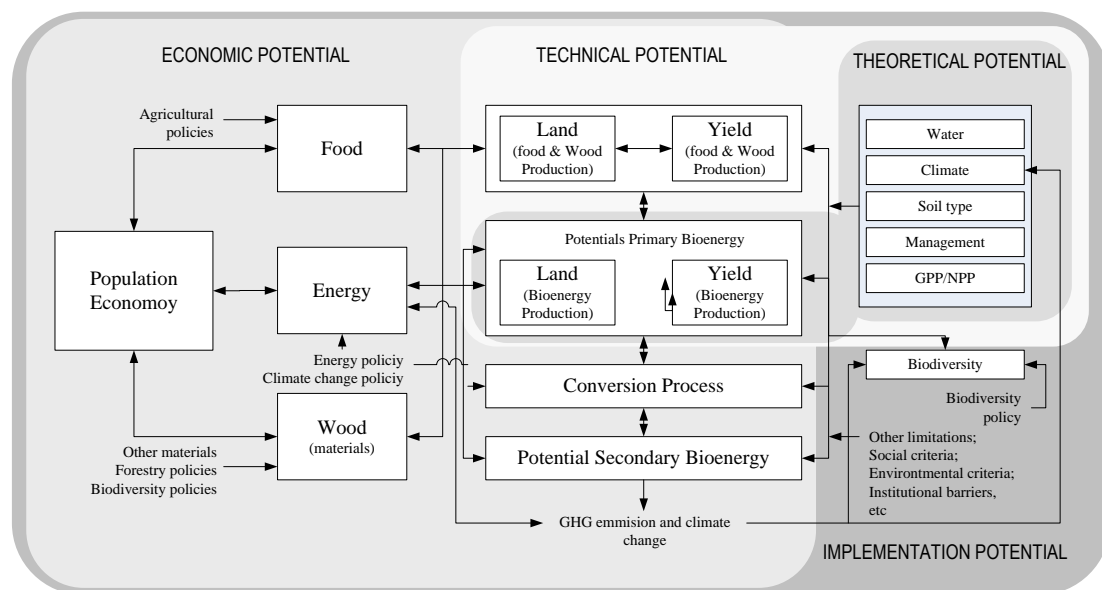


Figure 1. Biomassa potential classifications [10].

Technical potential is part of the theoretical potential that is available under the techno-structural condition with current available technology (eg harvesting techniques, infrastructure and accessibility, and processing techniques). The technical potential also considers the spatial conditions related to land use (eg for the production of food, feed, and fiber) including ecological aspects (ie natural reserves) and constraints due to the possibility of non-technical use. The technical potential is usually expressed in Joule primary energy, but sometimes also expressed in a secondary unit for energy.

Economic potential is part of the technical potential that meets the criteria of economical profits under certain conditions. The economic potential generally refers to the secondary bio energy, although sometimes the primary bio energy is also considered. The final results of the assessment of the economic potential is in the form of Supply Curve (IDR /tons).

Potential implementation is part of the economic potential that can be applied to both certain time period and the real socio-political, includes obstacles (and incentives) of economic, institutional and

social. Potential implementation is focused on the feasibility or impact of economic, environmental, and social from bioenergy policies.

Theoretically, there is the fifth type of potential biomass sources that is the sustainable implementation potential. Actually, that is not a new type of potential, but it is a combination of the criterias of environmental sustainability, economic, and social assessment of biomass sources. It describes that the sustainability criteria acts as a filter on the theoretical, technical, economical and implementation potential aimed to the sustainable implementation potential. Depending on the type of potential, the sustainability criteria can be applied into different levels. For example, to get the technical potential, criteria and environmental constraints are integrated to limit the available area and / or results that can be achieved.

2.1 Biomass Potential Energy Measurement

Information on the production and use of biomass energy is usually difficult to obtain because of the lack of long-term data. Even if available, the data and information is usually inaccurate and too focused on a specific location. This is usually caused by traditional biomass that is often considered as part of the non-formal economy so it is not included into the activities of statistical agencies. In turn, although biomass plays an important role in developing countries, the planning, management, production, distribution, and use of biomass rarely get the attention of policy makers and energy planners [9].

Determining the potential of biomass energy involves many factors such as the complexity of production and consumption, difficulty in determining the energy sources of biomass, the sustainability of long-term productivity, and economic aspects in production and use. In addition, the utilization of biomass energy also involves aspects of technology, ecology, and social. Three key issues in determining analysis of the potential of biomass are distinguish between potential and actual supply, measure the variation, and the number of units used in the measurement [9].

Biomass is usually collected from various plant species. The potential of biomass is the number of biomass sources produced by an area, while the actual supply of biomass is the number of biomass sources accessed for the purposes of energy conversion. The limitation factors to access biomass are topography, law or local regulation, and local traditions. The potential of biomass can be measured by conducted three main methods of geospatial technology, field surveys, and modeling [12].

a. Geospatial Technology

Including remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS). Remote sensing images such as aerial and satellite photos, provide an efficient and reliable way to monitor biomass resources over time.

This technique is used to estimate the growth in the stock of biomass and productivity estimates. RS provides an effective-cost way to gather the necessary information in outlying and inaccessible area. Remote sensing images are also the only practical approach to analyze land use and land cover changes in large economic scale, regional, and global. The resulting patterns can be studied by comparing images obtained at different times. Data derived from remote sensing imagery, such as land use / cover, altitude, and temperature of the surface, are further used in geographic information systems (GIS).

b. Field Survey

The field survey is used to collect data as part of an evaluation on a specific location. Usually, a field plot (size may vary) is selected as representative of the type of vegetation in an area of study, and parameters such as stem diameter, tree height, or the dimensions of the crown for resources of the forest and density, altitude, and the phenology development for easily measured plants are measured. Further extrapolation results in a larger area are used to develop equations that predict the availability of biomass. This sampling technique provides the most accurate estimation of biomass resources at specific locations, but not practical for large scale. The survey takes a long time, a lot of employees, therefore it is expensive, even with today's satellite communications technology (GPS). Currently, the

field survey in the assessment of biomass resources is used when other methods are not effective or when the ability to use other methods does not exist.

c. Modelling

Model is a framework that is simplified and designed to visualize a system or process that often uses mathematical techniques to facilitate the calculation or prediction. The complexity of the model and modeling techniques depends on the needs of assessment and data availability. Models can be as simple as an extrapolation of data that are measured using statistical methods, or as complex to balance process (set up as a separate module) to get the resource characteristics.

Both static (analytical) and dynamic (simulation) models are used in the assessment of biomass resources. Static model describes a mathematical system, in an equation, and can be built in a spreadsheet. For example, estimating the number and cost of crop residues (straw rice for example) with set a value (usually average) for several variables such as crop production, the resulting residues, labor costs, and the price (chemical, fertilizer, fuel, and planting).

3. Methodology

The study was conducted within the scope of Riau Province which consists of 12 districts and cities. In general, the data used was secondary data obtained from annual reports to the relevant agencies, including the Department of Agricultural, Department of Agriculture and Horticulture, Department of Mines and Energy and the Central Bureau of Statistics in the province of Riau.

This research included activities that consist of the studying the literature, surveying through secondary data collection on several relevant agencies, analyzing the data, and mapping classification. The data collected included all aspects within the scope of the purposes of the study. In general, the biophysical data can be collected from some types of exist agricultural commodities. Biophysical data included land resources and biological resources of food crops, including plantation crops.

Methods and approaches used in analyzing biomass potential referred to the guidelines developed by the Biomass Energy Europe [11]. The assessment of the level of potential energy biomass was based on the availability of such resources, and conducted using statistical methods. This method used statistical data based on land use, crop yields, crop production, and from the literature. Statistical data were then combined with the conversion factor, such as the yield per hectare, residues to crop factor, etc. These factors was based on an assessment / opinions of expert, field study, or review of the literature. In addition, the assumptions was carried out to determine the portion of biomass that can be used for energy production, by considering the needs for the land use for other purposes.

Furthermore, the biomass potential had been obtained in previous measurements would be converted into electrical energy units (MWh). Hierarchical Cluster Analysis approach was carried out to determine the classification of the energy potential of each region. In this method, the region cluster is formed due to the similarity (proximity) between clusters. In this study, cluster region was formed based on the potential of each commodity. Each region was divided into three levels of potential clusters: high, medium, and low potential. The range of potential biomass energy value of each type of commodity was different, depend on the range of the potential value of each commodity.

The use of this method is limited to the knowledge of the potential energy in theory only. To find a more realistic potential of energy, assessment processes needs to be done technically, economically and implementation. For that, it will require other supporting data as well as the number of population, the number of target customers will get a power supply, the data shrinkage during distribution, the conversion process or other data related to financing as the cost of production, transportation and electricity tariffs.

The following section outlined the measurement method of the biomass potential, and the classification method of biomass potential of each region.

a. Statistics Method –Primary Agricultural Residue (PAR)

Most important primary agricultural residues of available agricultural biomass for bioenergy was straw and rice straw. Parameters that influenced the potential of straw / rice straw was the area covered by these plants and the amount of straw / rice straw produced per hectare or per ton of plant. Other types of residues that should be included in the residual category was the primary product of the cultivation process (eg, pruning fruit trees).

The theoretical method of annual crop residues, such as rice, was estimated based on the cultivated area and agricultural production (AP) in ton per hectare, for each species of plant and the average ratio between the product and the residue (PtR). Primary agricultural residues (*THP_PAR*) was calculated by:

$$THP_PAR = \sum(CA_i \times AP_i \times PtR_i \times Av_i) \quad (1)$$

where: *THP_PAR* is an agricultural residues primary (eg, straw, rice straw), in tons, *CA_i* is the cultivated area for *i*-th crop, in hectares (ha), *AP_i* is the agricultural production for the *i*-th crop, in tons per hectare (tons / ha), *PtR_i* is product-residue ratio for *i*-th crop, while *Av_i* is the availability of residues for *i*-th crop according current harvest system.

Tons unit of the theoretical potential of agricultural residues was converted to energy units by multiplying the potential (in tons / year) with a lower calorific value of a particular residue (GJ / ton_{dry}). Energy value was calculated using a low heating value of 14.7 GJ / tonnes with a water content of about 20% [9]. The ratio of product-residue by plant species (*PtR_i*) was amounted to 1.757 [13]. The availability of residues for *i*-th crop according to current harvesting system (*Av_i*) was assumed equal to 1.

In oil palm plantation commodities, palm oil biomass portion was determined based on the net energy balance proposed by Hambali [14]. The processing of fresh fruit bunches (FFB) produced from a plantation, will produce palm oil, kernel, empty fruit bunches, fiber, shell, and liquid waste or POME. Processing the oil at a refinery industry will produce Refined Bleached Deodorized Palm Oil (RBDPL) and Palm Fatty Acid Destillated (PFAD). Furthermore, RBDPL through fractionation processes will produce Refined Bleached Deodorized Palm Olein (RBDPO) and Refined Bleached Deodorized Palm Stearin (RBDPS).

However, the energy potential was only measured in the palm oil biomass which consisted of empty fruit bunches, shells, fibers, kernel, and POME with a portion of each energy of 21%, 6.4%, 14.4%, 5%, and 58, 3%, respectively [14]. In general, the net energy balance of palm oil can be described in Figure 2.

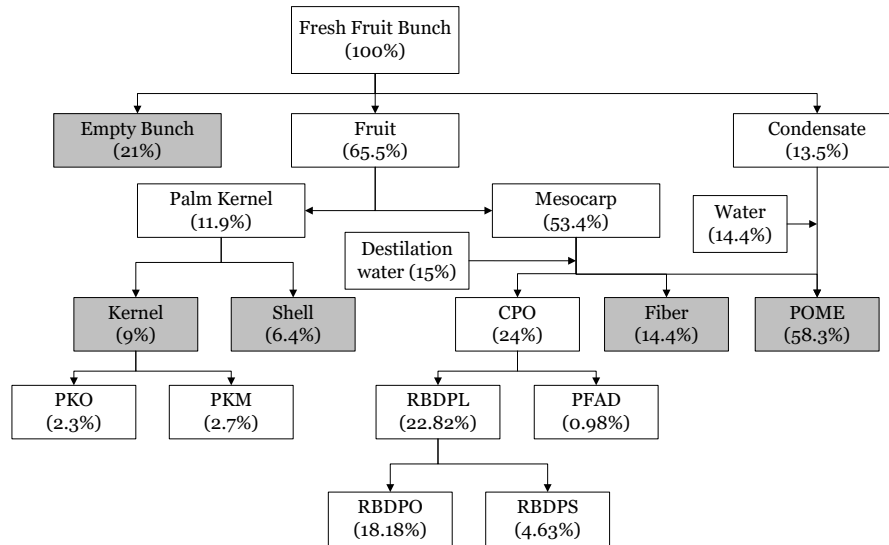


Figure 2. Palm oil mass balance [14].

b. Statistics Method– Secondary Agricultural Residue (SAR)

Secondary agricultural residues (SAR) were generated and collected from companies that process agricultural plant parts harvested to produce the food / feed. In some European countries, the company must report the volume and utilization of residues they produce to the local statistics agency. However, if the direct statistics are not available, the methodology for assessment using the following equation :

$$P_{ii} = Cr_i \times PtSR_i \quad (2)$$

where: P_{ii} is the theoretical potential of secondary agricultural residues of i -th crop (tons / year), Cr_i is the production of i -th crop (tons / year), and $PtSR_i$ is the ratio between products and secondary residues of i -th crop.

c. Hierarchical Cluster Method

Cluster is a method of distribution data into meaningful subgroups, when the number of subgroups and other information about their composition may not be known [15]. Classification can also be described as an activity to divide a set of objects into multiple objects that resemble each other in the same class while the different objects will form another class [17]. Hierarchical Cluster Analysis is a cluster method that produces a unique set of categories or groups by variables of sequentially couples, groups, or variables [18]. Hierarchical clustering methods is processed to the stage of generating sequence of partitions, each corresponds to a different number of clusters [19].

In multivariate data analysis, sampling units is generally represented as a multidimensional space in which the distance between pairs of points is defined as some function of observed sample value [20]. According to [16], determining the distance between clusters can be performed with agglomerative method. In this method, determining the distance between two possible clusters is built with a single n clusters, one for each point, and successively joining the pair nearest cluster to form a new cluster.

The general equation of Agglomerative Algorithm was developed by Lance and William [21] in which the difference between the new class is the union of $C_i \cup C_j$ and some other class C_k that is defined as:

$$d(C_i \cup C_j, C_k) = \alpha_i d(C_i, C_k) + \alpha_j d(C_j, C_k) + \beta d(C_i, C_j) + \gamma |d(C_i, C_i) - d(C_j, C_j)| + \delta_i h(C_i) + \delta_j h(C_j) + \epsilon h(C_k) \quad (3)$$

In this equation, $h(C_i)$ is the highest class in the dendrogram cluster of C_i , and $\theta \equiv (\alpha_i, \alpha_j, \gamma, \delta_i, \delta_j, \varepsilon)$ is a set of parameters which values determine the grouping strategy.

4. Results

4.1 Biomass Potential

The results of the measurement of the biomass potential was divided into three groups. The first group described the potential of biomass residues derived from primary agricultural products, including rice straw, dryland rice straw, corn stalks, and stems of cassava. The second group was the potential of biomass sourced from secondary agricultural residues, which consisted of rice husks, dryland rice husks, and corn cobs. The third group was the potential of biomass derived from oil palm plantations, which consisted of oil palm empty fruit bunches, fibers, shells, and waste water (POME).

a. Agricultural Residue Biomass Potential.

Table 1, describes the assessment results of biomass energy potential derived from primary residues on four agricultural commodities. Based on the theoretical potential assessment, it is known that there were three regions with the highest potential for primary agricultural residue biomass, which were to Rokan Hilir by 3,666,063 Gj (21.48%), Indragiri Hilir by 3,116,287 Gj (18.26%) and Kampar by 2,082,552 (12.20%).

Table 1. Theoretical potential of primary agricultural residue biomass

Districts	Paddy Rice Straw		Dry Rice Straw		Corn Stem		Cassava Stem		Energy Total/ Districts (Gj/yr)
	Production (Ton/yr)	Energy (Gj/yr)	Production (Ton/yr)	Energy (Gj/yr)	Production (Ton/yr)	Energy (Gj/yr)	Production (Ton/yr)	Energy (Gj/yr)	
Bengkalis	24,626	632,429	2,624	43,681	469	16,214	4,837	170,649	862,974
Indragiri Hilir	121,681	2,829,124	1,952	22,620	5,844	160,711	3,167	103,832	3,116,287
Indragiri Hulu	13,650	505,463	4,155	87,659	841	31,706	7,285	219,071	843,900
Kampar	29,346	910,835	9,656	431,177	3,146	142,991	19,552	597,549	2,082,552
Kuansing	44,275	1,255,925	13	224	389	22,123	4,677	153,155	1,431,427
Pelalawan	37,475	997,481	309	10,621	18,361	566,949	5,388	161,629	1,736,681
Rokan Hilir	157,959	3,512,679	385	12,140	774	34,005	3,383	107,239	3,666,063
Rokan Hulu	19,812	488,308	30,743	852,281	1,267	51,244	5,597	153,281	1,545,114
Siak	27,032	720,660	414	9,737	491	17,025	4,676	159,014	906,436
Dumai	694	112,428	3,620	85,837	225	9,987	6,505	160,310	368,563
Pekanbaru	32	744	6	207	1,312	44,523	12,348	217,247	262,720
Meranti	5,419	177,809	0	0	78	6,689	2,065	57,773	242,270
Total	482,001	12,143,883	53,877	1,556,184	33,197	1,104,166	79,480	2,260,750	17,064,985

Where: Primary Residues – Product Ratio (PrR_i) for straw= 1.757; corn dan cassava = 2. Residues available (Av_i) =1,

While Table 2, shows the potential of secondary biomass from agricultural residues in each district in the province of Riau. Based on the assessment results of potential had been conducted, it is known that there were two most potential regions, Rokan Hilir with theoretical potential of agricultural residues for biomass energy of 1,299,584 Gj (28.84%) and Indragiri Hilir with a potential of 1,033,295 Gj (22.93%).

Based on the four types of existing agricultural potential, it can also be known that the rice paddy yield had the largest biomass potential that was 75% of total primary and secondary agricultural biomass potential. Whereas dryland rice, corn, and cassava were respectively only 9%, 6%, and 10% of the overall potential of the existing agricultural biomass. (Figure - 3). Overall total theoretical potential agricultural biomass, which can be produced from residues of paddy rice, dry rice, corn and cassava, was 12,571,642 Gj.

Table 2. Theoretical potential of secondary agricultural residue biomass

Districts	Hull of paddy rice		Hull of dry rice		Corn hump		Energy Total/ District (Gj/yr)
	Production (Ton/yr)	Energy (Gj/Th)	Production (Ton/yr)	Energy (Gj/yr)	Production (Ton/yr)	Energy (Gj/yr)	
Bengkalis	24,626	201,687	2624	21,491	469	1664	224,842
Indragiri Hilir	121,681	996,567	1952	15,987	5844	20,740	1,033,295
Indragiri Hulu	13,650	111,794	4155	34,029	841	2985	148,808
Kampar	29,346	240,344	9656	79,083	3146	11,165	330,592
Kuansing	44,275	362,612	13	106	389	1381	364,099
Pelalawan	37,475	306,920	309	2531	18,361	65,163	374,614
Rokan Hilir	157,959	1,293,684	385	3153	774	2747	1,299,584
Rokan Hulu	19,812	162,260	30,743	251,785	1267	4497	418,542
Siak	27,032	221,392	414	3391	491	1743	226,525
Dumai	694	5684	3620	29,648	225	799	36,130
Pekanbaru	32	262	6	49	1312	4656	4968
Meranti	5419	44,382	0	0	78	277	44,658
Total	482,001	3,947,588	53,877	441,253	33,197	117,816	4,506,657

Where : Secondary Residues – Product Ratio (*PtRsi*) for hull of paddy rice = 0.7; corn hump (*PtRsi*) = 0.3

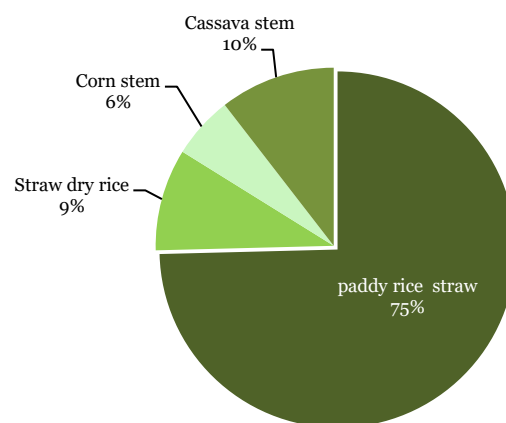


Figure 3. Pie diagram of agricultural biomass potential

b. Palm Oil Biomass Potential.

Riau Province is one of areas that has the largest area of palm oil plantations in Indonesia. According to statistics of the Agricultural Department of Riau Province (2013), the area under palm oil plantations in Riau Province is 2,401,460 million hectares and spread over 12 districts. 461,007 hectares of oil palm plantations from the existing total area, has produced a total production of 4,477,081 tonnes.

The largest community-owned palm plantation area is in Indragiri Hilir, with a plantation area reaches 580,627 Ha (24.1%). Indragiri Hilir regency could produce as many as 644,098 tonnes of palm oil during 2012. Other area in Riau Province that has the quite large resource potential of oil palm is in Rokan Hulu and Kampar regency with palm oil plantations respectively reach 256,696 ha (10.7%) and 289,156 ha (12.1%). During 2012, production of those regencies had reached respectively 579,011 tonnes (12.9%) and 573,338 tonnes (12.8%) of fresh fruit bunches (FFB) [22].

Based on Table 3, it can be seen that in total, biomass energy can be generated from the potential of palm oil plantations in Riau Province was 30,786,475.29 Gj / year. The largest potential could be produced from the utilization of fiber (coir) of palm oil, which was 8,800,474.52 GJ (27.9%), and the utilization of oil palm bunches with theoretical energy potential value of 8,402,587.5 Gj / year (27.2%).

Table 3. Theoretical potential of palm oil biomass (community – owned)

Districts	Fiber (Gj/yr)	Shell (Gj/yr)	Bunch (Gj/yr)	Kernel (Gj/yr)	POME (Gj/yr)	Total Potential (GJ/yr)
Bengkalis	696,520.02	443,782.24	680,493.90	394,489.22	277,995.25	2,493,280.62
Indragiri Hilir	1,237,312.26	88,343.75	1,208,843.13	700,778.62	493,836.38	4,429,114.13
Indragiri Hulu	468,047.81	298,212.97	457,278.57	265,089.02	186,807.36	1,675,435.73
Kampar	1,101,382.30	701,737.05	1,076,040.76	623,791.74	439,583.98	3,942,535.82
Kuansing	356,608.68	227,210.41	348,403.52	201,973.06	142,329.74	1,276,525.41
Pelalawan	937,326.98	597,210.49	915,760.16	530,875.46	374,106.18	3,355,279.26
Rokan Hilir	1,006,951.70	641,571.33	983,782.90	570,308.93	401,894.81	3,604,509.68
Rokan Hulu	1,112,280.13	708,680.51	1,086,687.84	629,963.97	443,933.52	3,981,545.98
Siak	1,076,645.58	685,976.24	1,051,873.20	609,781.57	429,711.05	3,853,987.65
Dumai	150,740.87	96,043.36	147,272.50	85,375.36	60,163.73	539,595.82
Pekanbaru	6437.27	4101.46	6289.16	3645.89	2569.25	23,043.02
Meranti	450,220.93	286,854.71	439,861.86	254,992.38	179,692.29	1,611,622.18
Energy Total/Biomass	8,600,474.52	5,479,724.51	8,402,587.50	4,871,065.22	3,432,623.54	30,786,475.29

Where: Primary Residues – Product Ratio(*PtRi*) of fiber = 0.170; shell = 0.065; bunch = 0.230; kernel = 0.064 and POME = 1.217)

Table 4 shows that theoretically, total energy potential of palm oil from private plantations could be produced in the province of Riau was 25,108,837.3 Gj / year. The largest energy potential could be produced from the utilization of oil palm fiber, which was 7,014,320.2 Gj / year (27.9%). Palm oil bunches waste of private plantations could, theoretically, produce energy by 6,852,928.8 Gj / year (27.2%). The biomass potential was in the district of Kampar with a total potential biomass energy of 5,162,942.44 Gj / year (20.6%).

Table 4. Theoretical potential of palm oil biomass (private-owned)

Region	Fiber (Gj/yr)	Shell (Gj/yr)	Bunch (Gj/yr)	Kernel (Gj/yr)	POME (Gj/yr)	Energy Total / Region(Gj/yr)
Bengkalis	322,192.04	205,282.12	314,778.77	182,480.45	128,593.37	1,153,326.75
Indragiri Hilir	911,274.38	580,611.28	890,307.00	516,120.00	363,708.06	3,262,020.71
Indragiri Hulu	364,440.59	232,200.45	356,055.24	206,408.83	145,455.62	1,304,560.73
Kampar	1,442,313.69	918,958.80	1,409,127.72	816,885.63	575,656.60	5,162,942.44
Kuantan Singingi	392,245.15	249,915.90	383,220.04	222,156.54	156,552.98	1,404,090.61
Pelalawan	1,378,480.79	878,288.16	1,346,763.53	780,732.48	550,179.60	4,934,444.55
Rokan Hilir	670,186.95	427,004.33	654,766.72	379,574.91	267,485.18	2,399,018.11
Rokan Hulu	786,799.34	501,302.99	768,695.99	445,620.86	314,027.55	2,816,446.73
Siak	592,029.15	377,206.70	578,407.24	335,308.54	236,290.82	2,119,242.45
Pekanbaru	58,751.86	37,433.29	57,400.05	33,275.39	23,449.06	210,309.65
Meranti	95,606.25	60,914.77	93,406.46	54,148.67	38,158.39	342,234.54
Energy Total/Biomass	7,014,320.20	4,469,118.80	6,852,928.80	3,972,712.30	2,799,557.20	25,108,637.30

Where: Primary Residues – Product Ratio(*PtRi*) of fiber = 0.170; shell = 0.065; Bunch = 0.230; kernel = 0.064 and POME = 1.217)

Based on the overall analysis, every potential area of biomass and the potential of each type of biomass can be summarized in Table 5.

Table 5. Recapitulation of biomass energy potential

Agricultural Commodity	Type of Biomass	Energy (Gj/Yr)	%	Higest Potential District
Wet Rice	straw, hull	16,091,472.1	20.7	Rokan Hilir
Dry Rice	straw, hull	1,997,436.9	2.5	Rokan Hulu
Cassava	Stem	2,260,750.2	2.9	Kampar
Corn	stem, knob	1,221,983.1	1.6	Pelalawan
Palm oil (community owned)	fiber, shell bunch, kernel, POME	30,786,475.3	39.7	Indragiri Hilir
Palm oil (private owned)	fiber, shell, bunch, kernel, POME	25,108,637.3	32.4	Kampar
Energy Total of Biomass		77,466,754.8		Kampar

4.2 Electricity Potential

As shown in Table 5, it can be seen that the overall theoretical potential of biomass could be produced from two groups of agricultural commodities and plantations in Riau Province was 77,466,754.8 Gj. This is equal to 21,518,542.8 MWh of electrical energy (where 1 Gj = 0.28 MWh).

4.3 Region Cluster Biomass Potential

Based on cluster analysis has been conducted, six types of clusters were formed which were cluster of areas based on the potential of biomass palm oil, clusters of rice biomass potential, cluster of corn biomass, cluster of cassava biomass, cluster of crops biomass (which is a combination of rice, corn, and cassava biomass), and clusters of the total biomass of agricultural commodities. Each type of clusters was classified into three levels of potential: high, medium, and low potential. The potential level value of each cluster type was different, depending on the range of values in a type of cluster.

Using Hierarchical Cluster Method and the calculation of proximity analysis, level value of each cluster type had been obtained. The values range of each potential level of each cluster type, are summarized in Table 6.

Table 6. Interval of potential level each cluster

Level	Palm oil biomass (Gj/yr)	Rice Biomass (Gj/yr)	Corn Biomass (Gj/yr)	Cassava Biomass (Gj/yr)
High	9,105,478	4,821,656	632,112	597,549
Middle	3,646,607	1,754,634	154,156	161,629
Low	365,278	1262	17,878	57,773

The agglomeration process of each parameter formed dendrogram of each cluster type as presented in Figure 4.

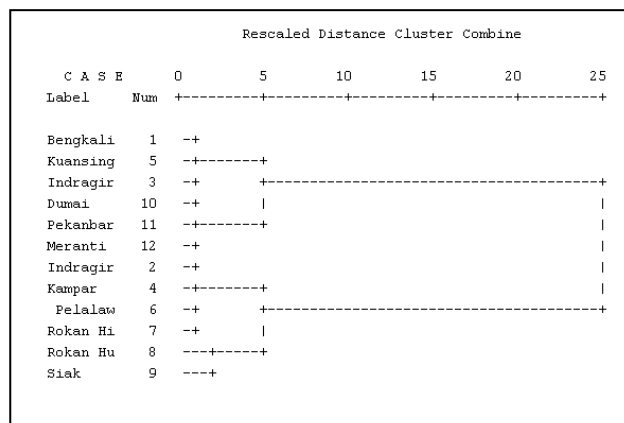


Figure 4a. Cluster Dendrogram of Palm Oil Biomass

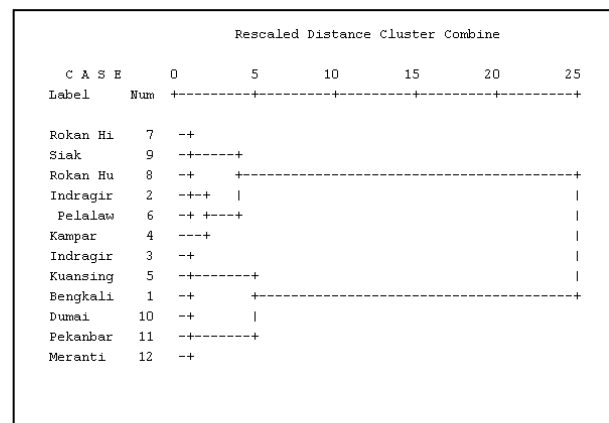


Figure 4b. Cluster Dendrogram of Rice Biomass

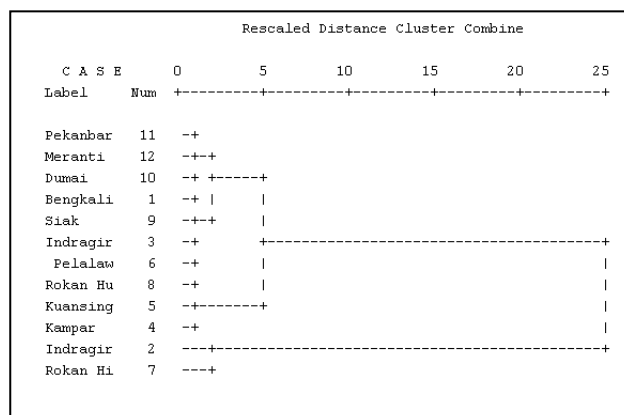


Figure 4c. Cluster Dendrogram of Corn Biomass

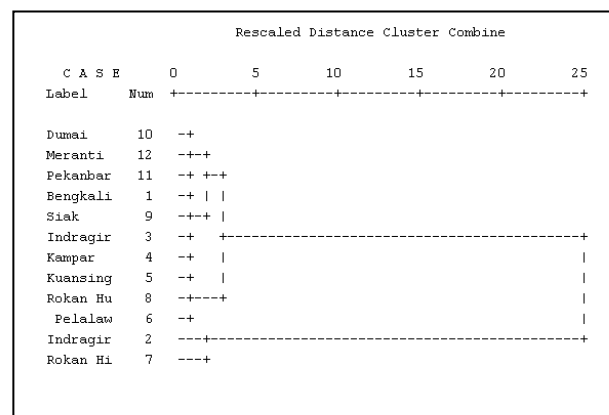


Figure 4d. Cluster Dendrogram of Cassava Biomass

Figure 4. Cluster Dendrogram of Biomass Potential

In the following section (see Figure 5), refers to the data of biomass potential of each region and the results of the cluster analysis, map of the biomass cluster in the province of Riau could be illustrated. Four maps were formed, consisted of cluster map of the palm oil biomass potential, cluster map of the

potential of the rice biomass, cluster map of the potential of corn biomass, and potential map of cassava biomass.

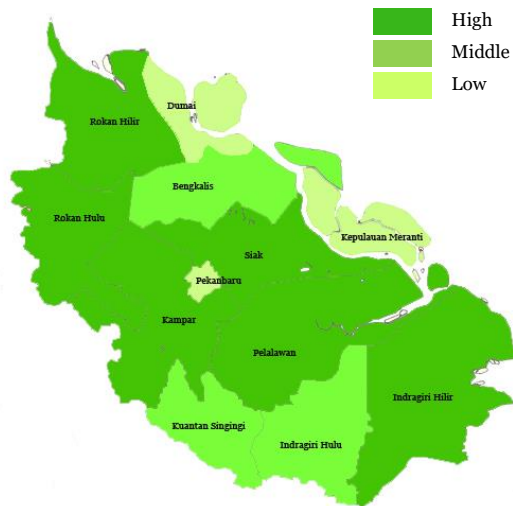


Figure 5a. Cluster map of palm oil biomass

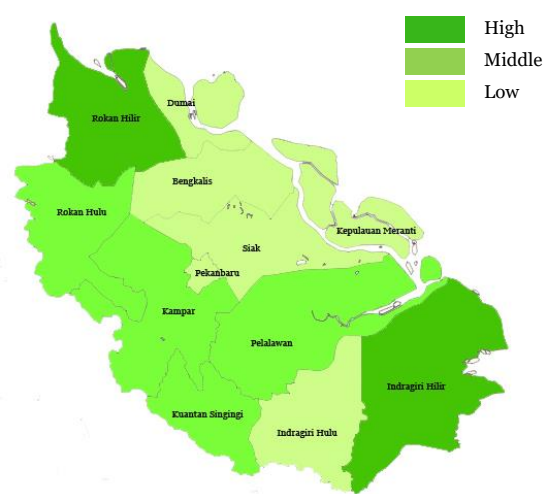


Figure 5b. Cluster map of rice biomass

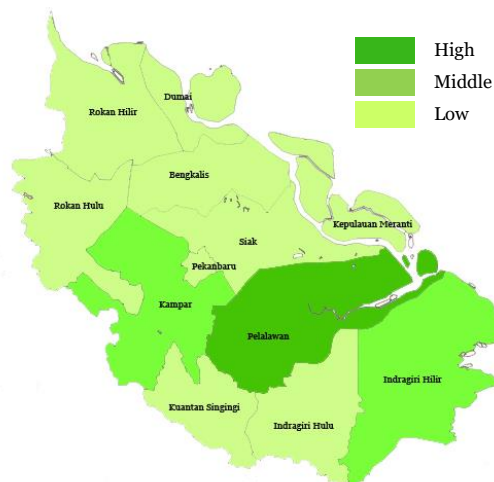


Figure 5c. Cluster map of corn biomass

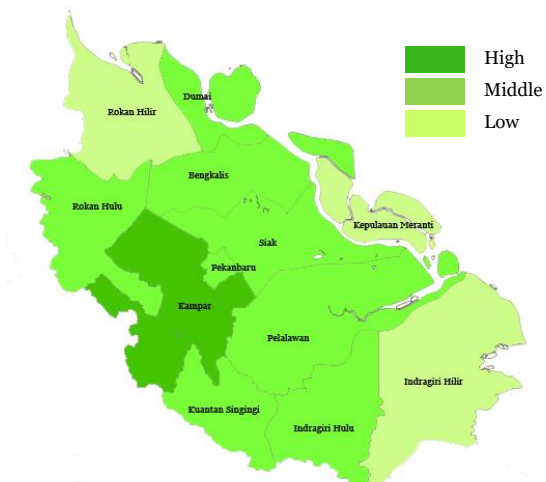


Figure 5d. Cluster map of cassava biomass

Figure 5. Cluster map of agricultural biomass potential in Riau Province

5. Conclusions

Based on the assessment of biomass potential in the province of Riau, a number of conclusions: **First**, theoretically biomass energy that can be produced from primary agricultural residues amounted to 17,064,985 GJ, whereas the potential of secondary biomass from agriculture amounted to 4,506,657 GJ. Straw and hull of paddy rice is the most potential compared to other agricultural resources, theoretically has the potential to generate energy by 16,091,472.33 GJ. **Second**, the potential of biomass that can be produced from oil palm plantations is amounting to 55,895,112.56 GJ, wherein, Kampar District is the area most potential to produce oil palm biomass energy which is equal to 9,105,478 GJ. **Third**, with a total of 77,466,754.8 GJ biomass energy, theoretically has the potential to generate electrical energy by 21,518,542.8 MWh / year.

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