User guide for Bioenergy Sector

Indonesia 2050 Pathway Calculator

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1. Overview of Bioenergy Supply

Bioenergy is energy obtained / generated / derived from biomass. Biomass is organic materials which are relatively young and sourced from plants / animals, products and aquaculture waste industry (agriculture, farming, forestry, animal husbandry, fisheries) (Soerawidjaja 2010). In Indonesia 2050 Pathway Calculator (I2050PC) modeling, bioenergy was classified into three, namely, liquid biofuels, biogas and solid bioenergy.

1.1 Biofuel

1.1.1 Biofuel Technology

As an agricultural country, Indonesia is blessed with abundant of biofuels materials. Several types of materials that can be used to produce biofuels are cassava, maize crops, sugarcane, sago, palm oil, jatropha, waste cooking oil and etc.. The abundant biofuels materials certainly require knowledge and mastery of advanced biofuel processing technology. The biofuels (BBN) technologies can be grouped by generation. The first generation biofuel derived from vegetable oils. But the first generation of biofuels is deemed contradictive against the food needs and security. Therefore, the experts then develop the second-generation biofuels from lignocellulosic materials. After the second generation, third generation biofuel was then developed utilizing algae as the materials.

Second-generation biofuels refer to biofuels made from non-food materials. Most experts agreed that the definition of non-food material is the solid biomass which is a material that has a lignocellulose, for example: agriculture and forestry solid wastes such as straw, chaff, empty fruit bunches of oil palm, sugarcane bagasse, woods, grass and other materials. The principle is the biomass material produced is not too dependent on land area and productivity of staple crops. The materials are processed in two ways; first biochemically that produce bioethanol and the second is Fisher-Tropsch gasification process to produce biodiesel. Currently there are a lot of research and large private institutions trying to develop this technology mainly to produce bioethanol. The technology has been mastered, yet the commercialization is still too costly (Ministry of Agriculture 2014).

The third-generation biofuels derive from algae. Algae consist of two types, microalgae and macro algae. Algae has the potential to be developed as a biofuel feedstock considering that Indonesia is an archipelagic country with the longest coastline in the world and has so many water resources, including shallow waters. The condition is very suitable for the algae cultivation because the algae require ample sunlight and carbon dioxide. In addition, the algae has high *Lemak Sel Tunggal* (LST) content, it can contain more than 50% LST (Briggs, 2004).[1] The great content of LST identified the great fatty acid content in algae (Cohen, 1999).[2] Based on Zuhdi, et al (2003) study, the more fatty acid content in the raw material and the greater amount of biodiesel that can be produced. Algae can be used for biodiesel production. When compared with various sources of future biodiesel

[1] LIPI, 2010. Eksplorasi Sumberdaya Mikroba Penghasil Lemak Sel Tunggal Untuk Pengembangan Bioenergi Alternatif Berbasis Biodiesel dan Biometan

[2] LIPI, 2010. Eksplorasi Sumberdaya Mikroba Penghasil Lemak Sel Tunggal Untuk Pengembangan Bioenergi Alternatif Berbasis Biodiesel dan Biometan

material, algae is a good alternative in terms of the biodiesel production intensity per hectare. Each hectare of algae culture land is able to produce biodiesel at approximately 50 kl, while one hectare of oil palm could produce only about 5-6 kl (BPPT 2014). Based on LIPI report (2010), algae productivity are 30 times more than terrestrial plants. Utilization of algae to produce biodiesel in Indonesia is still in the research stage and has not proceeded into the commercial stage yet. Some agencies are actively engaged in research related to algae as the raw material production, among others, Bogor Agricultural University (IPB), Institut Teknologi Bandung (ITB), Gadjah Mada University and LIPI.

Vegetable fuels (BBN) include biodiesel, bioethanol and bio oil. Vegetable oils are commonly used to produce biodiesel and usually obtained from coconut, palm oil, waste cooking oil, and Jatropha. Biodiesel is an ester form of vegetable oils after the trans esterification process by adding methanol.[3] Basically, the trans esterification process aims to transform triglycerides into fatty acid methyl esters (free fatty acid methyl ester / FAME). Generally, essential oils have low free fatty acid content (free fatty acid / FFA) (about 2%) that can be processed directly by the trans esterification method. If the FFA content in the oil is still higher than before, the pre-esterification process needs to be done to reduce the FFA content up to about 2%. Transesterification process is commonly used in Indonesia (Hambali, et al 2007). 1st generation biodiesel feedstock is still very dependent on palm oil. Development of non-food oil-fat plant sources (Pongamia pinnata, Calophyllum inophyllum, Cajanus cajan, Artocarpus altilis, Azadirachta indica, Jatropha curcas, etc.) still receives less attention.

Bioethanol is ethanol produced from vegetable raw materials. The raw material of bioethanol can be derived from plants containing starch / sugar such as sugar cane, cassava, sago, sorghum and lignocellulose.[4] After going through the fermentation process, then the ethanol is produced. The first-generation bioethanol is produced from materials that contain sugar or starch, such as molasses, sugar beet, sugar cane, barley, some types of wheat, maize, potato, cassava, and sugar cane. The technology to produce bioethanol is done through several process stages, namely: the saccharification, fermentation, melting process, separation and purification processes.

Bio Oil or also known as pure plant oil (PPO) is a pure vegetable oil from the fruit or seeds of various plants such as palm oil, cotton, sunflower, jatropha, Karanja, soybean, rapeseed, brassica, copra, peanuts, and so on. PPO is produced through a mechanical extortion process, extraction and purification to improve the oil quality (Bioliquids-CHP 2015). PPO can be used for low and medium speed diesel machines.

While bioethanol can be a substitute for gasoline, bio avtur is an alternative fuel for air transport. Bioavtur can be produced through the hydrogenation process of vegetable oils-fats. The demand of high level of safety in air transport requires bioavtur to be produced in the exact hydrocarbon chemistry form as avtur from petroleum. To produce a paraffinic hydrocarbon, which is the main

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[3] http://pustaka.litbang.pertanian.go.id/publikasi/wr304084.pdf

[4] Direktorat Bioenergi, Kementerian ESDM

component of avtur, the best raw materials manufacture bioavtur is lauric oils (C12 fatty acid) including coconut oil, palm-kernel oil, seed oil of Cinnamomum sp and Litsea sp (Soerawidjaja 2010).

1.1.2 Potential Biofuels Development in Indonesia

Currently, the use of biofuel in Indonesia is still limited; it is used by mixing 5% biodiesel with diesel oil. In fact, Indonesia is a potential country for the biofuel development. The potential production of first generation biofuels is reaching 6,730 million liters per year for ethanol and 3,670 million liters per year for biodiesel (APEC 2010). Potential development of biodiesel in Indonesia is strongly related to the fact that Indonesia is the largest palm oil producer in the world. The main raw material for biodiesel in Indonesia is palm oil. It is supported by the palm oil industry that has been established and has the potential for increased production. Indonesia surpassed Malaysia in palm oil production in 2007 and now a world leader. Together with Malaysia, Indonesia provides 90% of the world's palm oil. Indonesia produced 17.4 million tons in 2007; increased from 15.9 million tons in 2006 and about 12 million tons were exported. Currently, palm oil plantations in Indonesia have reached 10 million ha. Other potential biodiesel feedstock in Indonesia is coconut oil, which production reached nearly 0.9 million tonnes with 0.5 million tonnes for export commodities in 2006.

Currently, fuel bioethanol in Indonesia is produced mainly from sugar cane (molasses). Indonesia is among the 10 largest sugarcane producers in the world with a production rate of 30 million tons per year. Other material considered for ethanol production in Indonesia is cassava with an annual production of 17 million tonnes. For the second-generation bioethanol, an economic analysis of biomass resource has been conducted by the Agency for the Assessment and Application of Technology (BPPT).

Table 1. Potential Waste Wood and Agriculture in Indonesia

Biomass Residues	Quantity (million tonnes/yr)
Sugar industry	
Baggase	8.5
Leaf cane	1.3
Palm Oil Industry	
Shell	3.5
Fibre	6.7
Empty fruit bunch	12.9
Palm Oil Mill Effluent	31.0
Rubber	
Rubber wood	2.8
Coconut	
Shell	3.0
Fibre	6.7
Paddy	
Rice husk	13.5
Cassava waste	7.3
Wood waste	8.3
Total	**105.5**

Source: Febijanto 2007; Priyanto 2007

Table 1 presents statistics on lignocellulosic biomass resources (Priyanto 2007). As shown in Table 1, the second-generation biofuel feedstock (excluding Palm Oil Mill Effluent, or POME) amounted to approximately 74 million tons per year, which can produce 22 million kL of ethanol, equivalent to

10.7 million tons of gasoline per year. The volume will replace current 83% of gasoline consumption in Indonesia and 51% of crude oil (APEC 2008) imports.

1.1.3 Biofuels Development Policy

Policy related to biofuel is the mandatory biofuel acceleration in accordance with the Ministry of Energy and Mineral Resources regulation No. 20 of 2014. The regulation considers the availability of raw material for biodiesel that can be fulfilled from domestic palm oil production. Biodiesel production in 2012 amounted to 2.2 million kiloliters, increased 4 times from 2010 that were only about 500 thousand KL. Until December 2013, the temporary number of biodiesel production reached 2.8 million KL. Meanwhile, its utilization in the country reached 1.057 million KL.

Supporting policies of biofuels development are provision of assurance to manufacturers, policy on raw material management including the preparation of dedicated land for biofuel, and fiscal policy including tax exemptions. The government has also issued regulations on biofuel specification including biodiesel, bioethanol, CPO and partially esterified vegetable oils. Following is the roadmap of biodiesel and bioethanol development, which had been prepared by the government (Figure 1 and 2).

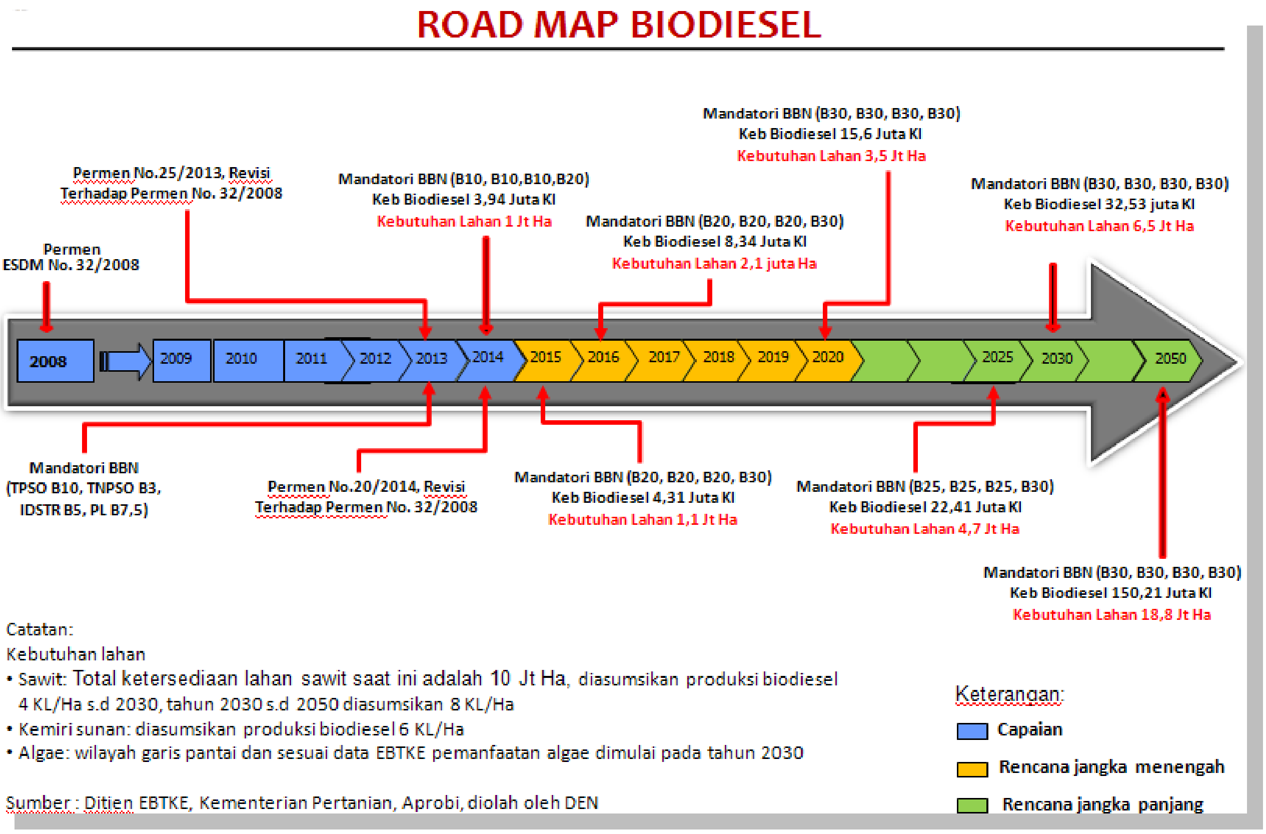


Figure 1. Biodiesel Development Roadmap

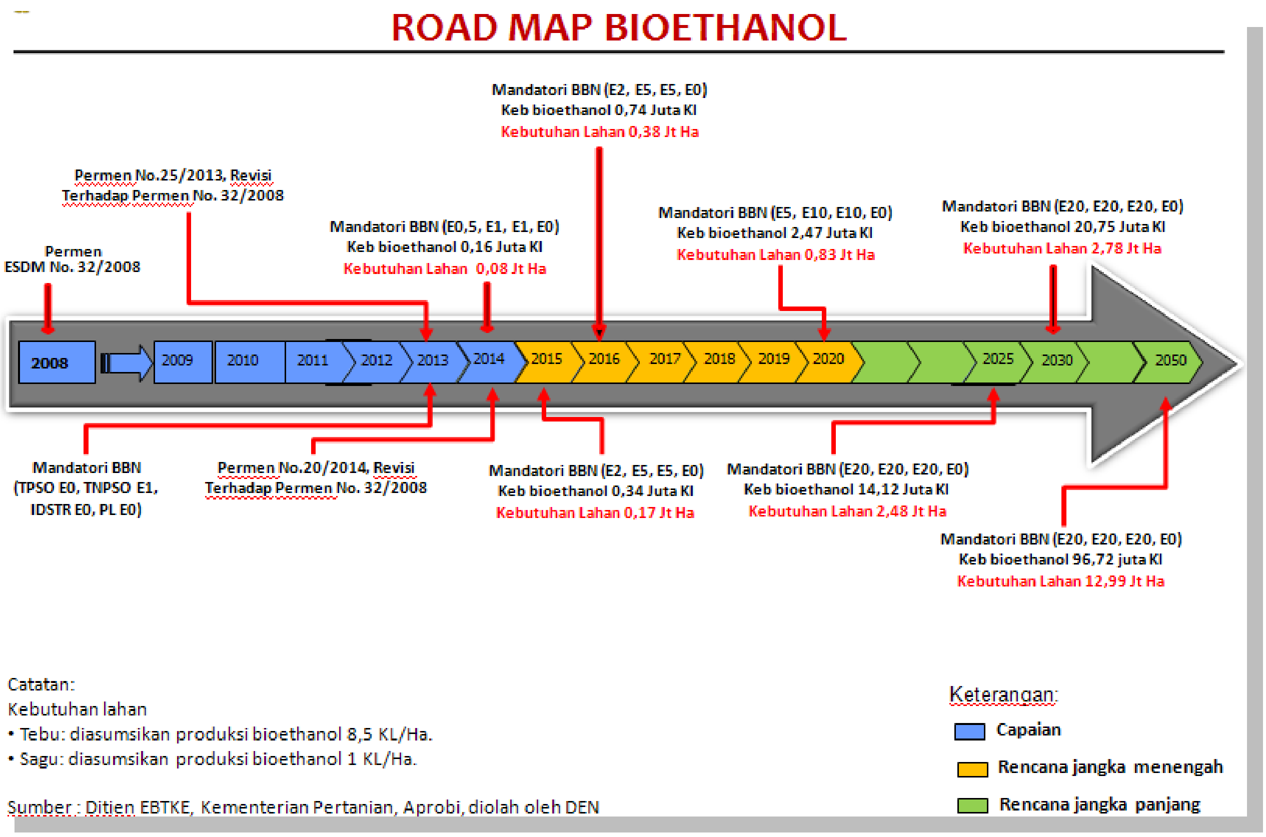


Figure 2. Bioethanol Development Roadmap

1.2 Biogas

1.2.1 Biogas Technology

Biogas can be produced from the anaerobic treatment of organic matter using bacteria. Organic materials that can be processed can be derived from: animal waste, household waste, municipal waste, organic waste from factories, and biomass. Anaerobic digestion is the organic substrates fermentation of biodegradable material in the absence of oxygen. Characteristics of organic matter, temperature and storage time in the digester are the factors that determine the amount of biogas produced. A result from the anaerobic digestion process is biogas (consists of different compounds) as well as sediment. Biogas contains energy while sediments have high nutrient content.

The main components of biogas are methane (CH4), carbon dioxide (CO2), oxygen (O2), nitrogen (N2), hydrogen sulfide (H2S), water (H2O) and other organic compounds. Each has a concentration that varies depending on the type of material being digested. Methane is a powerful greenhouse gas in terms of the ability to confine the heat; this gas is 21 times more potent in damaging the ozone layer than carbon dioxide. So, it is advisable to confine and destroy this gas in order to minimize the negative impact.

As previously mentioned, there are a lot of factors that affect the biogas composition. Table 2 shows the general range of biogas composition.

Table 2. The composition of biogas

Component	Formula	Concentration (%Vol)
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-45
Water vapor	H_2O	2-7
Oxygen	O_2	< 2
Nitrogen	N_2	< 2
Hydrogen sulfide	H_2S	< 2
Ammonia	NH_3	< 1
Hydrogen	H_2	< 1

Source : *Energi Bersih, Buku pedoman untuk lembaga jasa keuangan*, 2014, USAID

One important factor that determines the amount of biogas is the raw material type. Figure 3 below illustrates the average yield of biogas from several types of raw materials.

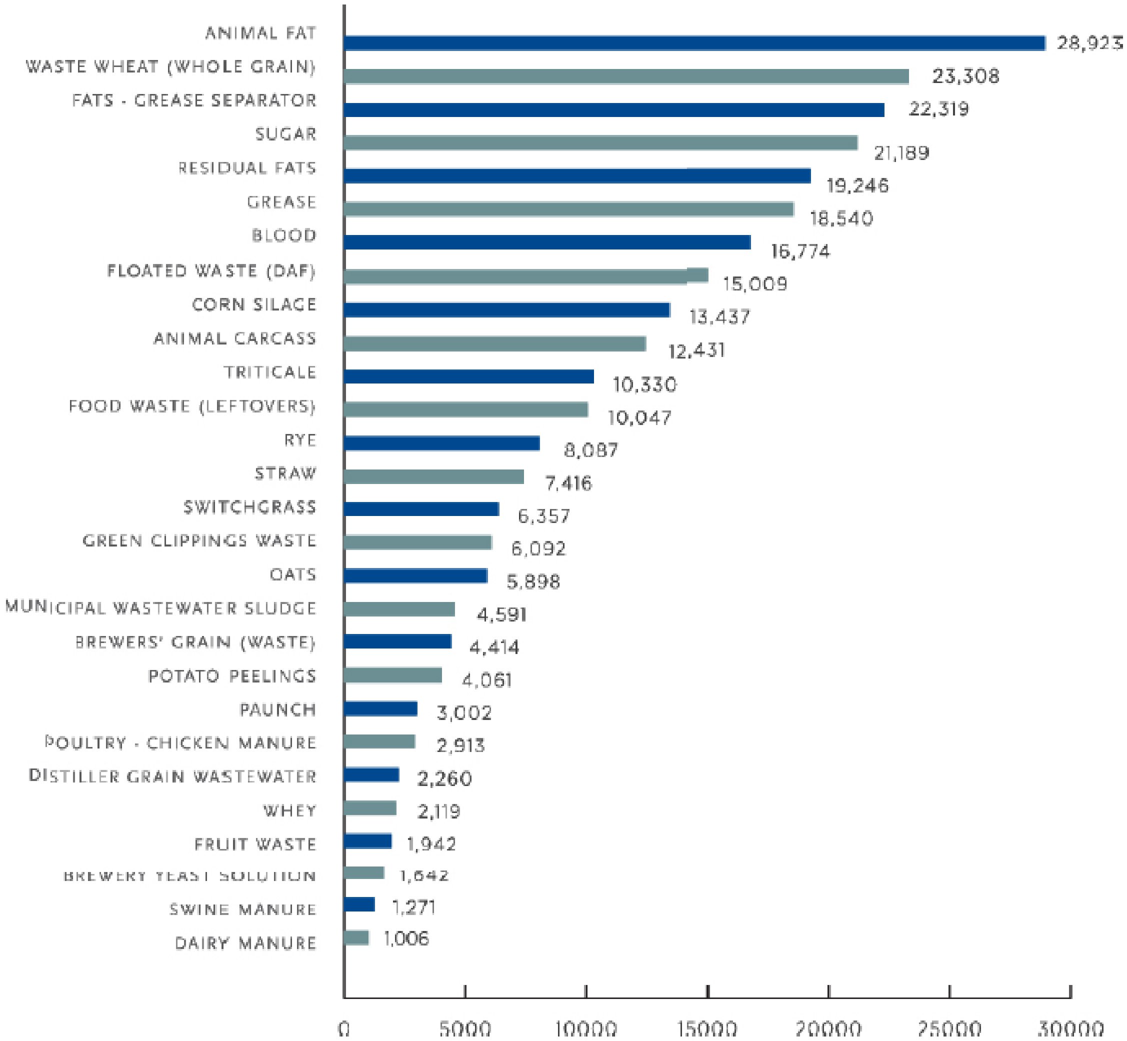


Figure 3. The average yield of biogas from several types of raw materials (ft3 / ton wet)

In general, the biogas production process has four stages, namely: (1) Hydrolysis, (2) Acidification, (3) Formation of acetic acid, and (4) The methane formation. Brief explanations of these processes are as follows.

1. Hydrolysis: At this stage, the organic substrates containing fats, proteins, and carbohydrates with varying proportions are hydrolyzed into dimers and short-chain polymers (fatty acids, amino acids and sugars).
2. Acidification: At this acidification stage, dimer and short-chain polymers are converted by bacteria into short-chain organic acids or volatile fatty acids.
3. The acetic acid formation: alcohol and volatile fatty acid are converted to acetic acid, acetic acid, CO2 and H2.
4. The methane formation: At this stage, the type archae bacteria methanogens will produce methane.

Here are some technology choice for anaerobic digestion facilities (AD) and biogas storage technology for medium and large scale.

Anaerobic digestion (AD)

1. Anaerobic Lake Closed
   In this type of technology, organic materials which are generally liquid waste such POME (Palm oil mill effluent) stored in a lake that is covered by an airtight membrane to capture biogas during aneorabic biological conversion processes. The Illustration of this technology can be seen in Figure 4.

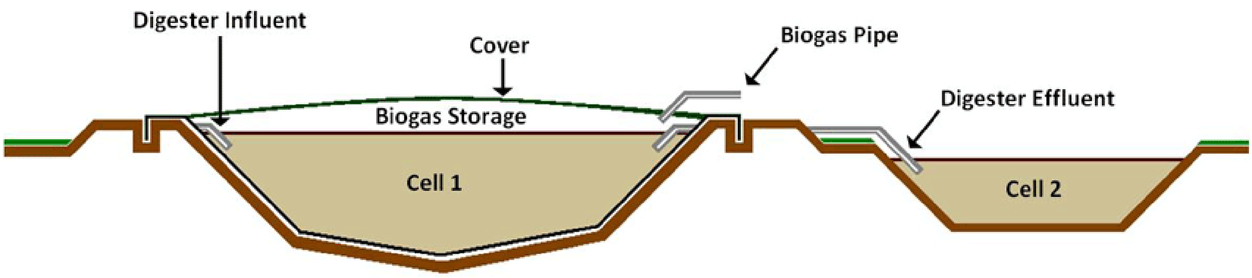
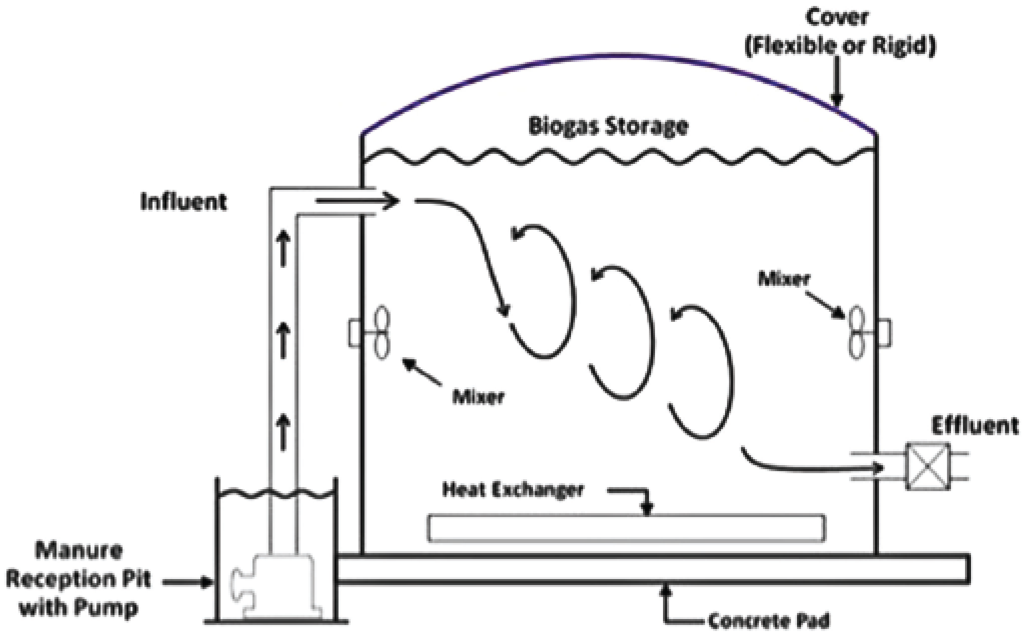


Figure 4. Anaerobic Lake Closed

2. Continuously Stirred Tank Reactor (CSTR)
   In this technology, liquid waste is stored in tanks to capture biogas during the anaerobic biological conversion process. In general, this type of technology has several stirrers in the tank that serves to stir the material that has higher solids content (≥12%) continuously (See Figure 5). In a large-scale facility, facilities have more than one tank arranged in series or parallel.



Source: www.daviddarling.info and IEA Bioenergy.

Figure 5. CSTR Digester Diagram

Table 3 presents a comparison of the advantages and disadvantages between the two technologies

Table 3. Comparison of Anaerobic Digestion Technology

Technology	Advantages	Disadvantages
Anaerobic Lake Closed	• Low capital and operating costs • Simple Technology • Large storage volume	• Requires a large land • Limited to a material with a low solids content • Airtight membrane is often not available in the local market
CSTR	• Neat • Longer economical age • Can accommodate a material with a high solids concentration	• High capital and O & M costs

Biogas storage

Biogas storage is required when the consumption of biogas is not continuous. Biogas storage would be beneficial to accommodate when demand is higher or lower than the biogas production. In general, the storage can be done in two ways: (1) in the digester tank (internal), and (2) outside the digester tank (external). Figure 6 illustrates the storage system (a) internal and (b) external.

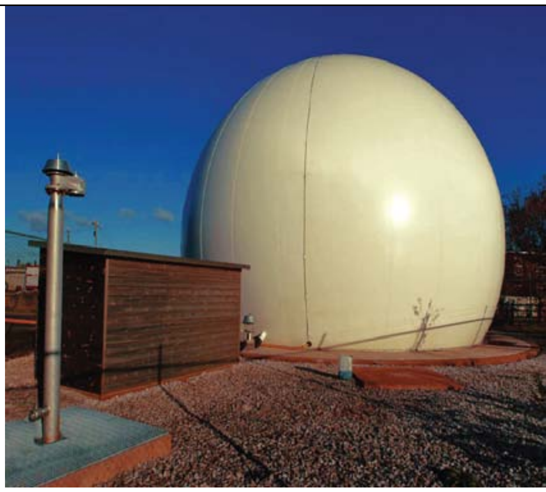
	
(a) Internal	(b) External

Figure 6. Biogas storage system technology

1.2.2 Potential of Biogas Development in Indonesia

As mentioned earlier, biogas can be produced from organic materials such as animal waste, household waste, municipal waste, organic waste from factory, and biomass. However, there are three main sectors that are potential for biogas development in Indonesia, namely agriculture, wastewater and urban waste. Those sectors are considered suitable for biogas development in Indonesia, both in terms of the characteristics, feed stock availability, technical and economic.

Agricultural sector

Biogas in this category is sourced from the waste from animal production facilities such as such as pigs, cows and dairy farming, and the waste from agro-industrial operations such as palm oil refineries, tapioca processing plant, milk processing facilities, refineries, abattoirs and other food processing facilities.

Liquid Waste Sector

This sector includes urban wastewater, which can be directly processed by the AD system,
Or sediment that derives from factory sediment that is activated for separate digestion.

Urban Solid Waste Sector

Municipal solid waste has a high organic content as feedstock for the AD process.

1.2.3 Biogas Development Policy

Currently there are no incentive policies for people who want to develop biogas. Another challenges in the biogas development are the relatively high investment costs for the community and the community's reluctance of using the energy that derives from the dirt. Thus the government needs to disseminate the information in this regard. Other issues that need to be considered in the biogas development by government are human resources competency in terms of biogas technology, and more installation of biogas processing (EMR 2011).

1.3 Solid Bioenergy

In general, biomass is a material that can be obtained from plants, either directly or indirectly and can be used as energy. Sources of biomass can be derived from the activities of Plantation, Agriculture and Forestry. From the plantation sector, biomass can be obtained from the crop residues or waste from processing palm oil, sugar cane, palm or rubber. While from agriculture sector, biomass can be obtained from the harvest residuals and the residuals from the processing of rice, maize, and cassava. From the forestry sector, biomass can be obtained from the residual of wood processing.

1.3.1 Potential of Solid Bioenergy Development in Indonesia

Based on the biomass database of the Ministry of Energy and Mineral Resources in 2013, the general potential of biomass from plantation sources, agriculture and forestry reached 27586.22 MWe[5]. 51% or 14191.75 MWe potential is obtained from plantation sector, 44% or 12085.64 MWe derived from agriculture and the rest is from forest resources (Figure 7). Indonesia's biomass optimization potential [6] reaches 3134.89 MWe, which is mostly generated from plantation sector.

Biomass utilization until 2013 was less than 5% (from the general potential) which only reached 865.73 MWe, with 689.43 MWe was off the grid and 176.3 MWe was on-grid (Figure 8). Most of the biomass that is utilized both off-grid and on-grid derived from plantation sector. IEA (2012) estimates that, in 2050 the world needs about 100 x 10^{18} joules (5 billion to 7 billion dry tons) of biomass. Various studies suggest that the biomass supply is continuously sourced from waste, residues and plants which have been designated for energy crops.

Table 4 presents the various sources and types of biomass that can be utilized. Table 5 presents the characteristic of biomass energy content and water content on any type of biomass resources.

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[5] Commercial potential is defined as: Raw materials including untapped and has been utilized, including the location of the biomass that is still scattered and not yet collected and not consider the ratio of collection yet and collection costs of raw materials

[6] Optimization potential is defined as: Raw materials have been used but not optimal or system utilization efficiency is still low, for example: the use of bagasse (bagasse) as fuel for power generation and steam at Sugar Factory, and the use of fiber and shells as fuel power plants and steam at mills

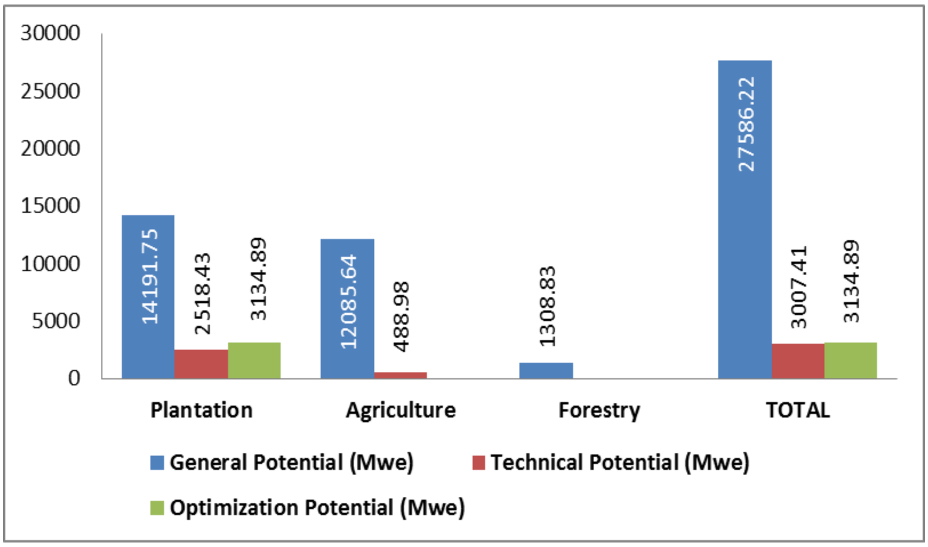

Figure 7. Indonesian Biomass Potential
(Source: Biomass Database DGNREEC MEMR, 2013)

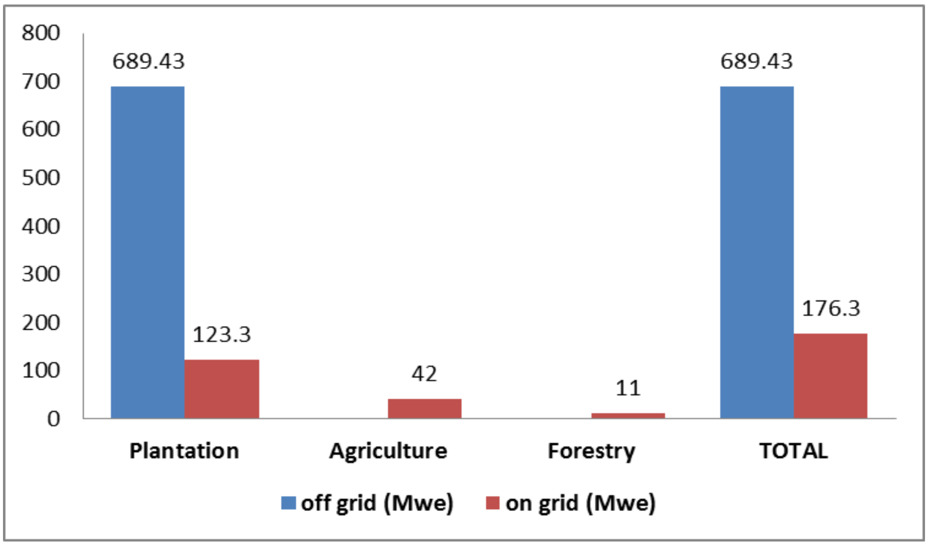

Figure 8. Biomass utilized until 2013
(Source: Biomass Database DGNREEC MEMR, 2013

Table 4. Sources and Types of Biomass

No	Biomass Sources	Type of Industry	Area Type Industry	Type of Biomass		
				The rest of the Harvest	Re-planting	Residual Processing
1	Plantation	Palm oil	Oil Palm Plantation	Palm midrib	Palm trunks	
					Palm midrib	
			Palm oil mill			Empty fruit bunches
						Palm fiber
						Palm Kernel Shell
						Liquid palm waste
		Sugar cane	Sugar cane plantations	Leaves and shoots		
			Sugar cane factories		Bagasse-Bagasse	
		Coconut	Coconut processing			Shell
						Coco
		Rubber	Rubber plantations		Rubber rod	
2	Agriculture	Paddy	Rice farming	Rice straw		
			Rice mill			Rice husk
		Corn	Corn Agriculture	Stems and leaves of corn		
			Corn processing			Corncob
		Cassava	Cassava Agriculture	Cassava stem		
			Cassava processing			Liquid waste cassava
3	Forestry	Wood	Forest industry	Woodchip		
			Sawmill			Woodchip
						Sawdust
			Plywood			Woodchip
						Sawdust
			Pulp and Paper			Black liquor
						Wood waste

(Source: Kementerian ESDM 2013)

Table 5. Calorific value and water content of biomass feedstock

Type of Industry	Feedstock	*Calorivic Value* (kkal/kg)	*Moisture* (%)
Palm Oil	Palm Fiber	3340	30
	Palm kernel Shell	4300	15
	Empty fruit bunches (EFB)	1200	45
	Frond	3350	20
	Trunk and Front	3500	20
Sugar cane	Bagasse	1850	50
	Cane and Top Cane	3000	30
Coconut	Coco	3300	30
	Coconut shell	4300	15
Rubber	Rod rubber replanting	4400	15
Paddy	Rice husk	3350	12
	Rice straw	2800	50
Corn	Corn cob	3500	14
	Corn Stem and leaves	2500	40
Wood	Wood waste	4400	15
Pulp and Paper	Black liquor	3300	70

(Source: Kementerian ESDM 2013)

Table 6 presents the database of potential biomass based on a study by the Directorate of Bioenergy, Ministry of Energy and Mineral Resources.

Table 6. Biomass Potential

No	NATIONAL	Unit	Availability Raw Materials (ton)	Potential Energy (GJ)	General Potential (MWe)
1	**Palm oil**				
	Fiber	Ton	12,830,950	180,778,665	1,231
	Shell	Ton	6,136,541	108,861,141	759
	Empty Fruit Bunches	Ton	23,988,298	118,757,608	827
	POME	M3	47,995,674	34,903,142	430
	Fronds	Ton	75,517,083	1,063,384,453	8,430
	Fronds and Stems	Ton	8,412,853	123,280,262	977
2	**Sugar cane**				
	Bagasse	Ton	9,559,395	73,470,505	582
	Leaves and shoots Cane	Ton	7,154,403	89,862,170	712
3	**Rubber**				
	Stems & Leaves	Ton	19,039,680	350,747,462	2,781
4	**Coconut**				
	Coconut Fiber	Ton	1,119,301	15,464,755	119
	Coconut Shell	Ton	383,760	13,262,898	59
5	**Paddy**				
	Rice husk	Ton	13,016,712	180,592,857	1,432
	Straw	Ton	90,370,365	1,056,602,982	8,376

6	**Corn**				
	Cob	Ton	4,263,116	62,470,849	495
	Stems & Leaves	Ton	14,920,906	156,177,123	1,238
7	**Cassava**				
	Liquid Waste	m3	111,796,967	10,089,673	271
8	**Wood**				
	Black Liquor	Ton	7,967,045	110,076,196	955
	Waste wood	Ton	2,678,782	49,348,299	380
9	**Cow**				
	Dirt	Ton	53,782,761	35,496,619	535
10	**Municipal Solid Waste**				
	Wet Organic Waste	Ton	18,499,755		
	Refuse Derived Fuel	Ton	9,816,034	260,649,740	2,066
	TOTAL NASIONAL		-	**4,094,277,399**	**32,654**

1.3.2 Solid Bioenergy Development Policy

Policy related to the biomass development under the Ministry of Energy and Minerals Regulation No. 27 of 2014 on the Power Purchase from Biomass Power Plant and Biogas Power Plant by PT. PLN.

2. Methodology

Bioenergy supply sector is divided into three, (1) the subsector of vegetable liquid fuels supply; (2) the subsector of solid bioenergy supply; and (3) the subsector of bioenergy gas supply. The structure of energy supply modeling is presented in Figure 9.

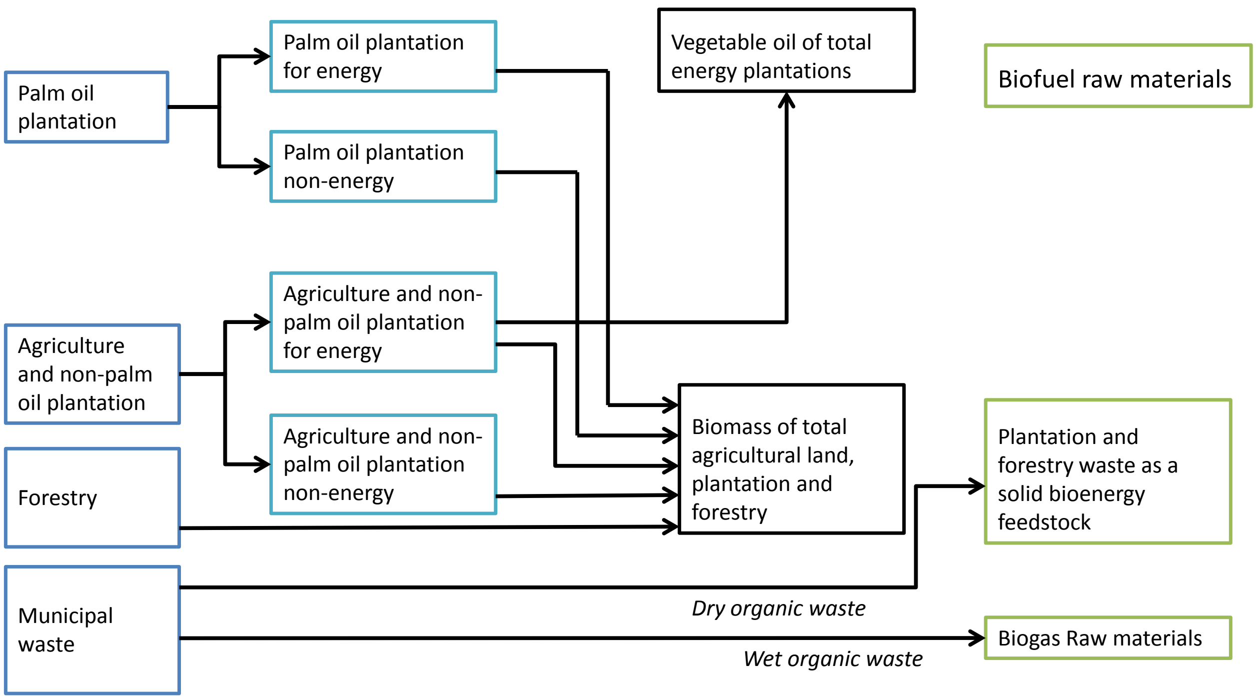

Figure 9. Bioenergy Resources Supply Modeling

Land use sector that is associated with bioenergy supply sectors are oil palm plantation sector, non-palm plantations and forestry. In Indonesia 2050 Pathway Calculator modeling, there are some simplifications for bioenergy supply sector, among others:

(1) It is assumed that most biofuel produced is the first-generation biofuels that is made of vegetable oils.
(2) It is assumed that solid bioenergy feedstock only derives from the wastes/residues of agriculture, plantation and forestry.
(3) It is assumed that biogas feedstock only derives from municipal solid waste.

Bioenergy supply is assumed to be limited by land area based on the user's selected one pager. Plantation areas for both palm oil and non-palm oil are assumed separated for bioenergy and non-energy supply purposes.

Determining one pager assumptions and parameters that affect bioenergy supply projections until 2050 were conducted through expert judgment and discussions with stakeholders including the government, associations, businesses and academia.

The bioenergy and solid bioenergy supply is calculated based on the following equation.

$$S = A \times P \times Y \times E$$

S *Supply* or liquid biofuels supply or solid bioenergy in energy units.

A *Area* or area that is dedicated to producing bioenergy

P *Biomass potential* or the biomass potential percentage that will be used for bioenergy supply

Y *Yield* or biofuel production and production of waste biomass for each land

E *Energy content* or energy content from biofuels or solid bioenergy produced

In the above equation, the land area parameter is set as trajectory assumption. The potential biomass parameter is used as a trajectory assumption only for solid bioenergy sector. Meanwhile, this parameter is set 100% for biofuel supply sector. The parameters of biomass production and energy content are set as the fixed assumptions that are taken from literature. The conversion efficiency parameter in the biofuels production is assumed to have been accommodated in the yield value or the biofuel production. The land area figure that is used as the input for the calculation of solid bioenergy supply only covers a total area of agricultural and plantation sectors including oil palm plantations and forestry sector. Meanwhile, the land area figure that is used as the input for the calculation of liquid biofuels supply only covers a total area of oil palm plantations and non-palm plantations, which are dedicated for biofuels production. The land area input is determined based on the user's selected level in land use sector and in the energy plantations sector.

Biogas supply is calculated by the following equation:

S = P x W x C x E

S *Supply* or biogas supply in energy units

P *Percentage of potential waste to energy* or a percentage of waste potential production that can be processed into biogas

C *Composition* or composition of municipal solid waste

W *Waste production* or the production of municipal waste by weight per capita per year

E *Energy content* or energy content of biogas produced for each unit of waste weight

In the above equation, the parameter of waste production potential percentage is set as trajectory assumption. Meanwhile, the parameter of municipal solid waste production, municipal solid waste composition and energy content are set as fixed assumption, which figures are taken from literature.

3. Liquid Biofuel Supply Sector

Fixed assumption

a. Biofuels Yield

Table 7. Biofuels Yield assumption (DEN)

Sector	Biofuels Yield
Agricultural and non-palm plantations for energy	7 kL/ha
Palm plantations for energy	6 kL/ha

b. Energy content of biofuel

Table 8. Assumptions of biofuel Energy content (BPPT)

Sector	Description	Energy content
Agricultural and non-palm plantations for energy	The first-generation biofuels	0.00759 MWh/L
Palm plantations for energy	The first-generation biofuels	0.010034 MWh/L

c. Own *use Energy Needs*

Own use energy needs to produce biofuel is assumed to be 5% from produced biofuel production (UK Calculator 2050).

Trajectory assumption

The trajectory assumptions for the liquid biofuels supply sector are the palm oil and non-palm plantation areas for biofuels until 2050. The area for energy plantation is calculated based on the percentage that is attached to each level selected by the user. The percentage is compared to the level of palm oil and non-palm plantations areas for non-energy, which is selected by the user in the land use sector. The total plantation area is obtained by adding the non-energy plantation area with the energy plantation area.

Plantation Area for Biofuels

The raw materials of first generation biofuels derived from vegetable oils. Palm oil is the best raw material for biodiesel production in terms of feedstock availability and commercially available technologies. In addition, palm kernel oil is also a raw material for bioavtur production. Apart from palm oil, vegetable oils derived from cassava, sugar cane, corn and *nypa* may be used to produce bioethanol; as well as from non-edible oil such as jatropha, *kemiri sunan*, *pongam, nyamplung*, rubber, and etc. Biofuels can also be produced from lignocelluloses-based raw materials and algae.

This one pager describes scenario that can be selected to determine the extent of plantations area dedicated to the production of biofuels by 2050 based on the scenario of non-energy plantations, including palm oil.

Level 1

Level 1 assumes plantation area for biofuels reaches 1.05 times of the non-energy plantations in 2050. It is assumed that it happens due to a very strict implementation of the policy on the restriction of new land clearing and the government incentives for intensification programs that increase productivity.

Level 2

Level 2 assumes plantation area for biofuels reaches 1.1 times of the non-energy plantations in 2050. It is assumed that it happens due to the implementation of the policy on the restriction of new land clearing and mandatory re-planting of energy plantation especially palm oil plantations.

Level 3

Level 3 assumes the plantation area for biofuels reaches 1.15 times of the non-energy plantations in 2050. It is assumed that the situation is triggered by the moderate implementation of policy on limiting new land clearing without the support of incentives for intensification program.

Level 4

Level 4 assumes plantation area for biofuels reaches 1.3 times of the non-energy plantations in 2050. It is assumed that the situation is triggered by the government's commitment to reduce greenhouse gas emissions from fossil fuels.

4. Solid Bioenergy Supply Sector

Biomass supply sector includes the utilization of waste biomass from agriculture, plantation and forestry.

Fixed assumption

a. Yield and energy content of waste biomass

Assumptions of yield biomass waste and biomass energy content are obtained from the database of the Directorate of Bioenergy Biomass of the Ministry of Energy and Mineral Resources. The land area is obtained from the Ministry of Agriculture (2011). Based on available data, assumptions of the yield and energy content of biomass are presented in Table 9. It is assumed that the yield and energy content are constant of the base year 2011 to 2050.

Table 9. Assumptions Yield and Energy Content of Waste Biomass

Type of Industry/ Sector	Raw Materials	Sources	Waste (ton/year)	Land area (ha)	Potential energy (GJ)	Yield of biomass (ton/ha)	Potential Energy (TWh/ million ton)
Palm oil plantation	Palm oil	Fiber	12,830,950	8,992,824	180,778,665	13.17	3.45
		Shell	6,136,541		108,861,141		
		EFB	23,988,298		118,757,608		
		Branch	75,517,083		1,063,384,453		
Agriculture & non-palm oil plantation	Paddy	Rice husk	13,016,712	38,683,978	180,592,857	3.64	3.25
		Straw	90,370,365		1,056,602,982		
	Corn	Cob	4,263,116		62,470,849		
		Stems & Leaves	14,920,906		156,177,123		
	Sugar cane	Bagasse	9,559,395		73,470,505		
		Leaves and shoots Cane	7,154,403		9,862,170		
	Coconut	Coconut Fiber	1,119,301		15,464,755		
		Coconut Shell	383,760		13,262,898		
Forestry		Industrial waste wood	8,345,932	10,046,839	153,645,269	0.27	5.12

(From various sources)

b. *Own use Energy Needs*

Own use energy needs to produce solids bioenergy is assumed to be 2% from the solid bioenergy production produced (UK Calculator 2050).

Trajectory assumption

The trajectory assumptions for biomass supply sector are the utilization level of biomass waste in Agriculture, Plantation and Forestry sectors until 2050.

a. Utilization of Agricultural and Non-Palm Oil Plantation Biomass Waste

Agricultural biomass waste includes straw and rice husks, stalks and cobs of corn, cassava stems and etc. Meanwhile, plantation wastes include bagasse, shell and coconut fiber, and rubber rods. Based on the biomass database of the Ministry of Energy and Mineral Resources in 2013, the biomass potentials from agriculture and plantation sectors are 12,085 Mwe and 14,191 Mwe respectively.

Level 1

Level 1 assumes the level of biomass potential used to produce solid bioenergy from agricultural waste and non-palm oil plantations in 2050 reaches 5%. It is perceived that at this level, biomass still adopts traditional method and the community is still not familiar with the supporting technology.

Level 2

Level 2 assumes the level of biomass potential used to produce solid bioenergy from agricultural waste and non-palm oil plantations in 2050 reaches 10%. It occurs by assuming that the policies on incentives and electricity feed-in-tariffs for biomass electricity are in place. The business entities in agriculture and plantation sectors have begun to use alternative energy from biomass waste for industrial activities.

Level 3

Level 3 assumes the level of biomass potential used to produce solid bioenergy from agricultural waste and non-palm oil plantations in 2050 reaches 25%. This figure is achieved through the policies on incentives, feed-in tariffs, green industrial policy, GHG emission reduction, fuel consumption reduction and etc. At this level, access to finance and human resource capacity increase.

Level 4

Level 4 assumes the level of biomass potential used to produce solid bioenergy from agricultural waste and non-palm plantations in 2050 has reached 80%. This figure is achieved through policy on incentives, feed-in tariffs, green industrial policy, GHG emission reduction, fuel consumption reduction etc. At this level, access to finance and human resource capacity increase along with supporting policies of local government.

b. Utilization of Palm Oil Plantation Biomass Waste

The potential biomass of palm oil plantation in Indonesia is estimated 14,191 Mwe. According to the biomass database of the Ministry of Energy and Mineral Resources in 2013, the biomass waste of palm oil plantation sector that can be used as the source of alternative energy are rods, shells and empty fruit bunches.

Level 1

Level 1 assumes that 25% of the biomass waste potential in palm oil sector has been used to produce solid bioenergy by 2050. It occurs based on the assumption that at this level the industry still utilizes biomass in a small-scale and the community still utilizes biomass using traditional method, without any infrastructure or supporting technology that the community is familiar with.

Level 2

Level 2 assumes that 35% of the biomass waste potential in palm oil sector has been used to produce solid bioenergy by 2050. It is assumed that at this level the policy on incentives and feed-in-tariff for electricity from biomass are in place, thus the biomass utilization as alternative energy for industrial activities by palm oil business entity increases.

Level 3

Level 3 assumes that 50% of the biomass waste potential in palm oil sector has been used to produce solid bioenergy by 2050. It is assumed that at this level, the supporting policy such as policy on incentives, feed-in tariffs, green industrial policy, GHG emissions reduction, fuel consumption reduction and etc. are in place. At this level, access to finance and human resource capacity increase.

Level 4

Level 4 assumes that 80% of the biomass waste potential in palm oil sector has been used to produce solid bioenergy by 2050. The main policies that support the use of biomass is the zero waste policy in palm oil industry activities, along with the availability of more efficient technologies for both large and small scale. At this level, funding schemes for biomass utilization activities have been developed and there are supports from government policies at national and local level.

c. Utilization of Forest Biomass Waste

Biomass waste can be utilized for alternative energy sources. Apart from its direct use for cooking in the household sector, biomass waste of forestry sector can be used as the feedstock to supply the biomass power plants. Based on the biomass database of the Ministry of Energy and Mineral Resources in 2013, the general potential of biomass from forestry sector is estimated 1,308 MWe.

Level 1

Level 1 assumes the level of biomass potential used to produce solid bioenergy from waste of forestry activities in 2050 reaches 5%. It is perceived that at this level, biomass is still utilized using traditional method and the community is still not familiar with the supporting technology.

Level 2

Level 2 assumes the level of biomass potential used to produce solid bioenergy from waste of forestry activities in 2050 reaches 10%. It is assumed that at this level the policy on incentives and feed-in-tariff for electricity from biomass are in place, thus the biomass utilization as alternative energy for industrial activities by forestry business entity increases.

Level 3

Level 3 assumes the level of biomass potential used to produce solid bioenergy from waste of forestry activities in 2050 reaches 15%. It is assumed that at this level, the supporting policy such as policy on incentives, feed-in tariffs, green industrial policy, GHG emissions reduction, fuel consumption reduction and etc. are in place. At this level, access to finance and human resource capacity is increases.

Level 4

Level 4 assumes the level of biomass potential used to produce solid bioenergy from waste of forestry activities in 2050 reaches 80%. The main policies that support the use of biomass is the zero waste policy in forestry industry activities, along with the availability of more efficient technologies for both large and small scale. At this level, funding schemes for biomass utilization activities have been developed and there are supports from government policies at national and local level.

5. Biogas Supply Sector

<u>**Fixed assumption**</u>

a. Waste production per person

Production of municipal waste is assumed to be 0.5 kg / capita / day; this assumption is based on the results of research conducted by NUDS (National Urban Development Strategy, 2003).

b. Municipal solid waste composition

Table 10. The assumption of Municipal Solid Waste Composition (UK Calculator 2050)

Type	Percentage
Dry waste	34.0%
Wet waste	65.0%
Inorganic waste	1.0%

c. The energy content of municipal waste

Table 11. Assumptions Energy content of Municipal Solid Waste (UK Calculator 2050)

Type	Energy Content (TWh/ million ton)
Dry waste	8.33
Wet waste	1.39
Inorganic waste	-

<u>***Trajectory assumption***</u>

Biogas from municipal waste processing is one of the components of bioenergy supply sector. Biogas is produced from organic waste through anaerobic process that uses microorganisms. Biogas can be used for cooking and electricity generation. Currently, municipal waste has not been used and dumped into landfills.

Level 1

Level 1 assumes the biogas potential that has been tapped is 1.87 MWe by 2050. It is supported by the construction of waste management facilities and bio-digesters in 20 major cities in Indonesia. The most efficient capacity of biogas plant from economic perspective is available in large cities with respect to the waste potential.

Level 2

Level 2 assumes the biogas potential that has been tapped is 2.8 MWe by 2050. It is supported by the construction of waste management facilities and bio-digesters in 20 big cities and 25 medium cities in Indonesia. It is also supported by the presence of feed in tariff policy and the increasing awareness of local government to jointly invest in the utilization of municipal solid waste for energy generation.

Level 3

Level 3 assumes the biogas potential that has been tapped is 3.7 MWe by 2050. It is supported by the construction of waste management facilities and bio-digesters in 20 big cities and 50 medium cities in Indonesia. It is also supported by the feed in tariff policy and the increasing awareness of local government to jointly invest in in the utilization of municipal solid waste for energy generation through the PPP (public private partnership) mechanism. The efficient small-scale Waste to energy (WTE) technology for is also assumed available.

Level 4

Level 4 assumes the biogas potential that has been tapped is 6.2 MWe by 2050. It is supported by the construction of waste management facilities and bio-digesters in 20 big cities and 100 medium cities in Indonesia. It is also supported by the feed in tariff policy and the increasing awareness of local government to participate in the utilization of municipal solid waste for energy generation through the PPP (public private partnership) mechanism. The efficient small-scale waste to energy (WTE) technology is assumed available, thus smaller towns utilize WTE technology in the waste management system.

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