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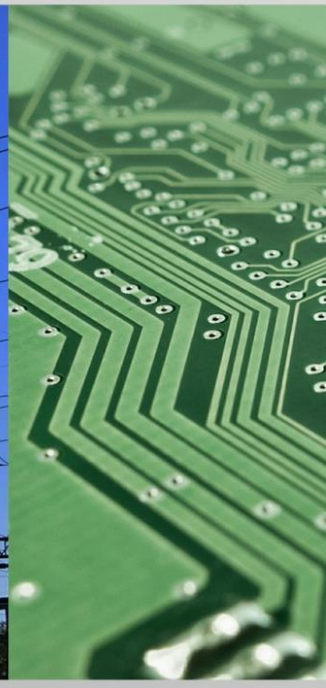

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A Review on Biomass For Electricity Generation In Indonesia

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Abstract The Indonesian National Energy Policy stipulates that renewable energy must contribute 23% of total energy consumption by 2025 and increase to 31% by 2050. Among many resources of the country, biomass is a renewable energy source whit the potential is estimated at 32,654 MW. This article reviews the biomass and electricity generation implementation in Indonesia to get insights on the development of the biomass for power generation of the country. Currently, the biomass electricity generation technology that has been applied in Indonesia includes direct combustion as fuel for coal power plants or co-firing, converted into refuse-derived fuel, gasification, sanitary landfills, and incinerators. From 2011 to 2019, the installed capacity of biomass power plants reached 1857.5 MW or 33.78% of the target of 5500 MW in 2025. The biomass power plants are located in North Sumatra, Jambi, Gorontalo, Riau, West Nusa Tenggara, Papua, Bangka Belitung, North Sulawesi, South Sumatra, East Java, and Jakarta. Considering the high 2025 electricity from biomass target, it is necessary to develop a more intensive biomass power plants because of its large potential, available technology, and its benefits to increase the electrification ratio especially for providing electricity for people in areas not yet covered by the utility network, realizing national energy security, and reducing the use of fossil-based fuels.

***Index Terms*— Bioenergy, biomass, biomass power plants, power generation, gasification**

I. INTRODUCTION

Indonesia is an archipelago consisting of 17,504 islands divided into 34 provinces' administrative areas [1]. It is a tropical country that is crossed by the equator with an area of 8 million hectares of agriculture and 86 million hectares of forest hence pose an enormous natural potential [2] [3]. Based on data from the Ministry of Energy and Mineral Resources in 2013, the potential for biomass was estimated at 32,654 MW. Biomass resources include palm oil, sugar cane, rubber, coconut, rice, corn, cassava, wood, livestock manure, and municipal waste.

In 2017, Indonesia's electricity system had an installed power capacity of 57,177 MW of which 50,408 MW were generated using conventional power plants and the rest of 6,769 MW were renewable energy power plants [4]. These figures show that Indonesia had only 11.83% of power plants that use renewable resources. According to the National Energy Policy (KEN), the Government of Indonesia stipulates that in 2025 as much as 23% of energy should come from renewable energy sources and increase to 31% by 2050 [5]. In the field of bioenergy, Indonesia has utilized 5.1% of the potential of bioenergy with an installed electric power of 1,671 MW in 2015 [6].

Bioenergy is a term that is widely used to describe gas, liquid, or solid energy products which are mostly derived from biological raw materials namely biomass [7]. Biomass is defined as material derived from living plants, including tree trunks, branches, leaves and residues from agricultural harvesting and processing of seeds or fruits [8]. Biomass is part of solid bioenergy that can be converted into other forms such as gases and liquids through chemical processes.

At present, the use of biomass energy constitutes around 10% of the world's primary energy production, equivalent to 1,277 Gt of oil or with 53.47 EJ of primary energy consumption of total biomass in 2012 [9]. The contribution of fossil fuels to energy production amounts to more than 80% of primary energy production. In 2011, 337 TWh of electricity was generated from renewable energy sources and combustible waste [10]. Countries such as the United States (20.6%), Germany (12.9%), Brazil (10.1%), Japan (6.9%) and the United Kingdom (4.4%) are producers of electricity from biomass and the biggest waste is seen from energy production. In terms of electricity production per capita, countries in Northern Europe such as Finland, Sweden, and Denmark have the highest levels of biomass and waste electricity production in the world [11].

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The utilization of biomass as a source for electric power generation is one solution that can be developed to increase the electrification ratio and realize the national energy security [12]. Biomass is a renewable and sustainable energy source, supplies more biomass than other renewable energy sources such as solar and wind power, and has the potential to supply even more [13]. Biomass is the main energy source of millions of people in the world, but its use decreases when coal, oil, and gas are abundant. The use of biomass to replace fossil fuels can reduce the problem of global carbon dioxide emissions [14].

The results presented here are a review on the development of biomass in Indonesia which covers the potential of biomass resource, types of biomass material in each province, the development of biomass for power generation from the early stage of development until today and the future plan. The review will look at the type of biomass, biomass-to-fuel processing technology, electrical power generation technology, and also the current progress and future plan of the country with respect to biomass power generation. The objective of this study is to obtain the latest status of biomass development in Indonesia and in particular its use in the power generation sector. The results will provide insights and quick reference in understanding the potential, progress, and future development of biomass and its conversion to electricity to date and plans for future development.

II. Material and Research Methods

The research uses data sourced from government policies and regulations, scientific publications such as journals and conferences, publications from renewable energy institutions, research and development institutions, industry, and mass media. Government agencies include the Ministry of Energy and Mineral Resources (MEMR), the Ministry of Home Affairs, the Office of Government Secretariate, the agency for technology research and application BPPT, the state-owned utility company PLN, research institute LIPI, and the agency for national planning and development BAPPENAS. The schematic of the study is shown in Figure 1.

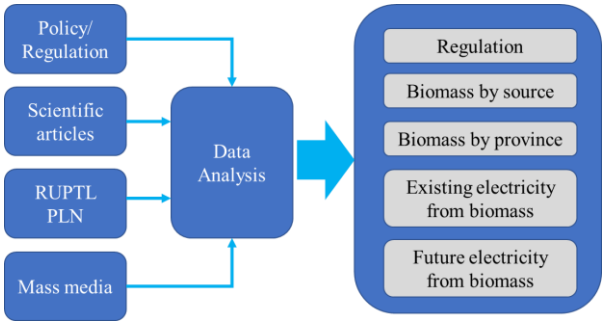


Fig. 1. Schematic of research methodology

III. Result and Discussion

A. Indonesian Biomass Policy and Regulations

The policies and regulations on biomass in Indonesia are in the form of laws, government regulations, presidential instruction, ministerial regulations, regional regulations, and other forms of government regulations. A list of biomass regulations is shown in Table 1.

TABLE I
POLICY AND REGULATION OF BIOMASS IN INDONESIA

POLICY/REGULATION	CONCERNING
UU 30 of 2017	Energy
PP 79 of 2014	National Energy Policy
PERPRES 18 of 2016	Accelerating the Development of Waste Based Power Plants in DKI Jakarta Province, Tangerang City, Bandung City, Semarang City, Surakarta City, Surabaya City, and Makassar City
PERPRES 35 of 2018	Acceleration of the Construction of Waste Processing Installations into Electrical Energy Based on Environment-Friendly Technology
PERPRES 22 of 2017	National Energy General Plan
INPRES 1 of 2006	Provision and Utilization of Biofuel as Another Fuel
PERMEN ESDM 21 of 2016	Purchasing Electricity from Biomass Power Plants and Biogas Power Plants by PT PLN (Persero)
PERMEN ESDM 39 of 2017	Implementation of Physical Activity Utilization of New and Renewable Energy and Energy Conservation
PERMEN ESDM 50 of 2017	Utilization of Renewable Energy Sources for the Supply of Electricity
PERMEN ESDM 53 of 2018	Utilization of Renewable Energy Sources for the Supply of Electric Power
PERGUB BALI 48 of 2019	Bali Clean Energy
PERDA JATENG 3 of 2016	Energy Management in Central Java Province

From Table 1, it can be seen that policies and regulations governing the use of biomass energy are contained in the law or UU #30/2017 concerning energy, government regulation PP #79/2014 concerning national energy policy (KEN), and PERPRES #22/2017 concerning general plans for national energy (RUEN). Then Perpres #18/2016 concerning the acceleration of construction of waste-based power plants and PERPRES #35/2018

regulates the acceleration of the development of environmentally friendly technology for municipal waste particularly for power generation or PLTSa installations. PLTSa is an abbreviation to describe electric power generation from municipal solid waste.

Ministry of MEMR regulation or Permen ESDM is issued by the ministry to regulate and particularly to accelerate the development of this field. Permen ESDM #21/2016 concerning the purchase of electricity from PLTBm and PLTBg by the utility which in this case is PLN the state-owned electricity company. PLTBm is an abbreviation to describe power generation using biomass. PLTBg is an abbreviation to describe power generation using biogas. Permen ESDM #39/2017 concerning the implementation of physical activities of renewable energy utilization and energy conservation, and Permen ESDM #53/2018 concerning the utilization of renewable energy sources for electricity supply. In addition to central government regulation, a number of the provincial government have released their regulations to accelerate the development of this field within their territory. For example, the Government of Bali has released Governor Regulation or Pergub #48/2019 concerning clean energy development fo Bali. Another example is the Government of Central Java has released Provincial Regulation or PERDA #3/2016 concerning energy management in Central Java Province.

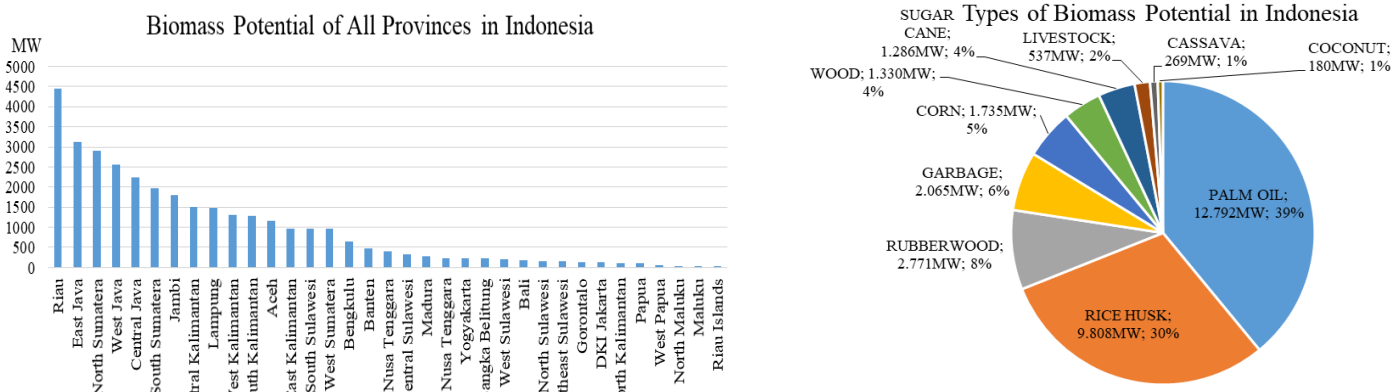
B. Biomass Potential in Indonesia

Currently, biomass potential data is available to the public up to the provincial level is available from Directorate of Bioenergy, EBTKE, Ministry of Energy and Mineral Resources. The following table presents the biomass potential of Indonesia by provincial areas.

TABLE II
BIOMASS POTENTIAL BY PROVINCE IN INDONESIA [15]

PROVINCE	ELECTRICAL POTENTIAL (MW)										
	PALM OIL	SUGAR CANE	RUBBER WOOD	COCONUT	RICE HUSK	CORN	CASSAVA	WOOD	LIVESTOCK	GARBAGE	TOTAL
Riau	2.888		430	24	88	5	1	962	6	32	4.436
East Java		630		11	1.476	460	35	4	140	367	3.123
North Sumatera	1.927	30	220	5	472	111	11	4	16	99	2.895
West Java	22	62		6	1.772	90	28	4	15	558	2.557
Central Java		138		10	1.431	262	39	3	70	278	2.231
South Sumatera	1.187	43	70	3	492	10	4	91	9	62	1.971
Jambi	840		687	6	96	4	1	148	4	15	1.801
Central Kalimantan	1.234		140	4	99	1	2	18	2	10	1.510
Lampung	179	326	114	6	448	217	89	6	27	57	1.469
West Kalimantan	758		285	4	205	19	3	7	6	23	1.310
South Kalimantan	574		386	2	281	9	1	13	5	19	1.290
Aceh	646		233	3	240	13	1		17	21	1.174
East Kalimantan	837		43	1	58	2	1	5	3	15	965
South Sulawesi	25	22		5	696	119	7	18	36	33	961
West Sumatera	485		55	5	337	36	2	1	12	23	956
Bengkulu	434		108		79	11	1		4	8	645
Banten	41			3	297	3	1		2	117	464
West Nusa Tenggara				3	315	31	1	1	25	28	404
Central Sulawesi	117			11	158	18	1	1	8	11	325
Madura				3	120	90	5		32	31	281
East Nusa Tenggara				3	90	64	17	18	28	20	240
Yogyakarta		15		3	126	30	9		14	27	224
Bangka Belitung	214				3					5	222
West Sulawesi	134			2	56	5	1		3	5	206
Bali				4	131	10	1		23	22	191
North Sulawesi				15	88	45	1		4	10	163
Southeast Sulawesi	47			2	69	11	3	1	8	10	151
Gorontalo		20		3	42	54			7	4	130
DKI Jakarta					1					126	127
North Kalimantan	118										118
Papua	42			13	16	1	1	9	2	12	96
West Papua	33			1	4			12	3	2	55
North Maluku				14	9	2	1	1	2	5	34
Maluku				4	13	2	1	3	3	7	33
Riau Islands	10			1					1	3	15
TOTAL	12.792	1.286	2.771	180	9.808	1.735	269	1.330	537	2.065	32.773

Based on Table 2, it can be seen there are ten types of biomass sources that can be utilized as an energy source. The source is palm oil, sugar cane, rubber, coconut, rice, corn, cassava, wood, livestock, and urban waste. Parts of palm oil that can be utilized are the meat and its kernel. These can be converted to biodiesel oil. Then coir and the shells can be used as fuel as co-firing in a coal power plant or PLTU. PLTU is an abbreviation to describe a coal power plant. Sugarcane bagasse can also be used as fuel for electricity generation. Then the rubber tree, the trunk that is no longer producing rubber latex is used as fuel for power plants. Then the shell and coconut fiber can also be used as fuel for electricity generation. Rice husk after harvest can also be used as fuel for power plants. Corn cobs after harvest can also be used as fuel for power plants. Cassava stems can also be used as fuel for power plants. Any type of wood can also be used as fuel for power plants. Livestock manure and urban waste can also be used as biofuels.



(a) Biomass potential by province

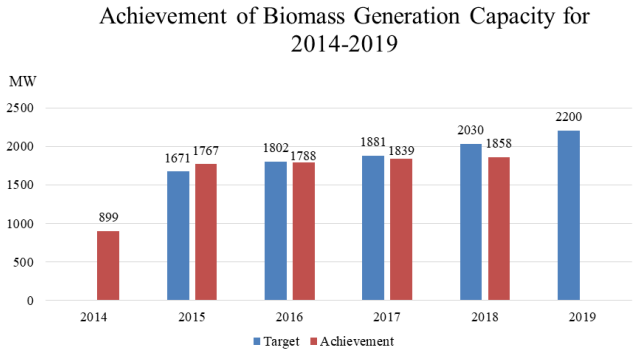
(b) Types of potential biomass in Indonesia

Fig. 2. Biomass potential and type in Indonesia

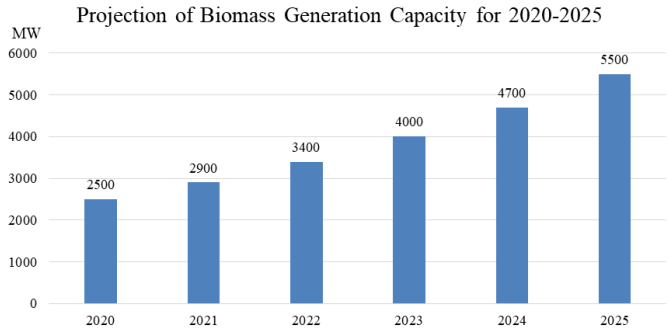
Based on Figure 2 it can be seen, the potential of Indonesia is the largest biomass in Riau Province and the potential of the smallest in the Riau Islands. Riau Province has a huge biomass potential because it has a palm oil plantation of 2 million hectares from the total area of Riau Province which is 8.7 million hectares. Meanwhile, Riau Islands Province has the smallest biomass potential because it only has an area of 1 million hectares with 96% of its territory is seawater. Riau and Riau Islands are two separate provinces. The estimated total biomass potential Indonesia 32 GW and of which the largest potential is found in the Riau Province of 4 GW, and the smallest potential is in the Riau Islands Province which is only 15 MW. Based on biomass raw material sources, the greatest potential exists in oil palm plants at 12 GW. Then there are also other sources of raw materials such as sugar cane, rubber, coconut, rice, corn, cassava, wood, livestock, and municipal waste.

C. Biomass Power Plant

The plan to develop a biomass power plant is contained in the presidential regulation number 22 of 2017 concerning the national energy policy. The capacity of biomass power plants has been recorded in the Ministry of Energy and Mineral Resources from 2014 to the end of 2018. The following is the biomass power generation capacity from 2014 to 2019 which shows targets and realization every year.



(a) Achievement of biomass generation capacity for 2014-2019



(b) Projection of biomass generation capacity for 2020-2025

Fig. 3. Biomass generation in 2014-2019 and plans for 2020-2025

In the development of biomass power plants in the last 5 years, it can be seen that in 2014 the installed capacity of PLTBm reached 898.5 MW. Then it is targeted to have 1672 MW in 2015 but the achievement can exceed the target of 1767.1 MW or 94.57% of the target. In 2016 it is targeted that PLTBm has an installed capacity of 1801.6 MW, but the achievement is only 1787.9 MW or 0.76% exceeding the target. In 2017 the installed capacity reached 1857.5 MW of the target of 2030 MW or reached 84.43% of the target. Then in 2019, it is targeted that PLTBm in Indonesia has 2200 MW of installed capacity, while in the media or new news there are 5.7 MW of new plants installed in 2019. The national energy policy also has a bioenergy utilization plan until 2025 as shown in Figure 3.

Until 2025 the Indonesian government targets to have 5500 MW of installed capacity from the use of Biomass, which is 2018 only has 1857.5 MW installed. This means that the government must catch up to 3643 MW in the next 6 years.

D.Development of Biomass Power Plant

The development of power plants that use biomass fuels on a large scale and was first recorded was in 2010. The first development began in the field of industrial fields, starting from Medan Industrial Zone (KIM) I and (KIM) II, then (KIM) III in the year 2013. Following is a table of biomass developments in Indonesia from 2010 to 2019 based on data from the Ministry of Energy and Mineral Resources, the news media, and the PLN RUPTL.

Processing biomass into electrical energy in Indonesia has implemented 3 types of technologies, namely, sanitary landfill, gasification, and combustion. Sanitary landfill technology converts solid biomass into biofuel by removing and stacking biomass in concave locations to be compacted and stockpiled with soil so that the decomposition results can later produce biofuels in the form of gases and liquids. Biofuel can be used as fuel for PLTD / PLTG Gasification technology is the processing of biomass into syngas by using a gasifier reactor to go through 4 stages of the process of drying, decomposition, oxidation, and reduction. Syngas produced can be used as fuel for PLTD / PLTG Combustion technology is a technology that utilizes heat from the combustion of biomass, both directly and mixed with coal. The heat generated in the combustion process can be used to heat the boiler at the power plant to produce steam which will move the steam turbine. The RDF technology or Refused Derived Fuel, which is the technology that converts biomass into small solids for fuel which is commonly called pellets or briquettes so that it can later be used as raw material for gasification and combustion.

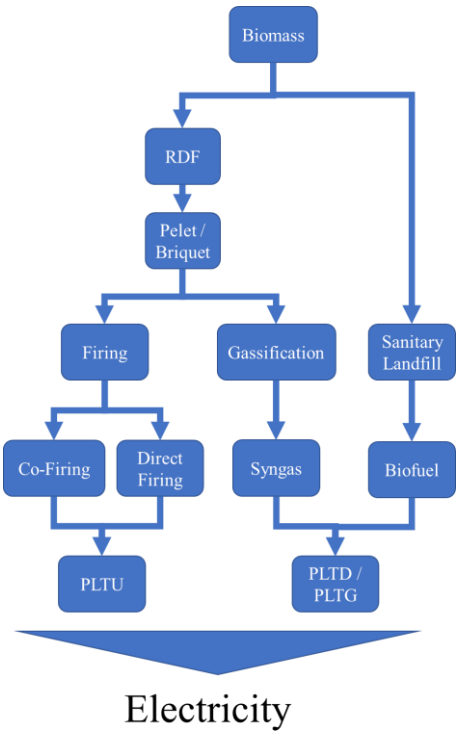


Fig. 4. Biomass Processing Technology in Indonesia

TABLE III
DEVELOPMENT OF BIOMASS IN INDONESIA FROM 2011-2019

NAME	LOCATION	YEAR	RESOURCES	TECHNOLOGY	CAPACITY	MANAGEMENT	STATUS
PLTBm North Sumatera	Industrial Area Medan I, Medan Deli, North Sumatra	2010	Palm shells, sugar cane, rice husks, corncobs, tapioca dregs up to sawdust	Firing	30 MW	PT. Growth Sumatra Industry	Operating excess 15 MW
PLTBm Riau	Perawang, Minas, Riau	2010	Palm Waste	Firing	3 MW	PT. Indah Kiat Pulp and Paper	Operating
PLTBm West Kalimantan	Kubu Raya, Pontianak, West Kalimantan	2011	Plywood Waste	Firing	7,5 MW	PT Harjohn Timber	Operating
PLTBm North Sumatera	Industrial Area Medan II, Deli Serdang, North Sumatra	2012	Palm shells, sugar cane, rice husks, corncobs, tapioca dregs up to sawdust	Firing	25 MW	PT. Growth Sumatra	Operating excess 20 MW
PLTBm North Sumatera	Industrial Area Medan III, Tangkahan, North Sumatra	2013	Palm shells, sugar cane, rice husks, corncobs, tapioca dregs up to sawdust	Firing	30 MW	PT. Growth Asia	Operating excess 20 MW
PLTBm Jambi	Payaselincah, East Jambi, Jambi City	2013	Palm Shells	Firing	30 MW	PT Rimba Palma Sejahtera Lestari	Already On Grid
PLTBm Banten	Cilegon, Banten	2013	Palm shells, sugar cane, rice husks, corncobs, tapioca dregs up to sawdust	Firing	30 MW	PT Indocoke	Without explanation
PLTBm North Sumatera	Simalunggun, North Sumatera	2013	Palm shells, sugar cane, rice husks, corncobs, tapioca dregs up to sawdust	Firing	30 MW	PT Harkat Sejahtera	Operating
PLTBm West Kalimantan	Ketapang, West Kalimantan	2013	Plywood Waste	Firing	7 MW	PT Suka Jaya Makmur	Development
PLTBm Gorontalo	Pulubala, Gorontalo	2014	Corncob	Gassification	500 KW	Kementrian BUMN dan PLN	Operating
PLTBm Riau	Bantan, Bengkalis, Riau	2015	Palm Waste	Firing	10 MW	PT Meskom Agro Sarimas	Operating
PLTBm North Sumatera	Industrial Area Medan I, Medan Deli, North Sumatera	2015	Palm Waste	Firing	3 MW	PT Victorindo	Operating
PLTBm North Sumatera	Medan, North Sumatera	2015	Palm Waste	Firing	1,8 MW	PT Perkebunan Nusantara III	Operating
PLTBm Riau	Kepenuhan, Rokan Hulu Regency, Riau	2015	Palm oil mill waste	Firing	25 MW	PT Riau Prima energi	Operating 10MW and Added 15MW in 2016
PLTBm East Kalimantan	Mook Manaar Bulath, West Kutai, East Kalimantan	2016	Wood Pellet	Firing	20 MW	PT Sekawan Intipratama Tbk	Without explanation
PLTBm East Java	Gedeg, Mojokerto, East Java	2016	Sugar Cane	Firing	2 MW	PT Perkebunan Nusantara X	Without explanation
PLTBm NTT	Bodo Hula, Lamboya, West Sumba, NTT	2016	Kaliandra Wood	Gassification	1 MW	PT Pasadena Engineering	Operating since 2017
PLTBm Papua	Wapeko, Merauke, Papua	2017	Forest products, in the form of various types of wood, such as acacia, Elucalyptus wood, Meulaluca wood	Firing	3,5 MW	PT Merauke Narada Energi	Without explanation
PLTBm Riau Islands	Tanjung Batu, Riau Islands	2017	Palm Waste	Firing	1 MW	Tanjung Batu	Without explanation
PLTBm Riau	Tembilahan, Riau	2017	Coconut	Firing	5 MW	PT Inhil Sarimas Kelapa	Operating
PLTBm Bangka Belitung	Bangka Belitung	2017	Palm Shells	Firing	18 MW	Kencana Agri Ltd	7 - 5 MW Operating and 6 MW Was Built
PLTBm Lampung	Teluk betung, Bandar Lampung City, Lampung	2017	Sugar Cane	Firing	5 MW	PT Gunung Madu Plantation	Operating
PLTBm North Sulawesi	Bailang, Manado, North Sulawesi	2018	Fermentation of cow dung with organic waste	Firing	45 KW	Pemkot Manado, Universitas Sam Ratulangi, Manado and Universitas Feng Chia Taiwan	Development
PLTBm West Kalimantan	Wajok Hulu Village, Siantan, Mempawah Regency, West Kalimantan Province	2018	The remaining agricultural produce, oil palm shells, empty fruit bunches, coconut fibers, and other agricultural wastes	Firing	15 MW	PT Rezeki Perkasa Sejahtera	Operating since 23 April 2018
PLTBm Bangka Belitung	West Bangka, Bangka Belitung	2018	Palm Waste	Firing	6 MW	PT Energi Karya Persada	Without explanation
PLTBm Bangka Belitung	Mempaya Village, Damar, East Belitung, Bangka Belitung	2018	Wood processed into wood chips, Palm Shells, Palm Fiber	Firing	7,5 MW	PT Bangka Biogas Sinergy, Belitung Energy, and Listrindo Kencana	Can Only Supply 3-4MW
PLTBm South Sumatera	Ogan Ilir Regency, South Sumatra	2019	Rice Husk	Firing	3 MW	PT Buyung Poetra Sembada	Targeted to operate on quartal III/2019
PLTSa East Java	TPA Benowo, Surabaya	2019	Municipal Solid Waste	Gassification & Sanitary Landfill	2 MW + 9 MW	PT Sumber Organik	Operating 2 MW from landfill gas and was built 9 MW Gassification
PLTSa Bali	Lepang, Klungkung, Bali	2019	Municipal Solid Waste	Gassification	20 KW + 40 KW	PT Indonesia Power, STT PLN, and Pemkab Klungkung	Operating 10 KW in Lepang and 40 KW in Pesanggaran unit
PLTSa Jakarta	TPA Bantargebang, Jakarta	2019	Municipal Solid Waste	Firing	700 KW	Menkomaritim, Menristek dan BPPT	Officialy Operated

Based on the biomass development table from 2010 to 2019, it can be seen that the PLTBm North Sumatera in the Industrial area is the first and largest PLTBm in Indonesia. North Sumatera PLTBm uses raw materials of palm shells, sugar cane, rice husks, corncobs, tapioca flour dregs, to wood dust with direct combustion technology for PLTU fuel. This power plant has a capacity of 30 MW and operates 15 MW for electricity needs in the industrial area then the excess power plant will be distributed to the PLN network.

The most widely used biomass is oil palm shells which are used as fuel for PLTU. The first power plant using gasification technology was in the PLTBm Gorontalo, with a capacity of 500 KW. In addition to oil palm shells, there are also fuels such as sugar cane, rice husk, corn cobs, flour pulp, wood powder, calliandra wood, acacia wood, eucalyptus wood, melaleuca wood, empty fruit bunches, coconut fibers, agricultural waste, livestock waste, woodchip oil palm fiber, and municipal waste. Then the plants that use municipal solid waste as raw material are classified as PLTSa or garbage power plants.

Based on Figure 5, it can be seen that the largest biomass generator is in PLTBm North Sumatra and the smallest is in PLTBm North Sulawesi.PLTBm North Sumatra Province is the largest because it is managed by the Growth Steel Group which is a multinational company and also this PLTBm has been in existence since 2010. The purpose of the construction of the Medan PLTBm is to supply the electrical energy needs of factories in Medan Industrial Estate and excess electricity production will be sold to PLN. Then the PLTBm North Sulawesi became the smallest PLTBm because it was still under development by the Manado City Government in collaboration with Sam Ratulangi University, and Taiwan's Feng Chia University.

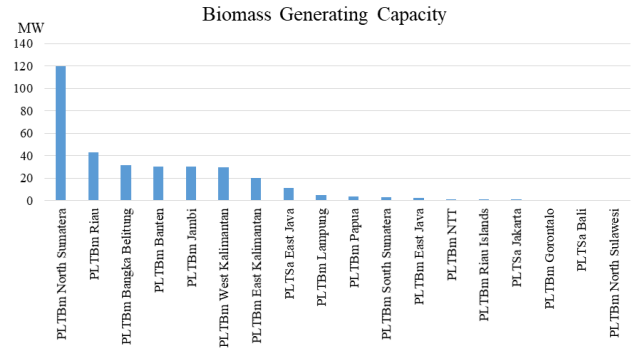


Fig. 5. Biomass Generating Capacity

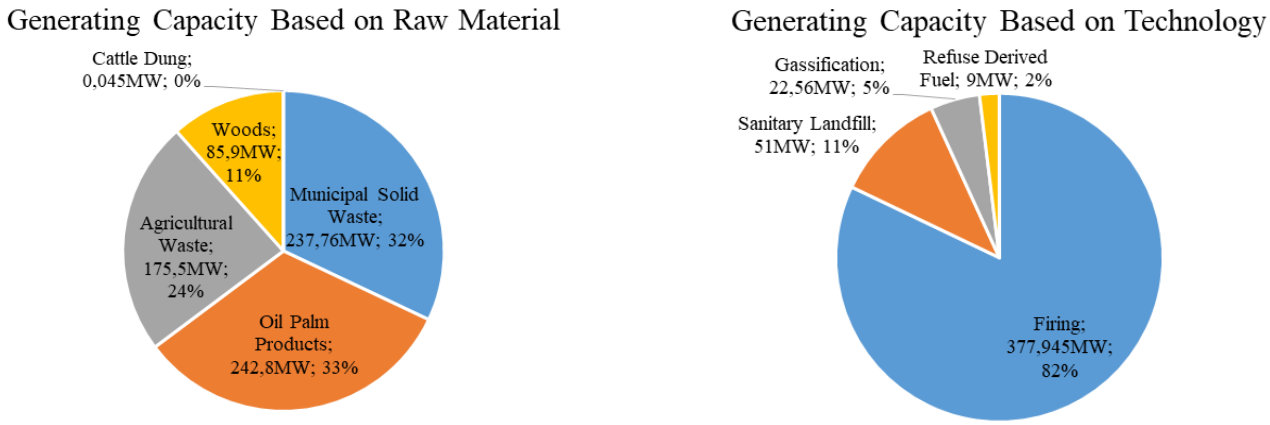
E. Future Plan for Biomass Power Generation

After 2019, there are several plants planned to be built. The following is a table of the development of biomass-fueled power plants after 2019 based on ESDM data, news media, and PLN RUPTL.

TABLE IV
BIOMASS FOR POWER GENERATION PLAN OF INDONESIA

NAME	LOCATION	YEAR	RESOURCES	TECHNOLOGY	CAPACITY	MANAGEMENT	STATUS
PLTBm North Sumatera	Tanjung Selamat, Deli Serdang, North Sumatera	2020	Rubberwood	Firing	9,9 MW	PT Cipta Multi Listrik Nasional	Reached the PPA Agreement Phase
PLTSa West Java	Bekasi, West Java	2021	Municipal Solid Waste	RDF	9 MW	PT Nusa Wijaya Abadi	Not yet in operation and damage has occurred during the trial
PLTSa Central Java	TPA Putri Cempo, Mojosongo, Solo, Central Java	2021	Municipal Solid Waste	Gassification	10 MW	PT Solo Citra Metro Plasma Power	Planned and already the signature stage of PPA or PJBTL
PLTSa Bali	TPA Suwung, Denpasar, Bali	2021	Municipal Solid Waste	Sanitary Landfill	20 MW	PT Indonesia Power and PT Waskita Karya	Planned and at the feasibility study stage
PLTSa Palembang	TPA Karya Jaya, Palembang, South Sumatera	2021	Municipal Solid Waste	Incenerator or Firing	20 MW	PT Indo Green Power	Planned
PLTSa Jakarta	TPA Sunter, North Jakarta, DKI Jakarta	2022	Municipal Solid Waste		35 MW + 3 MW	PT Jakpro dan Fortum	Planned and waiting for KLHK sweets
PLTSa West Java	TPA Gedebage, East Bandung, West Java	2022	Municipal Solid Waste	Direct Firing	29 MW	PT. Bandung Raya Indah Lestari	Planned and there is already a capacity of 7 MW
PLTSa Banten	TPA Rawa Kucing, Neglasari, Tangerang, Banten	2022	Municipal Solid Waste		20 MW	PT. Tangerang Nusa Global	Planned
PLTSa Central Java	TPA Jatibarang, Semarang, Central Java	2022	Municipal Solid Waste	Incenerator and Landfill Gas	20 MW	Pemkot and Denmark	Planned and already in operation 1.3 MW by 2019
PLTSa South Sulawesi	TPA Antang, Makassar, South Sulawesi	2022	Municipal Solid Waste		20 MW	Pemkot Makassar	Planned
PLTSa Banten	TPA Cipeucang, South Tanggerang, Banten	2022	Municipal Solid Waste		20 MW		Planned
PLTSa North Sulawesi	Manado, North Sulawesi	2022	Municipal Solid Waste		20 MW		Planned
PLTBm North Sumatera	Kepulauan Nias, North Sumatra		Bamboo		18 MW	PT Energi Infranusantara	Planned
PLTBm West Sumatera	Mentawai, West Sumatra		Bamboo		5 MW		
PLTBm West Kalimantan	Sintang, West Kalimantan		Palm Shells		10 MW		
PLTBm North Maluku	North Maluku		Forest Products		10 MW	PT Energi Bersih Halmahera	

Based on the biomass generator data table that will be built after 2019, there will be 12 power plants that will be built from 2020 to 2022. Then there will be 11 PLTSa that will be built in the future to overcome the waste problem in various cities. In addition to municipal waste, there is also PLTBm that uses rubberwood fuel, bamboo, and forest products. Based on the type of biomass, the fuel of the generator can be presented as shown in Figure 6.



(a) Generating capacity based on raw materials

(b) Generating capacity based on technology

Fig. 6. Biomass generation in Indonesia

In figure 6 it can be seen that 33% of biomass power generation capacity uses palm oil products fuel using, 32% of municipal solid waste, 24% of agricultural waste, 11% uses woody timber, and livestock filth is still below 0% of all generating capacity. Palm products here include oil palm shells and palm fiber. Timber here includes calliandra, acacia, eucalyptus, melaleuca, sawdust, wood chips, and bamboo. Then the agricultural waste here includes rice husks, sugar cane, corncobs, tapioca flour, and empty fruit bunches. Oil Palm Products dominates biomass generation capacity because palm oil production is very high in Indonesia.

The technology used there is that uses direct combustion as PLTU fuel, this technology can also be called direct firing which consists of biomass firing and co-firing. It is said firing if the PLTU only uses biomass fuel only and it is said co-firing when using coal as a fuel mixture. Then it is converted into refuse-derived fuel (RDF) or waste derived from waste, which is a fuel made from municipal solid waste (MSW) or municipal waste using briquetting or pelletization techniques. Gasification technology is the process of converting solid fuels to gas or syngas fuels for electricity generation fuels. Sanitary landfill is the process of decaying garbage in the soil to take gas and liquid as fuel. Then incinerators that use direct combustion technology or firing, usually applied to MSW or municipal waste, heat from combustion is used to heat the boiler and produce steam to drive the steam turbine. The percentage of generating capacity based on technology can be seen in Figure 6.

In Figure 6 it can be seen that 82% of biomass generating capacity uses direct combustion technology, 11% sanitary landfill, 5% gasification, and 2% is converted to RDF. This happens because direct combustion is the easiest and cheapest way to utilize biomass, besides those generators that use this technology also have large generating capacity.

IV. Conclusion

This article has reviewed the development of biomass potential and biomass electricity generation in Indonesia. Indonesia is rich in biomass with potential is estimated at 32,773 MW. The source or form of biomass is sugar cane, rubber, coconut, rice, corn, cassava, wood, livestock, and municipal waste.

A number of technologies have been used in the power generation of biomass-fueled electricity such as direct combustion as coal power plant's fuel, converted to refuse-derived fuel, gasification, sanitary landfills, and incinerators. Currently, the largest implementation of biomass for power generation is in municipal waste management through co-firing technology.

There is little information regarding biomass for power generation prior to 2011. From 2011 to 2019, the installed capacity of biomass for power generation was 1857.5 MW which is around 33.78% of the 2025 target. In the future, it is necessary to intensify the implementation of biomass for electricity programs both for remote and urban areas as a clean and sustainable source of electrical energy.

Nomenclature

Bappenas	National Development Planning Agency
BPPT	Agency for Assessment and Application of Technology

EBTKE	Renewable Energy and Energy Conservation
EJ	Exajoule
ESDM	Energy and Mineral Resources
Gt	Giga Tone
GW	GigaWatt
INPRES	Presidential Instructions
KEN	National Energy Policy
KIM	Medan Industrial Zone
KLHK	Ministry of Environment and Forestry
KW	KiloWatt
LIPI	Indonesian Institute of Sciences
MSW	Municipal Solid Waste
MW	MegaWatt
PERDA	Local Regulation
PERGUB	Governor's Regulation
PERPRES	Presidential Decree
PERMEN	Ministerial Regulation
PJBTL	Power Purchasing Agreement
PLN	National Electricity Company
PLTBm	Biomass Power Plant
PLTBg	Biogas Power Plant
PLTSa	Garbage power plant
PLTD	Diesel Power Plant
PLTG	Gas Power Plant
PLTU	Electric steam power plant
PP	Government Regulations
PPA	Power Purchasing Agreement
TPA	Final Dumping Site
RDF	Refuse-Derived Fuel
RUPTL	Electricity Supply Business Plan
TWh	TeraWatt hour
UU	Law

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