Chapter 8

Biomass Energy

Matthew Hardhi

A. Overview of Biomass Energy

Biomass energy is one of Indonesia's forefront options of renewable energy. Unlike fossil fuels, the net CO_2 emission of bioenergy use is close to 0 as, theoretically, the released CO_2 can be reabsorbed during the biomass growth stage. This condition makes bioenergy a very lucrative source of efficiently utilized renewable energy. On top of this, Indonesia is blessed with large forested areas, allowing differing options for optimizing biomass production capacity to produce biomass-based energy. In this chapter, we will look at the definition of biomass energy, how it is utilized, available sources, and its suitability as one of Indonesia's pillars of renewable energy to reach the target energy mix in 2045.

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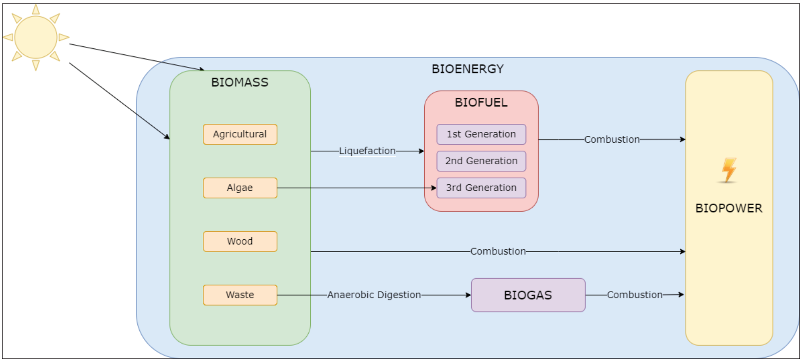
B. Definitions

The terms biomass, bioenergy, biopower, and biofuel are frequently used when describing this particular form of energy. Biomass is defined as living or dead biological material and its by-products, in the form of solid organic matter, which can be burned to provide heat, electricity, or both (*Are Biofuels Sustainable? First Report of Session 2007-08*, 2008; Bajpai, 2020). Biomass components may include lignin, celluloses, hemicelluloses, lipids, proteins, starches, water, ashes, and other compounds.

Therefore, bioenergy is the renewable gas, liquid, or solid energy product derived from biomass (Dahiya, 2020; Nyoman & Kumara, 2020). It falls into renewable energy because biomass absorbs the sun's power in its growth, converting CO_2 into carbohydrates through photosynthesis and storing them as chemical energy. Historically, civilizations had heavily relied on biomass to provide them with energy, usually for heating by burning wood. Today, it is the largest source of renewable energy use, accounting for 70% of the total world renewable energy supply and 10% of the total primary energy supply in 2017 (International Renewable Energy Agency, 2020).

Biofuels are liquid fuels mainly produced from food and fodder crops. This type of fuel is classified as the first generation of biofuels and can be differentiated into biodiesel or bioethanol. Biodiesel is made from oils of palm fruits and rapeseed, while bioethanol is produced from the fermentation of feedstocks containing high sugar or starch content. Wheat, barley, sugarcane, and maize are the common feedstocks used in bioethanol production.

Biopower is the electricity generated from biomass combustion (Dahiya, 2020), either the sole fuel or combusted with coal, natural gas, or other fuels. This joint combustion is termed co-firing. Biopower plants use biomass feedstocks as fuel for the boiler, which is burned to heat, passing water into steam, rotating the turbine, and producing electricity. The steam produced can also be directly used for process heating in industries. A graphical representation of how all these terminologies interact can be seen in Figure 8.1.



Source: Author documentation (2021)

Figure 8.1 Definitions of Biomass Energy-Related Terminologies

Bioenergy has several advantages compared to traditional fossil fuel usage. Firstly, biomass burning to produce energy does not release harmful gases such as sulfur dioxide or lead oxide (Bajpai, 2020). Burning biomass merely releases the CO_2 absorbed by the biomass in its growth to the environment. As long as the amount of CO_2 released as a fuel matches the amount absorbed during its development, it is carbon neutral. For further measures, bioenergy can be used in tandem with Carbon Capture and Storage (CCS) to create a net harmful emission of CO_2. In contrast, burning fossil fuel releases the CO_2 absorbed a long time ago back into the environment, contributing to the greenhouse effect.

Secondly, the utilization of biomass fits within the circular economy scheme. Bioenergy is just one form of biomass that also supplies humans with various uses such as food, feed, fiber, fertilizer, and so on (International Renewable Energy Agency, 2020). Production and processes of this biomass lead to wastes and residues. These wastes are usually disposed of due to not having any economic value. These wastes can be used as a potential bioenergy source, allowing to extract all of the potential energy contained within the wastes, reducing the number of wastes released. An example of this would be methane emission from the wastes, which could be refined into biomethane through anaerobic digestion or syngas through gasification (Ardolino & Arena, 2019).

Biomass energy offers the option to decarbonize many sectors. For example, biofuel can be used as an alternative to fossil fuel in the transport sector. Bioenergy can power the district heating systems in housing and building sectors instead of traditional coal boilers. In some industry sectors, biomass may replace fossil-based feedstocks (International Renewable Energy Agency, 2020).

C. Feedstocks

Once biomass has been processed through heating, microbial activities, chemicals, or any combinations of these processes, it will be termed "bioenergy feedstock." Biomass needs to be converted to feedstock as aside from direct combustion. Biomass cannot be directly converted to electricity. Biomass has a relatively low value in bulk density (weight per volume) (McKendry, 2002). This means for the same amount of volume, biomass has a relatively low energy value than other energy sources. Thus, we need to process more volumes of biomass to obtain the same amount of energy as the traditional energy source, like fossil fuel. Still, more logistics are also required to transport the biomass, which translates to higher costs.

Therefore, it is necessary to convert raw biomass into logistically feasible forms to transport. There are three processing steps: aggregation, densification, and palletization. Aggregation gathers up harvested biomass into easily handled units (such as bales). Densification is the process of increasing the feedstock's density through pressure and other means to create a condensed feedstock. Finally, palletization is the densification of feedstock into pellets. All of these are standard methods of increasing the energy density of biomass.

D. Generation of Biofuels

Biofuels can be classified as primary or secondary biofuels based on production. Primary biofuels are obtained from biomass in their natural forms (wood pellets, firewood, wood chips), while secondary biofuels are obtained after biomass processing. These secondary biofuels can be classified into first, second, or third-generation biofuels. First-generation biofuels are obtained from fermenting edible feedstocks (crops high in sugar content) to produce mostly bioethanol or biobutanol. Since they are obtained from edible food crops, the production of first-generation biofuels directly competes with increasing food demand in many parts of the world.

Second-generation biofuels are obtained from mostly inedible biomass through thermochemical and biochemical processes. Bioethanol and biobutanol are synthesized from non-food, lignocellulosic biomass. Since the main source of biomass is not food crops, second-generation biomass suffers no competition from increasing food demands. Lastly, third-generation biofuels are sourced from aquatic biomass. Commonly used biomass includes microalgae, seaweed, or other microorganisms to synthesize biodiesel and bioethanol. The advantage of this biofuel generation is low land usage, the high lipid content of the biomass, and high atmospheric CO_2 uptake. This means they have more potential to become a carbon-neutral energy source.

In the future, we might obtain biofuels from the fourth-generation biomass, sourced from genetic modification of third-generation biomass. However, this type of biofuel is still in the research and developmental phase. Table 8.1 lists a detailed explanation and description of the various generations of secondary biofuels, bioethanol.

Table 8.1 Generations of Bioethanol

Generation	Source	Examples	Processing Methods
1	Crops with high sugar and starch content	Corn sugarcane, Molasses, and Tapiocas	a. Direct fermentation with microorganisms (generally with the yeast Saccharomyces cerevisiae) into ethanol (7–10%) b. Distillation (up to 96%) The theoretical yield is 0.51 kg ethanol.kg glucose.
2	Cellulose	Bagasse, EFB, Corn pulp, and Rice husks	a. Simultaneous saccharification and fermentation (SSF) b. Batch/Fed-batch c. Separate hydrolysis and fermentation (SHF) d. Consolidated bioprocessing (GST)
3	a. Microalgae Rapid growth, Requires relatively smaller production area b. Bacteria Rapid growth, The metabolic pathway can be genetically engineered	Potential Microalgae Species: *Chlorella vulgaris* *Spirulina maxima* *Botryococcus* sp. *Chlamydomonas* sp.	a. Harvesting (flocculation + centrifugation) b. Extraction (homogenization + hexane solvent) c. Biodiesel production with transesterification

Source: Amrullah & Hambali (2021)

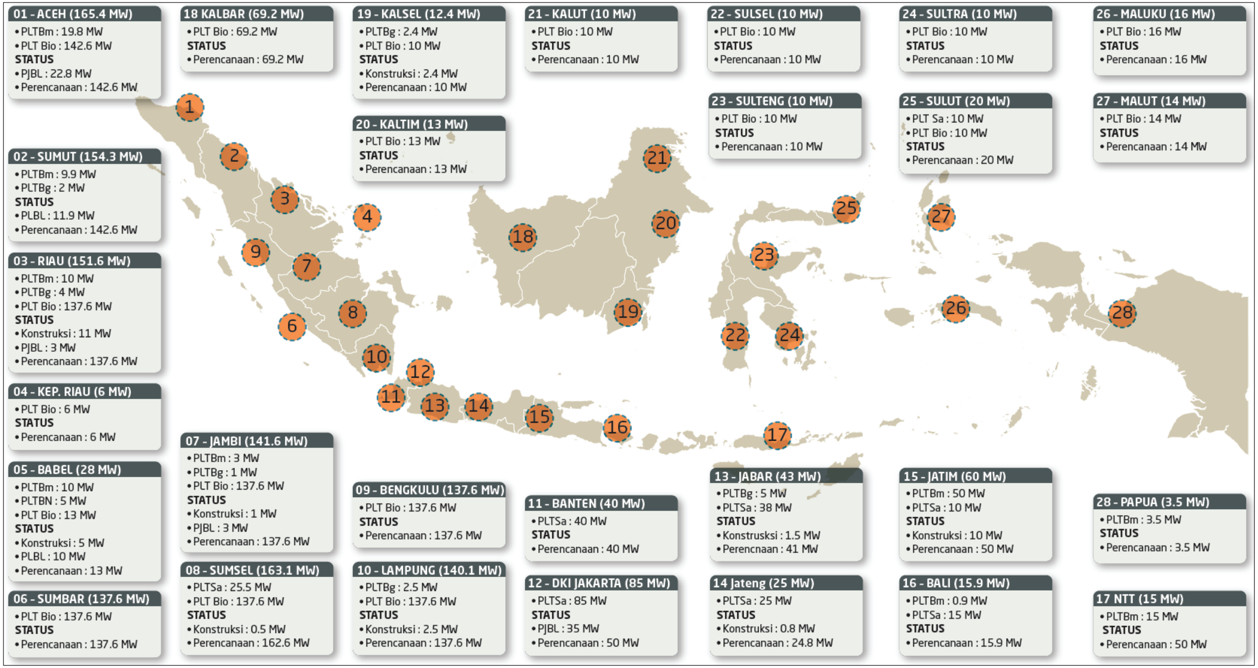
E. Current Conditions in Indonesia

According to the latest National Energy General Plan (RUEN) (Presidential Regulation No. 22/2017), Indonesia plans to achieve a 31% energy mix from New and Renewable Energy (NRE) in 2050. Just last year, the National Development Planning Agency (Bappenas) plans to achieve a 70% NRE mix in 2050 to meet the goal of a carbon-neutral Indonesia in 2060, where 100% of energy resources are projected to come from NRE (CNN Indonesia, 2021). In contrast, the NRE mix reached only 11.2% of the total energy mix in 2020. Naturally, concerns were raised due to several challenges that complicate the implementation of such directives in Indonesia. As follows:

1. Shortage of available land for production of NRE;
2. Relatively high investment costs in NRE still deter investments in the sector;
3. Government subsidy makes fossil fuels cost cheaper, hence slowing the transition to NRE;
4. Lack of knowledge and research in NRE technology, as well as lack of human resources;
5. High-interest rate from the banking sector for NRE investments due to high risk associated;
6. Intermittent energy supply from NRE power plants demands an efficient energy storage facility.

However, despite these facts, numerous efforts have been made to integrate more biomass sources into the total energy mix. The Ministry of Energy and Mineral Resources' 2020–2024 Strategic Plan (Ministry of Energy and Mineral Resources, 2021a) had set several directives as follows:

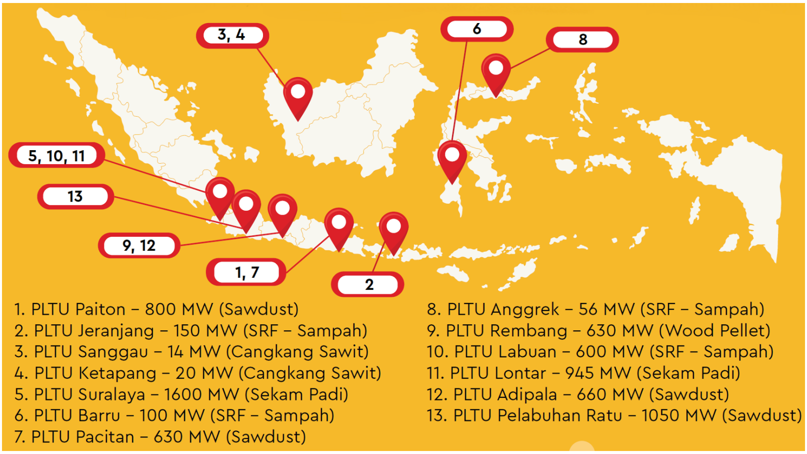
1. Develop bioenergy power plants with a total capacity of 1,295 MW in the five years between 2020 and 2024, utilizing crude palm oils (CPO) (Figure 8.2).
2. Implement co-firing method in existing coal-based steam power plants, where the co-firing feedstocks would come from garbage pellets, wood pellets, and wood chips (Figure 8.3).
3. Develop small-scale biomass power plants (with a capacity ranging from 20–200 kW) to be distributed strategically. Biomass wastes used as fuel include palm fibers, rice husks, and sugarcane bagasse.
4. Develop bio-based Compressed Natural Gas (CNG) utilizing >95% purity biogas consisting of methane (CH_4) to replace fossil-based natural gas.
5. Develop the market for waste-to-energy power plants.
6. Implement the B30 program to increase biofuel mixture in diesel fuel (30% instead of the previous 20%) to reduce imports.



Source: Ministry of Energy and Mineral Resources (2021a)

Abbreviations are as follows: PLTBm-biomass power plant, PLT Bio-bioenergy power plant, PLTBg-biogas power plant, PLTSa-waste-to-energy power plant, PLTBn-biofuel power plant

Figure 8.2 Bioenergy Power Plants Projects Based on National Electricity Supply Business Plan (RUPTL) for 2019–2025



Source: Ministry of Energy and Mineral Resources (2021b)
Co-firing is predicted to contribute as much as 18 GW to steam power plants in 2024.

Figure 8.3 Steam power plants implementing co-firing method commercially with 1–5% biomass portion.

Indonesia comprises 188.20 million hectares of land area with various soil and climate types in terms of land use. Agricultural farming of different kinds of valuable plant commodities is possible, including bioenergy plants such as palm oil, sugarcane, cassava, and others. According to Hambali et al. (2016), around 76.40 million hectares are suitable for growing these valuable crops, which gives plenty of potential for biomass utilization. However, efficient biomass utilization requires the maintenance of a stable feedstock supply.

An established supply chain of biomass feedstock can be selected by having local governments construct roads in rural areas. Currently, farm roads exist within biomass plantation areas for in-plant transportation needs. However, they are seldom connected to district arterial roads. Connected routes will allow easier transport of biomass feedstock into a centralized refinery location (Zhou et al., 2020). Both national and local governments must work on logistics laws to build better road infrastructures. These will assist in reducing the cost of biomass production, in which transportation and pre-processing can make up to 43% of the total production cost (Labriet, 2013).

F. Biomass and Indonesia

Due to being an archipelago with many scattered, isolated islands, perfectly distributed energy access is difficult due to technical issues related to electrical transmission and distribution (Haryana, 2018). As such, small islands in remote areas need to be equipped with the capacity to self-produce and supply their energy demands. As fossil fuel reserves are not available to most islands, biomass energy becomes a suitable source of energy resources. It is relatively simpler to process (combustion is sufficient) and is located near the equator; the year-long solar irradiation allows the year-long cultivation of biomass sources.

Therefore, as biomass sources are accessible even to households and small-scale farms, it is an important energy resource for Indonesia. One accessible option for biomass utilization is processing the biomass of agricultural residues, either wood waste or crop waste (herbaceous, fruit, etc.) (Brunerová et al., 2018). Currently, this waste biomass utilization in developing countries is relatively low, representing an untapped sector that could be developed further to fill the total energy demand (Brunerová et al., 2017).

As such, utilizing biomass as an energy source is an attractive proposition, especially considering the potential to reach a net-zero emission from its utilization, as long as the amount of carbon absorbed equals or is less than the amount emitted from its usage. While crop residues are large and have a significant energy potential, many residues must be left on-site to protect soil productivity and prevent erosion (Scarlat et al., 2010), ranging between 15–60% for most crops. However, the remaining amount still leaves a potential for further processing and use.

1. As with other Southeast Asian countries, Indonesia is one of the top producers of agricultural commodities. These commodities include rice, sugar, cane, palm oil, coconut, and rubber, with the most promising residues for biomass energy being rice husk, sugarcane bagasse, oil palm residue, and wood residues. Cur-

rently, applicable technologies to extract this energy source are direct combustion/biomass co-firing: direct heat and electricity production (Tun et al., 2019).

2. Anaerobic digestion: For animal wastes to produce biogas (methane/CH_4).
3. Pyrolysis: For bio-charcoal, gas, and oil production.
4. Gasification: For agricultural waste and woody residues (sawdust, wood chips, etc.)

The following table (Table 8.2) represents the total potential of biomass energy in Indonesia as of 2019.

Based on this data, there are ten total types of biomass sources in Indonesia, with palm oil dominating the potential for energy production. According to Nyoman & Kumara (2020), the meat and kernel of palm fruits can be converted to biodiesel oil, while their shells can be used as fuel in co-firing coal power plants (PLTU). We could extract methane from livestock waste, landfill garbage, and palm oil mill effluent to power biogas plants (Figure 8.5).

Until 2019, the total installed capacity of bioenergy power plants amounts to 1,890 MW (Ministry of Energy and Mineral Resources, 2021a). The estimated total potential for biomass in Indonesia is around 32 GW (Figure 8.4). Therefore, the gap between actual capacity and estimated potential can still be utilized to increase Indonesia's NRE energy mix.

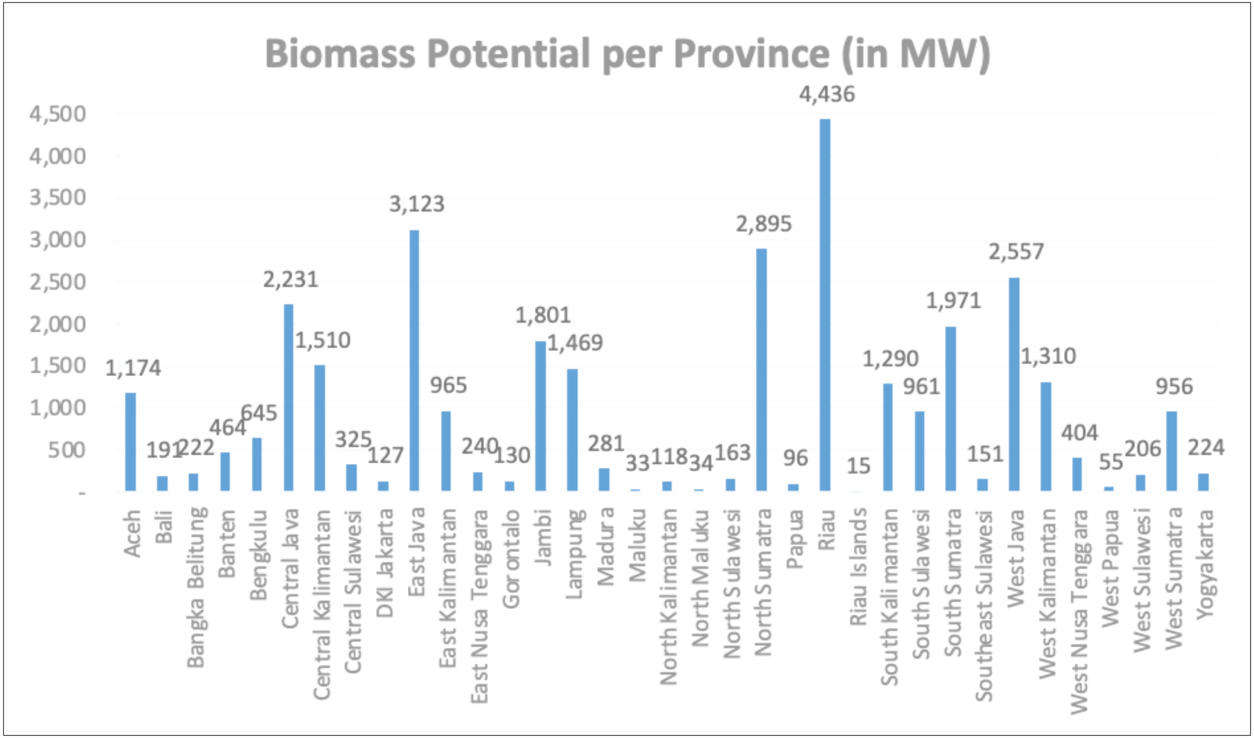
The rest of the biomass types, namely sugarcane bagasse, non-producing rubber tree trunks, coconut shells and fibers, rice husks, corn cobs, and cassava stems, can be converted into biofuel power plants. In general, as long as the waste biomass is plenty, possesses good sugar content, and comes from easy-to-grow crops (Amrullah & Hambali, 2021), it can be a potential source of biofuel production.

Table 8.2 Potential of Biomass Energy in Indonesia

Province	Energy Potential (in MW)										
	Palm Oil	Sugar Cane	Rubber Wood	Coconut	Rice Husk	Corn	Cassava	Wood	Livestock	Garbage	Total by Province
Aceh	646	-	233	3	240	13	1	-	17	21	1,174
Bali	-	-	-	4	131	10	1	-	23	22	191
Bangka Belitung	214	-	-	-	3	-	-	-	-	5	222
Banten	41	-	-	3	297	3	1	-	2	117	464
Bengkulu	434	-	108	-	79	11	1	-	4	8	645
Central Java	-	138	-	10	1,431	262	39	3	70	278	2,231
Central Kalimantan	1,234	-	140	4	99	1	2	18	2	10	1,510
Central Sulawesi	117	-	-	11	158	18	1	1	8	11	325
DKI Jakarta	-	-	-	-	1	-	-	-	-	126	127
East Java	-	630	-	11	1,476	460	35	4	140	367	3,123
East Kalimantan	837	-	43	1	58	2	1	5	3	15	965
East Nusa Tenggara	-	-	-	3	90	64	17	18	28	20	240
Gorontalo	-	20	-	3	42	54	-	-	7	4	130
Jambi	840	-	687	6	96	4	1	148	4	15	1,801
Lampung	179	326	114	6	448	217	89	6	27	57	1,469
Madura	-	-	-	3	120	90	5	-	32	31	281
Maluku	-	-	-	4	13	2	1	3	3	7	33
North Kalimantan	118	-	-	-	-	-	-	-	-	-	118
North Maluku	-	-	-	14	9	2	1	1	2	5	34
North Sulawesi	-	-	-	15	88	45	1	-	4	10	163

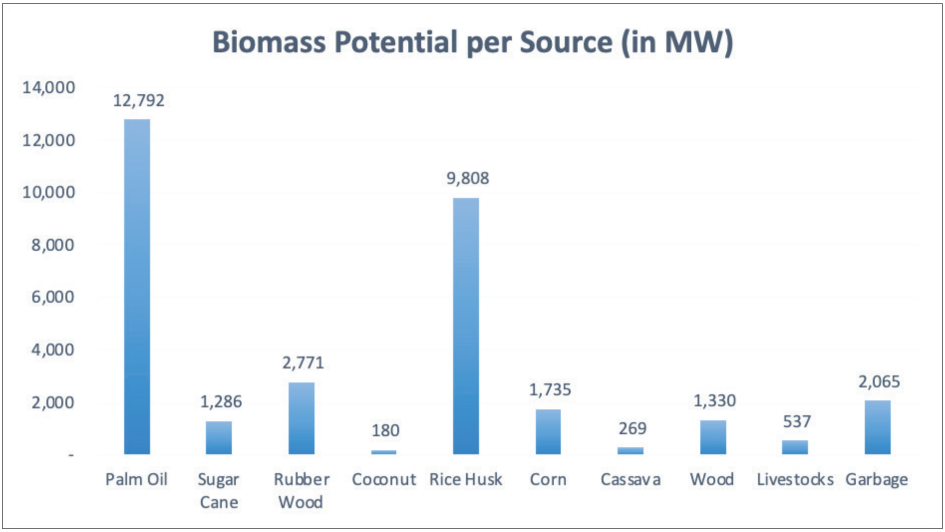
Province	Energy Potential (in MW)										
	Palm Oil	Sugar Cane	Rubber Wood	Coconut	Rice Husk	Corn	Cassava	Wood	Livestock	Garbage	Total by Province
North Sumatra	1,927	30	220	5	472	111	11	4	16	99	2,895
Papua	42	-	-	13	16	1	1	9	2	12	96
Riau	2,888	-	430	24	88	5	1	962	6	32	4,436
Riau Islands	10	-	-	1	-	-	-	-	1	3	15
South Kalimantan	574	-	386	2	281	9	1	13	5	19	1,290
South Sulawesi	25	22	-	5	696	119	7	18	36	33	961
South Sumatra	1,187	43	70	3	492	10	4	91	9	62	1,971
Southeast Sulawesi	47	-	-	2	69	11	3	1	8	10	151
West Java	22	62	-	6	1,772	90	28	4	15	558	2,557
West Kalimantan	758	-	285	4	205	19	3	7	6	23	1,310
West Nusa Tenggara	-	-	-	3	315	31	1	1	25	28	404
West Papua	33	-	-	1	4	-	-	12	3	2	55
West Sulawesi	134	-	-	2	56	5	1	-	3	5	206
West Sumatra	485	-	55	5	337	36	2	1	12	23	956
Yogyakarta	-	15	-	3	126	30	9	-	14	27	224
Total by Type	12,792	1,286	2,771	180	9,808	1,735	269	1,330	537	2,065	Total Potential: 32,773

Source: Nyoman & Kumara (2020)



Source: Nyoman & Kumara (2020)

Figure 8.4 Biomass Potential per Province



Source: Nyoman & Kumara (2020)

Figure 8.5 Biomass Potential per Type

As of 2019, the provinces of Riau, East Java, and North Sumatra ranked top three for potential biomass energy production. This is because Riau province possesses many palm oil plantations, contributing to a potential of 2,888 MW production. In East Java province, widespread rice farming contributes to the prospect of 1,476 MW out of 3,123 MW total potential. Lastly, for North Sumatra province, 1,927 MW out of 2,895 MW can be attributed to palm plantations. Palm oil and rice husk dominate Indonesia's potential energy production resource.

A very productive crop, the palm can produce oil seven times higher than rapeseeds and eleven times higher than soybean (per hectare) (Hambali & Rivai, 2017). Fresh fruit bunches (FFB) are harvested and converted into crude palm oil (CPO), producing an abundant amount of waste such as empty fruit bunches (EFB), mesocarp fiber (MF), palm kernel shell (PKS), palm kernel meal (PKM), and palm oil mills effluent (POME). The amount of waste is significant as palm oil plantations can be found in 65% of the provinces in Indonesia and, therefore, are a substantial source of biomass.

POME, for example, can be used as a feedstock for biogas production. The remaining liquid waste from this activity can still be used as a fertilizer and medium for microalgae growth as it is still rich in nutrients. Both mesocarp fiber (MF) and palm kernel shell (PKS) can still be utilized as boiler fuel to produce process heat in the palm oil mill, while PKS can also be processed as bio-pellets to be used as fuel. Empty fruit bunches (EFB) and tree trunks can be utilized as mulching material to help maintain soil humidity, inhibit weed growth, compost raw material, and be a source of fiber for various composite products. These qualities make the utilization of palm oil wastes an interesting proposition.

G. Suitable Biofuels for Indonesia

Simply under volume alone, as represented by the data in the previous section, rice husks and palm oil are seemingly the prime candidates for valorization into biomass energy sources. Rice husk can either be fermented into bioethanol or converted to solid biofuels, while palm oil wastes can be converted into solid or gaseous biofuel. POME can be treated before being discharged into the environment to produce biogas. Palm waste's mesocarp fiber (MF) and palm kernel shell (PKS) can be converted to solid biofuel.

Based on current challenges facing NRE implementation in Indonesia, the source of biofuels must meet several criteria for successful implementation, which can be seen in Table 8.3 below.

Table 8.3 Author's Concerns and Implications Toward Types of Biofuels

Concerns	Implications
Shortage of available land	It must be sourced from abundant sources without requiring extra land clearance.
High investment costs deter investors	Biofuel production processes selected must be relatively cheap.

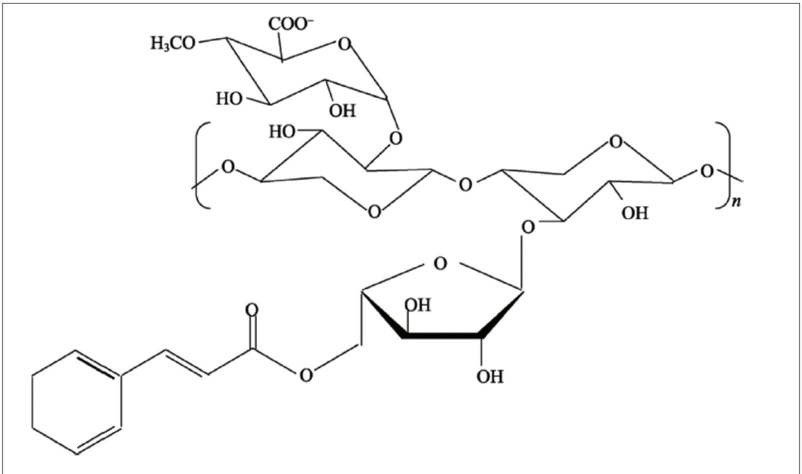
Concerns	Implications
Government subsidy on fossil fuels	The biofuel selected must be common and well-known to ease the transition from fossil fuel subsidy to NRE subsidy. A well-known biofuel type among the public will help ease implementation and integration.
Lack of research and human resources	Biofuel production processes must be kept simple. The processes must not require too high of an expert to run and rely on too specialized technology.
High-interest rate from finance sectors for high-risk technology	Technology for biofuel production must already be on commercial-scale. It must also already be established for a long time.
Intermittent energy supply requires an efficient energy storage facility	The biofuel must always be readily produced without delay.

H. Rice Husks

Rice husk is the main biomass by-product of rice harvesting, amounting to almost 20% of the total cereal production in the rice industry (Cacua et al., 2018). It has a low density at around 122 kg/m^3. Currently, rice husks possess close to zero economic value and are often thrown away post-rice harvesting. Rice husks waste contributes to a significant part of total biomass waste generated from rice cultivation. Moreover, rice husk contains low nutrients yet a high level of silica. Thus, it is not suitable to be processed as fodder. Instead, it is commonly used to produce porous sorbents, concrete with rice husk ashes, solid fuel, and feedstock in biofuel production (Nanda et al., 2020). Unlike corn grains- (starch) or sugarcane- (sucrose) based bioethanol (first-generation), rice husk is inedible, lignocellulosic biomass. It is not used as a food source and thus does not compete with the increasing demand for food in many parts of the world (Madu & Agboola, 2018).

However, Brunerová et al. (2017) and Bakker (2000) found that rice husks possess significant ash content (19–21%), alkali, and potassium which cause agglomeration fouling and melting in the components of boilers during combustion. High ash level is also reflected in the low calorific value of rice husks at around 14–16 MJ/kg. A high ash content leads to clogging in combustion device grates due to the presence of bottom ash, obstructing the pathway for combustion air (Malaťák & Passian, 2011).

Furthermore, its components (cellulose and hemicellulose) are hard to ferment/degrade biologically into ethanol. Proper pre-treatment methods and enzyme selections for the saccharification and fermentation steps are required to convert bioethanol from rice husk efficiently. The reason for this is that rice husks contain a combination of cellulose (28.6–41.5 wt%), hemicellulose (14–28.6 wt%), and lignin (20.4–41.5 wt%) (Nanda et al., 2020). Together, they form a stable 3-dimensional structure known as lignocellulose in the cell walls, making the individual monomers difficult to separate (Figure 8.6). The stability of these structures impedes access of cellulolytic enzymes to hydrolyze cellulose, the carbon source that will be fermented to ethanol by yeast. Therefore, the lignocellulose needed to be delignified by pre-treatment processes that available in various ways, including physical, physicochemical, chemical, and biological pretreatment.



Source: Goodman (2020)

Figure 8.6 3D Representation of Hemicellulose Linking to Cellulose and Lignin

Pre-treatment of biomass is usually done to alter its physical and chemical properties to aid in processing and transport. Preliminary pre-treatment steps usually taken include size reduction, leaching (washing), compaction (agglomeration), briquetting, and palletization (Nanda et al., 2020). They increase the low density of untreated rice husks complicating the transportation and subsequent biomass utilization.

Altering the chemical properties of the rice husks, i.e., the lignocellulosic structure, requires physical, physicochemical, chemical, or biological pre-treatment methods. All the pre-treatment processes have their specific advantages and disadvantages. Chemical pre-treatment is very accessible as no specialized equipment is required in the process, and the chemicals used are usually acid, alkali, sulfur dioxide, ammonia vapors, and lime (Nanda et al., 2020). Alkali-based treatments are the most effective because they break the ester bonds between lignin, hemicellulose, and cellulose (Goodman, 2020). However, chemical-based pre-treatment is relatively more expensive. Biologically based pre-treatment is often slower, while environmentally pre-treatment tends to be inefficient. All these pre-treatment processes have been extensively studied and can be applied commercially.

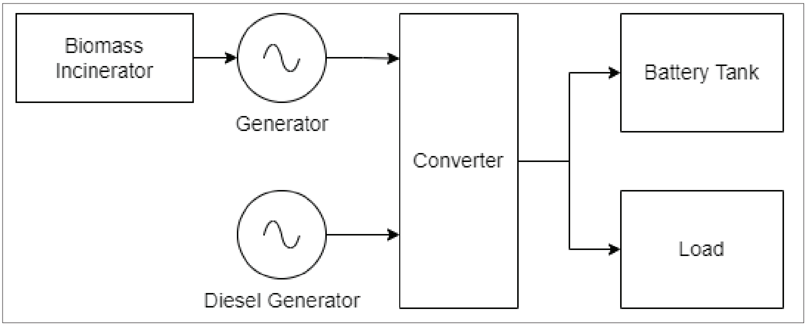
I. Re-evaluation of Investment and Subsidy Priority

As stated in previous sections, one of the major hurdles in utilizing the maximum potential of Indonesia's biomass energy resources lies in the lack of interest in the financial and economic sectors. Skepticism from investors, banks, and entrepreneurs toward renewable energy projects contributes to the relative lack of interest in transitioning to NRE. While regrettable, these concerns are valid due to the government's lack of incentives and push towards funding NRE projects. Currently, the Government is occupied with recovering economy hits by the pandemic. The amount the government plans to subsidize towards fossil-based energy rises to 134 trillion Rupiah in 2022, compared to 128.5 trillion Rupiah in 2021 (Ridwan, 2021). This huge number of investments can be partitioned to boost incentives towards NRE utilization, for example, by subsidizing biofuel prices in the market to become more competitive than fossil-based fuels.

However, the issue related to government subsidy is more than just a reluctance towards transitioning towards NRE. The 134 trillion Rupiah subsidy planned for 2022, for example, comprises a 77.5 trillion-rupiah subsidy towards LPG (3-kg) and fuel oil prices. These subsidies are meant to alleviate the rise in oil prices, impact the economy due to the pandemic, fluctuations of the currency exchange rate, and improve the livelihood of many people. All layers of society use fuel oils for various economic activities, and thus, disruption towards the price would impact heavily, thus explaining the need for subsidy for fuel oil. The same applies to LPG (3kg); they are a typical household and economic goods used by most societies. These include households, small-and-medium businesses, and street vendors. The subsidy is warranted to ensure that people's livelihood tied to this goods is not affected, which will impact the economy in various ways (increased LPG price would increase the price of goods too, reducing incentives of doing economic activities).

Therefore, subsidy allocation is sensitive and requires prudent planning from many sectors and stakeholders. Looking from a pure energy or environmental viewpoint would be tantamount to folly. However, considering only the welfare of the general society without feeling the burden the subsidy puts on the State Budget is also unwise. As of 2022, state spending exceeds state income by 868 trillion Rupiah, or about 4.5% of the GDP of Indonesia (Tim Kementerian Keuangan, 2022). To bring the deficit below 3% of the GDP in 2023, there is a limit on subsidies that can be allocated from the state budget.

An interesting point would be to discuss the remaining fraction of the 2022 energy subsidy, in which a 56.47 trillion-rupiah subsidy has been allocated towards assisting electricity costs. As of June 2021, out of 73.341 MW installed power plant capacity in Indonesia, coal-based steam power plant still dominates electricity production at 47% of total installed capacity (Indrawan, 2021). This implies at least half of the total investments are allocated to lowering the cost of electricity produced from coal power plants. Suppose this amount is instead redirected towards reducing the electricity price from NRE sources. In that case, this will help keep the electricity price affordable to the general public, while increasing the incentives for investments in NRE-based power plants. While the burden on the state budget may stay similar, the overall carbon emission would be reduced due to relying on carbon-neutral/carbon-negative NRE to produce electricity.



Source: Jena (n.d.)

Figure 8.7 Direct Biomass Combustion-Diesel Hybrid Power Generation System

A lucrative investment option would be small-scale power generation in rural communities situated in Indonesia's archipelago's remote, scattered part. Utilizing the cheap yet abundant agricultural wastes commonly produced on rural farms, biomass-based power plants can be alternative to diesel power generators widely used in remote areas. The biomass can be processed into electricity through direct combustion, gasification, or anaerobic digestion. All are well-known commercially mature technologies. A micro-gas turbine will be coupled with a generator to produce the required electricity. From the environmental side, the utilization of agricultural residues does not heavily affect the food supply in the region and can contribute to a net-zero CO_2 emission. The biomass generator system could even be coupled with a diesel generator to form a biomass-diesel hybrid system. When the electricity demand rises during peak load times, diesel generators could be activated to meet the extra demand from residents.

The main advantage of this setup of a hybrid system is the reduction in the Levelized Cost Of Electricity (LCOE) production from biomass resources. LCOE represents the average revenue per unit of electricity generated required to recover the building costs and operate a generating plant during an assumed financial life and duty cycle. The higher the LCOE, the higher the price required to produce said electricity. A techno-economic study regarding biomass-diesel hybrid system implementations was done by Dejucos et al. (2019) on thirteen off-grid islands in the Philippines. This study is fascinating as the area they surveyed was more or less similar to the numerous remote islands not connected to the electricity grid. They found that the LCOE of such a hybrid system can achieve an average reduction of 4.57%. Up to 25% reduction is possible in the case of low energy demand and high biomass availability and a moderate decrease in diesel fuel consumption of 5%. The LCOE of the hybrid system is lower than a purely diesel-based power generation system, implying the cost of producing electricity with an integrated biomass utilization is cheaper. With a high biomass availability in the individual islands due to farming activities and low energy demand due to low population density and lack of energy-intensive infrastructures, this hybrid system can be the solution for powering remote areas in Indonesia.

Aside from the reduction in LCOE, there are at least four non-technical advantages to implementing said systems. Firstly, we avoid connecting every island to the national electricity grid by producing locally on each remote island. This represents a major saving in costs. Secondly, implementing such systems gives extra stimulus to the local economy. By providing a value for the wastes produced from farming activities, we can increase the total income made by the locals by paying them a price to deliver their agricultural biomass for electricity production use. Thirdly, local electricity production alleviates locals' need to rely entirely on the national electricity grid. A localized electricity production means an uninterrupted supply of electricity as all the electricity produced by the plant, assuming sufficient generation capacity, is only used for the localized area. Excess electricity usually sent to the grid can be stored in storage systems (batteries) used in emergencies. Lastly, directly related to the reduced LCOE of the hybrid system, electricity prices would go lower, thus ensuring that electricity is available for all parts of the population, improving their life quality. By building numerous energy-independent remote areas, we could reduce the state budget required to subsidize electricity use in these areas and thus alleviate the economic burden caused by energy subsidy.

The last point of discussion would be to benchmark the current investment climate abroad toward green funding projects. Looking at France as one of the forerunners among EU countries toward a net carbon emission, there are at least three central institutions related to climate commitments in the French financial sectors: banks, insurers, and asset management companies. All banks and insurers, with the majority of asset managers, have adopted a thermal coal exit date in 2030 for OECD countries and 2040 for the rest of the world. In addition, an increasing number of participants are now excluding the financing of companies developing new coal projects. In contrast, for oil and gas projects, the financial actors are still reluctant to complete the phase-out from oil and gas financing (ACPR & AMF, 2021). While improvement in commitments is still warranted from these financial actors, some entities like La Banque Postale, one of the prominent banks in France, have decided to stop financing oil and gas projects by 2030. Another major bank, Société Générale, has also signed an agreement with the European Investment Bank for a collective risk-sharing and funding participation for a total of EUR 240 million dedicated to supporting renewable energy projects. Such agreement is an example of financial institutions' commitments toward energy transition.

Taking note of the above example, it is natural that Indonesia's financial sectors need goodwill to follow suit with their actions. To support the commitment toward clean and renewable energy transition, it is imperative to concentrate investments, loans, and projects in the NRE sector, leaving behind a portfolio of fossil-based energy. While a radical change is warranted, progress can be made in small steps. This change includes improving the attitude against NRE projects, from one that is purely economical and cost/benefit concentrated to a more holistic approach. That is to say, to have a future for everyone, it is dire to switch to NRE as soon as possible, and that means looking beyond mere investment returns.

In closing this chapter, it is also essential to consider the need for talented human resources and researchers to fully integrate biomass energy into the national energy mix. Fresh graduates, professionals, and academic researchers all contribute to successfully implementing a feasibility study, all the way into the commercial application of biomass energy. When we all work together, united under a common cause of alleviating climate change, we can achieve our goal of sustainable clean energy accessible to all Indonesians. Therefore, academic lecturers need to ensure that young students and fresh graduates are aware of the urgency of climate change. Without haste, there will be no incentive for action.

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