Bioethanol prospect from agricultural crops and its biomass in Indonesia

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Abstract. Contradiction between the surplus domestic bioethanol supply and the failure to fulfill the bioethanol E2 biofuel program in 2020 is because the fuel grade ethanol price is still more expensive than gasoline. Indonesia's fuel consumption needs, especially gasoline is increased from 37.49 million kL in 2020 to 43.59 million kL in 2025, with a deficit that is met with gasoline imports. Bioethanol production is still in surplus, the remainder is exported, still unable to supply the E2 bioethanol program and the import of non-fuel-grade ethanol is carried out. The abundance of mollase is not only the main raw material for bioethanol, but it is in competition with other industries such as MSG, and the decline in sugar cane land will reduce the availability of mollase in the future. In 2015, world bioethanol produces 1,390 million liter from 2G bioethanol, still in TRL4~TRL8 status, yet to commercial. To maintain ethanol supply security, potential biomass and waste-crops, and a lot of available sources that are not in competition with food needs, technological aspects, productivity, availability, and other aspects, biomass commodities need to continue to be developed with more intensive collaboration between institutions (academic, government, private). This study assesses the greatest potential of non-food biomass in Indonesia, including the 2nd generation bioethanol, 3rd generation, and the current biggest challenge in the readiness and maturity of the technology and its economic feasibility.

Keyword: Bioethanol, biomass, technology, economy.

1. Introduction

According to the Indonesia government to encourage national energy mix targets for new and renewable energy (EBT) by 23% in 2025, also through the Minister of Energy and Mineral Resources regulation No. 12 year 2015 on the third amendment to regulation of the Minister of Energy and Mineral Resources No. 32 year 2008 on the provision, utilization and commerce of biofuels. Regulation of the Minister of Energy and Mineral Resources No. 12 of 2015, said that the use of bioethanol E5 was required at 2020, with a formulation of 5 % ethanol and 95 % TRD (revised to E2 which was apparently also not achieved by reason of high production cost) and increased to E20 at...
2025. In support of Presidential decree No. 22 of 2017 about the National Energy General Plan (RUEN), renewable energy from plants and/or biomass including its waste needs to be planned, examined, and implemented in the meeting, from the carrying stage that is industrial scale. Despite the efficiency, development of new refinery, increase of lifting petroleum, projected petroleum imports are still deficits as shown in Figure 1.

![Figure 1 Indonesia's supply and fuel supplies balance [12].](image)

On the production side, there are currently 15 producers of ethanol producing 245 – 408 million liters per year of installed capacity [22], 180 million liters of production annually and the domestic consumption rate of 100 million liters annually [9], 4 factories of them produce FGE, and 11 remaining factories of industrial grade; distribution of export and imported ethanol shown surplus export up to 2020 (Table 1). It means that the ethanol commodity is still surplus so the excess is exported. Only at the time of the Covid-19 pandemic, the Indonesia government stopped awhile exporting ethanol due to the increase in demand for hand sanitizer (6 million liters per year). Therefore, there are still contradictions from the government side and the manufacturer about the pattern and the fulfillment strategy and balancing the needs and supply, on the side of the fuel still achievement deficit bioethanol E2, during pandemic the tap export is closed due to the addition of 6 million liters for the sanitation effect COVID19, but the manufacturer feared excess 80 million liters per year is not absorbed in the country. It seems that there is still a lot of disparity between supply network, needs, economics and government policy so that the ethanol industry in particular bioethanol to sustain.

![Table 1. Export and import of ethanol status in Indonesia [11].](image)

The cost of ethanol production by the plant in Indonesia reaches IDR 6,000 per liter on April 2018, excluding transportation costs according to Untung [24]. Market index price of BBN bioethanol fuel grade (99.5 %) During the average of 2020 IDR 10,838/liter, along 2019 amounting to IDR 10,226/liter, at 2018 amounting to IDR 10,181/liter and at 2017 amounting to IDR 10,729/liter which
means relatively stable during the last 3.5 years. Therefore, ethanol is still very prospective and interesting both as bioenergy products and non-bioenergy especially the export sector because the slot 80-90 million liters per year surplus as non FGE, and there are ethanol importing countries that sell in the country with a price up to IDR 17,700/liter [10]. The ethanol main export destination market is the Philippines, Singapore, Japan, Thailand.

![Figure 2 Bioethanol fuel grade market index price](image)
(Source: Ministry of Energy and Mineral Resource, Republic of Indonesia)

The actual realization of the fulfillment of FGE bioethanol for E2 to the end of 2020 is surely not fulfilled, due to the Market Price Index of ethanol that is still above the price of gasoline (Pentalite/Gasoline 90, Pertamax/ Gasoline 92, Pertamax Turbo 95/98), as reported by Rahmanulloh, MC Donald [9], as well as less or limited support of the Government/Pertamina in the FGE+Gasoline blending facility.

The Indonesia government initially provided protection of local ethanol producers against imports in the form of 30 % import tax. However, in February 2019 (Finance Minister Regulation, on the recommendation of the Ministry of Trade, has liberated ethanol import duty (grade ≥ 80%, HS Code 2207.1000 non FGE) to 0 % from Pakistan (exporter of the 4th largest ethanol in the world) through the importer of PT Karsavicta Satya as much as 5 million liters, in year 2020 proposed another import of 5 million liters. Prima Gandi [23] proposed the formation of LEIT (ethanol import export agency) to accommodate potential conflicts of interest between the exporter and importer of ethanol and protect the domestic ethanol industry and should prioritize the procurement of FGE ethanol (99.5 %) to trigger the fulfillment of the bioethanol E2 program. Figure 3 shows the status imported ethanol FGE from 2016 to 2019.
Figure 3. Fuel Grade Ethanol (FGE) import in January 2016 – December 2019 [11].

This phenomenon is interesting to be examined from various aspects, technically whether the local ethanol product is not yet able to meet the local consumer specifications of the industry (pharmaceutical, personal care, cosmetics, printing, solvents, cleaners, fabric softener, beverages, etc.), in price or non-technical aspects. Not only trade agreements with Pakistan, some trade tariff regulation agreements with several other countries have also formulated an ethanol import rate reduction of up to 0 % as shown in Table 2. This article reviews more of its technical and economic aspects, despite policy of government play very important role on the sustainability of ethanol local industry.

Table 2. Import tariff of denatured and undenatured ethanol.

| Trade agreements      | Tariff Regulation | Import Duty Ethanol (HS Code 2207.xxxx) |
|-----------------------|-------------------|----------------------------------------|
| Import Denatured Ethanol | Permenkeu 06/2017  | 30 %                                   |
| Import Undenatured Ethanol | Permenkeu 06/2017  | 30 %                                   |
| ATIGA ASEAN           | Permenkeu 25/2017  | 0 %                                    |
| AKFTA ASEAN-Korea     | Permenkeu 24/2017  | 5 % (2017--)                           |
| IJEP A Indonesia-Japan | Permenkeu 30/2017  | 11.25 % (2017)                         |
|                        |                   | 9.38 % (2018)                          |
|                        |                   | 7.5 % (2019)                           |
|                        |                   | 5.63 % (2020)                          |
|                        |                   | 3.75 % (2021)                          |
|                        |                   | 1.88 % (2022)                          |
|                        |                   | 0 % (2023--)                           |
| AJCEP ASEAN-Japan     | Permenkeu 18/2017  | 13.82 % (2018)                         |
|                        |                   | 12.35 % (2019)                         |
|                        |                   | 10.88 % (2020)                         |
|                        |                   | 9.41 % (2021)                          |
|                        |                   | 7.94 % (2022)                          |
|                        |                   | 6.47 % (2023)                          |
|                        |                   | 5 % (2024--)                           |

More than 60 sugar mills operate and produce mollase in Indonesia, and it is estimated to produce 2.1 million tonnes of sugar and 1.4 million tonnes of mollase at 2019/2020 of 29.1 million tons of sugarcane [13]. To obtain ethanol 200 million liters, it takes 815,000 tons of mollase. The mollase is not only used for ethanol, but also other industries such as monosodium glutamate in relatively numerous amounts as well.
Indonesia produces a variety of agricultural commodities and biomass products, which have potential of starch or sugar to be processed into bioethanol besides mollase. Cassava, sago, *Arenga pinnata*, sorghum are several agricultural commodities, and biomass such as giant king grass, hump corn, EFB (empty fruit bunches) and food factory waste (soy sauce, ice cream, syrup). This study shows their potential to be developed into bioethanol.

2. **Agriculture and biomass as biofuels feedstock**

2.1. **Plant and/or biomass for bioethanol production**

Some types of plant raw materials and biomass for bioethanol production are presented in Table 3.

| Plant/Biomass | Productivity (ton/ha/year) | Starch content | Glucose content | Yield ethanol (L/kg substrate) | Harvest period (Day) |
|---------------|----------------------------|----------------|----------------|-------------------------------|----------------------|
| 1) Starch & Sugar: | | | | | |
| Cassava | 30–40 | 21.75% | 2.5%–3% | 0.167 | 90 |
| Sago | 25 | 22% | 1.2%–1.6% | 0.090 | - |
| Mollases | 3–3.8 | - | 85% | 0.250 | 270 |
| Corn | 7–8 (composite) | 71.5% | 6%–7% | 0.2–0.7 | 90 |
| *Arenga pinnata* | 900 | 0.016 | | | |
| Sorgum | 46–65 | 0.1% | 10-14.4 | 0.025 | 109 |
| 2) Biomass | | | | | |
| Giant King Grass | 210 | 20% | 2.8%–4.7% | 0.317 | 120 |
| EFB | 1.2 | 42.23% | - | n/a | 1 |
| Ice cream waste | 6 ton/day | - | 45% | 0.04 | 1 |
| Soy sauce waste | 1 | - | 79% Brix | 0.032 | 30 |
| Bagasse | 21 - 27 | - | n/a | 270 |
| Corn-tissue peel | 2.9 - 5 | 69.25% | - | 0.2 – 0.3 | 90 |

a Nurdyastuti [7]
b SBRC, IPB
c Ni Ketut Sari, page 57,103 [1]
d Unit in liter/ tree/ year;
e This study;
e Euis [6]
+f Graeme MW [8]
n/a: unavailable data

2.2. **Selection of plants and/or biomass for the production of bioethanol**

Some criteria in the selection of plant commodities and/or potential biomass for bioethanol in Indonesia are as follows: 1. Food ingredients that are surplus; 2. Biomass waste or sewage products (food and beverage industry) with adequate sugar content; 3. Crop productivity; 4. Sugar content within crops; 5. Multipurpose energy plants; 6. Development readiness; 7. Government policy; 8. Ease of growing in the marginal land.
Euis H [6] predicts the potential of ethanol production per year in Indonesia from biomass (corn cob, coconut coir, cassava heaps, cane-leaf, bagasse, EFB) will likely in amount 200,000 to 1,400,000 kiloliters for each biomass or total 4,500,000 kiloliters.

3. Process development and commercialization of Bioethanol

3.1. Ethanol Application

Ethanol is used in a wide range of applications, from vehicle fuels, cosmetics, pharmaceuticals, beverages, intermediate/downstream chemical industries to laboratory reagents. With various types of purity, ethanol development efforts are attractive. This study, specifically studying in the bioenergy sector and the potential of ethanol raw materials in Indonesia, shows the development of bioethanol production from renewable resources, especially agricultural and biomass products.

Currently, Pertamina (an Indonesian state-owned oil and natural gas corporation) is conducting research and studies on the program of Gasoline-Methanol-Ethanol (GME) initiative, which has been implemented in several countries in the world, Europe and China, one of the GME-A20 programs namely fuel mixture consisting of methanol 15 %, ethanol 5 % and the remaining Gasoline (88 Octane number) [12].

3.2. First Generation Bioethanol

First generation bioethanol is produced from crops that are high in sugar and starch content such as corn, sugarcane, molasses, sweet sorgun, sweet fruits, tapioca from cassava/potatoes. This material is directly fermented, e.g. with yeast Saccharomyces cerevisiae into ethanol in low content (7-10 %) The next in the distillation to purify up to 96 % at its azetotropic point (78.5 °C). If desired purity above 96 % further separation is applied, such as azetrop distillation (solvent-distillation extraction), or by dehydration-distillation (dehydration with adsorbent water absorber and further conventional distillation). Some other types of microbes used are: Pichia stipitis, Candida shehatae, Kluyveromyces marxianus, Pachysolen tannophilus. The reaction of fermented sugar on the theoretical fermentation (stoichiometry) as follows:

\[
\begin{align*}
\text{C}_6\text{H}_{12}\text{O}_6 & \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \\
180\text{kg} & \rightarrow 92\text{kg} + 88\text{kg}
\end{align*}
\]

Theoretical yield of ethanol is 0.51 kg ethanol per kg of glucose. In fact, the closer the 0.51, the more efficient the process of fermentation.

3.3. Second Generation Bioethanol

Second generation bioethanol is produced from cellulose, a non-food category. For example: Bagasse, EFB, elephant grass, corn pulp, rice husk, soft wood/branches. The second generation of bioethanol process which is common commercially such as Simultaneous Saccharification and Fermentation (SSF). The unconverted lignin is still quite large with this SSF process, about 17-26 % [8]. Other processing methods: batch, Fed-batch, simultaneous saccharification and fermentation (SSF), saccharification and co-fermentation (SSCF), separate hydrolysis and fermentation (SHF), consolidated bioprocessing (GST) and drop-add.

Currently, Pertamina is conducting research on the Gasoline-Methanol-Ethanol (GME) initiative program, which has been implemented in several countries in the world. One of the GME-A20 programs namely fuel mixtures consisting of methanol 15 %, ethanol 5 % and the remaining gasoline [12]. Pertamina, RNI, PTPN, Toyota Motor Corporation has made the same work since 2015, the development of second generation bioethanol from the raw material of elephant grass (Napier Grass),
harvesting period per 4 months, production of 70-80 tons per hectare. Pilot project on an area of 7 hectares in Jatitujuh, Majalengka, Indonesia. Pertamina, RNI: MoU 19 March 2019, RNI through a subsidiary engaged in the sugar industry, namely PT PG Rajawali I, will supply molasses to be processed with Pertamina to become Bioethanol Fuel Grade with a capacity of 30,000 KL/year. RNI: Date 16 Oct 2015, ethanol factory around sugarcane plantation in Rajawali II sugar Factory of Jatitujuh Unit, Majalengka, West Java with an investment of about IDR 200 billion. The bioethanol plant with a capacity of 50 kiloliters per day (60.000 KL/year) is targeted to produce from the year 2018. To date, there has been no report on the research readiness on commercial scale. This example shows that time and innovation are required so that it can be scale-up commercially.

3.4. Third Generation Bioethanol

The third generation of bioethanol in the form of algae, i.e., microalgae. With the rise of research to find alternative sources of energy, microalgae have excellent prospects to be developed as one of the candidates for biofuel feedstocks. Microalgae are chosen because they have the ability to grow rapidly and do not require a large area for production activities. In addition microalgae have the ability to absorb carbon dioxide so as to reduce the greenhouse effect [14].

Microalgae as the third generation of biofuels has been widely tested for its potential and its sustainability, generally the last important parameter is Life Cycle Assesment (LCA) or Nett Energy-balance Ratio (NER). The NER is defined as the comparison of the energy contained in biodiesel divided the input energy consumed, so that the ratio of NER is greater than 1 signifying the desired process. Arcigni et al. [14] systematically quantified and reviewed the harmonization of the potential of microalgae energy, analyzing the stages of biodiesel production process, total forecasting energy consumption, substantial uncertainty of some literature data, reviewing the NER, as well as the uncertainty of each combination process each stage of the process series that generates the NER (with metadata analysis), i.e., harvesting using flocculation + centrifugation; extraction using homegenization + extraction using hexane solvent; and biodiesel production with transesterification. The study of some literature showed that the average lower heating value (LHV) of biodiesel from microalgae amounted to 40.62 MJ/kg.

Khan et al. [16] reported on the microalgae species of Tribonema, Ulothrix and Euglena potentially good for biodiesel, as well as genetic engineering technology in microalgae. Table 4 shows a list of microalgae that are widely researched for biodiesel.

| Microalgae                     | Oil Content | Productivity         | Reference                                      |
|-------------------------------|-------------|----------------------|------------------------------------------------|
| *Chlorella vulgaris*          | 20-30 %     | 24.75 g/m²/day       | Gouveia and Oliveira [5], Lardon [18], Pertamina [12] |
| *Spirulina maxima*            | 4-9 %       | (no data)            | Gouveia and Oliveira [5], Pertamina [12]        |
| *Nannochloropsis* sp.         | 28.7 %      | 3-25 g lipid/m²/day  | Gouveia and Oliveira [5], Lardon [18], passel (2013), Pertamina [12] |
| *Nannochloropsis* gaditana (mutagen) | 40-45 %   | (no data)            | Exxon Mobil [20], Ajjawi et al. [21]           |
| *Neochloris oleoabundans*     | 29 %        | (no data)            | Gouveia and Oliveira [5]                        |
| *Scenedesmus obliquus*        | 16-40 %     | (no data)            | Gouveia and Oliveira [5]                        |


| Microalgae                        | Oil Content | Productivity | Reference               |
|----------------------------------|-------------|--------------|-------------------------|
| Dunaliiella tertiolecta          | 20-25 %     | (no data)    | Gouveia and Oliveira [5]|
| Oedogonium                       | 10-15 %     | (no data)    | Sharif et al. [19]      |
| Spirogyra                        | 20-25 %     | (no data)    | Sharif et al. [19]      |
| Navicula saprophila              | 10-28 %     | (no data)    | Pertamina [12]          |
| Botryococcus                     | 75 %        | (no data)    | Pertamina [12]          |
| Euglena                          | 8-18 %      | (no data)    |                         |
| Chlamydomonas. reinhardtii       | 1.5 times lipid content higher than wild strain | (no data) | Ng et al. [4] |
| (transgenic)                     |             |              |                         |
| Phaeodactylum tricornutum        | 1.5 times lipid content higher than wild strain | (no data) | Ng et al. [4] |
| (transgenic)                     |             |              |                         |

Since 1980s, genetic engineering efforts have been started a on several strains of bacteria so that the metabolism of these bacteria is digesting substrates such as sugar, carbohydrates, glycerol and other biomass can produce ethanol. Some of the advantages of bacteria are its rapid growth so that ethanol production is also comparable, and bacteria are relatively resistant to a wide range of substrates (ranging from carbohydrates, sugars, proteins and others) to other abiotics. The use of bacteria that is reported such as E. coli etanologenic, in which the metabolic pathways are engineered to produce ethanol. However, development towards industrial scale has not been realized.

Utilization of metabolic engineering in microalgae for the production of biofuels is still not optimal, Ng et al [4] proposed to acquire all data of microalgae genome especially with CRISPR technique or Omics approach, to obtain recombinant microalgae strains that produce more economical and competitive biodiesel. Some transgenic microalgae species have been researched for biofuels, i.e., C. reinhardtii and P. tricornutum which can increase lipid levels by 1.5 times and improve photosynthesis performance. The UDEASP (U.S. Department of Energy's Aquatic Species Program) in 2010 has mapped around 300 potential microalgae species for biofuels.

3.5. Feasibility and commercialization of ethanol

Ethanol plants in Indonesia, almost all of which are made from the raw cane drops as shown in Table 5, where total 15 bioethanol plants produce 180 million kL/year ethanol, with average 100 million kL/year for local demand and 80 million kL/year for export. Three of the plants are able to produce Fuel Grade Ethanol. In 2019, there is also a people's business that cultivate traditionally the molasses into ethanol, scattered in various regions, especially in the Java Island. Besides ethanol, the side result of liquid fertilizer also biogas is obtained from natural materials biomass and/or agricultural commodities.
Table 5. Bioethanol production plant in Indonesia [25].

| No | Plant | Capacity (x1,000 kL/year) | Location | Raw Material |
|----|-------|---------------------------|----------|--------------|
| 1  | PT. Molindo Raya           | 30                        | Lawang   | Mollases, corn |
| 2  | PT. Molindo Raya           | 50                        | Lampung  | Mollases     |
| 3  | PT. Indo Lampung Distillery| 30                        | Lampung tengah | Mollases |
| 4  | PT. Indo Acidatama         | 45                        | Solo     | Mollases     |
| 5  | PT. Aneka Kimia            | 17                        | Mojokerto | Mollases |
| 6  | PASA Djatiroto             | 7.5                       | Lumajang | Mollases     |
| 7  | PT. Madu baru              | 7                         | Yogyakarta | Mollases |
| 8  | PSA Palimanan              | 7                         | Cirebon  | Mollases     |
| 9  | Basis Indah                | 5.5                       | Makasar  | Mollases     |
| 10 | Permata Sakti              | 5                         | Medan    | Mollases     |
| 11 | Molasindo Alur Pratama     | 3.6                       | Medan    | Mollases     |
| 12 | PT. Medco Ethanol Indonesia| 69                        | Lampung  | Cassava      |
| 13 | Sampoerna Bio Energi       | 60                        | East/Central Java | Cassava |
| 14 | RNI                        | 100                       | East Java | Cassava/Mollases |
| 15 | PT. Enero                  | 30                        | Jombang  | Mollases     |

The costs of ethanol production from some biomass are presented in Table 6. The variation in production cost is very related to the fluctuations in the price of raw materials, as well as the raw material of lignocellulose (third generation bioethanol) will be prospective with more efficient technological discovery in the future.

Table 6. Production cost of bioethanol compared to gasoline [8], exchange rate 14.300 IDR/Euro.

| Biomass Source          | Production Cost (IDR/Liter) |
|-------------------------|----------------------------|
| Gasoline                | 3,575                      |
| Corn (USA)              | 6,006                      |
| Corn Stove              | 6,435 – 8,294              |
| Wheat (Europe)          | 3,861 – 6,149              |
| Crystal sugar (Europe)  | 4,576 – 7,722              |
| Sugarcane (Brasil)      | 2,288 – 4,004              |
| Mollase (Cina)          | 3,432                      |
| Sweet Sorghum (Cina)    | 3,146                      |
| Corn Fibre              | 5,863                      |
| Wheat fibre             | 6,292                      |
| Fine wood               | 6,292 – 9,009              |
| Hardwood                | 6,864 – 10,153             |
| Lignocellulose          | 1,573 – 4,576              |
In October 2019, the Ministry of Energy and Mineral Resources [17] established the price of bioethanol market index resulting from the molasses (bioethanol generation 1) in October 2019 for IDR 10,273 per liter, and Pertamax 92 at the time of IDR 9.850 per liter. In the USA, the bioethanol price of corn (bioethanol generation 1) was IDR 5.200 per liter in June 2017, the same time bioethanol from lignocellulose (bioethanol generation 2) was higher, about IDR 11.610 per liter. Therefore, for bioenergy product applications, bioethanol is still not able to compete without the intervention and alignments of the government. Nonetheless price subsidy patterns are also less good in the long term and draining the country's budget. For the fuel sector, bioethanol in Indonesia is still not competitive, where the price tariff order of ethanol is still under gasoline both pertalite (gasoline 90), Pertamax (Gasoline 92). While continuing research for the readiness of technology, the business sustainability needs to support the Government to maintain a policy of E5, E10 that can continue to be performed by bioethanol producers.

4. Conclusion

The potential of agricultural products and/or biomass in Indonesia is quite abundant and continuous, with adequate levels of essential starch/glucose/lignocellulose. Some of the factors that have become the challenge of bioethanol business continuity are technology readiness, ease of Government policies need to continue to find solutions.

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