Sustainability of biodiesel B30, B40, and B50 in Indonesia with addition of emulsifier

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Abstract. Sustainable energy is one of the main challenges of the 21st century. Indonesia is a developing country and ranked fourth in the world population. The total increase in average population growth between 2000 and 2025 is projected at 33.2%. Thus, the problem of energy deficits must be addressed by the Government of Indonesia to overcome the shortage of energy resources in the future. The Indonesian government's policy on biodiesel began in 2015 and continues to undergo renewal. Starting in September 2018, Indonesia set the B20 rule, and then in January 2020, it began to shift to B30. By the end of 2020, it was targeted to have moved to B50. The concept of sustainability focuses on two things: a combination of environmental and economic considerations. One of the crucial points in sustainable development related to the development of biodiesel B30, B40, and B50 is that economic growth needs to be harmonized with efforts to preserve the environment through long-term maintenance of the availability of biological resources and increasing productivity of the agricultural systems, stability of the human population, limitations on economic growth, and make improvements to the quality of the environment and ecosystem. Biodiesel in Indonesia, Fatty Acid Methyl Ester (FAME) is synthesized from palm oil. Emissions from biodiesel from vegetable oils still contain high NOx gas. When viewed from the side of the impact on the environment, the concept of biodiesel sustainability needs additives/emulsifiers so that the quality and stability of biodiesel increases. That way, the biodiesel effect may show to be environmentally friendly compared to fossil fuels.

1. Introduction
Energy is a fundamental need for human life and a key to the modernization of the existing sector. Meeting sustainable energy needs is one of the main challenges of the 21st century. Indonesia is a developing country and number four for the world population. The population and energy needs are increasing day by day. The total population in Indonesia rose from 205,132,000 million in 2000 to 233,477,400 million in 2010 and is projected to reach 273,219,200 million in 2025 [1]. Thus, the total increase in average population growth between 2000 and 2025 is projected to be 33.2%. The Indonesian government must address this problem to overcome the lack of energy resources in the future [2]. The Indonesian government's biodiesel policy began in 2015 through the Ministry of Energy and Mineral Resources and continues to undergo renewal. In September 2018, it was changed to B20, then began to switch to B30 in 2020. By the end of 2020, it was targeted to have shifted to B50 (Balitbang ESDM).
Emissions from fuel oil consumption produce 40.9% of CO₂ emissions in Indonesia. Although quite varied, emissions from natural gas consumption and coal use have increased steadily since the early 1970s and accounted for 15% and 38% of Indonesia's total emissions. With more than 225 million people, Indonesia's emissions per capita level of 0.48 metric tons of carbon is well below the global average but has grown fivefold since the late 1960s [3]. Currently, fossil fuel-based energy such as oil, coal, and natural gas is Indonesia's primary energy source. The primary energy mix in 2019 was shown in Figure 1. Petroleum is the single largest energy source (38.8%), followed by coal 33.3%, natural gas 19.7%, and new and renewable energy (EBT) at 8.5%. The projections for 2025 (Figure 2) of the energy mix are EBT utilization by 23% and petroleum by 25%, which means more energy conversion from fossil fuels to EBT. The presence of biodiesel B30, B40, and B50 must continue to be sustainable regarding environmental aspects, social aspects, and economic aspects.

Fuel consumption needs in Indonesia have increased relatively high from year to year. This consumption can be seen in Figure 3. Data on oil consumption in Indonesia shown in the blue line continued to increase from 1965-2017. In contrast, oil production has decreased, starting in 2000. In Figure 4, we can see that Indonesia has experienced an oil deficit since 1981-2017. Based on these data, for now, Indonesia must have switched to using alternative energy gradually, one of which is
biodiesel. The government began to implement the use of B20 in 2018. The use of B20, which has only been running for one year, was increased to B30. Of course, this becomes a challenge for policymakers to continue to make improvements so that B30 is better prepared to be applied.

Through the Ministry of Energy and Mineral Resources (ESDM), the government has set a biodiesel plan in Indonesia in the Minister of Energy and Mineral Resources Regulation No. 12 of 2015, which was later renewed in 2018. These regulations made the positioning of the B30 application even more vital to be applied in Indonesia. The application of biodiesel usage has been determined for the micro-business sector, fisheries business, agricultural business, transportation, and Public Service Obligation. It also applies to the types of Non-Public Service Obligation, industrial and commercial transportation sectors, and power plants.

Besides that, the application of biodiesel B30 is also supported by the availability of FAME (Fatty Acid Methyl Ester) supply. The availability of FAME supply for B30 can meet the needs in Indonesia. FAME's industrial processing capacity currently reaches 12 million kiloliters. While the need for 2016 is 6 million kiloliters and 1.5 million kiloliters of exports. The estimated increase in FAME consumption of 3 million kiloliters when B30 is applied is still sufficient. Moreover, there is a guarantee of supply of raw materials in crude Palm Oil (CPO), which currently produces 42 million tons per year (Indonesian Biofuel Producers Association 2020).
Today, the realization of the application of B30 biodiesel in Indonesia is being campaigned since the end of 2019 and officially implemented starting in 2020, triggering the industry's pros and cons. Industry players feel burdened by this policy (Indonesian Biofuel Producers Association 2020) because B30 can cause various problems, including biodiesel is more wasteful because of incomplete combustion, the engine used in the production process requires extra care. This condition is burdensome for businesses because they will incur additional costs for maintaining their production machines. Also, the mixture of FAME with diesel causes water to be formed, causing incomplete combustion and the deposition/crust resulting from this combustion process [4, 5]. This incomplete combustion can cause emissions produced to be higher [6, 7].

Some business operators have also accepted the government's policy regarding the implementation of B30 in Indonesia this year. The industry supports the program of using 30 percent biodiesel blends on diesel or B30 by 2020, on condition that the government must first test several types of vehicles. According to the General Secretary of the Indonesian Automotive Industry Association (Gaikindo) (2020), he hopes that the government can make sure the fuel matches the vehicle engine and does not add to the burden of maintenance. Besides, the use of B30 fuel can encourage producers to use cleaner fuels and reduce fossil fuels. Gaikindo's support also includes vehicles' provision to be tested in as many as four passenger vehicles and three trucks. The selection of these vehicles is based on the most significant domestic diesel vehicle users (Directorate General of Land Transportation, 2019). The application of B30 will increase FAME production, which means it will also increase byproduct production from the process. This byproduct can provide opportunities for other industries because the production of FAME from palm oil can produce derivative products from byproducts such as glycerol. Glycerol is widely used as a raw material for cosmetics and pharmaceutical industries [8]. Based on the regulations that have been implemented by the government, the use of biodiesel B30 replacement needs to get support from all parties so that it can be appropriately realized.

2. **Concept of Sustainability**

According to Bautista [9], sustainability has three frameworks that must be met in the classification of sustainability standards. Hierarchically, a sustainability standard is divided into principles, criteria, indicators, and guidelines. According to Hambali [10], there are ten indicators of bioenergy sustainability in Indonesia: 2 indicators on environmental aspects, three indicators on social aspects, and five indicators on economic aspects. One of the sustainability indicators discussed in this paper is the environmental aspect, with indicators in the form of air quality produced from raw material production, biodiesel production processes, transportation, and usage. The reference parameter is biodiesel's emission in PM 2.5, PM10, NOx, SO2, and other pollutants.

Mankoff [11] stressed that sustainability is a form of human interaction with the environment. Sustainability focuses on two things: sustainable development is more than just growth, but it is necessary, especially in terms of reducing the materialistic nature, making it more efficient, and balancing the benefits. Second, integration between environmental and economic considerations. One crucial point in sustainable development related to the development of biodiesel B30, B40, and B50 is that economic growth needs to be harmonized with efforts to preserve the environment through long-term maintenance of the availability of biological resources and increasing productivity of the agricultural system, stability of the human population, limitations economic growth, and continuously improve the quality of the environment and ecosystem. In terms of biodiesel development in Indonesia, one of the factors that can be seen regarding the sustainability side is the emission of gas produced to the environment. This can strengthen the sustainability aspect of this policy; besides, according to Hambali [10], sustainability can be seen from two aspects: environmental and social.
3. **Biodiesel Emissions from Various Raw Materials**

Biodiesel emissions are important to emphasize and become a concern because it is one of the parameters for environmental aspects. Biodiesel in Indonesia is developed from oil palm, fatty acid methyl ester (FAME). However, many biomass sources can be developed into biodiesel raw materials in Indonesia, derived from Jatropha curcas oil, palm oil, used cooking oil, and other vegetable oils. During the process of burning, incomplete fuel will cause CO emissions. If there is enough oxygen, CO will be oxidized to CO₂ [12, 13]. CO emissions increased at high load and reduced at low load for emulsified biodiesel. This is caused by higher latent heat evaporation causing incomplete combustion. More CO is produced at low and medium loads.

The cooling layer that occurs due to ethanol and water's evaporation effect can increase CO production [14]. However, at a 100% load, CO emissions for emulsion mixes are 50-70% higher than diesel because of the lower air-fuel ratio [12]. CO emissions in emulsified fuels are higher than diesel fuel at full load due to the area of engine contact with less fuel and greater fuel droplets. However, a significant reduction in CO emissions is found when nano additives are added, such as carbon nanotubes (CNT). The addition of nano additives will cause a better fuel distribution to the engine and maximum emulsified fuel [15]. CO emissions often increase with increasing water concentration [16]. The CO emissions produced by water-emitted biodiesel are 5%, 6.5%, and 8.5% lower than 10% and 15% emulsified biodiesel water. A higher amount of water means a higher amount of OH radicals, which can increase carbon oxidation. However, it turns out that fuels with high water content have lower CO emissions than diesel fuels [16]. For emulsified fuels, CO₂ emissions increase when CO decreases and vice versa. [17] found a reduction in CO₂ emissions at higher loads caused by better combustion. For the comparison, emission from emulsified biodiesel emissions from various raw materials can be seen in Table 1.

| Ref | Emulsion type | Composition of biofuels | Gas Emissions | Smoke Opacity |
|-----|---------------|-------------------------|---------------|---------------|
|     |               |                         | HC            | CO            | CO₂          | NOx          |               |
| [18] | W/O          | Jatropha Methyl Ester (JME 93%)+2% emulsifier+water 5% | The highest compared to JME and addition of CNT | Higher compared to JME and addition of CNT | Lower compared to JME | Lower compared to JME |
|     |               | JME93%+2% emulsifier+water 5%/25/50/100 ppm CNT | Partially reduced | Significantly reduced compared to JME and emulsified JME |               |               |
| [17] | W/O          | Jatropha biodiesel 10%+0.5% emulsifier+10/15% water | Increases at low loads and decreases at high loads | 7-8% lower emission than high load diesel | Reduced |               |
| [19] | W/O (metanol in oil) | Biodiesel-canola oil (88.4/83.07%)+metanol (9.8/14.66%)+emulsifier (1.8/2.27%) | Reduced | Reduced | Increased | Reduced |
| [20] | Microemulsion | Waste cooking palm oil (B70)+0.5% water | Slightly decreased compared to biodiesel | Slightly decreased compared to biodiesel | Slightly decreased compared to biodiesel | Increased compared to biodiesel |

Table 1. The comparison of emission from emulsified biofuels
4. **Addition of Nano Additives to Reduce Biodiesel Emissions**

Gas emissions of NOx produced by biodiesel fueled engines are still relatively high, so NOx emissions in biodiesel are still a concern for researchers to reduce. To be sustainable, NOx gas emissions on biodiesel must be as minimal as possible. Many researchers have made several attempts to reduce NOx emissions from biodiesel-fueled diesel engines. [22] A previous study tried water-emulsified biodiesel and conducted experiments in a research machine. The results show that increasing the water concentration in biodiesel can reduce NOx emissions due to the absorption of latent heat by water particles during the combustion process. [16] Another study tried the water emulsification method with methyl esters of palm oil and diesel mixtures. [23] [24] Other studies tried the process of water emulsification with used cooking oil and castor oil (jatropha methyl ester). The water emulsified biodiesel experiment results showed a positive effect on engine performance, NOx, and smoke for all test fuels. However, unburned hydrocarbons (HC) and carbon monoxide (CO) increase the emissions that result from a longer ignition delay (Ignition Delay Period / IDP). The more extended period of ignition delay during the combustion process will also lead to rough engine performance [12]. Comparison of adding nano additive to biodiesel can be seen in Table 2.

### Table 2. Comparison emission biodiesel by adding nano additive

| Ref | Fuels Composition | Nano Additive | Emissions Parameters (ppm) |
|-----|-------------------|--------------|---------------------------|
|     |                   |              | NOx | CO | HC |
| [17] | Jatropha biodiesel | Alumina       | 8   | 40 | 12 |
| [25] | Biodiesel         | Carbon        | 70  | 40 | 26 |
| [26] | Biodiesel+water   | Zinc Oxide    | 32  | 25 | 10 |
| [27] | Biodiesel+ethanol | Cerium Oxide  | 16  | 34 | 39 |
| [28] | Biodiesel+ethanol+Castor oil | Cerium Oxide | 54  | 32 | 14 |
| [19] | Diesel+Canola oil | Zinc oxide    | 19  | 14 | 50 |
| [18] | Jatropha oil+water | Carbon       | 29  | 29 | 7  |
It is necessary to add nano additives to emulsified biodiesel to reduce IDP and refine engine performance and reduce NOx gas emissions. Several nano additives, including metal-based, such as nano cerium, nano alumina, and nano zinc oxide. During the combustion process, nanoparticles' presence can contribute to better thermal conductivity and better contact and fuel contact area ratios. Besides, nanoparticles can also react with water and carbon atoms, thereby increasing the soot's oxidation [30]. [12] A study used alumina nanoparticles as additives for water-emulsified diesel fuel and produced a significant reduction in NOx emissions. [18] One study showed an increase in combustion processes, performance, and emission levels of water-emitted biodiesel fuel using carbon nanotubes (CNT) as additives. [12] It also showed that zinc oxide nanoparticles could shorten engine ignition and increase emission levels in emulsified biodiesel fueled engines. Nanoparticles have the potential to store energy, which can cause high reactivity. The addition of nano additives in the emulsified biodiesel fuel needs to be investigated in Indonesia because this strongly supports the sustainability of FAME-based biodiesel in Indonesia. In the future, research on the use of nano additives in fuels can also be viewed from the techno-economic aspect. The sustainability of biodiesel must be proven and convincing, lest there is a negative side to biodiesel, which in the future reduces the value of biodiesel as a renewable fuel. Biodiesel is no longer an alternative fuel that replaces fossil fuels, but fossil fuels must be replaced because it is not sustainable.

5. Conclusions

One of the concepts of sustainability or biodiesel sustainability in Indonesia can be achieved by adding additives to biodiesel. These additives can be in the form of emulsifiers or nano additives. The addition of these additives has proven to reduce NOx gas emissions, which is still touted as a weakness in biodiesel. The concept of sustainability, one of which is seeing aspects of the environment, must be considered and become the focus of all parties. Do not let high NOx gas emissions affect the green concept and environmentally friendly biodiesel in replacing fossil fuels. The idea of biodiesel is no longer an alternative fuel to replace fossil fuels as fossil fuels are not sustainable. The problems that exist in biodiesel must gradually be resolved so that in the future, the application of biodiesel with B100 will no longer have a problem that arises, especially in environmental aspects.

6. References

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