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The Carbon Footprint of Fossil Power Plants and Potential Opportunities for Renewable Energy (Palm Oil Biodiesel) to Reduce Carbon Emissions in Indonesia

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Abstract

Power generator is one of sector that contributes to carbon emissions, because power plants in Indonesia are still dominated by the use of fuel. It is important to analyze the resulting carbon footprint to determine the extent of its impact, especially on the environment and its contribution to the greenhouse gas (GHG) effect, so that appropriate emission reduction measures can be identified. The method used is a literature study by collecting secondary data from the previous research existed in Indonesia. The average amount of carbon footprints are produced by Indonesia from fossil power plants (Coal, Natural Gas, and Diesel Fuel) in the last 5 years is 5538.11 KgCO2/MWh. The potential demand for electricity and the emissions resulted by-products will continue to increase every year, so solutions are needed best way to reduce emissions. Emission reduction can be resolved by increasing the use of New and Renewable Energy (NRE) as a raw material for Diesel Power Plants (DPT). The type of EBT used is biodiesel from palm oil. The carbon footprint of palm oil biodiesel production process is only 2281.66 KgCO2/MWh. 41% lower than that of fossil power plants. The push for NRE development needs to be further increased in order to reduce energy emissions and to achieve the target of using New and Renewable Energy (NRE) of at least 23% and 31% in 2025 and 2050. The type of EBT used is biodiesel from palm oil. The carbon footprint of palm oil biodiesel production process is only 2281.66 KgCO2/MWh. 41% lower than that of fossil power plants. The push for NRE development needs to be further increased in order to reduce energy emissions and to achieve the target of using New and Renewable Energy (NRE) of at least 23% and 31% in 2025 and 2050.

Keywords: Carbon Footprint, Fossil Power Plant, Greenhouse Gas, New and Renewable Energy (NRE), Palm Oil Biodiesel

INTRODUCTION

Energy consumption is one of indicator of increasing concentrations of greenhouse gas (GHG) in the atmosphere which is responsible for climate change (Adjei, 2018). Carbon Footprint is the total greenhouse gas (GHG) emissions caused directly or indirectly by individuals, organizations, events or products. The carbon footprint is calculated by adding up the emissions resulting from each stage of the life of a product or service (material production, manufacturing, use, and end-of-life). Throughout the product's life cycle, the resulting emissions are able to be carbon dioxide (CO2), methane (CH2), and nitrous oxide (N2O) . Carbon footprint is used as an indicator to assess the impact of human activities or activities on the potential for global warming.

According to the World Health Organization (WHO), the carbon footprint is a measure of the impact of activities on the amount of carbon dioxide (CO2) produced from burning fossil fuels and is expressed as the weight of CO2 emissions produced in tons. Indonesia, as the fourth most populous country in the world also contributes carbon emissions from electricity use. Electricity consumption in Indonesia increases each year by an average of about 3.6% (from 2015-2020) and contributes to carbon emissions (Center for Sustainable Systems, 2021).

Fossil fuels, including coal, petroleum and other liquids, account for the largest share (44%-55%) of global energy consumption (Adiansyah and Haque, 2021) while renewable energy growth is expected to increase significantly during 2018-2050. (EIA, 2019). The mix of gas-fired

power plants continues to increase by 24 percent. Oil-fired power plants decreased from 18% to 4%. The remaining electricity supply is obtained from hydropower and geothermal which only accounted for 13% in 2017. This value is still far from the target of the National Energy Policy and the National Energy General Plan, where the share of renewable energy is at least 23% and 31% in 2025 and 2050 (First Nationally Determined Contribution Republic of Indonesia. 2016)

Indonesia signed the international agreement The Paris Agreement which resulted in an agreement on the maximum limit of global warming of 2 to 1.5 °C for the earth's conditions before the industrial revolution. Implementation efforts are carried out by minimizing greenhouse gas (GHG) emissions to zero net so that the target of a neutral climate in 2050 is achieved. One clear strategy is to increase the share of renewable energy use in Indonesia's energy mix. In particular, Indonesia is pushing for a target of using New and Renewable Energy (EBT) of at least 23% and 31% in 2025 and 2050 through the Minister of Energy and Mineral Resources Regulation No. 12 of 2015 (Falkner 2016).

The use of renewable energy in Indonesia, especially biodiesel, is starting to grow rapidly. In 2018, Indonesia's biodiesel production, exports and demand were 4706, 1512, and 2,618 kilo liters (kL), respectively. The Indonesian government continues to be optimistic about further developments in the use of biodiesel especially palm oil biodiesel (Suharyati, 2019).

RESEARCH METHODS

This study intends to calculate the emissions generated from fossil power plants. Then it analyzes the potential of renewable energy in the form of palm oil biodiesel in order to reduce by-product emissions from fossil power plants. The data for this study is secondary data that presents the total carbon footprint of power plants in Indonesia, produced from fossil energy and new and renewable energy (EBT). Reference sources are then analyzed to obtain potential solutions for the use of EBT in the context of reducing emissions generated from power plants in Indonesia

RESULT AND DISCUSSION

Carbon Footprint from Fossil Power Plant

The calculation of the carbon footprint of fossil power plants using a mathematical model. The first step taken to calculate the carbon footprint is to calculate the emission factor of several power plants derived from fossil energy. The type of fossil used is divided into 3 types: namely diesel fuel, coal and natural gas. The following is the installed power generation capacity of power plants in Indonesia presented in table 1.

Table 1. Installed Power Generation Capacity of Fossil Power Plants in Indonesia

Raw Materials	**Capacity (MWh)**	**(tCO_2)**
Diesel Fuel	5247.87	10921.22
Coal	20069.23	3670.32
Natural Gas	13968.27	154725.81
Total	39285.37	202017.35

Source : Statistics of PLN (2020) (“Statistics of Perusahaan Listrik Negara (PLN) 2020,” 2020)and Azmi *et al* (2022)(Azmi et al., 2022)

Average Emission Factor = $\frac{\Sigma \text{ t CO2}}{\Sigma \text{ Capacity}} = \frac{39285.37}{202017.35} = 5.14$

After obtaining the average, the emission factor used for the next calculation is 5.14. Then calculate the carbon footprint of fossil power plants in Indonesia.

***Table* 2**. Calculation of the Carbon Footprint of Fossil Power Plants in Indonesia in the Last 5 Years

year	Electricity Consumption (kWh/capita)	Emission Factor	CO2 Emission _ ($KgCO_2$)
2016	956	5.14	4913.84
2017	1021	5.14	5247.94
2018	1064	5.14	5468.96
2019	1084	5.14	5571.76
2020	1084.36	5.14	5573.61
Average			5355.22

Source: Statistics of PLN (2020).

From the Table 2, it is known that the average carbon footprint derived from the use of fossil power electricity per year is 5538.11 $KgCO_2$. The carbon footprint of electricity demand in Indonesia from 2015-2020 has an increasing trend and when viewed from the perspective of industrial development, electricity demand will increase. This situation is also proportional to the increase in the amounts of emissions produced. If this situation continues, it is possible that the resulting impact could have worsen the environment and increase the potential for greenhouse gases.

Renewable Energy Potential

Fossil power plants produce emissions that are not environmentally friendly. To reduce the emissions, it is necessary to innovate in the management and production of fossil power plants using technologies such as; the use of Carbon Capture Usage and Storage (CCUS) technology, EBT generators (Natalia et al., 2022), the use of fuel cell technology (Manab Idris et al., 2022)and the application of carbon taxes in Indonesia (Pandey et al., 2022). Some of these steps are considered capable of contributing to controlling emissions towards net zero emission.

In addition, Indonesia has also to start moving to transition energy from fossil-based energy to renewable energy. (Natalia et al., 2022)The use of NRE needs to be maximized in order to achieve Indonesia's new and renewable energy mix target of at least 23% by 2025. Until 2020, the supply of new and renewable energy continues to increase, a lot of research and technology updates are carried out to produce more efficient and effective EBT. The following is the development of the installed capacity of renewable power plants in Indonesia which is presented in Table 3.

Table 3. The Development of Installed Capacity of Bioenergy Power Plant in Indonesia

Year	Types of Power Generation	Installed Capacity (Megawat)
2016	Bioenergy	1783
2017	Bioenergy	1857
2018	Bioenergy	1742
2019	Bioenergy	1783
2020	Bioenergy	1857

Source: 2020 Annual Report. Directorate General of New Renewable Energy (EBT), and Energy Conservation (DITJEN BTKE) (2020).

One of the types of bioenergy which is widely produced in Indonesia is the type of biodiesel as a raw material in Diesel Power Plants (PLTD). Biodiesel in Indonesia mostly uses palm oil. The potential of oil palm in supporting bioenergy development policies is quite large. In 2016, approximately 3.4 million tons of crude palm oil (CPO) were used for biodiesel(Wright, 2017) Indonesia is the world's largest palm oil producer, responsible for half of the world's CPO production (FAOStat., 2020). To find out how far the difference in the emissions produced

between palm oil biodiesel and fossil power plants, it is necessary to calculate the carbon footprint for biodiesel from palm oil.

Carbon Footprint of Palm Oil Bioesel

This Palm Oil Biodiesel calculation uses the Life Cycle Assessment (LCA). There are four categories of impacts, namely fossil CO_2 eq, biogenic CO_2 eq, CO_2 eq from land transportation and CO_2 uptake. Fossil CO_2 eq is carbon that comes from fossil fuels, while biogenic CO_2 eq comes from burning biomass which is part of the natural carbon cycle. In biomass combustion, the carbon stored in organic matter will be released into the atmosphere and captured back into the natural carbon cycle as the biomass grows back. CO_2 from land transformation has an immediate impact, and CO_2 uptake is CO_2 that is stored in plants and trees as they grow. The carbon footprint of biodiesel production is detailed in Table 4.

Table 4. Carbon Footprint of Biodiesel Production

Impact Category	Unit	Biodiesel Production	Methanol	Sodium Hydroxide	Water, Ultrapure	CPO-Palm Oil Production	Electricity, Low Voltage	Total
Fossil CO_2 eq	Kg CO_2 eq	0	32.992	32.922	55.968	2316.939	171.200	2893.613
Biogenic CO_2 eq	Kg CO_2 eq	0	1.332	1.132	17.644	17.644	6.370	28.777
CO_2 eq from land transportation	Kg CO_2 eq	0	0.080	0.080	6.685	6.685	0.463	7.451
CO_2 uptake	Kg CO_2 eq	0	1.137	1.337	37.634	37.634	5.980	48,184
Total Carbon Footprint								**2881,657**

Source : Wahyono et al (2020)(Wahyono et al., 2020)

The total carbon footprint is resulted from biodiesel processing is 2881,657 kg CO_2. The biggest contributor to the emission of biodiesel is the use of fossil materials in the production process. The results of this calculation are greater than the research conducted by Hartono et al. (1258) (Hartono dan M. Indra A.I, 2011), Choo et al. (1113) (Choo et al., 2011), Siregar et al. (2570) (Siregar et al., 2015). Calculation results may differ due to differences in the types of raw materials used, as well as differences in research locations.

Table 5*Comparison of Carbon Footprint Between Fossil Power Plant and Biodiesel Fuel*

No	Type Of Power Plant	Total CO_2 Emission (Kg CO_2/MWh)
1	Palm Oil Biodiesel	2281.66
2	Fossil Power Plant	5573.61

Based on the Table 5, the total carbon footprint produced in the palm oil biodiesel production process as a raw material for power plants is still much lower by about 41% when compared to the total carbon footprint from fossil power plants. It means that biodiesel from palm oil is lower in emissions, more environmentally friendly and has great potential as a complementary material or substitute for raw materials in power plants in Indonesia.

CONCLUSION

The carbon footprint is generated from fossil-based power plants (coal, diesel fuel and natural gas) in the last 5 years (2016-2020) is 5538.11 $KgCO_2$/MWh. This number will continue to increase along with the increasing demand and demand for electricity in Indonesia. For this reason, the solution which can be done to minimize the resulting emissions is to use new and renewable energy (EBT), palm oil biodiesel. It is known that the resulting carbon footprint is only 2281.66 $KgCO_2$/MWh, which is 41% lower. Palm oil biodiesel is lower in emissions, more environmentally friendly and has great potential as a complementary material or substitute for raw materials in Indonesia power plants.

There has to be an encouragement and seriousness from the government in the use, management and development of EBT, especially palm oil biodiesel. Without a strong push, Indonesia will not be able to get out of the trap of using fossil energy which is not good for the environment. Supporting technology and efficient production lines are needed to minimize production costs so that the NRE produced has an equal economic value toward fossil prices.

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