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Article

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International Journal of Energy Economics and Policy

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(5), 457-465.

Land Use for Renewable Energy Power Plant and the Impact of CO_2 Emission: An Indonesian Case Study

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Received: 24 May 2022 **Accepted:** 28 August 2022 **DOI:** https://doi.org/10.32479/ijeep.13298

ABSTRACT

The energy crisis, global warming, emissions, and greenhouse gas effects have become a global issue and an urgent problem to be resolved. CO_2 is One of the contributors to global warming. The operation of fossil energy generation produces CO_2 significantly. This paper examines the use of land for renewable energy power plant and the impact. The operation of 648 MW renewable energy power plants can reduce CO_2 emissions by 94.78% compared to the coal-fired power plants at the same capacity. However, the construction of renewable energy plants requires a much larger area, which is 44.89 to 78.51 times the land requirement for coal-fired power plants. So, land clearing for renewable energy power plants will result in a much larger loss of land absorption for CO_2 emissions compared to coal-fired power plants. The use of plantation land can reduce CO_2 emissions due to the total operation and clearing of land of 4,444,907.97 tons/year up to 4,452,016.56 tons/year compared to the construction of the coal-fired power plant, at the same capacity. The use of plantation land for the construction of renewable energy power plant reduces the impact of CO_2 emissions by up to 95.39% compared to the construction and operation of the coal-fired power plants.

Keywords: Land Use, Impact, CO_2 Emission, Coal-Fired, Renewable Energy
JEL Classifications: Q0, Q2, Q4, Q42, Q54

1. INTRODUCTION

The energy crisis, global warming, emissions, and greenhouse gas effects have become global issues and are urgent problems to be solved (Nutongkaew, 2014). Various international agreements related to climate change and the effects of greenhouse gases have also been signed by several countries, such as the Paris Agreement and the Kyoto protocol. One of the contributors to global warming is CO_2 emissions. The operation of fossil energy plants, particularly coal, produces CO_2 significantly (Cebrucean et al., 2014). The Indonesian government is very serious in carrying out greenhouse gas control efforts, this is shown through government policies in the form of a presidential regulation on the implementation of a national greenhouse gas (GHG) inventory (Perpres No. 71, 2011). This policy aims to provide periodic information on the level, status, and trend of changes in GHG emissions and removals including carbon storage at the national, provincial, and district/city levels as well as information on the achievement of GHG emission reductions from national climate change mitigation activities.

In 2020, Indonesia has an installed power plant capacity of 72.75 GW which is still dominated by fossil energy power plants and only about 10.46 GW from renewable energy (Electricity Statistics, 2020). Meanwhile, Indonesia has huge reserves of renewable energy resources. Therefore, the Indonesian government has a strong commitment to developing new and renewable energy (NRE) resources. The potential of Indonesia's renewable energy (RE) sources reaches 443.21 GW consisting of geothermal (29.54 GW), hydroelectric (75.09 GW), Mini/micro hydro (19.39 GW), Bioenergy/Biomass (32.65 GW), Solar (207.9 GW), Wind (60.65 GW), and Ocean (17.99 GW). The government's commitment is stated in Presidential Regulation no. 22 of 2017 concerning the General National Energy Plan (Perpres. No. 22, 2017), which targets the energy mix of 2025 and 2050 at 23% and 31%, respectively. Various efforts have been made by the government, through coordination with local governments by synchronizing the General National Energy Plan (RUEN) with the Regional Energy General Plan (RUED), as well as through the Indonesian State-Owned Electricity Company (PLN) program in developing RE power plants. In 2022, PLN plans to develop 647 MW of RE power plants consisting of the geothermal power plants, the hydropower plant, the mini/micro hydropower plants, the solar power plants, the wind power plants, and the biomass power plants, as shown in Table 1.

From Table 1, the operation of renewable energy plants still produces CO_2 emissions, namely from geothermal power plants and biomass power plants, but of course, it will be very small when compared to CO_2 emissions generated by the operation of the coal-fired power plant. However, it is necessary to calculate the impact of these emissions as a whole, where land clearing for the development of renewable energy power plants will certainly cause a loss of land absorption of CO_2.

Table 1: Renewable energy power plant development

No	Renewable energy power plant	Capacity (MW)
1	Geothermal	108
2	Hydro	53
3	Mini/Microhydro	154
4	Solar	287
5	Wind	2
6	Biomass	43
Total		647

This paper consists of four main parts, the first part discusses research mindset and methods. The second part contains the calculations and research results. The third part contains the discussion, and the last part reveals the conclusions.

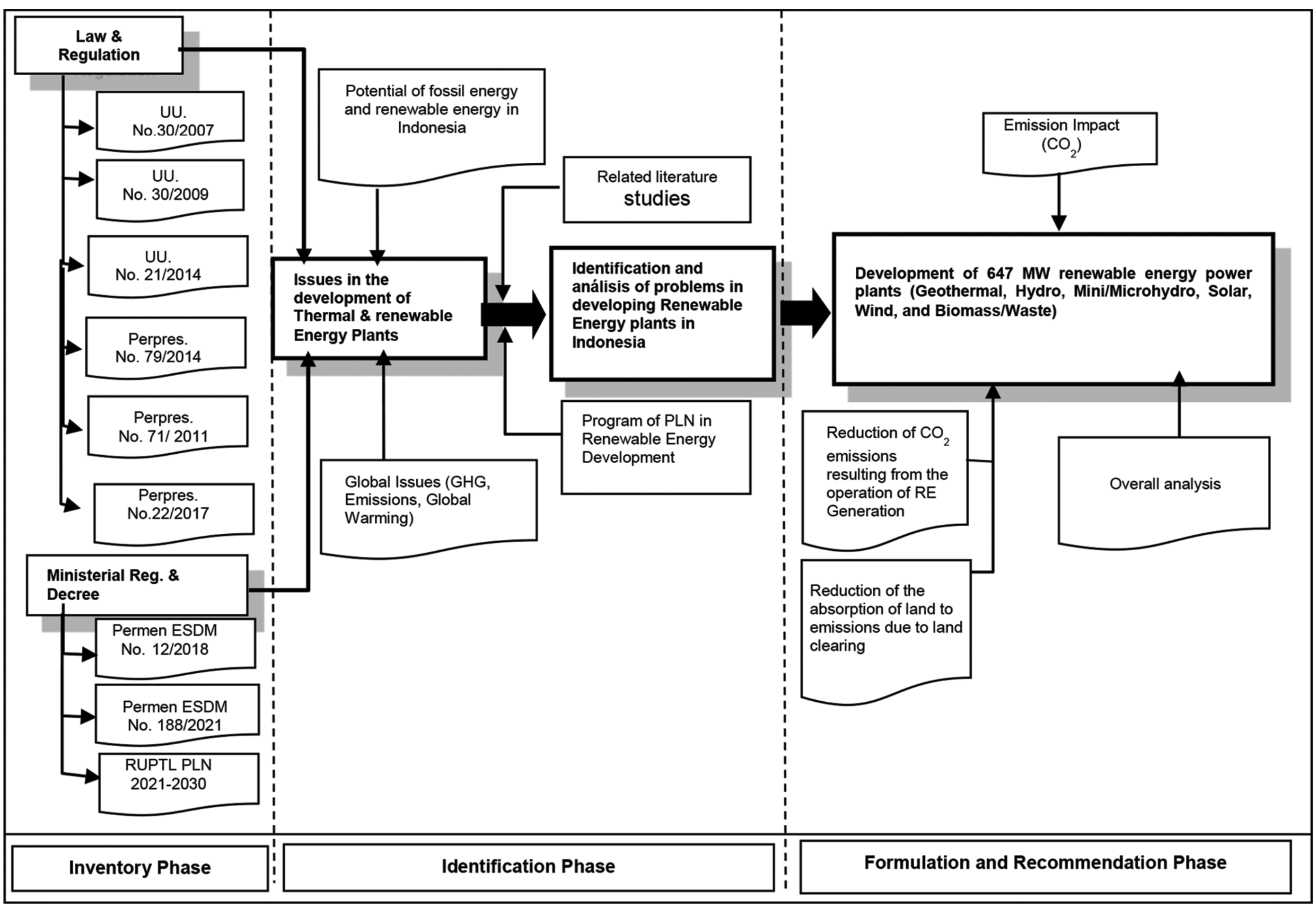
2. MATERIALS AND METHODS

2.1. Research Mindset

The research mindset on land use for RE power plants and their impacts is shown in Figure 1.

This mindset is divided into three phases. The first phase is the internalization phase which contains regulations and policies related to encouraging the use of RE. Several regulations related to this research include the Law on energy (UU. No. 30, 2007), and the Law on Electricity (UU. No. 30, 2009, the Law on Geothermal (UU. No. 21, 2014), Government Regulation on National Energy Policy (PP. No. 79, 2014), Presidential Regulation concerning the General Plan of National Energy (Perpres No. 22, 2017), Regulation of the Minister of Energy

Figure 1: Research mindset



and Mineral Resources, concerning the Implementation of Physical Activities Utilizing New and Renewable Energy and Energy Conservation (Permen ESDM. No. 12, 2018), PLN's policy which in 2022 will build a renewable energy plant with a capacity of 647 MW consisting of 108 MW geothermal power plants, 53 MW hydropower plants, 154 mini/micro-hydropower plants, 287 MW solar power plants, 2 MW wind power plants, and 43 MW biomass/waste power plants, as stated in the Business Plan for the Provision of Electricity (RUPTL PLN 2021-2030), which was ratified by the Decree of the Minister of Energy and Mineral Resources (Kepmen. ESDM No.188, 2021). The second phase is the identification phase in the form of global and national issues related to emissions, installed capacity, and potential of renewable energy sources in Indonesia, as well as the PLN program as the provider of electricity facilities in planning the development of renewable energy plants.

The third phase is the formulation and recommendation phase of the impact of CO_2 emissions due to the development of renewable energy plants. What is meant by the impact of CO_2 emissions here is not only the impact of CO_2 emissions from the operation of the power plant but also the emission impact due to land clearing for it. From this third phase, it will be known how big the impact of emissions from the development of renewable energy plants is when compared to the development of fossil energy plants, especially coal-fired power plants.

2.2. Research Method

The research method is shown in Figure 2, with the steps described as follows:

i. Based on the PLN program which will build a 647 MW power plant from various types of RE power plants, the CO_2 emissions generated due to the operation of these plants are calculated
ii. To illustrate that the operation of RE power plants produces CO_2 emissions which are much lower than the coal-fired power plant, it is necessary to first calculate the CO_2 emissions resulting from the operation of a coal-fired power plant with the same capacity
iii. Compare steps (i) and (ii), so that the difference in emissions is obtained between the operation of coal-fired power plants and RE power plants
iv. Calculate the land requirements for the construction of coal-fired power plants from various types of land, namely forest land, foreshore land, and plantation land
v. Calculate the loss of land absorption to CO_2 emissions due to land clearing for coal-fired power plants (step iv) for each type of land (forest, foreshore, plantation)
vi. Calculate the amount of emission generated between the emissions due to the operation of the coal-fired power plant (step ii) and the loss of absorption of CO_2 emissions due to land clearing for the coal-fired power plant (step v)
vii. Repeat step (iv) for RE power plants
viii. Repeat step (v) for RE power plants
ix. Repeat step (vi) for RE power plants
x. Compare the results from steps (vi) and (ix) for each type of land
xi. Results.

3. RESULTS

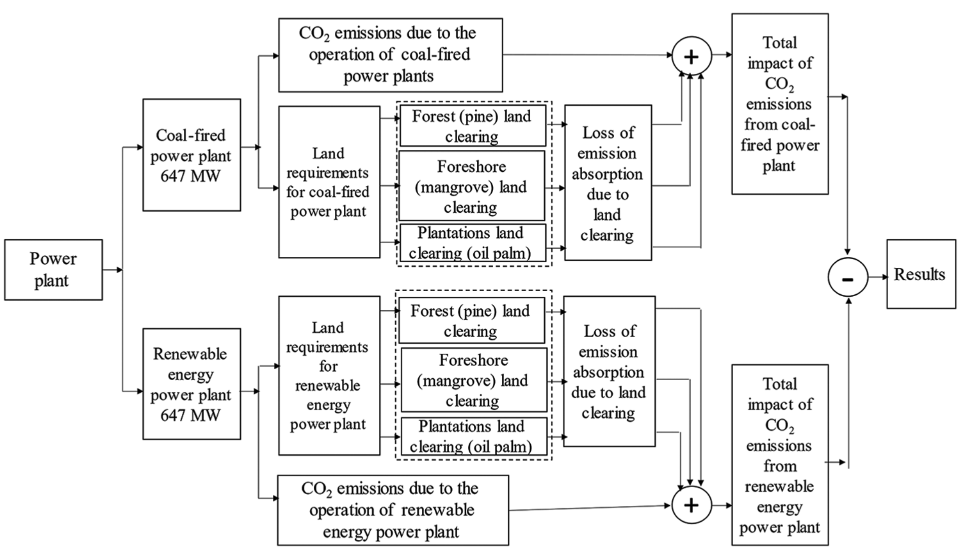
3.1. CO_2 Emission from Power Plants Operation

According to PLN's policy in 2022, several types of RE power plants will be built with a total capacity of 647 MW. The CO_2 emissions produced from those renewable plants will be calculated and compared with those produced by thermal power plants (in this case: coal-fired power plants). So, it is necessary to calculate the CO_2 emissions produced by the 647 MW coal-fired power plant.

Several assumptions were used in calculating CO_2 emissions from the coal-fired power plant.

- The coal used is medium calorie coal (bituminous coal) with 66.6% carbon (Firmansyah et al, 2013)
- Thermic efficiency (30%–33.4%) (Firmansyah et al, 2013), in the calculation of this study taken 33%.
- 80% capacity factor.

Figure 2: Research method



Calculation of CO_2 emissions generated by the operation of the plant uses equations (1) to (5).

$$\text{Emission}\left(CO_2\right) = \text{Fuel rate} \times \text{ \% Fuel} \times \frac{44}{12} \times \text{ Operating time} \quad (1)$$

$$\text{Fuel rate} = \frac{\text{Fuel energy}}{\text{Net calorivic value} \times \text{ Operating time}} \quad (2)$$

$$\text{Fuel energy} = \frac{\text{Generated electrical energy}}{\text{Thermal efficiency}} \quad (3)$$

$$\text{Fuel consumption} = \frac{\text{Fuel energy}}{\text{Net calorivic value}} \quad (4)$$

The net calorific value (NCV) for bituminous (medium) coal is 25.8 Tjoules/kTon or 7.2 kWh/kg, while for sub-bituminous (low) coal, the NCV is 18.9 Tjoules/ktons (Firmansyah et al, 2013). The CO_2 emissions can also be calculated through equation (5).

$$\text{Emission } (CO_2) = \text{generated electrical energy x emission } (CO_2) \text{ factor} \quad (5)$$

By using the assumption that the bituminous coal for the coal-fired power plant, the CO_2 emissions can be calculated from the 647 MW coal-fired power plant.

Generated electrical energy =647 MW × 0.8 year × 365 days/year × 24 h/day = 4,534,176,000 kWh.

Fuel energy = 4,541,184,000 kWh/0.33 = 13,761,163,600 kWh.

Fuel consumption = 4,534,176,000 kWh/(7.2 kWh/kg) = 1,908,323,232 kg

Emission (CO_2) = 1,908,323,232 kg × 0.66 × (44/12) = 4,667,122.52 ton/year.

Meanwhile, based on Table 1, only geothermal power plants and biomass power plants produce CO_2 emissions.

The CO_2 emission factor of the geothermal power plant is 0.1267 tons/MWh (Alimuddin et al, 2018) so that a geothermal power plant with a capacity of 108 MW and an operating factor of 80% (or 7008 h), the CO_2 emissions produced in 1 year are: 108 MW x 7008 h x 0.1267 tons/MWh = 95,894.67 tons.

Whereas, based on (Yoon et al, 2008) and, the CO_2 emission factor of RDF biomass power plants is 94.8 tons/TJ or equal to 0.341253 kg/kWh or 0.341253 tons/MWh. So, with a capacity of 43 MW and an operating factor of 80%, the CO_2 emissions produced by RDF biomass power plants per year are 43 MW × 7008 h × 0.341253 tons/MWh= 102.834.54 tons. Therefore, the total CO_2 emissions from renewable energy power plants of 647 MW is only the summation of the emissions generated from geothermal and biomass power plants or 198,729.21 tons/year.

3.2. Land Requirement for Power Plants

Reference data related to land use for the construction of coal-fired power plants are obtained from the existing power plant in Indonesia. For example, Paiton coal-fired power plant has 9 units with a total generation capacity of 4885 MW and occupies an area of 400 hectares (ha). So, its power density is 12.213 MW/ha. From the collected data, the power density of the coal-fired power plants ranges from 12.213 MW/ha (Paiton coal-fired power plant) to 30.933 MW/ha (Tanjung Jati coal-fired power plant).

Based on these real conditions, the land use for the construction of coal-fired power plants with a capacity of 647 MW can be calculated.

$$\text{Minimum} = \frac{648 \text{ MW}}{30{,}933 \text{ MW / Ha}} = 20{,}95 \text{ ha}$$

$$\text{Maximum} = \frac{648 \text{ MW}}{12{,}213 \text{ MW / Ha}} = 53{,}06 \text{ ha}$$

To build a coal-fired power plant with a capacity of 647 MW, an area of 20.95 ha up to 53.06 ha is required.

Whereas the land requirement for several types of renewable energy generation can be calculated as follows:

- **Geothermal Power Plant 108 MW**

Indonesia has a huge potential for geothermal energy. Some have been used for geothermal power plants. The power density of geothermal power plants varies between 0.000465 MW/ha to 0.451467 MW/ha. However, under certain considerations, PLN determines that the power density of a geothermal power plant is 0.75 MW/ha (PLN, 2021). Refers to (PLN, 2021), to build a 108 MW geothermal power plant, it is necessary to have an area of

$$\frac{108\,\text{MW}}{0.75\text{MW / ha}} = 144\,\text{ha.}$$

- Hydroelectric power plant 53 MW

According to data from Cirata and Saguling Hydroelectric Power Plant (Indonesia), the capacity of each plant is 1008 MW and 700.72 MW, while the required area is 6200 ha and 5340 ha respectively. It shows that the power density is 0.1626 MW/ha to 0.1312 MW/ha. Refers to that power density, the construction of a 53 MW hydropower plant requires an area of:

$$\text{Minimum} = \frac{53 \text{ MW}}{0.1626 \text{ MW / ha}} = 325.95 \text{ ha}$$

$$\text{Maximum} = \frac{53 \text{ MW}}{0.1312 \text{ MW / ha}} = 403.96 \text{ ha}$$

To build a 53 MW hydropower plant, an area of 325.95 ha up to 403.96 ha is required.

- Mini/Microhydro Power Plant 154 MW

Based on some real conditions for mini/micro hydropower plants in Indonesia, the power density of mini/micro hydropower plants are similar to the power density of hydropower plants. So, to build a 154 MW mini/micro-hydropower plant, an area of 947.11 ha to 1173.78 ha is required.

- Solar Power Plant 287 MW

The intensity of sunlight reaching the ground level is about 1000 W/m^2 (Abdelhamid, 2014) in sunny conditions at sea level. The theoretical efficiency of commercial PV ranges from 18.7% for thin film to 25% for Mono crystalline (Saleem et al, 2016). Practically assumed, the photovoltaic (PV) efficiency is 20%. This means that each m^2 of solar panels can produce 1000 × 20% = 200 W/m^2 = 0.2 kW/m^2. In other words, every 200 W of solar panels requires an area of 1 m^2 and it is only for the solar panels themselves. By inserting a frame and other accessories, every 200 W of solar panel power generation requires an area of up to 1.5 m^2, or every 1 kW requires an area of 7.5 m^2. The power density of a solar power plant is 1.3333 MW/ha. Thus, to build a 287 MW solar power plant requires an area of: 287 × 1000 kW × 7.5 m^2 = 2,152,500 m^2 = 215.25 ha. Based on (Global, 2017), PV power density ranges from 10-40 W/m^2, however, based on the construction of Likupang's solar power plant (Indonesia) with a capacity of 15 MW, it requires an area of 29 ha, so the power density is 0.517 MW/ha. Referring to Likupang's construction, building the 287 MW solar power plant requires an area of $\frac{287\text{ MW}}{0.517\text{ MW/ha}}$ =554.867 ha. So, by practical calculations and referring to the existing condition, the construction of the 287 MW solar power plant requires an area of 215.25 ha up to 554.87 ha.

- Wind Power Plant 2 MW

Referring to the construction of the Sidrap Wind Power Plant in Sidenreng Rappang Regency, South Sulawesi (Indonesia) with a capacity of 75 MW and occupies an area of 100 ha. It can be calculated that the power density of Sidrap Power Plant is 0.75 MW/ha. So, to build a wind power plant with a capacity of 2 MW, an area of 1.5 ha is required.

- Biomass Power Plant 43 MW

Several waste energy power plants in Indonesia which are already in operation, under construction, or in the planning stage are presented in Table 2. The power density of Waste-to-Energy Power Plants varies greatly between 0.429 MW/ha up to 5.0 MW/ha. It is of course influenced by the limited land that is different in each city and also by the technology used. Thus, building the waste power plant with a capacity of 43 MW requires the area of minimum of $\frac{43\text{ Ha}}{5\text{ MW / Ha}} = 8.6$ ha

maximum of $\frac{43\text{ MW}}{0.429\text{ MW / Ha}} = 100.23$ ha

3.3. Loss of CO_2 Emissions Absorption Due to Land Clearing

3.3.1. Coal-fired power plants

Building the coal-fired power plant with a capacity of 647 MW, an area of 20.95 ha up to 53.06 ha is required. The loss of absorption of CO_2 emissions due to land clearing was calculated by considering various types of land (in this case three types of land were reviewed): forest land, foreshore land (mangroves), and plantation land.

i. Forest Land

Forests can absorb CO_2 emissions very well. For example, pine forests where each hectare can absorb CO_2 emissions in a total of 2,916.94 tons/year (Fitrada et al, 2020). It indicates that if the 647 MW Coal-Fired Power Plant is built using pine forest land, there will be a loss of CO_2 emission absorption capacity of the following:

- Land area of 20.95 ha.

On an area of 20,949 ha, the absorption capacity of CO_2 emissions will be lost by 20.95 ha x 2,916.94 tons/ha/year = 61,107 tons/year.

- Land area of 53.06 ha.

On an area of 53.058 ha, the absorption capacity of CO_2 emissions will be lost by 53.058 ha x 2,916.94 tons/ha/year = 154,767 tons/year.

Clearing the pine forest to build the 647 MW coal-fired power plants will have an impact on the loss of the ability to absorb CO_2 emissions by 61,107 tons/year up to 154,767 Tons/year.

ii. Foreshore Land (Mangrove)

Mangrove land is very effective in absorbing CO_2 emissions, where it can produce CO_2 emissions of 3.32667 tons/ha/year, but it is also able to absorb CO_2 emissions of 442.969 tons/ha/year (Afifudin, 2019). So, the mangrove land can absorb a total CO_2 emission of (442,969-3,32667) 439.64 tons/ha/year. In other words, clearing the mangrove land for other purposes such as the construction of the power plant, causes a loss of ability to absorb CO_2 emissions

Table 2: Biomass (Waste) power plant in indonesia

No	Waste power plant (PLTSa)	City	Capacity (MW)	Land area (ha)	Power density (MW/ha)
1	PLTSa Benowo	Surabaya	10	15.4	0.649
2	PLTSa Sumur batu	Bekasi	9	21.0	0.429
3	PLTSa Putri Cempo	Surakarta	10	13.0	0.769
4	PLTSa Keramasan	Palembang	20	22.0	0.909
5	PLTSa Sarbagita Suwung	Denpasar	20	5.0	4.000
6	PLTSa Bantar gebang	Jakarta	0.4	0.7	0.571
7	PLTSa Gede Bage	Bandung	7	5.0	1.400
8	PLTSa Makasar	Makasar	20	4.0	5.000
10	PLTSa Cipeucang	Tangerang Selatan	20	5.0	4.000
11	PLTSa Rawa Kucing	Kota Tangerang	20	34.0	0.588
12	PLTSa Jatibarang	Semarang	20	15.0	1.333

Table 3: The comparison of the impact of CO_2 emissions from various types of land for coal-fired power plant

CO_2 emissions produced (tons/year)	Reduction of CO_2 emission absorption (tons/year)					
	Forest land		Foreshore land (mangrove)		Plantation land	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
4,667,122.52	61,107.00	154,767.00	9,210.02	23,326.42	211.59	535.89
TOTAL	4,728,229.52	4,821,889.52	4,676,332.54	4,690,448.94	4,667,334.11	4,667,658.41

by 439.64 tons/ha/year. Reduction of CO_2 emission absorption due to the conversion of mangrove land into the 647 MW coal-fired power plant can be calculated.

- Land area of 20.95 ha.

On an area of 20.949 ha, the absorption capacity of CO_2 emissions will be lost by 20.95 ha × 439.64 tons/ha/year = 9,210.02 tons/year.

- Land area of 53.06 ha.

On an area of 53.058 ha, the absorption capacity of CO_2 emissions will be lost by 53.06 Ha × 439,64 tons/ha/year = 23,326.42 tons/year.

Building the 647 MW coal-fired power plant on foreshore land by clearing the mangrove forest land will result in a loss of ability to absorb CO_2 emissions by 9,210.02 tons/year up to 23,326.42 tons/year.

iii. Plantation land

The plantation land used as an example here is an oil palm plantation. Based on (Enonomi.bisnis.com), each hectare (ha) of oil palm plantations produces emissions of 3.6 tons of CO_2, but one ha of it can absorb 13.7 tons of CO_2. So, each ha of oil palm plantations can absorb a total CO_2 emission of 13.7 tons– 3.6 tons or 10.1 tons. The clearing of oil palm land for other purposes will cause a loss of ability to absorb 10.1 tons of CO_2 emission every year. If the construction of the 647 MW coal-fired power plant is done by clearing oil palm plantations, the loss of CO_2 emissions absorption can be calculated.

- For land area of 20.95 ha.

On an area of 20.95 ha, the absorption capacity of CO_2 emissions will be lost by 20.95 ha x 10.1 tons/ha/year = 211.59 tons/year.

- For land area of 53.06 ha.

On an area of 53.058 ha, the absorption capacity of CO_2 emissions will be lost by 53.06 ha x 10.1 tons/ha/year =535.89 tons/year.

Land clearing for oil palm plantations for the construction of the 647 MW coal-fired power plant will cause a loss of CO_2 emission absorption of 211.59 tons/year up to 535.89 tons/year (Table 3).

Under certain considerations, coal-fired power plants are usually built on the foreshore (except Mine-Mouth Power Plants). One of the reasons is the ease of access to coal transportation which is usually via ship transportation. So, the construction of the 647 MW coal-fired power plant has an impact on CO_2 emissions of 4,676,332.54 tons/year up to 4,690,448.94 tons/year.

Table 4: Land requirement for RE power plant

Power plant	Land requirements (ha)	
	Minimum	Maximum
Geothermal	144.00	
Hydro	325.95	403.96
Mini/Micro Hydro	947.11	1173.78
Solar	215.25	554.87
Wind	1.50	
Biomass	8.60	100.23
TOTAL	1642.41	2378.34

Table 5: Land requirement for Coal-fired and RE power plant

Coal-fired power plant (ha)		RE power plant (ha)	
Minimum	Maximum	Minimum	Maximum
20.95	53.06	1642.41	2378.34

3.3.2. Renewable energy power plants

The land requirement for any renewable energy power plants are shown in Table 4. Meanwhile, the emission produced from construction of the 647 MW renewable energy plant is 243,835.154 tons/year.

Thus, the comparison of the land area required for the construction of 647 MW of coal-fired power plants and 647 MW of renewable energy power plants is shown in Table 5.

From Table 5, the construction of 647 MW RE power plants requires a much larger area than the land required for the 647 MW coal-fired power plant, which is 44.82 times up to 78.40 times. The land requirement for the construction of renewable energy plants is so large and of course, it results in a significant loss of CO_2 emission absorption from the land. Furthermore, the emission impact from the land use of renewable energy plants were calculated on various types of land such as forest, foreshore, and plantation land.

i. Forest Land

The loss of CO_2 emission absorption due to forest land clearing for the construction of renewable energy plants with an area of 1642.41 ha up to 2378.337 ha can be calculated as follows:

- For land area of 1642.41 ha, the absorption capacity of CO_2 emissions will be lost by 1642.41 ha × 2916.94 tons/ha/year = 4,790,811.43 tons/year
- For land area of 2378.34 ha, the absorption capacity of CO_2 emissions will be lost by 2378.34 ha × 2916.94 tons/ha/year = 6,937,475.08 tons/year.

ii. Foreshore Land (Mangroves)

The loss of CO_2 emission absorption due to the conversion of coastal land for the construction of renewable energy plants with an area of 1642.41 ha up to 2,378,337 ha can be calculated as follows:

Table 6: Comparison of the impact of CO_2 emissions from various types of land for renewable energy power plant

CO_2 emissions produced (tons/year)	Reduction of CO_2 emission absorption (tons/year)					
	Forest land		Foreshore land (mangrove)		Plantation land	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
198,729.21	4,790,811.43	6,937,475.08	722,069.13	1,045,613.40	16,588.34	24,021.23
TOTAL	4,989,540.64	7,136,204.29	920,798.34	1,244,342.61	215,317.55	222,750.44

Table 7: Comparison of CO_2 emission between coal-fired power plant and renewable energy power plant

Power plant	Emission (CO_2) (tons/year)	CO_2 emission impact (tons/year)					
		Forest land		Foreshore land (mangrove)		Plantation land	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Coal-Fired (CF)	4,667,122.52	61,107.00	154,767.00	9,210.02	23,326.42	211.59	535.89
	TOTAL	4,728,229.52	4,821,889.52	4,676,332.54	4,690,448.94	4,667,334.11	4,667,658.41
Renewable Energy (RE)	198,729.21	4,790,811.43	6,937,475.08	722,069.13	1,045,613.40	16,588.34	24,021.23
	TOTAL	4,989,540.64	7,136,204.29	920,798.34	1,244,342.61	215,317.55	222,750.44
Reduction: CF-RE		-261,311.12	-2,314,314.77	3,755,534.20	3,446,106.33	4,452,016.56	4,444,907.97

- For land area of 1642.41 ha, the absorption capacity of CO2 emissions will be lost by 1642.41 ha × 439.64 tons/ha/year = 722,069.13 tons/year
- For land area of 2378.34 ha, the absorption capacity of CO2 emissions will be lost by 2378.337 ha × 439.64 tons/ha/year = 1,045,613.40 tons/year.

iii. Plantation Land

The loss of CO_2 emission absorption due to plantation land clearing for renewable energy plants with an area of 1642.41 ha up to 2378.337 ha can be calculated as follows:

- For land area of 1642.41 ha, the absorption capacity of CO2 emissions will be lost by 1642.41 ha × 10.1 tons/ha/year = 16,588.34 tons/year
- For land area of 2378.337 ha, the absorption capacity of CO2 emissions will be lost by 2378.34 ha × 10.1 tons/ha/year = 24,021.23 tons/year.

The construction of RE power plants consisting of the geothermal power plants, the hydropower plants, the mini/micro hydropower plants, the solar power plants, the wind power plant, and the biomass/waste power plants require an area of 1,642.41 ha up to 2378,34 ha. Meanwhile, land clearing in the area will eliminate the land's ability to absorb CO_2 emissions, especially on forest land, foreshore land (mangroves), and plantation land. From those types of RE power plants, only geothermal power plants and biomass/waste energy power plants will produce CO_2 emissions of 198,729.21 tons/year due to their operation. So that the impact of the construction of RE power plants on CO_2 emissions is the summation of the emissions generated due to the operation and the loss of land capability to absorb CO_2 emissions due to land clearing. The comparison of various types of land for the construction of renewable energy power plants is shown in Table 6.

From Table 6, the biggest impact of land use is the clearing of forest land because forests (pine forests) have a very large contribution in absorbing CO_2 emissions.

3.3. Comparison of CO_2 Emission Between Coal-fired and Renewable Energy Power Plant

From the calculation results obtained from Tables 3-5, it can be seen the comparison of two parameters: the land area and the emissions impact from the construction of coal-fired power plants and renewable energy power plants. The total emission summary from both power plants along with different types of land can be seen in Table 7.

4. DISCUSSION

Based on the calculations in section 3, shows that the operation of a renewable energy plant of 647 MW consisting of various types (Table 1), it produces CO_2 emissions of 198,729.21 tons/year. Meanwhile, coal-fired power plants with the same capacity, in operation, produce emissions of 4,667,122.52 tons/year. This indicates that the replacement of coal-fired power plants with renewable energy plants can reduce CO_2 emissions by up to 95.74%. However, the construction of RE power plants requires 44.82 times up to 78.40 times more land area than coal-fired power plants. The larger the land required, of course, the greater the loss of land absorption of CO_2 emissions. So that the loss of land absorption of CO_2 emissions due to land clearing for RE power plants is 44.82 times up to 78.40 times compared to the coal-fired power plant (Tables 3 and 6).

The total emission impact of RE power plant construction compared to coal-fired power plant is shown in Table 7. The absorption capacity of forests is very high on CO2 emissions, the construction of RE power plant on forest land will produce a greater negative impact than coal-fired power plants.

Building the RE power plant on foreshore land will reduce the impact of CO_2 emissions by around 3,446,106.33 tons/year up to 3,755,534.20 tons/year compared to coal-fired power plants. Meanwhile, if the EBT plant is built on plantation land, it will reduce the impact of CO_2 emissions, which range from 4,444,907.97 tons/year up to 4,452,016.56 tons/year compared to coal-fired power plants.

5. CONCLUSION

The construction of renewable energy power plants with a capacity of 647 MW consisting of the geothermal power plant, hydroelectric power plant, micro/mini hydropower plant, wind power plant, solar power plant, and biomass/waste power plant requires a much larger land area compared to the construction of coal-fired power plant. It implies that the construction of renewable energy power plants will lead to wider land clearing thereby reducing the land's ability to absorb CO_2 emissions. Table 6 presents the impact of CO_2 emissions resulting from the construction of RE power plants. From Table 6, the CO_2 emission produced during the operation of the renewable energy power plants can be reduced up to 95.74% compared to the CO_2 emissions generated during the operation of a coal-fired power plant with the same capacity.

On the other hand, the land clearing required for the construction of renewable energy plants is much wider, and the loss of absorption of CO2 emissions is also much greater than the land clearing for the construction of steam power plants. Table 7 shows that if RE plants are built on forest land, it will have a greater negative impact than coal-fired power plants because the emissions resulting from the construction of RE power plants are greater than coal-fired power plants. To minimize the impact of emissions significantly, it is better to build RE power plants on plantation land, considering that the absorption capacity of plantation lands to emissions is much lower than mangrove forest land, especially compared to pine forest land. From Table 7, if RE power plants are built on plantation land (oil palm) it will minimize the impact of CO_2 emissions ranging from 4,444,907.97 tons/year up to 4,452,016.56 tons/year.

The impact of CO_2 emissions on the RE power plant, both from the results of its operation and the impact due to land clearing, if it is built on forest land (pine) will have a greater negative impact (ranging from 5.53% up to 48%) on the impact of emissions due to coal-fired power plants. However, if the RE power plant is built on the foreshore land (mangrove), it will be able to reduce the impact of CO_2 emissions ranging from 48% up to 73.47% compared to the coal-fired power plants. Meanwhile, the use of plantation land for the construction of RE power plants will reduce the impact of CO_2 emissions by up to 95.39% compared to the construction and operation of the coal-fired power plants.

6. ACKNOWLEDGEMENT

The authors want to thank PT. PLN. This research is funded by PT. PLN through the Memorandum of Understanding No. 006.Pj/HKM.02.01/C30000000/2022 and No. 034/SAM4/RC-DBE/2022 and PLN's Letter of Assignment No. 1086/LIT.00.01/C30000000/2022.

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