The carbon footprint from the power plant in Indonesia and renewable energy supply for reduce the carbon emission

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Abstract. The causes of the carbon emissions is the one use of electrical energy. According to PLN (Perusahaan Listrik Negara), the electricity sector contributes 14% of carbon emissions of the total national emissions. The International Energy Agency (IEA) reported that the total of carbon dioxide (CO$_2$) emissions reached 33.9 gigatons throughout 2020. A total of 13.5 gigatons of which came from electricity and heating, being the most compared to the other sources. Indonesia as the fourth most populous country in the world also contributes to carbon emissions from electricity use. The electricity consumption in Indonesia each year increases by an average of about 3.60% (from 2015-2020) and contributes to these carbon emissions. Indonesia with the largest potential sources of renewable energy (wind, solar power, geothermal and other sources), is expected to be able and develop and become a leader, especially in the Association of Southeast Asian Nations (ASEAN) Region. This paper will discuss the analysis of carbon footprint from electricity demand in Indonesia and renewable energy supply that can be used to reduce carbon emissions in dealing with climate change problems. The results of the analysis show that the carbon footprint of electricity usage per year on average is 5242.3 KgCO$_2$. The Projection of Renewable Energy Growth in Indonesia in 2045 will reach 20711.67 megawatt. Estimates of net-zero carbon emissions in Indonesia conclude that Indonesia has not yet achieved net-zero carbon emissions in 2045.

Keywords: carbon footprint; electricity consumption; sustainability; carbon emission; climate change; renewable energy.

1. Introduction

A carbon footprint is the total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product. It is calculated by summing the emissions resulting from every stage of a product or service’s lifetime (material production, manufacturing, use, and end-of-life). Throughout a product’s lifetime, or lifecycle, different GHGs may be emitted, such as carbon dioxide (CO$_2$), methane (CH$_4$), and nitrous oxide (N$_2$O), each with a greater or lesser ability to trap heat in the atmosphere. These differences are accounted for by the global warming potential (GWP) of each gas, resulting in a carbon footprint in units of mass of carbon dioxide equivalents (CO$_2$e) [15].

The concept of carbon footprint (CF), namely the greenhouse gases expressed in carbon dioxide equivalents, emitted during the life cycle of an examined system, has been known for several decades as an indicator for assessing the impact of human activities to global warming potential [1].

Despite the fact that carbon dioxide is a natural component of air, high concentrations or exposure over a long time period can cause significant problems in human health [7].
CF estimation is helpful for the efficient management of greenhouse gas emissions and the evaluation of measures to reduce them. CF analysis can identify significant sources of emissions and prioritize the areas with the greatest potential for improvement, thereby increasing environmental efficiency and optimizing financial costs of amelioration actions. Several tools for CF calculation are available in current literature [2].

Various human activities cause an increase in the concentration of greenhouse gases (GHG) in the earth's atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) defines six types of greenhouse gases produced by human actions: Carbon dioxide (CO$_2$), Methane (CH$_4$), Nitrogen Oxide (N$_2$O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride. (SF$_6$). It is estimated that currently the concentration of Carbon dioxide (CO$_2$) is the most dominant in the atmosphere. The International Energy Agency (IEA) reported that total carbon dioxide (CO$_2$) emissions reached 33.9 gigatons throughout 2020. A total of 13.5 gigatons of which came from electricity and heating, being the most compared to the other sources [1].

The value of carbon emissions produced by an organization, event, product, and human activity is referred to as its carbon footprint. According to the World Health Organization (WHO), the carbon footprint is a measure of the impact of our activities on the amount of carbon dioxide (CO$_2$) produced by burning fossil fuels and is expressed as the weight of CO$_2$ emissions produced in tonnes. Indonesia as the fourth most populous country in the world also contributes to carbon emissions from electricity use. Electricity consumption in Indonesia each year increases by an average of about 3.6% (from 2015-2020) and contributes to these carbon emissions. The following is a graph of the growth of electricity consumption in Indonesia from 2015-June 2020 per kWh/capita [1].

![Figure 1. Growth of Electricity Consumption in Indonesia from 2015- June 2020 per kWh/capita.](image)

**Source:** Directorate of General of Electricity, Ministry of Energy, and Mineral Resources (2021).

The Ministry of Energy and Mineral Resources (ESDM) (2019) also released the Decree of the Minister of Energy and Mineral Resources Number 143K/20/MEM/2019 concerning the General Plan of National Electricity for 2019 to 2038. ESDM in that decision, projects the average growth of national electricity energy needs to be around 6.9% per year [15].

This projection is achieved if the average national economic growth is around 6%, the average inflation is around 3.5%, the average population growth is around 0.8%, the electrification ratio target is around 99.9% in 2019 and 100% in 2020. Besides that, it also accommodates all potential demands for special economic zones (SEZ), industrial areas, smelters, and electric vehicles [15].

Electricity is the one of the causes of greenhouse gas emissions and climate change. Therefore, the use of renewable energy must be increased even more. In addition to minimizing greenhouse gas emissions and climate change, electricity use from renewable energy can also minimize the cost of using electricity. Various policies have also been implemented in various parts of the world, such as the Paris Agreement. It is hoped that various policies implemented in several countries in the world can also be
applied in Indonesia. However, policies made in Indonesia must be adapted to various conditions. It is important to understand that efforts to reduce greenhouse gas emissions and the development of renewable energy sources must be promoted from an early age to all levels of society [11].

Although climate change action needs to be massively increased to achieve the goals of the Paris Agreement, the years since its entry into force have already sparked low-carbon solutions and new markets. More and more countries, regions, cities and companies are establishing carbon neutrality targets. Zero-carbon solutions are becoming competitive across economic sectors representing 25% of emissions. This trend is most noticeable in the power and transport sectors and has created many new business opportunities for early movers [11].

The gap between aspiration and the reality in tackling climate change remains as significant as ever, despite mounting evidence of the harm that climate change is causing. Negative effects of climate change are becoming more evident year by year (NASA, WMO, 2020). Yet global energy related CO₂ emissions, despite levelling off periodically, have risen by 1% per year on average over the last decade [14].

In order to respond to climate change, Indonesia has stated its commitment at the Conference of Parties (COP) 15 of 2009 to reduce greenhouse gas (GHG) emissions by 26% (with its efforts) and by 41% (if it receives international assistance) by 2020. Indonesia’s commitment was strengthened through the first Nationally Determined Contribution (NDC) document of the Republic of Indonesia in November 2016. The stipulation of an unconditional target of 29% and a conditional target of up to 41% compared to the business as usual (BAU) scenario in 2030. Nationally, the emission reduction target in 2030 based on the NDC is 834 million tons of CO₂ on the unconditional target (CM1) and 1081 million tons of CO₂e on the conditional target (CM2). To meet these targets, nationally, various mitigation actions have been carried out in all sectors by those in charge of mitigation actions [15].

2. Methodology
In such circumstances, it is essential to carry out an analysis of the carbon footprint of the power generation company so that the methodology adopted and the policy implications can be shared by the managers of the power generation company. As a result, the purpose of this paper is to present an innovative method for analyzing carbon footprints in power generation companies and analyzing carbon footprints if the power plant is converted to renewable energy fuels, where the result can be seen by what percentage of greenhouse gas emission reductions can be reduced from use of renewable energy fuels in power generation companies. A case study approach is used to describe the feasibility and application of this method. The whole paper is arranged as below. Following this introductory section, we provide our research methodology, including an overview of studies related to the carbon footprint that identifies the relevant research literature and sets the stage for these studies and the data collection process. We then present the results of the case studies and provide policy implications. The purpose of this paper is to analysis of carbon footprint from electricity demand in Indonesia and renewable energy supply that can be used to reduce carbon emissions in dealing with climate change problems.

The method used in this research is quantitative. Quantitative method is a systematic scientific study of parts and phenomena and their relationships. This method aims to develop and use mathematical models, theories and hypotheses related to natural phenomena.

3. Result and discussion
3.1. Average factor emission
Before calculating the carbon footprint, first to calculate the emission factor from several power plants. Data of PT Perusahaan Listrik Negara (Persero) power plants based from Statistik PLN 2020. PT PLN (Persero) is a state-owned company that handles all aspects of electricity in Indonesia. The following is the installed power generation capacity from power plants in Indonesia [19]:
### Table 1. The Installed Power Generation Capacity From Power Plants in Indonesia. **Source:** Statistics of PLN (2020) and Dong et al (2013).

| No. | Power Plant                      | Type of Power Plant                  | Raw Materials | Emission Factor (tCO$_2$/MWh) | Capacity (MWh) | (t CO$_2$) $\times 10^2$ |
|-----|----------------------------------|--------------------------------------|---------------|-------------------------------|----------------|---------------------------|
| 1   | UIW Aceh                         | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 142.39         | 440.84                    |
| 2   | UIW Sumatera Utara               | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 4.11           | 0.00                      |
| 3   | UIW Sumatera Barat               | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 35.36          | 0.00                      |
| 4   | UIW Riau                         | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 125.31         | 0.00                      |
| 5   | UIW Kepulauan Riau               | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 114.31         | 0.00                      |
| 6   | UIW Sumatera Selatan             | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 6.01           | 0.00                      |
| 7   | UIW Jambi                        | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 17.38          | 0.00                      |
| 8   | UIW Bengkulu                     | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 35.78          | 0.00                      |
| 9   | UIW Bangka Belitung              | Electric Steam Power Plant            | Coal          | 2.030                         | 129.80         | 0.00                      |
| 10  | UID Lampung                      | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 4.96           | 15.36                     |
| 11  | UIW Kalimantan Barat             | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 70.29          | 0.00                      |
| 12  | UIW Kalimantan Selatan           | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 16.28          | 0.00                      |
| 13  | UIW Kalimantan Tengah            | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 43.60          | 0.00                      |
| 14  | UIW Kalimantan Timur dan Utara   | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 35.70          | 0.00                      |
| 15  | UIW Sulawesi Utara               | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 43.29          | 0.00                      |
| 16  | UIW Gorontalo                    | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 3.53           | 0.00                      |
| 17  | UIW Sulawesi Tengah              | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 99.53          | 0.00                      |
| 18  | UIW Sulawesi Selatan             | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 10.23          | 0.00                      |
| 19  | UIW Sulawesi Tenggara            | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 23.17          | 0.00                      |
| 20  | UIW Sulawesi Barat               | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 2.77           | 0.00                      |
| 21  | UIW Maluku                       | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 302.33         | 0.00                      |
| 22  | UIW Maluku Utara                 | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 14.00          | 28.42                     |
| 23  | UIW Papua                        | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 101.61         | 314.58                    |
| 24  | UIW Papua Barat                  | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 103.30         | 0.00                      |
| 25  | UID Bali                         | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 283.96         | 0.00                      |
| 26  | UIW Nusa Tenggara Barat          | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 2.96           | 0.00                      |
| 27  | UIW Nusa Tenggara Timur          | Diesel Electric Power Plant           | Diesel Fuel   | 3.096                         | 377.14         | 0.00                      |
| 28  | PT PLN Batam                     | Electric Steam Power Plant            | Coal          | 2.030                         | 77.00          | 156.31                    |
|     |                                  | Gas Power Plant                       | Natural Gas   | 2.030                         | 284.47         | 880.72                    |
|     |                                  | Gas & Steam-Electric Power Plant     | Natural Gas   | 2.030                         | 47.00          | 95.41                     |
| No. | Power Plant       | Type of Power Plant       | Raw Materials | Emission Factor (tCO₂/MWh) | Capacity (MWh) | (t CO₂)  |
|-----|-------------------|---------------------------|---------------|-----------------------------|----------------|----------|
| 29  | UIK Sumatera Bagian Utara | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 133.18         | 412.33   |
|     |                   | Steam-Electric Power Station | Coal          | 2.030                       | 1798.00        | 3649.94  |
|     |                   | Gas Power Plant           |               |                             | 302.46         | 6539.19  |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 817.88         | 0.00     |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 752.53         | 2329.83  |
| 30  | UIK Sumatera Bagian Selatan | Steam-Electric Power Station | Coal          | 2.030                       | 1109.00        | 2251.27  |
|     |                   | Gas Power Plant           |               |                             | 352.87         | 7629.05  |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 160.00         | 0.00     |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 216.08         | 668.98   |
| 31  | UIKL Kalimantan   | Steam-Electric Power Station | Coal          | 2.030                       | 773.63         | 1570.47  |
|     |                   | Gas Power Plant           |               |                             | 255.55         | 5524.99  |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 60.00          | 0.00     |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 894.90         | 2770.61  |
| 32  | UIKL Sulawesi     | Steam-Electric Power Station | Coal          | 2.030                       | 459.00         | 931.77   |
|     |                   | Gas Power Plant           |               |                             | 222.72         | 4815.21  |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 510.46         | 1580.38  |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 33.07          | 0.00     |
| 33  | UID Jawa Timur    | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 0.74           | 0.00     |
| 34  | UID Banten        | Steam-Electric Power Station | Coal          | 2.030                       | 3700.00        | 7511.00  |
|     |                   | Gas Power Plant           |               |                             | 520.88         | 11261.43 |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 3172.98        | 0.00     |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 375.26         | 1161.80  |
| 35  | PT Indonesia Power | Steam-Electric Power Station | Coal          | 2.030                       | 1800.00        | 3654.00  |
|     |                   | Gas Power Plant           |               |                             | 1188.20        | 25688.88 |
|     |                   | Gas & Steam-Electric Power Plant | Natural Gas | 21.620                      | 2747.36        | 0.00     |
|     |                   | Diesel Electric Power Plant | Diesel Fuel   | 3.096                       | 3.19           | 9.88     |
| 36  | PT Pembangkitan Jawa Bali (PJB) | Steam-Electric Power Station | Coal          | 2.030                       | 2840.00        | 5765.20  |
|     |                   | Gas Power Plant           |               |                             | 2170.00        | 0.00     |
| No. | Power Plant                                      | Type of Power Plant   | Raw Materials    | Emission Factor (tCO₂/MWh) | Capacity (MWh) | (t CO₂)  |
|-----|--------------------------------------------------|----------------------|-----------------|-----------------------------|----------------|----------|
| 40  | UIK Jawa Bagian Tengah                          | Steam-Electric Power Station | Coal            | 2.030                       | 3330.00        | 6759.90  |
|     | Gas & Steam-Electric Power Plant                 | Natural Gas          | 21.620          | 3489.09                     | 75434.13       |
| 41  | UIK Jawa Bagian Timur, Bali, dan Nusa Tenggara  | Steam-Electric Power Station | Coal            | 2.030                       | 1990.00        | 4039.70  |
|     | Gas & Steam-Electric Power Plant                 | Natural Gas          | 21.620          | 501.00                      | 10831.62       |
| 42  | UIW Papua dan Papua Barat                        | Steam-Electric Power Station | Coal            | 2.030                       | 24.00          | 48.72    |
|     | Diesel Electric Power Plant                       | Diesel Fuel          | 3.096           | 91.95                       | 284.68         |
| 43  | UIP Kaltim Bagian Timur                          | Steam-Electric Power Station | Coal            | 2.030                       | 7.00           | 14.21    |
| 44  | UIP Sulawesi Bagian Selatan                      | Steam-Electric Power Station | Coal            | 2.030                       | 10.00          | 0.00     |
| 45  | UIP Sulawesi Bagian Utara                        | Steam-Electric Power Station | Coal            | 6.00                        | 0.00           |
| 46  | UIP Nusa Tenggara                                | Diesel Electric Power Plant | Diesel Fuel     | 3.096                       | 30.00          | 151.39   |
|     | Total                                            |                       |                 | 39285.37                    | 202017.35      |

Average Emission Factor = \( \frac{\sum (\text{Emission Factor} \times \text{capacity})}{\sum \text{capacity}} = \frac{202017.36 \text{tCO}_2}{39285.37 \text{MWh}} = 5.14 \text{ kg CO}_2/\text{kWh} \) (1)

After being averaged, the emission factor used for the next calculation is 5.14 kg CO₂/kWh.

3.2. Carbon footprint from electric demand in Indonesia

The data to carry out made by electorate General of Electricity at the Ministry of Energy and Mineral Resources of Indonesia. The Directorate General of Electricity or if it is abbreviated as Directorate General of Electricity or can be called DJK is the implementing element of the Ministry of Energy and Mineral Resources (ESDM) in charge of the electricity sub-sector. The Directorate General of Electricity has the task of carrying out the formulation and implementation of policies in the fields of development, business, engineering, work safety, and the environment in the electricity sub-sector in Indonesia. The following is the calculation of carbon footprint from electricity demand in Indonesia from 2015 – June 2020.
Table 2. The Calculation of the Carbon Footprint from Electricity Demand in Indonesia 2015 –2020.

| Year | Electricity Consumption (kWh/capita) | Emission Factor | CO₂ Emission (Kg CO₂) | Percentage Increase Electricity Consumption |
|------|--------------------------------------|-----------------|------------------------|---------------------------------------------|
| 2015 | 910                                  | 5.14            | 4677.40                |                                             |
| 2016 | 956                                  | 5.14            | 4913.84                | 5.05%                                       |
| 2017 | 1021                                 | 5.14            | 5247.94                | 6.80%                                       |
| 2018 | 1064                                 | 5.14            | 5468.96                | 4.21%                                       |
| 2019 | 1084                                 | 5.14            | 5571.76                | 1.88%                                       |
| 2020 | 1084.36                              | 5.14            | 5573.61                | 0.03%                                       |
|      | **Average**                          |                 | **5242.25**            | **3.60%**                                   |

Source: Statistics of PLN (2020).

Based on the calculation, the carbon footprint from electricity usage per year on average is 5242.3 KgCO₂ and increase of 3.60% on percentage. Based on the table above, it can be seen that the calculation of the carbon footprint from electricity demand in Indonesia 2015 –2020 from year to year trends to increase and when viewed from the development of the industry, the needs of the electricity usage will also increased.

Based on the data in the table above, the projected growth and development of the carbon footprint of electricity in Indonesia in the future can be estimated using the Least Square method with the following formula:

\[ Y = x + bx \]  

(2)

So with this formula, the following table is obtained the calculation of the carbon footprint from electricity demand in Indonesia 2021 – 2045:

Table 3. The Projection of the Calculation of the Carbon Footprint from Electricity Demand in Indonesia 2021 – 2045.

| Tahun | y (Kg CO₂) | X |
|-------|------------|---|
| 2021  | 5909.83    | 3 |
| 2022  | 6100.56    | 4 |
| 2023  | 6291.30    | 5 |
| 2024  | 6482.04    | 6 |
| 2025  | 6672.77    | 7 |
| 2026  | 6863.51    | 8 |
| 2027  | 7054.25    | 9 |
| 2028  | 7244.98    | 10|
| 2029  | 7435.72    | 11|
| 2030  | 7626.46    | 12|
Figure 2. Calculation of the Growth of the Carbon Footprint of Electricity Demand in Indonesia 2021 – 2045. 

**Source:** Statistics of PLN (2020).

### 3.3. Project 35000 MW

Press release number 25/SJI/2015 dated on May 4, 2015 by the Ministry of Energy and Mineral Resources of the Republic of Indonesia. The President of the Republic of Indonesia Joko Widodo accompanied by the Minister of Energy and Mineral Resources (ESDM) Sudirman launched the 35000 Megawatt Power Plant Development Program in Samas, Bantul Regency, Yogyakarta Special Region Province. The 35000 megawatt program is the one of the flagship programs in order to achieve one of the Nawacita targets, namely realizing economic independence by moving strategic sectors, especially
energy sovereignty. The 35000 megawatt power plant program will also be a potential that produces more carbon emissions if the resources are not from renewable energy [20].

3.4. Renewable energy supply

3.4.1. New energy potential and renewable energy

The reduced production of fossil energy, especially oil, and the global commitment to reducing greenhouse gas emissions, has encouraged the Government to continuously increase the role of new and renewable energy as part of maintaining energy security and independence. According to PP No. 79 of 2014 concerning National Energy Policy, the target for the new and renewable energy mix in 2025 are at least 23% and 31% in 2050. Indonesia has a large enough potential for new and renewable energy to achieve the primary energy mix target, as shown in Table 4 [7].

| Type of Energy       | Potential          |
|----------------------|--------------------|
| Hydroelectric Power Plant | 94.3 GW            |
| Geothermal           | 28.5 GW            |
| Bioenergy            | Bio: 32.6 GW       |
|                      | BBN: 200000Bph     |
| Solar                | 207.8 GWp          |
| Wind                 | 60.6 GW            |
| Ocean Energy         | 17.9 GW            |

**Table 4. Renewable Energy Potential in Indonesia.**

*Source:* Direktorat Jenderal Energi Baru, Terbarukan (EBT) dan Konservasi Energi (DITJEN EBTKE) (2018).

3.4.2. Realization renewable energy generation in Indonesia

The total renewable energy potential equivalent to 442 GW is used for power generation, while BBN and Biogas of 200 thousand Bph are used for fuel purposes in the transportation, household, commercial and industrial sectors. The utilization of NRE for power plants in 2018 was 8.8 GW or 14% of the total power generation capacity (fossil and non-fossil) which is 64.5 GW [7].

The lack of use of NRE for electricity is due to the relatively high production price of EBT-based power plants, making it difficult to compete with fossil generators, especially coal. In addition, the lack of support from the domestic industry related to the components of renewable energy generation and the difficulty of obtaining low-interest funding has also caused the development of renewable energy to be hampered. The use of NRE in the transportation sector, especially biodiesel, has begun to develop rapidly in line with the implementation of the mandatory biofuel policy which mandates: the mixture of biofuel to fuel by 20% (B20) in the transportation sector. The development of biodiesel production, export, and utilization is shown in Figure 1 [7].
The renewable energy supply is continuously increasing. A large amount of investment has been made during recent years and the advancement of technology has enabled countries to produce renewable energy more cost effectively. It is forecasted that the number of countries producing above 100 megawatts (MW) of renewable energy will increase significantly by 2017 (IEA, 2012d). Due to some negative and irreversible externalities coming with conventional energy production, it is necessary to promote and develop renewable energy supply technologies. These technologies may not be comparable with conventional fuels in terms of production cost, but they could be comparable if we consider their associated externalities, such as their environmental and social effects. Also, it should be noted that economies of scale could play a key role in reducing the unit production cost. Transmission and distribution costs, as well as technologies, do not differ much among the conventional and renewable energies [13].

The following is the development of installed capacity of renewable power plants in Indonesia 2015-2020:

Table 5. The Development of Installed Capacity of Renewable Power Plants in Indonesia 2015-2020.

| Year  | Hybrid | Solar | Wind | Bio Energy | Geothermal | Water | Total  |
|-------|--------|-------|------|------------|------------|-------|--------|
| 2015  | 4      | 33    | 2    | 1742       | 1438       | 5278  | 8497   |
| 2016  | 4      | 43    | 2    | 1783       | 1533       | 5621  | 8986   |
| 2017  | 4      | 51    | 2    | 1857       | 1808       | 5658  | 9380   |
| 2018  | 4      | 68    | 144  | 1883       | 1948       | 5742  | 9789   |
| 2019  | 4      | 137   | 154  | 1890       | 2131       | 5976  | 10292  |
| 2020  | 4      | 154   | 154  | 1904       | 2131       | 6121  | 10468  |

Source: 2020 Annual Report. Direktorat Jenderal Energi Baru, Terbarukan (EBT), dan Konservasi Energi (DITJEN EBTKE) (2020).
Based on the table above, it can be seen that the development of installed capacity growth for renewable energy power plants from year to year trends to increase and when viewed from the development of industry, the need for renewable energy power plants will also increase. Based on the data in the table above, the projected growth and development of renewable energy power plants in Indonesia in the future can be estimated using the Least Square method. The following table is obtained the projected of renewable energy growth in Indonesia 2021 – 2045:

Table 6. The Projection of Renewable Energy Growth in Indonesia 2021 – 2045.

| Tahun | y (Megawatt) | X |
|-------|--------------|---|
| 2021  | 10986.87     | 3 |
| 2022  | 11392.07     | 4 |
| 2023  | 11797.27     | 5 |
| 2024  | 12202.47     | 6 |
| 2025  | 12607.67     | 7 |
| 2026  | 13012.87     | 8 |
| 2027  | 13418.07     | 9 |
| 2028  | 13823.27     | 10|
| 2029  | 14228.47     | 11|
| 2030  | 14633.67     | 12|
| 2031  | 15038.87     | 13|
| 2032  | 15444.07     | 14|
| 2033  | 15849.27     | 15|
| 2034  | 16254.47     | 16|
| 2035  | 16659.67     | 17|
| 2036  | 17064.87     | 18|
| 2037  | 17470.07     | 19|
| 2038  | 17875.27     | 20|
| 2039  | 18280.47     | 21|
| 2040  | 18685.67     | 22|
| 2041  | 19090.87     | 23|
| 2042  | 19496.07     | 24|
| 2043  | 19901.27     | 25|
| 2044  | 20306.47     | 26|
| 2045  | 20711.67     | 27|
Figure 4. The Projection of Renewable Energy Growth in Indonesia 2021–2045.

The following is percentage of installed capacity for renewable energy power generation:

Table 7. Percentage of Installed Capacity for Renewable Energy Power Generation.

| Year | Oil   | Coal  | Gas   | Renewable Energy |
|------|-------|-------|-------|------------------|
| 2015 | 42.12 | 30.14 | 22.77 | 5.32             |
| 2016 | 44.90 | 27.84 | 21.12 | 4.97             |
| 2017 | 41.42 | 30.53 | 21.39 | 6.66             |
| 2018 | 38.71 | 33.00 | 19.68 | 8.61             |
| 2019 | 35.03 | 37.28 | 18.51 | 9.18             |
| 2020 | 30.49 | 38.68 | 19.52 | 11.31            |
Figure 5. Percentage of Installed Capacity for Renewable Energy Power Generation 2015-2020.
Source: 2020 Annual Report. Direktorat Jenderal Energi Baru, Terbarukan (EBT), and Konservasi Energi (DITJEN EBTKE) (2020).

3.5. Estimation net zero carbon emission from renewable power plant in Indonesia
Press release number 389.Pers/04/SJI/2021 dated on November 21, 2021 by the Ministry of Energy and Mineral Resources of the Republic of Indonesia. Indonesia's commitment to climate change mitigation is reinforced by the formulation of a number of policies, especially in the energy sector. Indonesia has set the targets for emission reduction and Net Zero Emission by 2060 or sooner [21].

Zero carbon emission from power plants in Indonesia can be achieved if the source of power generation is 100% using renewable energy. The following is an estimation timeline Indonesian renewable power plants can reach zero carbon emission:

Table 8. Electricity Consumption for non-Renewable Power Plant In Indonesia.

| Year | The Power Plant Growth for non-Renewable Energy (MW) (y) | x | xy | x² |
|------|--------------------------------------------------------|---|-----|----|
| 2010 | 28038                                                  | -5| -140190 | 25 |
| 2011 | 30723                                                  | -4| -122892 | 16 |
| 2012 | 39062                                                  | -3| -117186 | 9 |
| 2013 | 39660                                                  | -2| -79320  | 4 |
| 2014 | 46822                                                  | -1| -46822  | 1 |
| 2015 | 47983                                                  | 0 | 0     | 0  |
| 2016 | 52580                                                  | 1 | 52580.37| 1  |
| 2017 | 51394                                                  | 2 | 102788  | 4  |
| 2018 | 56012                                                  | 3 | 168036  | 9  |
| 2019 | 57078                                                  | 4 | 228312  | 16 |
| 2020 | 57224                                                  | 5 | 286120  | 25 |
Table 9. The Power Plant Growth for non-Renewable Energy (MW) (y) In Indonesia

| Year | The Power Plant Growth for non-Renewable Energy (MW) (y) | X |
|------|----------------------------------------------------------|---|
| 2021 | 64130.20                                                 | 6 |
| 2022 | 67143.17                                                 | 7 |
| 2023 | 70156.13                                                 | 8 |
| 2024 | 73169.10                                                 | 9 |
| 2025 | 76182.07                                                 | 10|
| 2026 | 79195.03                                                 | 11|
| 2027 | 82208.00                                                 | 12|
| 2028 | 85220.97                                                 | 13|
| 2029 | 88233.94                                                 | 14|
| 2030 | 91246.90                                                 | 15|
| 2031 | 94259.87                                                 | 16|
| 2032 | 97272.84                                                 | 17|
| 2033 | 100285.80                                                | 18|
| 2034 | 103298.77                                                | 19|
| 2035 | 106311.74                                                | 20|
| 2036 | 109324.70                                                | 21|
| 2037 | 112337.67                                                | 22|
| 2038 | 115350.64                                                | 23|
| 2039 | 118363.61                                                | 24|
| 2040 | 121376.57                                                | 25|
| 2041 | 124389.54                                                | 26|
| 2042 | 127402.51                                                | 27|
| 2043 | 130415.47                                                | 28|
| 2044 | 133428.44                                                | 29|
| 2045 | 136441.41                                                | 30|

Table 10. The Projection of Power Plant Growth for non-Renewable Energy (MW) (y) In Indonesia

| Tahun | The Power Plant Growth for Renewable Energy (MW) (y) | x  | xy     | x2  |
|-------|--------------------------------------------------------|----|--------|-----|
| 2010  | 6001.51                                                 | -5 | -30007.55 | 25 |
| 2011  | 5181.51                                                 | -4 | -20726.04 | 16 |
| 2012  | 5521.23                                                 | -3 | -16563.69 | 9  |
| 2013  | 6546.66                                                 | -2 | -13093.32 | 4  |
### Table 1. The Power Plant Growth for Renewable Energy (MW) (y) In Indonesia

| Year | The Power Plant Growth for Renewable Energy (MW) (y) | X |
|------|-----------------------------------------------------|---|
| 2021 | 7651.92                                             | 6 |
| 2022 | 7821.41                                             | 7 |
| 2023 | 7990.90                                             | 8 |
| 2024 | 8160.38                                             | 9 |
| 2025 | 8329.87                                             | 10 |
| 2026 | 8499.36                                             | 11 |
| 2027 | 8668.84                                             | 12 |
| 2028 | 8838.33                                             | 13 |
| 2029 | 9007.82                                             | 14 |
| 2030 | 9177.30                                             | 15 |
| 2031 | 9346.79                                             | 16 |
| 2032 | 9516.27                                             | 17 |
| 2033 | 9685.76                                             | 18 |
| 2034 | 9855.25                                             | 19 |
| 2035 | 10024.73                                            | 20 |
| 2036 | 10194.22                                            | 21 |
| 2037 | 10363.71                                            | 22 |
| 2038 | 10533.19                                            | 23 |
| 2039 | 10702.68                                            | 24 |
| 2040 | 10872.17                                            | 25 |
| 2041 | 11041.65                                            | 26 |
| 2042 | 11211.14                                            | 27 |
| 2043 | 11380.63                                            | 28 |
| 2044 | 11550.11                                            | 29 |
| 2045 | 11719.60                                            | 30 |
Figure 6. The Projection of Power Plant Growth for Renewable Energy & non Renewable Energy (MW) (y) In Indonesia 2021–2045.

From the table and figure above, it can be concluded that Indonesia has not yet achieved the net-zero carbon emission target in 2045. If Indonesia wants to achieve net-zero carbon emission, the development of renewable energy power plants must be increased more massively so that net-zero carbon emissions can be achieved at the target in 2060.

4. Conclusion and outlook

Power plants are one of the main areas of carbon emission because intensive power generation consumes a lot of fossil fuels and electricity has become a primary human need. Therefore, it is essential to conduct a carbon footprint analysis in power plants companies so that key sectors can be identified and appropriate emission reduction policies can be improved. To carry out this mission, we calculated carbon emissions from power generation capacity and averaged emission factors. In addition, we also estimate the carbon footprint that will be generated and the percentage of renewable energy power plants' growth from 2021-2045 and estimation net zero carbon emission from renewable power plant in Indonesia.

While electrical energy has a significant effect on producing carbon emissions and is still increasing by the year, an increase in greenhouse gas emissions and the problem of climate change will be inevitable. A future to use renewable energy technologies is expected to create the desired climate change where there are fewer floods, storms, droughts and other extreme conditions because the global warming. All levels of society must work together so that the world can accelerate its transition to sustainable energy and a sustainable future.

From the data above, it can be conclude that from 2015-2045 there is an increase in electricity demand which will also result in an increase in the amount of the carbon footprint. However, with the growth and increasing of the installation capacity of renewable energy power plants, it is expected that the amount of the carbon footprint generated can be reduced, in line with the increase in line with the growth of renewable energy power plants.
In general, electricity consumption in Indonesia will increase, so in order to reduce the carbon footprint, the increase in the volume of renewable power generation capacity must be increased as well as its development needs to be expanded in various sources, such as geothermal, wind, water, and others.

Based on the data in the table above, it can be concluded that to reduce the carbon footprint in Indonesia, the construction of renewable energy power plants requires an increase in capacity of 4 times the current renewable energy power plants. Therefore, a zero carbon footprint from power generation can be obtained by 2050.

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