GREENHOUSE GASSES INVENTORY ON TEXTILE FINISHING INDUSTRY PT X

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Abstract

The textile industry has the biggest impact on environmental pollution in the world, and is responsible for 10% of global carbon production. Most of the waste in the textile industry, is generated from the dyeing process and textile processing. PT X is a textile finishing industry, that focuses on finishing processes like dyeing and textile processing. In this research, GHG (greenhouse gasses) emission inventory was carried out to see how much GHG generated in the textile finishing industry. The inventory will focus on CO_2, CH_4, and N_2O from generator, curing machine, operational vehicle, and electricity usage. The inventory methodology was based on IPCC 2006, that stated to determine GHG emission, an activity data and emission factor from that source is needed. This emission inventory results on the total emissions of 666.38 tonCO_{2eq} or 258.629 kgCO_{2eq}/ton$_{product}$ GHG emission from PT X in 2021. The GHG emission in PT X are dominated by CO_2 gas. Which most of comes from electricity usage source. GHG emission produce by PT X are not high compared with similar industries, but can be improved further more with mitigation measures such as installing a solar panel, and constructed wetland.

Keywords: *Emission inventory, greenhouse gasses, mitigation, textile finishing industry*

Introduction

Global warming is a phenomenon of the rising in the average temperature of the atmosphere, land and oceans on the surface of the earth caused by long-wave solar radiation (heat waves or infrared) that is trapped, and reflected back to earth by greenhouse gasses (Houghton, 2005). Apart from being caused by an increase in greenhouse gasses, global warming is also caused by the depletion of the ozone layer, which causes shortwave solar (ultraviolet) radiation to penetrate the earth's surface (Dewarani, 2019). Rusbiantoro (2008) said that this global warming phenomenon has had many adverse effects on life on earth, such as increasingly extreme climate change, high sea level rises due to melting polar ice, also affecting our activities in the agricultural sector, affecting the lives of several species of animals and plants, including humans, whose health is also affected by this global warming phenomenon (Triana, 2008).

The textile industry is one of the industries with the greatest impact on the environment. According to the United Nations Environment Program (UNEP) it takes 2720 liters of water to make a T-shirt and about 3781 liters of water to make a pair of jeans. Textile industry discharges as much as 300-500 million tons of chemical waste each year into water bodies, and around 20% of wastewater worldwide comes from the process of dyeing and textile processing. The fashion industry also contributes to 10% of global carbon emissions, which can exceed the

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total emissions from both aviation and shipping. Thus, not only polluting the environment, but also one of the largest contributors to greenhouse gas emissions.

Therefore, this study aims to measure the greenhouse gas emissions potentials per ton product of textile industry, especially the textile finishing industry that focuses on final processes such as dyeing and textile processing. This research was conducted by taking an inventory of greenhouse gas emissions at PT X that is a textile finishing industry operating in Sragen, Central Java, which expected to obtain results that can represent the potential of greenhouse gases from textile finishing industry in Indonesia.

Research Methodology

In this study, the sources of greenhouse gas emissions that was examined will be limited to scopes 1 and 2, where scope 1 is the source of emissions that come from processes/activities that exist in the company or are controlled by the company, and scope 2 is the greenhouse gas emissions that comes from the generation process of the electricity used by the company (Ranganathan, 2015). Calculation of scope 1 GHG emissions will use the tier 1 calculation method and scope 2 GHG emissions will use the tier 2 method from the 2006 IPCC document. The greenhouse gasses emission result then converted to $kgCO_{2eq}$ to be compared with one another (Menteri Lingkungan Hidup Republik Indonesia, 1999).

Scope 1

Stationary emission sources that will be examined in this study come from generators and curing machines. Emissions from these two sources come from the fuel combustion of these machines, where generators use diesel and curing engines use LPG. In this study, the emissions that will be inventoried are CO_2, CH_4, and N_2O with calculations using Eq. (1) which refers to the 2006 Intergovernmental Panel on Climate Change (Garg & Tinus, 2006).

$$Em_{GHG,fuel} = FC_{fuel} \times EF_{GHG,fuel} \quad (1)$$

where $Em_{GHG,\ fuel}$ is emissions of a given GHG by type of fuel (kg GHG), FC_{fuel} is amount of fuel combusted (TJ), and $EF_{GHG,\ fuel}$ is default emission factor of a given GHG by type of fuel (kg gas/TJ).

Emissions from mobile sources calculated in this study are from company-owned operational vehicles. Emissions from these operational vehicles come from the vehicle engine fuel combustion, where the company trucks use diesel, then courier motorbikes and company cars use Pertalite gasoline. Emissions from operational vehicles are classified as mobile combustion. In this study, the emissions that will be inventoried are CO_2, CH_4, and N_2O with calculations using Eq. (2) which refers to the 2006 Intergovernmental Panel on Climate Change (Garg & Tinus, 2006).

$$Em = \sum_a [F_a \times EF_a] \quad (2)$$

where Em is emissions of a given GHG by type of fuel (kg GHG), a is type of fuel (diesel, gasoline, LPG, etc.), F_a is amount of fuel combusted (TJ) and EF_a is default emission factor of a given GHG by type of fuel (kg gas/TJ).

The greenhouse gas emissions from the wastewater come from organic waste that is processed in the WWTP at the factory site. Organic waste, depending on the treatment process used, will produce greenhouse gas emissions in the form of methane gas or CH_4. The CH_4 emission that will be estimated in this study is limited to the CH_4 produced at the on-site WWTP located in the company's factory area. The amount of organic waste in wastewater can be described from the COD of the wastewater. Inventory of CH_4 emissions from WWTP will be calculated using Eq. (3) which refers to the 2006 Intergovernmental Panel on Climate Change (Pipatti & Vieira, 2006).

$$CH_4Em = \sum_i[(TOW_i - S_i)EF_i - R_i] \quad (3)$$

where CH_4Em is emissions of CH_4 (kg GHG), *i* is industrial sector, TOW_i is total organically degradable material in wastewater from industry *i* in inventory year (kg COD/yr), S_i is organic component removed as sludge in inventory year (kg COD/yr), EF_i is emission factor for industry *i* for treatment/discharge pathway or system(s) used in inventory year (kg CH_4/kg COD) *If more than one treatment practice is used in an industry this factor would need to be a weighted average and R_i is amount of CH_4 recovered in inventory year (kg CH_4/yr) *collected for reuse purpose, such as for combustion fuel.

The emission factor used depends on the wastewater treatment system used in the WWTP. The emission factor is obtained by multiplying the maximum CH_4 gas production potential (B_o) with the methane correction factor (MCF) for the processing system used. Emission factors will be calculated using Eq. (4) which refers to the 2006 Intergovernmental Panel on Climate Change (Pipatti & Vieira, 2006).

$$EF_j = B_o \times MCF_j \quad (4)$$

where *j* is each treatment/discharge pathway or system, EF_j is emission factor for each treatment/discharge pathway or system (kg CH_4/kg COD), B_o is maximum CH_4 producing capacity (kg CH_4/kg COD) and MCF_j is methane correction factor.

The activity data used in the calculations is in the form of total degradable organic waste in the company's wastewater. the total amount of organic waste is obtained by using Eq. (5) which refers to the 2006 Intergovernmental Panel on Climate Change (Pipatti & Vieira, 2006).

$$TOW_i = P_i \times W_i \times COD_i \quad (5)$$

where *i* is industrial sector, TOW_i is total organically degradable material in wastewater for industry *i* (kg COD/yr), P_i is total industrial product for industrial sector *i* (t/yr), W_i is wastewater generated ($m^3/t_{product}$), and COD_i is chemical oxygen demand, industry *i* degradable organic component in wastewater (kg COD/m^3).

Scope 2

Greenhouse gas emissions from electricity consumption are emissions produced by power plants to produce electricity that companies buy and use for operational purposes. Emissions from electricity consumption are classified into scope 2 where emissions are generated indirectly by company activities, where the source of emissions is not within the company environment but as a result of the company's activities these emissions are produced. In this study, greenhouse gas emissions from electricity consumption that will be inventoried are CO_2 gasses which are calculated using Eq. (6) which refers to the greenhouse gases protocol. (Ranganathan, 2015).

$$CO_2Em = E \times EF_{PLTN} \quad (6)$$

where CO_2Em is emissions of CO_2 produced by the company electricity usage (kg CO_2), E is the amount of electricity used by the company (MWh) and EF_{PLTN} is emission factor of CO2 from the power plan that produced the electricity used by the company.

Results and Discussion

Scope 1

In Figure 1 to Figure 3, the greenhouse gas emissions resulting from generator engine operation throughout 2021 is shown. The most dominant gas from engine emissions is CO_2, then N_2O, and CH_4 has the smallest value. In Figure 4, CO_2 gas has the greatest percentage, namely 98.43%, followed by N_2O of 1.41% and the smallest CH_4 with a value of 0.16%. The amount of greenhouse gas emissions generated in February is higher than in any other month, it can be concluded that in February there were many problems with the flow of electricity from PLN, which resulted in high diesel consumption by the generator engine.

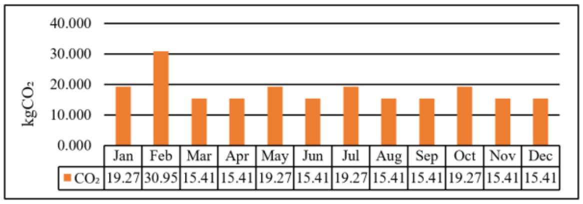

Figure 1. CO_2 Emission Load of PT. X's Generator 2021 ($kgCO_2$)

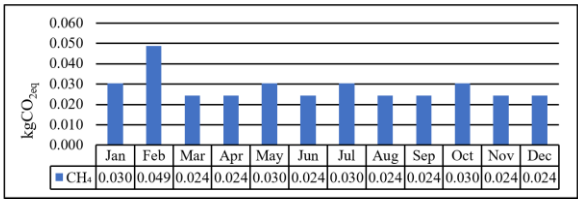

Figure 2. CH4 Emission Load of PT. X's Generator 2021 ($kgCO_2eq$)

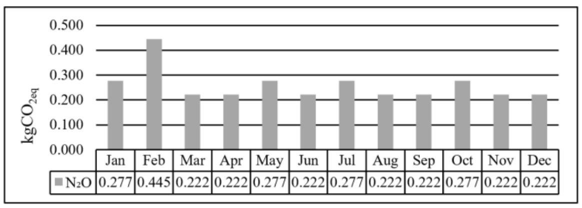

Figure 3. N2O Emission Load of PT. X's Generator 2021 ($kgCO_2eq$)

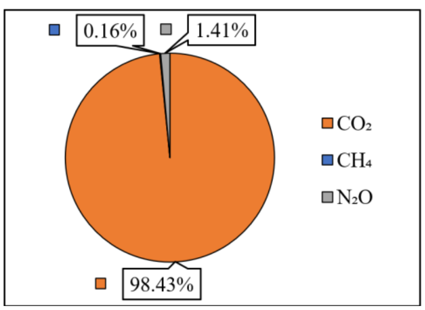

Figure 4. Greenhouse Gasses Percentage of PT. X's Generator 2021

In Figure 5 to Figure 7 the greenhouse gas emissions resulting from the operation of the curing machine throughout 2021 is shown. The most dominant gas from engine emissions is CO_2, then CH_4, and N_2O has the smallest value. Then in Figure 8, CO_2 gas has the greatest percentage, namely 99.91%, followed by CH_4 of 0.05% and the smallest N_2O with a value of 0.04%. The amount of greenhouse gas emissions generated in January is higher than in any other month, it can be concluded that in January there were many productions that requires the use of curing machine, which resulted in high LPG consumption by the curing machine.

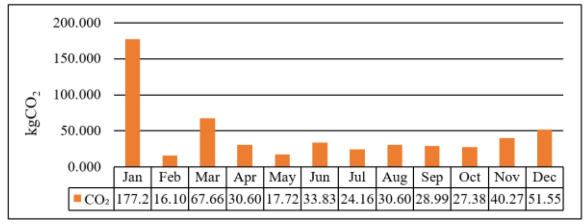

Figure 5. CO2 Emission Load of PT. X's Curing Machine 2021 ($kgCO_2$)

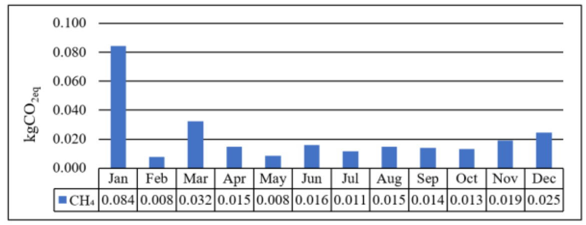

Figure 6. CH4 Emission Load of PT. X's Curing Machine 2021 ($kgCO_2eq$)

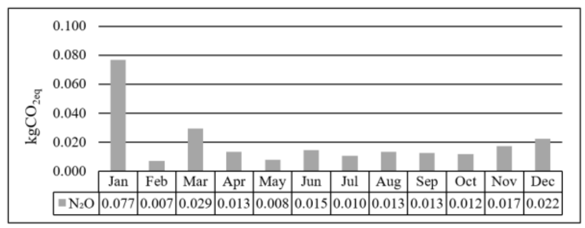

Figure 7. N2O Emission Load of PT. X's Curing Machine 2021 ($kgCO_2eq$)

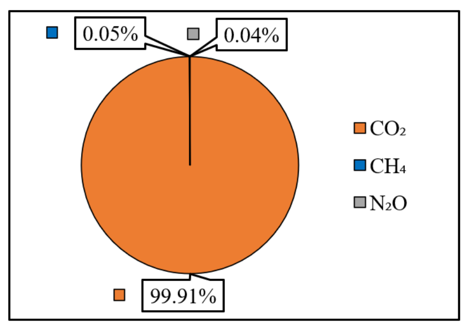

Figure 8. Greenhouse Gasses Percentage of PT. X's Curing Machine 2021

In Figure 9 to Figure 11, the greenhouse gas emissions produced from operational vehicles throughout 2021 is shown. The most dominant gas from vehicle emissions is CO_2, then CH_4, and N_2O has the smallest value. It can also be seen that diesel-fueled vehicle produce more emissions than those from petrol-fueled vehicles. In CO_2 and N_2O emissions, the comparison between the total emissions from the diesel and pertalite usage is approximately 2:1, while in CH_4 emissions, pertalite is more dominant, this is because pertalite's CH_4 emission factor is much larger than that of diesel, which indicates that in its combustion, pertalite type fuel produces CH4 emissions in larger quantities compared to diesel. In Figure 12, CO_2 gas has the greatest percentage, namely 98.10%, followed by N_2O of 1.36% and the smallest CH_4 with a value of 0.54%. The amount of greenhouse gas emissions generated in December is higher than in any other month, it can be concluded that a lot of products were shipped to and from consumers in December, resulting in a high use of operational vehicles.

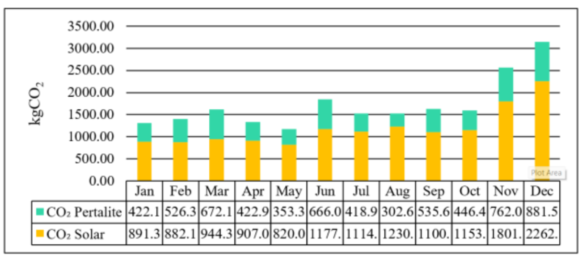

Figure 9. CO2 Emission Load of PT. X's Operational Vehicle 2021 ($kgCO_2$)

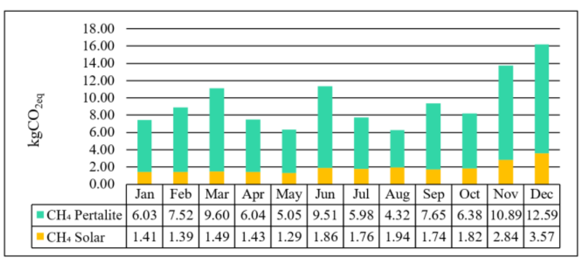

Figure 10. CH4 Emission Load of PT. X's Operational Vehicle 2021 ($kgCO_2eq$)

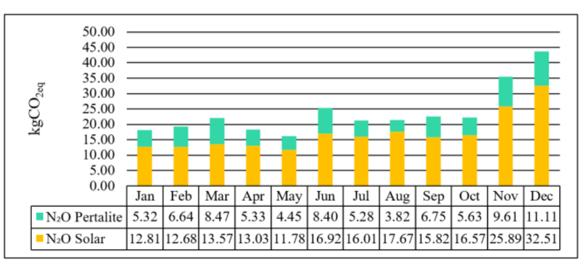

Figure 11. N2O Emission Load of PT. X's Operational Vehicle 2021 ($kgCO_2eq$)

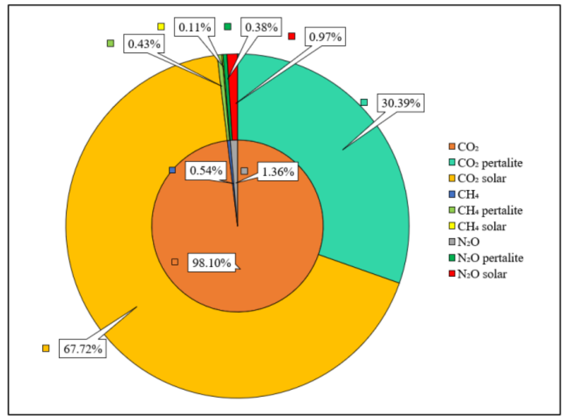

Figure 12. Greenhouse Gasses Percentage of PT. X's Operational Vehicle 2021

In Figure 13, the greenhouse gas emissions from wastewater sources throughout 2021 is shown, in the form of CH_4 gas. The trend of CH_4 emissions, is a combination of the trend from wastewater discharge trend and COD removal trend, where each has the same weight in calculating the amount of CH_4 emissions from wastewater sources.

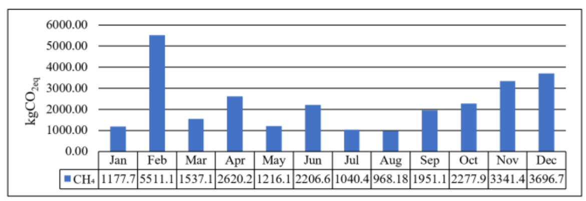

Figure 13. CH4 Emission Load of PT. X's WWTP 2021 ($kgCO_2eq$)

The amount of greenhouse gas emissions generated in February is higher than in any other month, it can be concluded that in February there was an increase of product from consumer that required dyeing and rinsing processes, resulting in an increase in the COD content in the wastewater.

Scope 2

In Figure 14, the greenhouse gas emissions from ELHI electricity consumption throughout 2021 is shown, in the form of CO_2 gas. The resulting greenhouse gas emissions have the same trend as the amount of electricity used because in Eq. (6), CO_2 emissions and the amount of electricity usage have a ratio of 1:1. The amount of greenhouse gas emissions generated in December is higher than in any other month, which means that production activity at the ELHI peaks in December, due to high demand from consumers, or due to increased administrative activity at the end of the year.

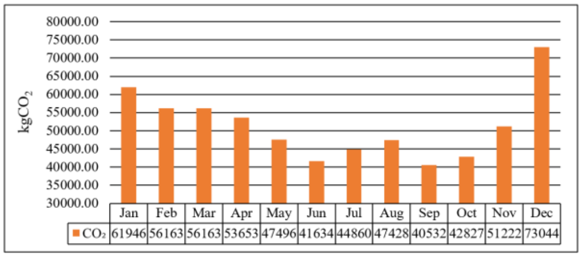

Figure 14. CO2 Emission Load of PT. X's Electricity Usage 2021 (kgCO$_2$)

Overall Analysis

From Figure 15 and Figure 16, it can be seen that the source that produces emissions with the greatest potential for greenhouse gasses is from scope 2 sources, or emissions from electricity consumption, which is equal to 92.59% of the total ELHI greenhouse gas emissions in 2021.

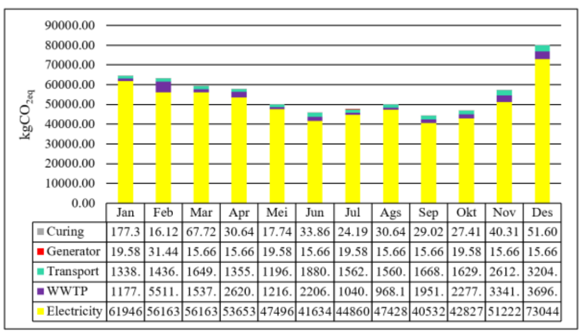

Figure 15. PT. X's Greenhouse Gasses Emission Load from 2021 Production Activity (kgCO$_2$eq)

Although in this study, only CO_2 gas from sources of electricity consumption is counted, but this source remains the most dominant source of greenhouse gasses compared to other emission sources. This is not only due to the very large amount of activity data for sources of electricity consumption when compared to other sources, but also due to the large amount of greenhouse gas emissions produced per activity data. Based on this, it means that in the process of generating electricity, it requires a very large calorific value, which means that it consumes a lot of fuel and produces a very large number of emissions in the process.

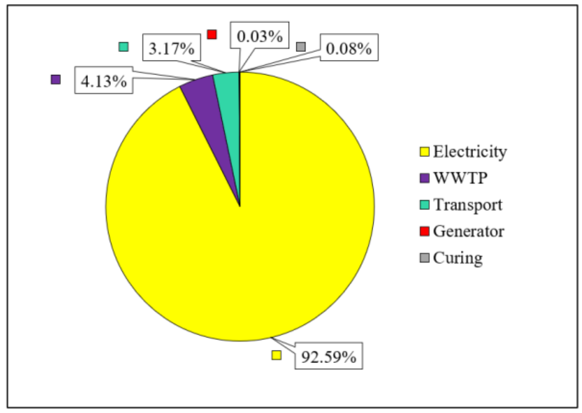

Figure 16. PT. X's Greenhouse Gasses Emission Percentage from 2021 Production Activity

From Figure 17, it can be seen that the most dominant greenhouse gas in ELHI is CO_2 gas, which has a value of 95.81% of the total emissions, followed by CH_4 of 4.15% and the smallest N_2O with a value of 0.04 %.

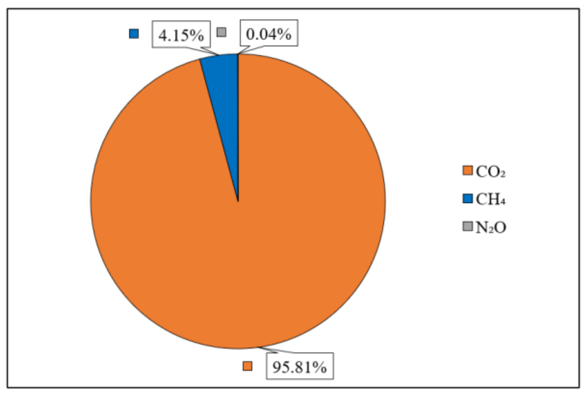

Figure 17. ELHI's Total Greenhouse Gasses Percentage from 2021 Production Activity

The biggest contributor to CO_2 emissions comes from sources of electricity usage, CH_4 emissions from waste water sources, and N_2O emissions from operational vehicle sources.

Comparison with Similar Companies

Table 1 presents an inventory of greenhouse gas emissions from dyeing and finishing processes of 3 different process samples, from a study conducted by Murugesh and Selvadass (2013). Each sample studied has a different desired color so that the composition of the dye used in each sample will be different. Then there is another difference in sample 3 from the other samples, the coloring and drying processes will use different techniques.

Table 1 Greenhouse Gasses Emission from Dyeing and Finishing of 1 ton of Garment (kgCO_2eq) (Murugesh & Selvadass, 2013)

Sample	Dyeing	Rinsing and Softening	Drying	compaction	Transportation	Total
Sample 1	12243.1033	75.5960	71.6625	135.5898	146.0293	12671.9810
Sample 2	16878.4208	75.5960	71.6625	135.5898	146.0303	17307.2995
Sample 3	6586.8637	75.5960	113.3417	135.5898	146.0303	7057.4216

Whereas in ELHI for every 1 ton of product, 258.629 kgCO_{2eq} greenhouse gas emissions are produced. When compared with the greenhouse gas emissions from Table 1, the greenhouse gas emissions produced at ELHI are quite low. This means that the management of greenhouse gas emissions at ELHI is good when compared to comparable greenhouse gas emissions from similar company.

Mitigation

Even though greenhouse gas emissions in ELHI are actually quite low, they can still be improved. To reduce the amount of greenhouse gas emissions produced, mitigation measures can be taken. Several mitigation measures that can be taken include using solar panels, fiberglass roofs, routine maintenance of production machines and vehicles, and creating constructed wetlands. By taking mitigation measures, total greenhouse gas emissions in 2021 can be reduced by 7.32%, with the biggest contributor being solar panels with a capacity of 125kVA which can reduce emissions by 5.7%.

Conclusions

Greenhouse gas emissions in ELHI come from several sources, namely generator engines and curing machines, operational vehicles, wastewater, and electricity usage. These greenhouse gas emissions generated as a result of the fuel combustion process, and from the by-products of wastewater treatment. In 2021, PT X produced a total of 666.38 tonCO_{2eq} or 258.629 kgCO_{2eq}/$ton_{product}$ greenhouse gas emissions consisting of CO_2, CH_4 and N_2O gasses. The electricity usage source emits the most CO_2, while the wastewater source produces the largest emission of CH_4 and the operational vehicles source emits the most N_2O. The greenhouse gas emissions produced by PT X to process 1 ton of garment are very low, when compared to similar companies, which produce emissions of 7,057.42-17,307.30 kgCO_{2eq} per 1 ton of garment. Mitigation measures that can be carried out by PT X include using solar panels, fiberglass roofs, routine maintenance of production machines and vehicles, and creating artificial wetlands, which can reduce total greenhouse gas emissions in 2021 by 7.32%.

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