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Greenhouse Gas Emission from Energy Consumption in Dyeing Factory at Samut Prakan Province, Thailand

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The textile industry is identified as one of the largest producers of greenhouse gases (GHG) worldwide. It has been reported to generate the highest GHG emission per unit of material. Since, the growing demand for textile products, global textile production has increased rapidly in recent years. Considering the existing studies have limited GHG emissions from energy consumption in the dyeing process. This study aims to estimate GHG emission in the dyeing factory at Samut Prakan province, Thailand, from 2017 to 2019. These were calculated based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The result showed that the textile production in the dyeing factory during 2017, 2018, and 2019 were 2,040.52, 3,389.62, 3,741.68 t. The GHG emission from the production process were 10,541.84 ±1 05.45, 12,320.31 ± 121.65, 12,545.53 ± 121.87 t $CO_{2\,eq}$. The greatest GHG emissions were produced from natural gas utilization (70 % of the total GHG emissions), followed by electricity, fuel oil, gasoline, LPG, and diesel oil. GHG emission flow from the production process found that the supporting processes section was the processes with the largest GHG emissions, accounting for 75 %, followed by finishing, dyeing, and preparation. GHG emissions per production found that GHG emissions per yard reduced from 4.93 ± 1.76, 3.63 ± 0.31, 2.68 ± 0.31 kg $CO_{2\,eq}$/kg of production for 2017 to 2019, because energy type was moved from fuel oil to natural gas.

1. Introduction

The global warming crisis has become a keyword for many countries worldwide, which is a phenomenon that the average temperature of the earth’s surface and oceans tends to increase more than in the past, since the industrial revolution. Scientific evidence is believed to be caused by an increase in the accumulation of greenhouse gases in the atmosphere (DEQP, 2020). The amount of each GHG_S in the atmosphere, it was found that CO_2 was the largest, accounting for 76 %, which was mainly caused by the burning of fossil fuels, about 65 %, from the forest and land use, about 11 %, followed by 16 % of CH_4, 6 % of N_2O, 2 % of fluorocarbon groups, and 2 % of NF_3 (IPCC, 2014). According to major GHG emission in tourism activity was energy consumption of gasoline and diesel in transport sector (Promjittiphong et al., 2018). The CO_2 emission of tourist transportation was depending on type of vehicle, number of tourist and distance (Hanpattanakit et al., 2018). Excessive accumulation of GHG_S in the atmosphere can cause sudden changes in the global temperature. It is a phenomenon that causes global warming. It leads to regional or global climate change (Niveta et al., 2015), of 97 % of climate scientists agree that climate change is happening right now, primarily driven by human activity (Public Health Institute and Center for Climate Change and Health, 2016). From the study of scientists, it was found that the change in global average temperature was related to the concentration of CO_2 in the atmosphere. This relationship has now been proven to be true because the concentration of CO_2 in the atmosphere has increased, since the industrials revolution (DEQP, 2020). Today’s environmental change’s most obvious and apparent impacts include more frequent occurrences of extreme weather events such as heatwaves, droughts, floods, heavy rainfall events, and the extinction of living things (Niveta et al., 2015).

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In recent years, China has been the world's number one in GHG_S production. Due to economic growth and opening up more countries (Chen and Fu, 2011). It surpasses the United States, which has long been the world's largest GHG_S producer. In 2019, the country with the most GHG_S emissions in the world was China. Total emissions of GHG_S were 10,541 M t $CO_{2\ eq}$, followed by United States, EU28, India, Russia, and Japan were 5,335, 3,412, 2,342, 1,766, and 1,279 M t $CO_{2\ eq}$. In Thailand, total GHG_S emissions of 271 M t CO_{2eq} (Tiseo, 2021) were close to the average amount of GHG_S emissions per population (Global Carbon Project, 2015). Currently, global economic growth and population growth have mainly been driven by increasing GHG_S emissions, especially the burning of fossil fuels in the industry sector and various processes related to the production of industrial products (Niveta et al., 2015). One sector is the textile sector, which is still in demand for people worldwide. Emission of the textile industry has been identified as one of the largest producers of GHG_S globally. It has been reported to have the highest GHG emissions per unit of product. According to estimates, the textile sector emits about 1.7 B t $CO_{2\ eq}$/y and is an important factor that causes global warming (Loetscher et al., 2017). The textile industry' GHGs emissions account for 10 % of total global emissions. It remains the second-largest industrial polluter after the oil industry (Conca, 2015).

Thailand's GHG emissions from energy utilization tend to increase after the economic downturn in 1998 from 145.5 M t $CO_{2\ eq}$ increased to 263.4 M t $CO_{2\ eq}$ in 2018, or 3 %/y. This corresponds to the country's energy consumption that has increased by an average of 3.7 %/y (THA DEDE, 2018). GHG emissions from energy utilization in 2019, if separated by sector, the industrial sector had a portion of GHG emissions, accounting for 28 % of the country's total GHG emissions. GHG emissions from the industrial sector that uses the highest energy utilization were steel and metal, textile, electronics, and automobiles. The primary fuels that generate GHG emissions were petroleum products, natural gas, and coal/lignite. In 2019, petroleum products had the highest share of GHG emissions, followed by natural gas, and coal/lignite accounted for 39, 33, and 28 %. Energy consumption in the textile industry in Thailand tends to increase every year. In 2017, it was found that the energy consumption was 959 k toe, this is divided into 56 % of electricity, 25 % of coal, 10 % of petroleum products, 8 % of natural gas, and 1 % of renewable energy (THA DEDE, 2019).

The literature review found that there are several studies the greenhouse gas emission in textile industry in many countries because of major source of GHG emission in the human activity. Few studies have been conducted to investigate the GHG emissions of the Thailand's textile industry. These were the limitation of lacking updated data, and consider limited energy sources. The study of greenhouse gas emissions from energy consumption in the dyeing factory at Samut Prakan province, Thailand, was of great importance for an estimate of GHG emissions from the dyeing factory, which is midstream industry with the most GHG emissions (Huang et al, 2016). Research studies on this subject are still quite limited due to the complex production process and need for detailed information in the dyeing factory to calculate bottom-up GHG emissions levels at each step of the dyeing process. This study aims to estimate GHG emission in the dyeing factory at Samut Prakan province, Thailand.

2. Methodology

2.1 The definition of GHG emissions

This study calculated GHG emissions in the dyeing factory, which referred to the guideline of the Greenhouse Gas Protocol – A Corporate Accounting and Reporting Standard (Ranganathan et al., 2004). GHG emissions were divided into 2 types: direct GHG emissions (Scope 1) and indirect GHG emissions (Scope 2, Scope 3). Direct GHG emissions (Scope 1) are caused by energy sources owned or controlled by the factory. For example, the emissions were produced from energy combustion in boilers, machines, and vehicles. Second, indirect GHG emissions (Scope2) were GHG emissions from the generation of purchased electricity consumed by the factory but Scope 3 was factory's activities but occur from energy sources not owned or controlled by the factory, which this scope excludes in the study.

2.2 GHG emissions calculation

Both direct and indirect GHG emissions in this study referred to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Activity data was energy consumption from the factory (Table1). Emissions factors used the country specific from Thailand Greenhouse Gas Management Organization (THA TGO, 2020). This unit collected emission factor from several references and combined them in Table 1. The major GHG emissions were carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). All above GHG_S were converted into carbon dioxide equivalents ($CO_{2\ eq}$). The formula of GHG emission from stationary and mobile combustions were showed in Eq(1) and Eq(2).

$$Emissions_{GHG,fuel} = Fuel\ Consumption_{fuel} \cdot Emission\ Factor_{GHG,fuel} \qquad (1)$$

where; Emissions $_{GHG, fuel}$ represents emissions of a given GHG by type of fuel (kg $CO_{2\ eq}$), Fuel Consumption $_{fuel}$ represents the amount of fuel combusted (unit), and Emission Factor $_{GHG,fuel}$ represents default emission factor of a given GHG by type of fuel (kg gas/unit).

$$Emission = \sum_{a}[Fuel_a \cdot EF_a] \tag{2}$$

where; Emission represent emissions (kg $CO_{2\ eq}$), $Fuel_a$ represents fuel consumed (unit), EF_a represents emission factor (kg gas/unit), and a represents the type of fuel but in this study, both direct and indirect GHG emissions shall use physical unit multiply with local emission factor in Table 1.

Table 1: Activity data and emissions factor

Items	Data Sources	Unit	Emissions Factor			
			CO_2	CH_4	N_2O	Total
			(kg CO_2/unit)	(kg CH_4/unit)	(kg N_2O/unit)	(kg $CO_{2\ eq}$/unit)
Scope 1						
1.1 Stationary Combustion						
Natural gas for boiler and finishing machine	Consumption	MJ	5.61E-02	1.00E-06	1.00E-07	0.0562
Fuel oil for boiler	Consumption	L	3.24E+00	1.25E-04	2.51E-05	3.2455
1.2 Mobile Combustion						
LPG for forklift	Consumption	kg	3.11E+00	3.06E-03	9.86E-06	3.1988
Gasoline for forklift	Consumption	L	2.18E+00	1.04E-03	1.01E-04	2.2373
Diesel for forklift	Consumption	L	2.70E+00	1.42E-04	1.42E-04	2.7403
Scope 2						
Electricity	Consumption	kWh	0.4954	6.10E-05	1.04E-05	0.4999

3. Result and Discussion

3.1 GHG Emissions

Figure 1 shows dyeing fabric production and energy-related GHG emissions from 2017 to 2019. GHG emissions from 2017 to 2019 were increasing, which were emitted 10,541.84 ± 105.45, 12,320.31 ± 121.65, and 12,545.53 ± 121.87 t $CO_{2\ eq}$. The dyeing fabric production was increased from 2017 to 2019, about 2,040.52, 3,389.62, and 3,741.68 t. The major energy consumption in the dyeing factory was natural gas, which emitted approximately 70.62 ± 1.96 %/y of total emission, followed by electricity (22.28 ± 0.75), fuel oil (6.96 ± 2.20). But gasoline, LPG, and diesel oil were amount lower than 1 %

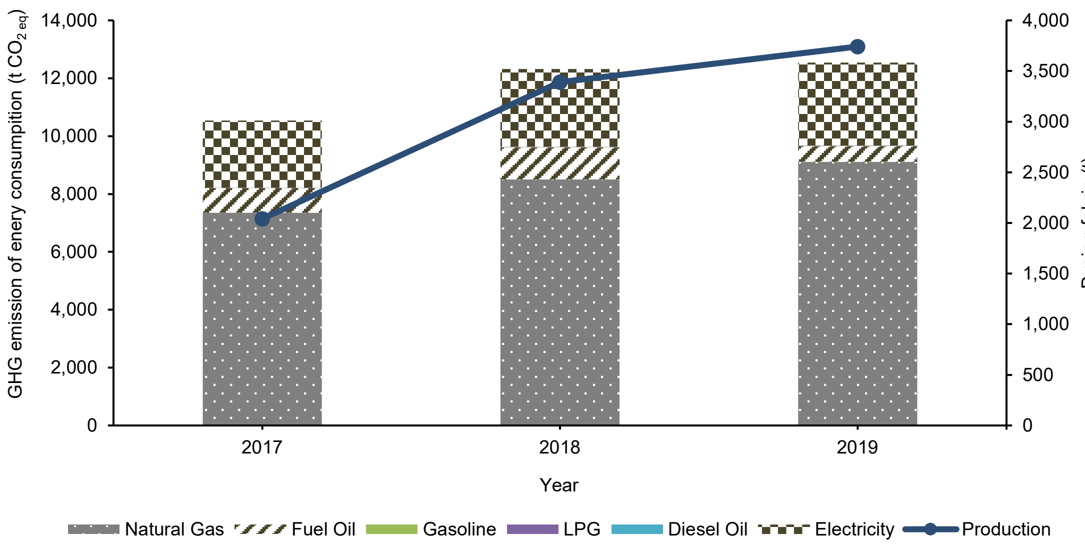

Figure 1: GHG emission of energy consumption and dyeing fabric production during 2017 - 2019

According to Turkey, the fabric dyeing factory was used heat and electricity energy are the main energy types used in the textile industry extensively. Average energy consumption in 2015 to 2018 consumed 7,314 toe. It reduced 49 % due to the implementation of the energy saving actions by waste heat, flash steam and cooling water recovery, and insulation in dyeing machine (Özer and Güven, 2020) but the difference from China textile industry, which is used coal as the main source in this sector that emitted the highest GHG emission in the textile industry. The current energy-saving measures in China's textile industry are frequently practiced with speed motor drives, heat recovery from fuel, and hot washing water but have not yet been widely applied (Huang et al., 2016). The production of dyeing fabric showed GHG emissions decreasing per unit of production from 2017 to 2019, which emitted 4.93 ± 1.76, 3.63 ± 0.31, and 2.68 ± 0.31 kg $CO_{2\ eq}$/kg of dyeing fabric production, due to major energy utilization moved from fuel oil to natural gas. Because of policy from government, customer, and company to reduce GHG emission according to UNFCCC, Kyoto Protocol, and Paris Agreement.

3.2 GHG emissions flow in dyeing factory

The dyeing factory in Samut Prakan province, central Thailand, consisted of 3 main processes such as preparation, dyeing, and finishing, including the supporting process section such as boiler, etc. In Figure 2 shows the GHG emission flow of the dyeing factory in 2019. The total GHG emission in 2019 emitted 12,545.53 t CO_{2eq}, which can divide into fossil energy and electricity. GHG emission flow in the dyeing factory showed supporting process unit was the highest GHG emission approximated 9,415.66 t $CO_{2\ eq}$, accounting for 75 % of total GHG emission (Figure 2). Energy intensity in the textile industry found most energy utilization applied in boiler accounting 70 %, followed by process machine 13 %, and water treatment (DEDE, 2014). The main process showed the highest GHG emission in the finishing process, which emitted 1,653.82 t $CO_{2\ eq}$, followed by dyeing, preparation process, 744.52, 731.53 t $CO_{2\ eq}$. GHG emission flow showed dyeing/finishing fabric GHG emissions.

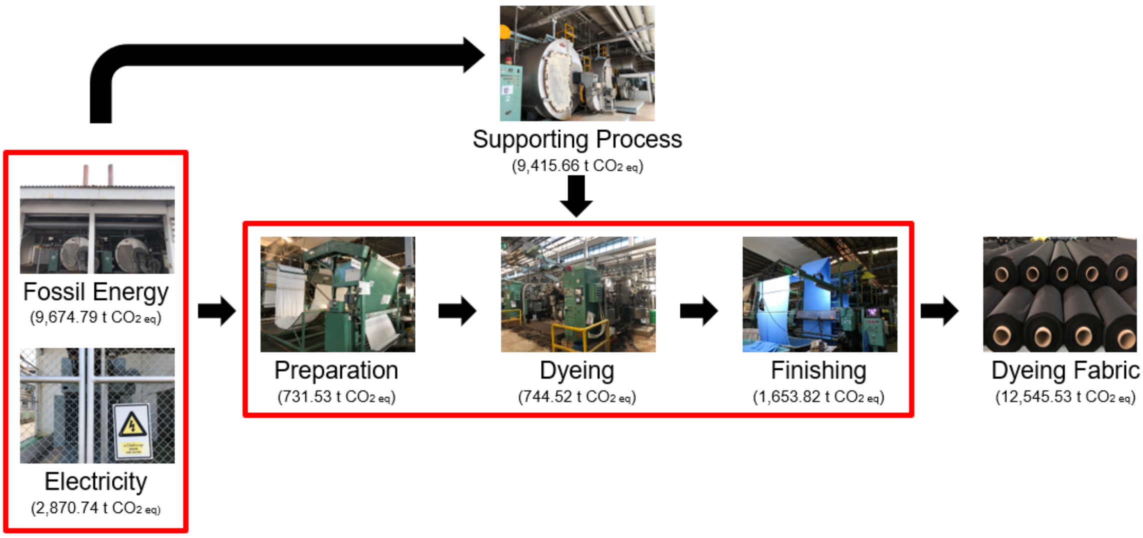

Figure 2: GHG emissions flow in dyeing factory in 2019, Samut Prakan province.

3.3 Mitigation Options

The energy-saving for wetting processes, this study recommends energy-efficiency measures and technologies referred to Energy-Efficiency Improvement Opportunities for the Textile Industry (Hansanbeigi, 2010). A Review of Energy Use and Energy Efficiency Technologies for the Textile Industry (Hansanbeigi and Price, 2012). This study focused on wetting processes, namely preparation, dyeing, and finishing process. The result selected and showed especially the highest energy efficiency measures and technologies in the wetting process in Table 2. The preparation process showed a combined initial treatment in wet processing. This process can save up to 80 % for energy use, followed by the use of counter-flow current for washing estimate of 41 – 62 %, and introducing point-of-use water heating in continuous washing machine estimate 50 %. Dyeing processes found that discontinuous dyeing with airflow dyeing machine can save up to 60 % of machine's fuel use, followed by a selection of hybrid systems estimate 25 – 40 %, reducing the need for re-processing in dyeing estimate 10 – 12 %. Finishing processes showed optimize exhaust humidity can save 20 – 80 % of stenter energy use, followed by introducing mechanical de-watering or contact drying before stenter estimate 13 – 50 %, install heat recovery equipment 30 %, and the use of sensors and control systems in stenter can save 22 % of stenter fuel use.

Table 2: Energy-efficiency measures and technologies in wetting processes

Measures and Technologies	Energy Saving (%)	Payback Period (y)	References
Preparation Process			
Combine preparatory treatment in wet processing	80	-	Hasanbeigi and Price, 2012
Use of counter-flow current for washing	41 - 62	-	Hasanbeigi and Price, 2012
Introducing point-of-use water heating in continuous washing machine	50	-	Hasanbeigi and Price, 2012
Dyeing Process			
Discontinuous dyeing with airflow dyeing machine	60	-	Hasanbeigi, 2010
Reducing the need for re-processing in dyeing	10 - 12	-	Hasanbeigi and Price, 2012
Selection of hybrid systems	25 - 40	-	Hasanbeigi and Price, 2012
Finishing Process			
Introduce mechanical de-watering or contact drying before stenter	13 - 50	-	Hasanbeigi and Price, 2012
Optimize exhaust humidity	20 - 80	-	Hasanbeigi and Price, 2012
Install heat recovery equipment	30	1.5 - 6.6	Hasanbeigi and Price, 2012

The energy management system (ISO 50001) is an approach to implementing systematic improvements in the energy management system. This includes energy efficiency, energy consumption characteristics, and energy consumption. The requirements of this standard apply to the characteristic and energy consumption, includes measurement, documentation, reporting, design, equipment procurement, related processes and personnel, and covers all factors affecting energy performance, which can be monitored and controlled by the factory itself. But it does not define specific performance in terms of energy because it is freely designed to be deployed or integrated with other systems. ISO 50001 is therefore another measure in energy management with an emphasis on the economy (DEDE, 2014). Greenhouse gases – Part 1: Specification with guidance at the organization level for qualification and reporting of greenhouse gas emissions and removals (ISO 14064-1) is another approach of the process of quantifying, monitoring, reporting, and verifying emissions and reductions of greenhouse gases of their own factory correctly and appropriately according to academic principles. This increases the ability to effectively manage the greenhouse gas emissions of industrial factory. It also helps to enhance the potential of entrepreneurs and textile businesses to be able to compete with the world market (DIW, 2016).

4. Conclusions

The textile industry was an important industry in the world. Since this industry still had in demand of population around the world. The textile industry has been reported that be emitters the second-highest GHG emissions after the oil industry. A study found that the dyeing factory was the highest GHG emissions in the textile industry. This study studied GHG emissions related to energy consumption in dyeing factory and provide the guidelines to mitigation options in dyeing factory as followed.

In this study, GHG emissions had been continually increased from 2017 to 2019 in dyeing factory. The main energy related to GHG emission was natural gas, which emitted an estimated 70 percent of total emissions. The second largest GHG emissions were electricity consumption, followed by fuel oil, gasoline, LPG and diesel oil. In the production of dyeing fabric related to GHG emissions in dyeing factory found that production continually increased from 2017 to 2019. The result showed GHG emissions per dyeing fabric were decreasing per unit of production from 2017 to 2019, which emitted 4.93, 3.63, and 2.68 kg $CO_{2\,eq}$/kg of dyeing fabric, since changing energy from fuel oil to natural gas utilization. the main process that emitted highest GHG emissions was the finishing process, followed by dyeing and preparation process.

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