The effects of industrialization on climate change

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ABSTRACT

The greenhouse effect simply is a natural process to balance greenhouse gas concentration throughout the atmosphere. However, due to anthropogenic activities, this natural effect becomes an environmental problem for the entire world. It tends to occur global warming. The world's climate always varied naturally, but climate change largely variates due to the concentration of "greenhouse gases" in the earth's atmosphere since the industrial revolution began. Now overriding this natural variability and leading to irreversible climate changes. If no climate policy interventions are implemented or modified, future climate changes will be caused by harmful effects on Sri Lanka islands. This study focuses on discussing the Sri Lankan contribution to global warming from industries. We mainly discussed four industries' GHG emission sources and further aim to discuss the Sri Lankan rules and regulations and implementation options.

Keywords: climate change, GHG emission, Global warming, industrialization.

1 INTRODUCTION.

What is climate change? According to U.N.F.C.C.C. (1992), climate change means "a change of climate, attributed directly to human activity. That alerts the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods." When we compare about Natural greenhouse effect with the enhanced greenhouse effect, Natural levels of greenhouse gases in the atmosphere are essential for life on earth. Since the industrial revolution, we have increased GHG emissions, mainly carbon dioxide (CO_2), causing an enhanced greenhouse effect. The enhanced greenhouse effect by us has led to global warming (climate change).

When we consider legislation on industries National Industrial Pollution Management Policy was adopted in 1996, and a National Strategy for Solid Waste Management launched in 2000, Environmental Protection Licensing Scheme was an amendment to the gazette and published in 1990. The government institutionalized National Environmental Act No 47 in 1980, and this act established the Central Environmental Authority (C.E.A.) in 1981 for the "formulation and implementation of policies and strategies for the protection and management of the environment in Sri Lanka." [1]. In 1992 The United Nations Framework Convention on Climate Change was established, and the objective is to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. (UNFCC,1992). According to I.P.C.C. (2006), key GHG sectors are energy, industrial processes, and product use, agriculture, forestry, land use, and waste. Here we mainly focus on the effects of industrialization to increase GHG emission. Coal usages of the different industries mainly contribute to climate change. However, according to C.C.P.I. 2020 (Climate Change Performance Index) International Press Release mentioned that the majority of countries are low to deficient performance in emission, and most of them develop renewable energy systems [2].

2 The link between industrialization and climate change.

Global warming gradually increased because of greenhouse gasses. It can be identified these gases like carbon dioxide (CO_2), methane (CH_4), nitrous oxide(N_2O), Hydrofluorocarbons (HFCs), perfluorocarbons (P.F.C.s), Sulphur hexafluoride (SF_6) and water vapor. As mentioned above, the greenhouse effect is natural. However, human activities like industrialization lead to global warming and attendant anomalies in local temperature, humidity, wind speed, precipitation, soil moisture, and sea level. Studies that reveal the ocean have a high contribution to controlling greenhouse gas concentration because the ocean has a storehouse of carbon dioxide, and it controls the movement of this gas to and from the atmosphere. That means the ocean represents a large reservoir for the CO_2 because it covers 70% of the earth's surface.

However, that natural event becomes an environmental problem because of human activities. Natural fluxes of CO_2 through the atmosphere and anthropogenic activities like fossil fuel burning and deforestation are also released CO_2 into the atmosphere. The industrial revolution had played a significant role in emitting greenhouse gasses in the past two centuries because human activities led to the use of machines and the mechanization of processes, which were erstwhile performed by hand. So, technological innovations, rapid transportation of economies, territorial expansions, unprecedented population growth, emergency of urban areas, and transformation of the global science system are leads to the beginning of the industrial revolution.

Since the industrial revolution, humans have migrated mainly to the urban areas, and as a side effect, population growth enlarges around urban areas. Because of that, agricultural, industrial practices, and the pumping of greenhouse gasses into the atmosphere tremendously increase. As a side effect, deforestation rises due to land use for the agriculture and urban areas, fossil fuel burning rise to accomplish energy requirements. Fig. 1. shows the connection between industrialization, social behavior, and climate change [3].

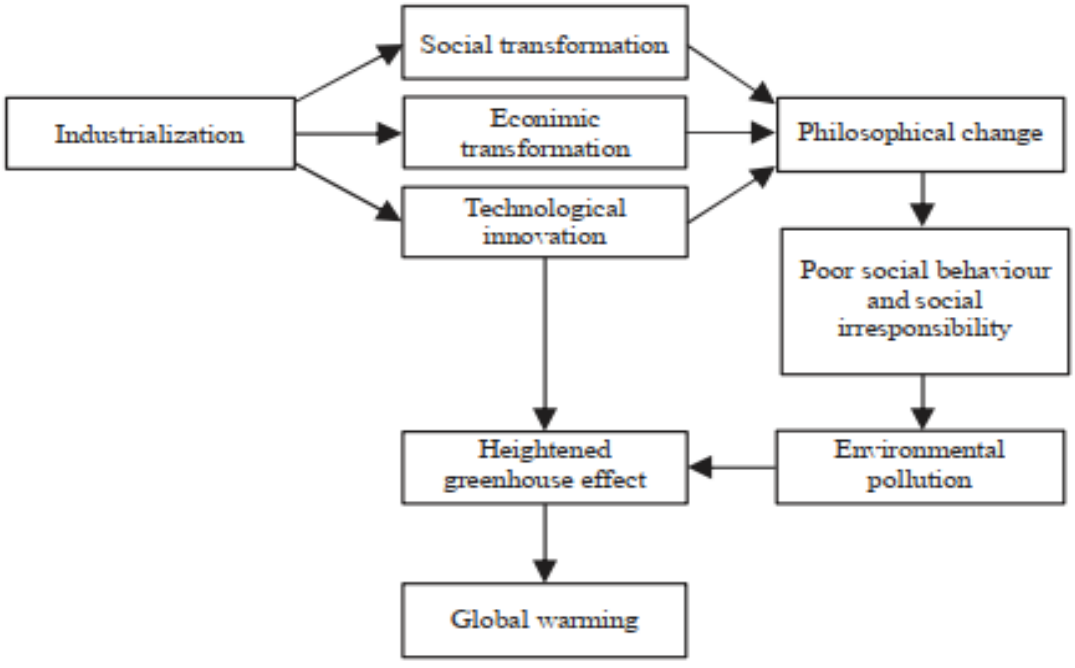

Fig. 1. Industrialization- social behavior- global warming link [3].

The industrialization has opportunities and challenges, but to overcome climate change, we need to concentrate more on the challenges. The main challenge of industrialization is global warming; on the other hand, high energy demand, exposure to dangerous machinery and equipment, and higher industrial waste generation.

3 The GHG emissions from different industries of Sri Lanka.

In Sri Lankan industrial sectors categorize as energy-consuming industries, technology-intensive industries, small and medium enterprises, and micro industries. According to I.N.D.C.s (Intended National Determined Contributions.), key industries contributing to GHG emissions are cement manufacture and lime production [4]. Especially the governmentmentioned to mitigate GHG emission and modernize and facilitate to follow recognized standards like ISO 14000, ISO 14040 series, ISO 14062, design for environment, ISO 14064-greenhouse gas emission standards, hazard Account Critical Control Points(H.A.C.C.P.) or ISO 22000/25 certification [4]. As well as continue fuel switching to biomass in industries, encourage industries to reduce GHG emission by introducing a reward system, and introducing high efficient motors for the entire industrial sector are some of them.

Statistics indicate that CO_2 emissions of Sri Lanka increased from 2,658.58kt in 1965 to 18,393.67kt in 2014, growing at an average annual rate of 4.61%. Sri Lanka CO_2 emission intensity in 2018 was 0.09 tonnes per 1000-dollar G.D.P. CO2 emission per capita of Sri Lanka tremendouslyincrease from 0.53 metric tons in 1999 to 1.14 metric tons in 2018; it indicates by Fig. 2. It is growing at an average annual rate of 4.50% [5]. Methane emitted during production and transport of oil, decomposition of organic waste generated by the industries. Methane gas has 28 times more potent than CO_2. Nitrous oxide emission occurs during the combustion of solid waste and fossil fuels. Halocarbons (HFCs and P.F.C.s) and SF_6 are emitted during the melting and processing of polymers and polymer-based materials and from a variety of industrial processes such as waste management, foam blowing, cement production, and refrigeration.

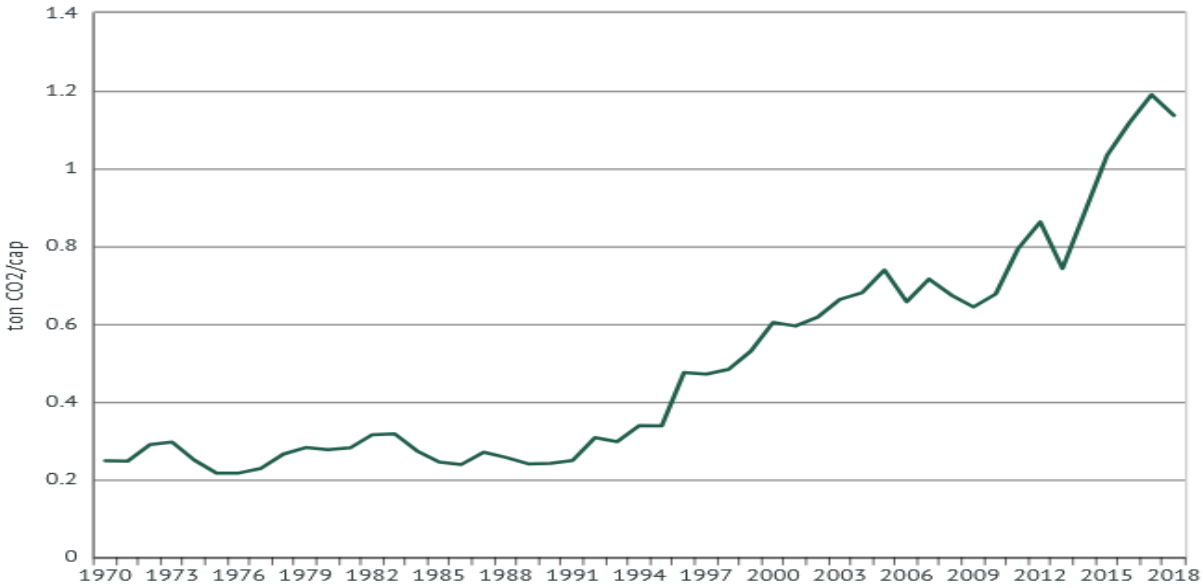

Fig. 2. Sri Lanka CO_2 emission per capita 1970-2018[5].

Sri Lankan annual total electricity demand is about 13,227 GWh and comprises 29% from industries. Electricity generation for the national grid consisting of 900MW of coal power, 1,128 MW of oil-burning thermal power, and 1,860 MW of renewable energy [4]. So this indicates that most of the power generation requirement fulfill by fossil fuels. According to statistics in 2017, total fossil fuel usage for electricity net generation in Sri Lanka was 10.54 billion kilowatt-hours. So, our GHG emissions rise because of the power plants and the boiler operation using fossil fuels in the industries. That means all the industries which are operating in Sri Lanka indirectly contribute to GHG emission. GHG emissions shall aggregate into the two categories, like direct and indirect emission sources. Direct GHG emissions are occurring from sources that are owned or controlled by the organization. Indirect GHG emissions can be recognized as the generation of purchased electricity consumed by the organization. This research paper selects a few industries with high GHG emissions (textile industry, cement manufacturing industry, tea, and rubber). Fig. 3 shows the Sri Lankan industry sector GHG emission [6].

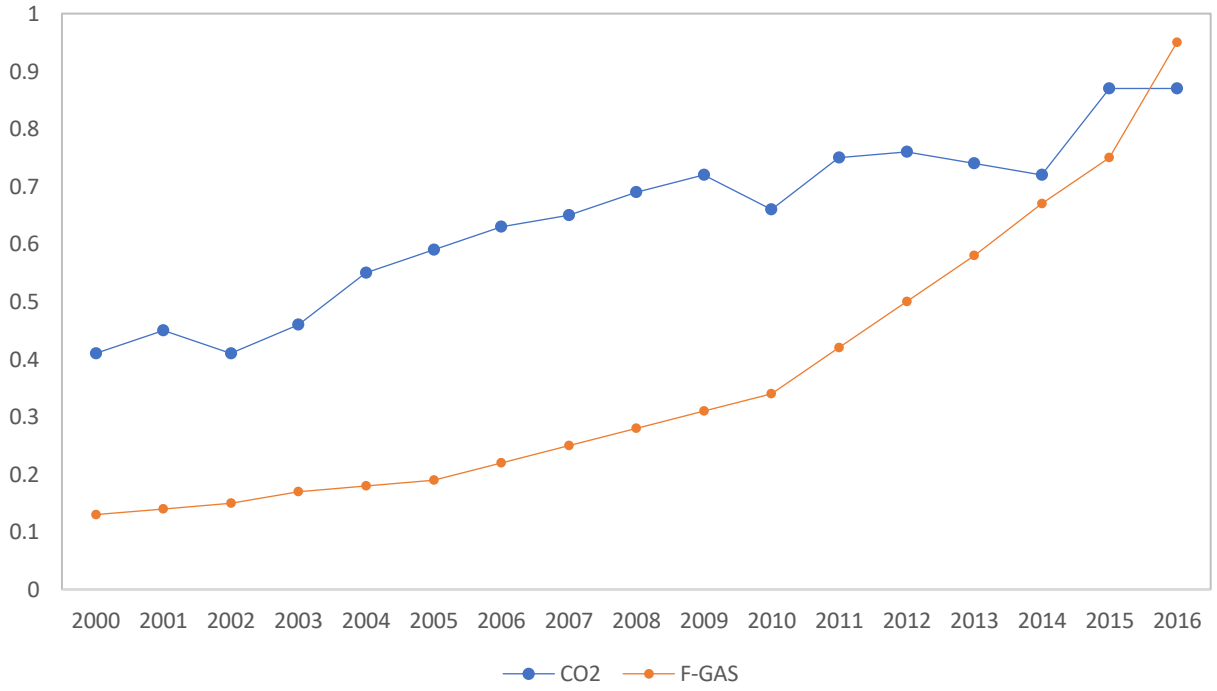

Fig. 3. Sri Lanka industry sector GHG emission [6].

3 Textile / Apparel industry.

The textile and apparel industry in Sri Lanka plays a significant role in the economy. However, also it is an energy-intensive industry sector that releases a large amount of CO_2 to the atmosphere. Under the direct and indirect categories, we can identify all the emission sources. Examples for the direct emission sources in the textile industry are emissions from combustion in owned or controlled boilers, furnaces, vehicles, emission from chemical production in owned or controlled process equipment, and wastewater treatment. Indirect GHG emissions from purchased electricity, upstream transport, and distribution for goods are emission from freight services paid for by the organization.

Today's most of the garment factories play a significant role in sustainable and eco-friendly concepts. However, the production process, like dyeing and finishing, makes intensive use of chemical products and natural resources, and generates excellent environmental problems. The production process steps are yarn manufacturing, knitting, weaving, pretreatment, dyeing, and washing. The wetting process in the textile industries generates a high amount of GHG emission, and regarding downstream products, cotton textiles carry the most GHG emission [7].

Textile materials like synthetic fibers, acrylics made from mineral oils or other hydrocarbons such as benzene, are more energy and water-intensive than polyester, and produce NO_2 emissions. Nylon, polyester is manufactured based on crude oil and natural gas converted to plastic through several chemical processes. When materials convert into fibers, lubricants usually added as the form of spindle oil and antistatic agents. These processes release volatile organic compounds (V.O.C.s), particulate matter, CO_2,N_2O, hydrocarbons, Sulphur oxides, carbon monoxide, acetaldehyde, and acid gases like hydrogen chloride [8]. The GHG emission of different textile products has proportion according to production quantity. Hence, the 2019 Economic and Social Statistics of Sri Lanka report indicates the export of yarn, fabric, and fiber quantity gradually increase up to 2018.That means the quantity of the product is proportional to the GHG emission.

3 Cement industry.

One of the leading industries which operate in Sri Lanka is the cement manufacturing industry and cement processing plants located in the Galle, Puttalam, and Trincomalee. Around this cement industry, environmental pollution is playing a significant role, especially GHG emission is very high because of the production process. Studies reveal 0.613 tons of CO_2emission from one ton of clinker's production. The main production processes are mining, crushing, and grinding raw materials, and then calcining the materials in a rotary kiln, cooling, resultant clinker, mixing the clinker with gypsum and milling bagging the finished cement. Power consumption, emission of fuels (CO_2, NOx, SO_2, and C.O.) mostly happened from the kiln process [9].

Mainly GHG emission factors consist of the fuel gasses are CO_2, N_2, SO_2, CO, NOx, water vapor, and micro components. Gas emission occurred within two stages. The first one is calcination, which emits CO_2 with water vapor during CaO formation. The second one is fuel combustion, which emits carbon, hydrogen, sulfur, and nitrogen in mixing fuel with oxygen. In 2014, Sri Lanka Carbon emission by the cement industry has increased up to 256 thousand metric tons[10].It indicates by Fig. 4.

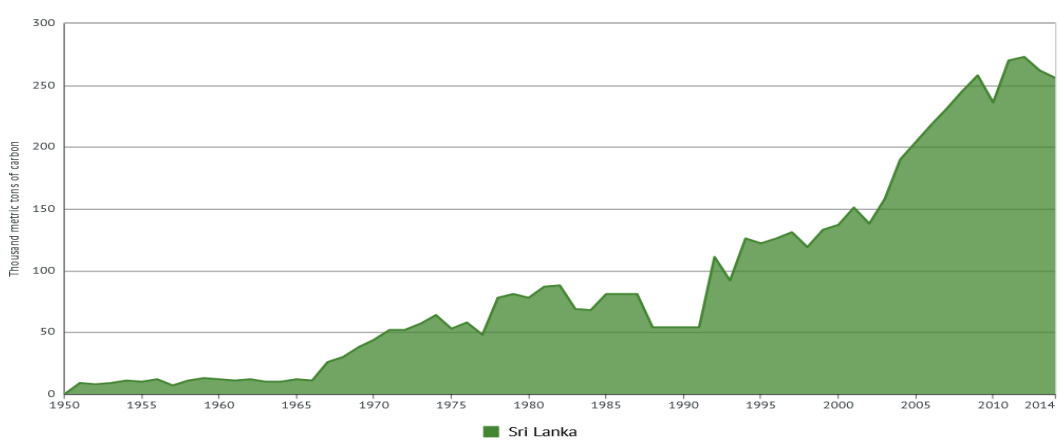

Fig. 4. Sri Lanka fossil fuel CO_2 emission from cement production [10].

3 Rubber Industry.

Rubber Products are one of the most significant export agricultural products in Sri Lanka. As a country, it is also a good source of income, and we produce one of the best quality natural rubber. In Sri Lanka, our rubber production is about 82560 metric tons per year, and we export 13982 metric tons of rubber products (R.R.I.S.L.,2018).Those are crepe, RSS (Ribbed Smoked Sheet), T.S.R. (Technically Specified Rubber), reprocessed rubber, and finished products(Dipped products, tires). From rubber plantation to final products, it contributes to GHG emissions. In the rubber industry, these emissions happen due to plantation, transportation and raw rubber processing stages such as,

- Use Diesel for transportation (From the plantation to Raw rubber processing facilities and then to the rubber product manufacturing industries).
- Use electricity and Diesel In raw rubber processing Factories and latex centrifuging industries.
- Use electricity for milling operations and biomass for drying in crepe and RSS rubber factories.
- Use electricity, fuel oil, Diesel, and biomass in value-added rubber industries.

Table 01 indicates GHG emission from the rubber plantation and Fig. 5 indicates the GHG emission from different phases in the rubber sector [11].

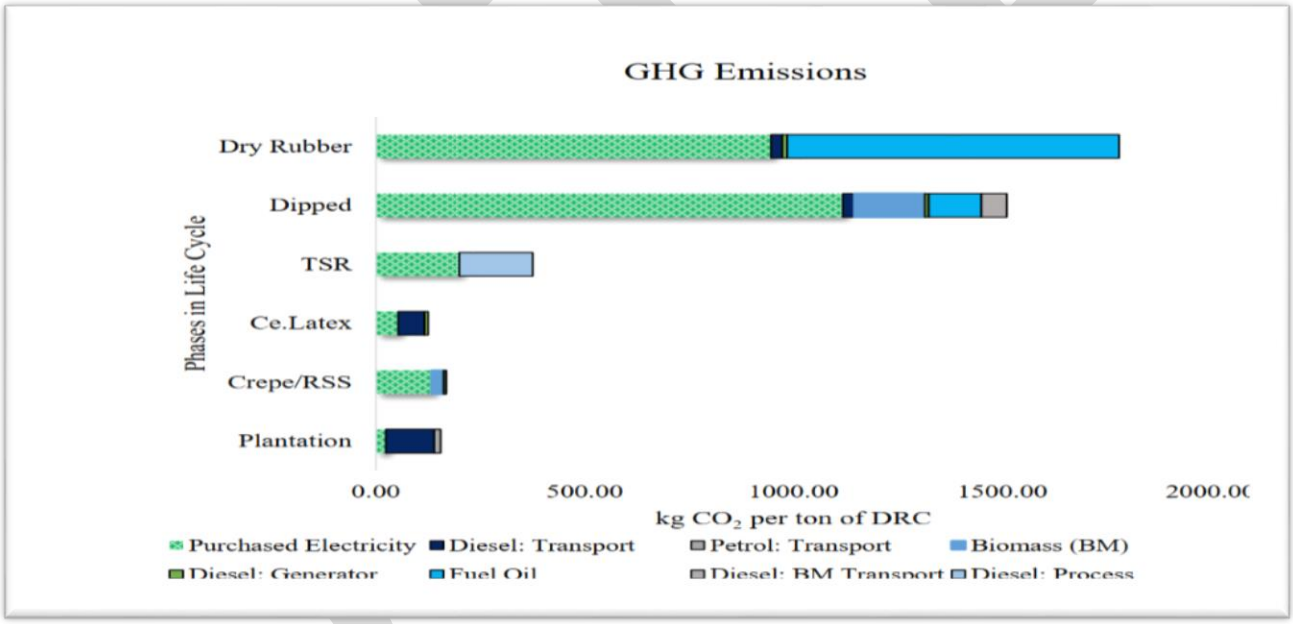

Fig.5. GHG emissions from different phases in the rubber sector [11].

Table 01. GHG emission from the rubber plantation [11].

Annual (GHG Emission Source)	GHG emission (kg CO_2e (ton DRC)$^{-1}$)
	Mean
Purchased Electricity	23.6±15.3
Diesel use	116±42.6
Petrol use	16±11.3
Total Emission	155.6±47.4

3 Tea Industry.

Tea is also one of the leading agricultural products that export to foreign countries and earn a good income. In 2015, Sri Lanka produced 328800 metric tons of tea that were worth about 1339 million USD. There are three tea categories in Sri Lanka. Those are high grown, medium grown, and low grown. Categories are based on the growing elevation and cultivated across 14 districts. GHG emission from the tea industry happen in many ways such as,

- Green leaf transportation
- Processing of tea and packaging
- Energy sources in tea plantation
  - Electricity from national supply
  - Diesel, Petrol for transportation and generators
  - Biomass

Table 02 indicates the GHG emission from the tea sector, and Fig. 6 shows GHG emission from different phases in the tea sector [11].

Table 02: GHG emission from the Tea Sector [11].

GHG source	Kg CO_2e per ton of made tea			
	High Grown	**Medium Grown**	**Low Grown**	**Uva Region**
	Mean	**Mean**	**Mean**	**Mean**
Plantations:				
Purchased Electricity	33.68±14.83	42.05±23.43	65.37±59.27	53.88±25.65
Diesel	18.4±17.05	20.15±8.69	66.38±59.39	19.43±7.53
Petrol	7.8±4.01	12.87±6.09	38.11±29.01	12.89±5.69
Green Leaf Transportation:				
Diesel	33.84±15.37	60.38±18.64	58.71±38.86	83.33±32.63
Tea Processing:				
Purchased Electricity	307.76±42.69	317.64±59.98	284.74±70.58	340.9±113.15
Diesel (For generator)	8.51±1.28	0.02±0.01	0.01±0.004	0.01±0.01
Biomass (CH_4, N_2O)	70.741±3.13	85.18±11.38	76.72±17.53	78.47±28.22
Diesel (Biomass transport)	33.53±16.72	15.34±14.27	13.06±9.62	10.94±7.73
Total	514.27±68.66	553.62±108.34	603.1±191.58	599.86±135.06

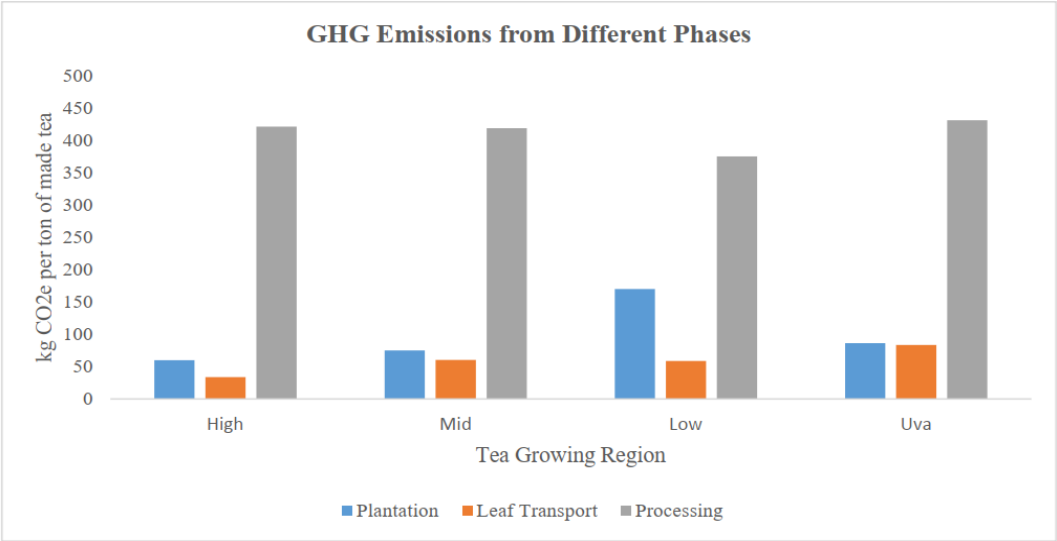

Fig. 6. GHG Emission from Different Phases in the Tea Sector [11].

4 CONCLUSION.

For this research paper, we only use a few significant industries that operate within Sri Lanka, not only these but also many industries contribute to release GHG gases into the atmosphere. Here we observed high GHG emission occurred due to the electricity purchasing because there has been an increasing trend in the use of petroleum-based fuels- coal and liquid petroleum fuels in the energy sector. Therefore, the I.N.D.C.s report indicates, as atarget to achieve a 20% GHG emission reduction in the energy sector for the period 2020-2030 [4]. It indicates different modes of intervention under the energy sector, such as the establishment of large-scale wind (514 MW), solar (115 MW), and biomass (105 MW) power plants. The remaining emission could be offset by participating in or implementing renewable energy contexts such as mini-hydro projects, fuel switching projects, wind power projects. Then industries can indirectly contribute to reducing GHG emissions from their energy consumption section.

All the industries must follow the GHG management hierarchy for the factory premises. It indicates four steps, such as avoid, reduce, replace, and offset. Mitigate Green House Gasses; industries can follow mitigation options. They need to give more priority to avoid the GHG emission, for they can use the C.P. concept, ISO standards, and sustainable and eco-friendly concepts for the factory premises. Environmental Impact Assessment (E.I.A.), Energy Management System ISO 50001, and ISO 14064 Environment Management System should implement to drive the organization towards GHG emission reduction measures. Energy efficiency improvement in the factory facility can be achieved by using more efficient equipment(inverter type air conditioners), daylight much as possible in terms of reducing electricity consumption for lighting purposes, Optimization of internal and external transport, minimizing waste generation using composting. Offsetting the remaining emission is the consecutive step to achieve carbon neutralization within the factory.

Possible carbon offsetting applications that need to implement within the facility are essential.Apply renewable energy for factory premises such as biomass fired steam boiler, biofuel boilers, solar P.V. for electricity, solar thermal for water heating and replacement of L.P.G. usage for cooking purpose with biomass or locally generate biogas sources. Implementation of forestation projects or managing a forest with the capacity to absorb an equivalent amount of carbon and maintain a plantation with timber/economic value. [cultivation of rubber as

a mono-crop for 30 years to produce C.R. accounts for -1544.71 CO_2 eqton of net GHG emission (total emission-total sequestration) per hectare with an average annual value of -51.49 CO_2eq ton per hectare.]

Monitor the O_2 content in flue gas regularly with a flue gas analyzer or a ferrite kit to maintain the air-fuel ratio by adjusting the damper of the F.D fan. Nevertheless, Sri Lankan industries have not proper flue gas control technologies, Sox, NOx, and CO_2 capturing systems like scrubbers and S.C.R. mechanisms.Fluorescent bulbs incandescent bulbs have been replaced with L.E.D. bulbs. Replace old refrigerators by C.F.C. free units and eco-friendly fridges.Sri Lanka has NO_2,SO_2, and O_3 capturing sites in the Dutuwewa and measurement of particulate matter concentration in ambient air monitoring sites in the Doramadalawa [12].

After all these studies, we identified that anthropogenic activities have more responsibility for climate change. Due to the rising of GHG emissions, global temperature becomes caused by climate change. If we introduce a continuous monitoring system to measure industrial emission, we can reduce our contribution to global warming. For that, proper Environmental assessment methods, industry evaluation methods, and green reporting systems need to implement for the industries. Moreover, we need to establish rules and regulations more strictly.

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