

Carbon Footprint Analysis: Promoting Sustainable Development

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Abstract: An overview of the carbon footprint analysis indicates a measure of sustainability in various countries. Their carbon footprint values, carbon emission in MtCO₂, carbon per capita emissions used to identify their sustainability patterns by comparatively observing the world's top rank countries, and their root causes. The greenhouse gas reduction has become a key concept in the global contest because the carbon footprint values are different from one country to another. China, European countries, the United States like developed countries have a responsibility for more carbon emission rather than developing countries. India also has large CO₂ emission due to a larger population, likewise, the countries and their values and the certain causes for that have described thoroughly in further topics in this paper. The carbon footprint is one of the most important "climate change" environmental sustainable manner indicators. That used as an evaluation tool to measure environmental impacts. How the climate changes are happening, what are the causes for that and what are the existence impacts and how we interpret the future risk according to the carbon footprint value of certain nations have been discussed in this paper.

Index Terms: carbon footprint, carbon neutrality, greenhouse gas effect, per capita emission, sustainability development

1 INTRODUCTION

The carbon footprint analysis shows the amount of greenhouse gas emission assessments and evaluations. There are many greenhouse gasses such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF₆), etc. Among them, CO₂ is the predominant contributor because the emission rate of CO₂ is higher than other gases. The releasing amount of CO₂ results from an individual, organization, community, or nation. Human activities such as fuel combustion during vehicle transportation, power generation, construction operations, and other industrial operations have been recognized as major CO₂ emission sources.

Environmental protection has become a trend, especially after the significant negative consequences of economic development since the industrial revolution. People identified more and more greenhouse gas emissions cause many tragic situations to occur for humanity, animals, and the whole of Mother Nature. Hence people develop the term "Carbon Footprint" (CFP) by addressing the impact of human activities on the environment in the sense of climate conditions in terms of the total amount of CO₂ emission caused by an organization, product, or nation. That is a tool, and that can be used to identify high emission root sources and their emission, weaknesses, etc. According to the calculated CFP value, emission can be eliminated or improved the weaknesses by gaining relevant actions according to the mitigation targets. That's why CFP called an indicator of sustainability development.

Sustainability development is the growing principle among governments, nations, policymakers, researchers, organizations, and the public. Sustainability development means the development that acquires the present's needs without compromising the ability of future generations to meet their own needs. Observing CFP values can predict future risks than can easily implement measures, policies, and targets to reduce CFP values by obtaining present and long-term achievements in a sustainable manner.

2 CARBON FOOTPRINTS OF DIFFERENT COUNTRIES

The countries with larger populations, larger economics, larger manufacturing & process industries, or above all tend to be the largest emitting of greenhouse gases that mean have larger carbon footprint values because their carbon dioxide emitting is higher than other greenhouse gases. There are countries with the

largest total emissions and the highest per capita emissions to identify where the position they have been among the other countries in a global contest to carbon footprint values. Fig.1. shows where most of the world’s CO₂ emissions come from sorted by country and ranked as the world’s top 10. The data in Fig.1 shows absolute emissions of countries. Large economies such as China, the United States, and India have almost half the world’s emission, which means they are the major emitters globally.

Territorial (MtCO₂)

Rank	Country	MtCO ₂
1	China	9839
2	United States of	5271
3	India	2457
4	Russian	1647
5	Japan	1188
6	Germany	798
7	Iran	686
8	South	641
9	Saudi	633
10	Indonesia	584

Fig.1. the World’s top 10, CO₂ emission countries [1]

The largest carbon dioxide emitter considered as China, and it is 30% of emission in total global emission [2]. China mainly depends on coal as their primary energy source for their industries and the construction sector, cement production, more petroleum refineries and steel production, and other activities that highly cause more CO₂ emissions. Aside from the CO₂, china has emitted like methane and nitrous oxide in larger quantities with high global warming potential than carbon dioxide.

However, not only China, European countries, and the United States are also responsible for more carbon dioxide emissions, which means more pollution & climate crises. Urbanization, Industrialization, population growth, and Deforestation are the cause of the significant concept for the high greenhouse gas emissions in all countries. But the world’s population isn’t distributed equally across the globe. Hence the CO₂ emission should divide by own population value of each country to get the carbon emissions to shake out on a per capita basis. Fig.2 shows the world’s top 20 countries with the highest emission per capita.

According to Fig.2, the highest per capita emitters are Qatar, UAE, Kuwait, and Bahrain because of small populations' result, producing Greenhouse gas-intensive values highly for those countries. The small-islands also have the highest rank, such as Trinidad & Tobago, Singapore, etc. Those countries are well industrialized with a low total population. Hence their per capita values are high. Some countries have larger economies with significant fossil fuel resources such as Estonia, the Czech Republic, and Russia. When counting only energy-related CO₂ compared to other all gases and their primary power source primarily consists of carbon compounds and refining more and more created high CO₂ levels in the atmosphere.

The carbon footprint per capita values are changing according to the country's rich or poorness when considering only energy-related carbon dioxide emissions are considered. The CFP tends to increase with

higher income because these impoverished countries have many disparities rather than rich countries. The land-use change also affects per capita emission. Geography is also related to it because we can avoid CO₂ emission with absorption by plants and trees. The majority of forest cover lands are not in today's century because most of them are influenced by human activities, and they use that land for their purposes.

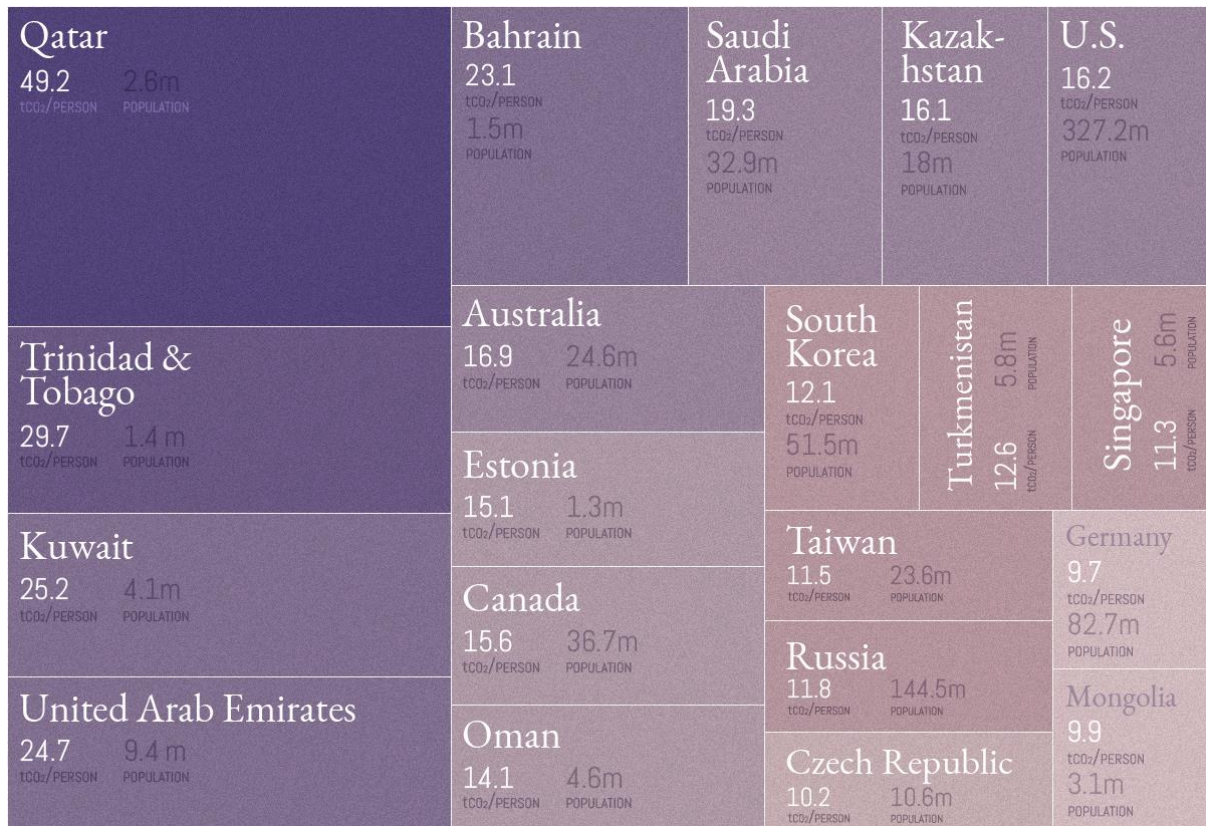


Fig.2. the highest CO₂ emission per capita basis top 20 countries [3]

Compared to all greenhouse gas per capita emissions, not only CO₂ but also CH₄ & N₂O mainly from agriculture and other activities cause larger GDP in developing countries than developed countries, which causes the gap between per capita emissions in various countries. Developing countries have continuously increased carbon footprint values. The developed countries always have high per capita because many industries and urbanized populations are in the maximum contest because they are all the resources. The higher birth rates or immigration can significantly cause greenhouse gas emission growth. For example, the US, Canada, and Australia are highly industrialized with a higher population growth rate and more people willing to immigrate to those countries for their prosperity, and now that becomes a trend as “New World” with high per capita emission.

Some countries have advanced developing economies with high per capita emissions rather than well-industrialized countries. For example, Singapore ranks higher than many European countries, and South Korea has per capita value like the United Kingdom. When considering Taiwan and Russia, the population values are largely different, but their per capita values nearly equal [4]. The countries more on the planet are carbon positive, but some countries are carbon-neutral, that means their production of greenhouse gas is equal to their consumption. There is only one carbon negative country in the world. It is Bhutan. The carbon-negative means the removal of more greenhouse gases from the atmosphere that is emitted.

Bhutan is a developing country in Asia, the state covers an area of 14 824 square miles and has a population of around 800 000. More than half of Bhutan is under forest cover. The trees are in the forest absorb carbon

dioxide during the photosynthesis effect that emits by civilization. The government always uses hydroelectric power rather than fossil fuel burning power plants, most prefer for electric vehicles and highly protected their forest cover by strict laws and regulations, etc. All the mitigation measures they have taken for their prosperity and now become the world’s only one carbon negative country [5]. The other countries who are not gaining the carbon neutrality yet have undergone various mitigation practices and legislation other than that they have a principle called “carbon price”.

The price of carbon or carbon trading is the country that has high emissions of carbon can purchase from other countries, and having fewer emissions of carbon can sell for other countries. There are two methods for carbon pricing called emissions trading systems (ETS) and carbon taxes. The ETS function is the total greenhouse gas emissions low industries can sell to larger emitting industries willing to purchase while creating supply and demand. The carbon taxes has a pre-defined price on carbon. There is a set price on carbon according to the tax rate on greenhouse gas emissions. Their carbon tax is not pre-defined. By using those principles, the polluters can continue their polluting because they pay for it. But the overall environmental goal can be achieved through this principle in the least cost way to society. At the same time, low carbon emitters can earn money by achieving their economic growth. This is a really good principle when the countries that cannot mitigate their emissions after some level. Then we have to use this phenomenon and earn advantages for both sides while protecting the environment too.

3 CARBON FOOTPRINT ANALYSIS FOR THE SRI LANKA

Fig.3 shows Sri Lanka’s greenhouse gas emission. According to Fig.3, Sri Lanka’s greenhouse gas emissions by rapidly changing from 1990 to 2015. The CO₂ emission is majorly increased with this period rather than other gases.

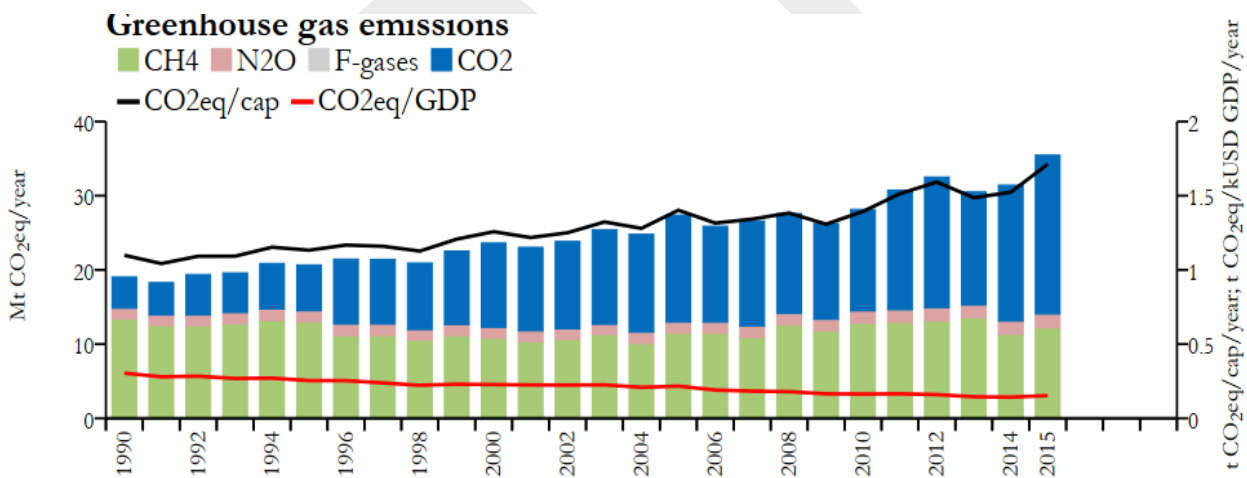


Fig.3. Greenhouse gas emission of Sri Lanka[6]

The energy emissions increased largely with electricity generation and transportation contribution. The municipal solid waste, domestic and commercial waste, and industrial hazardous waste contribute to many GHG emissions by un-standard waste disposal methods like open dumpsites and landfills. The burning of hospital waste also highly cause for GHG emission in Sri Lanka.

Fig.4 shows Sri Lanka’s GHG profile in 2011. The total GHG emission in Sri Lanka by 2011 is 45 MtCO₂eq. According to the World Resources Institute Climate Analysis Indicators Tool, The sector emissions in Sri Lanka was dominated as follows, energy (40%), waste (28%), land-use change and forestry (15%), agriculture (14%), industrial processes (3%). Sri Lanka has 2.16 tCO₂ per capita. In the world ranking, we are in 121st place [6].

Sri Lanka’s greenhouse gas emissions grew by almost 43% from 1990 to 2011. The annual average change was 2% for past periods. When observing Fig.4, the major contributor is the energy sector for greenhouse

gas emissions in the past decades. In the energy sector, electricity and transportation is the major contributor with almost 80%, within that 48% of all CO₂ emission due to fossil fuel combustion through the transportation sector. In Sri Lanka two and three-wheeled vehicle usage is higher than other vehicles.

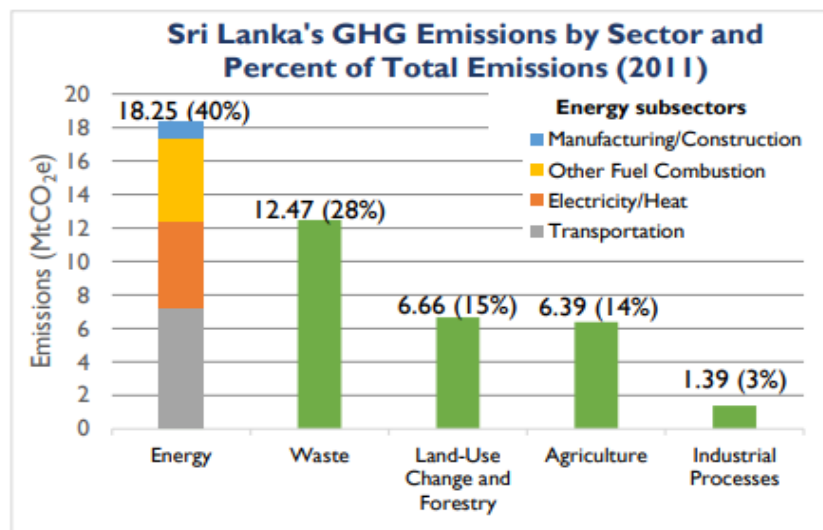


Fig.4. Sri Lanka's GHG Emissions by sector and total emission percentages [6]

And also in Sri Lanka, the power generation capacity is 4050MW. It consists of 900MW of coal power, 1375MW of hydropower, and 442MW of non-renewable energy sources. According to that, a considerable quantity of electricity generation is gain from coal-burning, and that causes major greenhouse gas emissions in Sri Lanka [7].

4 IMPACTS ON CLIMATE

The climate changes always related to carbon emission and carbon footprint analysis. The carbon footprint or carbon emissions from various activities or any organization accumulate in the atmosphere directly affects the biologically productive space. The large quantity of carbon dioxide emissions needs a large amount of productive land to absorb those carbon dioxide emissions. In simply, it shows how much bio-capacity we need to neutralize the emissions of untreated carbon dioxide waste to avoid carbon build up in the atmosphere. Climate problems create because the planet does not have enough bio-productive space to neutralize the CO₂ emission.

Climate change refers to the warming of the climate as a consequence of an increase in greenhouse gases. The human enhanced greenhouse gas effect (The greenhouse gas layer becomes thick due to human activities. When the solar radiation comes to the earth, due to the thickness of the greenhouse gas layer, less heat escapes into space and more re-emitted to the earth's atmosphere) is the key cause for the increase in earth's temperature. If the CO₂ percentage goes high, it has a directly proportional relationship with the earth's temperature. That increase in temperature in a global manner called global warming. That leads to changes in temperature, humidity, wind speed, precipitation, soil moisture, and sea level, and also it causes many disasters like catastrophic weather events. To combat global warming, reduce the carbon footprint is much essential.

In furthermore about the temperature of the planet, the global mean temperature is rising, and it rose by 0.7°C in the 20th century, and continuous on an upward trend. If the temperature increases of 2°C above the pre-industrial levels, the changes cannot be reversible, and it will become beyond the controllable manner.

Suppose the eventual temperature change and CO₂ concentration goes high [8]. Fig.5 shows how global temperature trends from 1988 to 2017 in Celsius per decade.

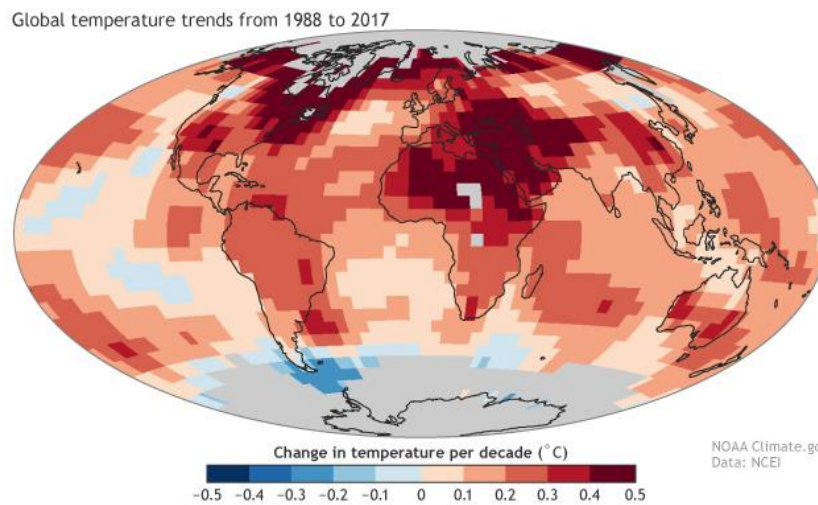


Fig.5. global temperature change per decade[9]

Food – falling crop yields in many developing countries, rising number of people at risk from hunger, finally entire regions experience major declines in crop yield.

Water – small mountain glaciers disappear worldwide, significant water availability changes, decrease in the runoff in mainly African countries, sea-level rise threatens major world cities.

Ecosystems – coral reef ecosystems eventually irreversible damage, the collapse of the rainforest, many species face extinction and a large fraction of ecosystems unable to maintain current form.

Extreme weather events – the rising intensity of storms, forest fires, droughts, flooding and heat waves

Risk of rapid climate change and major irreversible impacts – the onset of irreversible melting of the Greenland ice sheet, risk of weakening of natural carbon absorption, large scale shifts in the climate system[10].

Another adverse effect of GHG or high carbon footprint value is ocean acidification. The ocean's acidity means its pH scale value decreasing since the beginning of the industrial era. That is directly affected by the aquaculture ecosystem and its production. The agricultural activities and over-exploitation of land resources will negatively impact multiple pressures, including climate change, on the ecosystem and society. The farming activities also advanced with high technologies, and more land uses for that becomes more and more release in greenhouse gases. In recent times, the COVID-19 pandemic makes an unprecedented change in global behaviors, including reducing industrial processes, power generation, and transportation. Due to this, temperature rise in 2°C is assuring the planet remains under the threshold while recovering the ozone layer depleting and healing other impacts made by the human activities. This shows us the activities created by the human that badly affect the environment and climate change. Those are having strong bonds among them hence to protect the environment; we should break down the bonds related to greenhouse gas emissions.

5 CARBON FOOTPRINT ANALYSIS IN THE SENSE OF SUSTAINABLE DEVELOPMENT

Sustainability simply shows how we should manage our resources efficiently while they preserve for future generations. The carbon footprint values can also predict present consequences and future risk implications by using strategic decisions. Hence we say, the carbon footprint values show the measure of sustainable development as a nation, organization, or product.

The term sustainability describes three aspects called environmental, economic, and social. That implements the preservation of natural resources; protect the environment, leading to economic growth by improving and maintaining the quality of a people's life. Hence, to achieve quality life mentioned above, we have to mitigate impacts created under certain three aspects. The developing countries contribute rapidly rising emissions that mean they have high carbon footprint values and higher climate issues in the sense that it is a development issue. Already in practice, climate change & crisis were established all over the planet. Hence the development process would be reversed; severe social, political, and economic aspects should be sustainably changed for the foreseeable future.

A reduction in carbon emissions requires a reduction in a parameter directly caused for GHG emissions such as population, income, energy intensity, carbon intensity, etc. The highest carbon footprint values are not favourable with sustainable development. The countries established sustainable development goals in the sense of reduction of the CFP values. For example, the European Union committed to reduce GHG emissions by 20% by 2020, compared to the value of 1990. Not only Europe but also Rumania has the same 20% reduction goal. Likewise, most countries, along with worldwide have certain sustainability goals to reduce their CFP values towards the protection environment from hazardous events accruing by GHG emission [11].

The accurate carbon footprint value of a nation helps to understand the limitations of resources, sources of emissions, energy consumption, and the number of emissions, etc. that is a summarized indicator of a certain nation. That value can use for decision-making aspects and making legislations towards environmental protection. As an example, the activities that have a large carbon footprint produce many greenhouse gasses that have a large impact on the environment. Hence, we have to understand the major activities within the country and cause major greenhouse gas emissions. Then we have to suggest what are alternative activities that we can have to reduce carbon emission. Then we have to take decisions and make legislations towards the concept called a negative carbon footprint. Then we can reverse most of the impacts already exists within the country, and also we can have a sustainable future for our future generations. Hence, most countries worldwide have identified the importance of the carbon footprint as a tool for measuring sustainability.

6 CONCLUSION

The world's top CO₂ emission country is China, but the world's top CO₂ emission per capita basis country is Qatar. Most countries have carbon footprint values, but one country already achieves carbon negative footprint values while others try to reduce their carbon emissions. The carbon footprint values are different from one country to another because there are many causes for population, economy, land use, no manufacturing and process industries, birth rates, immigration trends, etc. The greenhouse gas emission and carbon footprint values become high, cause major impacts; some of them create extremely irreversible impacts which are hazardous to Mother Nature.

Environmental impacts – climate change, resource depletion, land use, water use, biodiversity, ozone depletion, toxicity, acidification, etc.

Social impacts – human rights, working conditions, health and safety, cultural heritage, etc.

Economic impacts – material cost, labour cost, etc.

Climate change is the most leading problem globally because it is caused by global warming, extreme weather events, biodiversity depletion, and the bad effects on food, water, ecosystem, etc. In simply, the path of the carbon footprint value to sustainability is, understanding the footprints, gathering information to reduce footprints, the relevant options for actions, the resources available, and measuring the progress for our generation while preserving them to generation come. If there is any action to reduce GHG emission is welcomed because there is an extreme need to shift from the actual development to a sustainable lifestyle by reducing negative impacts. Along with any type of emission like direct, indirect, upstream, downstream or any, that emission should include monitoring, maintaining, developing by adopting efficient systems for land use planning, industrial plants, projects, forestry and protection of all-natural resources will be expected for carbon emission reduction, by promoting and supporting sustainable development.

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