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# Carbon Foot Print: An Ideal First Step for Mitigating Climate Change

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**ABSTRACT:** Humans leave a "carbon footprint" when they emit a certain quantity of carbon dioxide or its equivalents into the atmosphere. The sectors accountable for the carbon imbalance have been identified by an assessment of carbon emission and sequestration inventories. At more granular levels, this would facilitate the execution of suitable plans for the management and mitigation of climate change. Transportation, power production, and household soil are the three main contributors to India's carbon emissions. Carbon foot print helps in identifying the most urgent need strategies to be implemented to mitigate/ nullify climate change.

**KEYWORDS :** Green House Gas (GHG) emissions, Carbon Footprint, Climate Change, Renewable Energy

## 1. Preamble

The carbon cycle helps to keep the world at a constant temperature by controlling the amount of carbon dioxide in the air. The continued existence of temperature on Earth that is hospitable to human habitation is made possible, in part, by the greenhouse effect. Too much carbon dioxide in the air might cause the world's temperature to rise, which could have disastrous consequences. As the climate and global warming crises continue to worsen, there is an increasing need to put restrictions on the production of greenhouse gases (GHG) that are caused by humans and to lower the amounts of GHG in the atmosphere. This is a growing necessity as the climate and global warming crises continue to worsen (IPCC, 2022). The term "climate change on a global scale" denotes the gradual and consistent elevation in the mean temperature of the Earth, resulting from certain gases that linger in the atmosphere over an extended duration. These gases encompass carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (PFCs), sulfur hexafluoride (SF<sub>6</sub>), and hydrofluorocarbons (HFCs).

If weather patterns changed because of global warming, a great number of species would either become extinct or face an extremely high risk of extinction. The expansion of the global economy in 2021 resulted in a rise of 4.8% in the amount of carbon dioxide emissions produced by the energy sector all over the world when compared to the previous year. In spite of the rise, emissions in 2020 were still lower by 1.2% (or 400 Mt. reversing 80% of the decline) that was anticipated to occur. The potential for negative climatic impacts might grow if emissions keep increasing at their current pace, as this could cause the carbon cycle to lose dynamic equilibrium, due to the urgent need to reduce carbon emissions shown in **Figure1**. It shows that while simultaneously increasing the amount of carbon that is sequestered, appropriate social, economic, and technological action is urgently required.

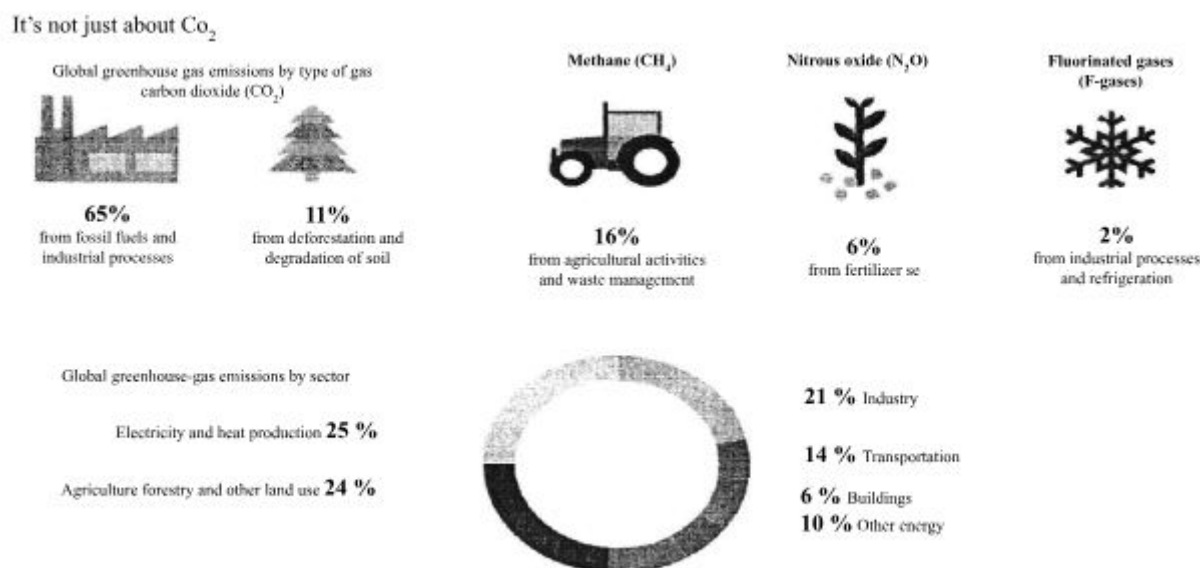


Figure 1:Description of major Emission point of carbon enhancement (Source: Reuters)

There is a range of conceptual frameworks for reaching carbon neutrality; however, each of these frameworks fails to account for the intricacies of ecological, social, and economic systems and their interplay. Consequently, achieving carbon neutrality will not be possible. In order to figure out how to reduce emissions of greenhouse gases (GHG), it is important to find out where those emissions are coming from and where they're going in a group of towns. The use of a participatory approach to the construction of villages, in the quest of carbon neutrality is examined, along with some of its potential benefits and drawbacks, and some specific instances are provided. [1][2]

According to the IPCC's Special Report on Global Warming of 1.5°C, "carbon neutral" denotes that an organization has offset its annual carbon dioxide emissions by carbon dioxide elimination technology. In other words, there would be no carbon dioxide emissions at all. [3] The term "carbon neutral" was first put out in the Special Report on 1.50C Global Warming. To attain "carbon neutrality," a requisite 45% decrease in greenhouse gas emissions from the levels observed in 2010 must be accomplished by the year 2030.

Meanwhile, by the year 2050, we hope to have realized net-zero CO<sub>2</sub> emissions. The primary goal of the endeavor for carbon neutrality is to ensure that the increase in the global average temperature does not exceed 1.5 degrees Celsius by the close of the century. Achieving carbon neutrality would be a huge step forward in protecting our planet's ecosystems and combating climate change [4]. Additionally, it helps in preventing further species extinction and preserving the ecosystem. The worldwide economy has reached a new high point as a result of the quest for carbon neutrality, which has accelerated the transition toward a low-carbon and ecologically friendly energy resource system. Carbon neutrality may have many positive effects, including a 2.4% increase to global GDP and the creation of 7 million energy-related employment, according to the Energy Transformation 2050 study by the International Renewable Energy Agency. [5]

### 1.1 The Significance of COP26 summit in Glasgow

Presently, the unsettling truth about carbon-based activities and the outcomes, ramifications, and repercussions of those actions can be found everywhere you turn in the media. Carbon is to blame for a wide variety of catastrophes that threaten the Earth and the people who live on it, such as climate change, global warming, rising sea levels, disappearing lakes, melting permafrost, decreasing biodiversity, extreme floods, famines, and wildfires. Carbon is the culprit behind all of these problems. Carbon is becoming an increasingly central issue in contentious political debates that have repercussions on a global scale [6].

When the two-week climate summit in Glasgow, United Kingdom, began on October 31, 2021, and was attended by many leaders from around the world, ends, the focus of the world once again turned to the climate. Multiple analyses have shown that there is still no agreement among world leaders on how to keep the temperature of the planet below 1.5 degrees Celsius by 2030. In order to mitigate the most severe consequences of climate change and cut emissions of



greenhouse gases by 55 percent, this is crucial, as stated in the Paris Climate Agreement of 2015. If the promises and duties to reach net zero emissions by the year 2050 are not fulfilled, it would not come as a surprise.

The goal is to improve our understanding of the size of the carbon footprint left behind by human activities, the processes that help to regulate that footprint, and the relationships between the carbon footprint and other environmental factors that affect the services offered by ecosystems. The research will center on three key areas; the methods used to manage the footprint, the procedures used to govern the footprint, and the connections between the footprint and other environmental elements that have an impact [7].

When it comes to greenhouse gas emissions, an individual's "carbon footprint" is defined as their total output measured in terms of CO<sub>2</sub> equivalents. As a useful instrument for energy and environmental management, this has served as an environmental indicator for identifying and quantifying the primary sources of emissions. This data may help us determine the amount of carbon released by different companies, which would allow us to put a number on the impact that humans have on the ecosystem and climate.

From the onset of the industrial revolution, there has been a continuous and gradual rise in the concentration of atmospheric carbon dioxide, reaching 379 parts per million (ppm) compared to the pre-industrial revolution level of 280 ppm. In India's 12th Five-Year Plan, the Planning Commission of the government pushes for low-carbon development. By implementing these measures, India's emission intensity would be decreased. Efforts to lower emission intensity may be made by governmental interventions such as fuel-efficiency regulations, green construction rules, and energy efficiency certifications. The rapid increase in population, together with other related factors such as urbanisation, industrialization, and the development of necessary infrastructure and transportation options, poses a number of problems that must be solved in this setting. To reduce carbon emissions, decentralised mitigation measures are required, which needs a greenhouse gas inventory broken both by industry and by location. When formulating plans to address climate change, national greenhouse gas emission inventories that adhere to the UNFCCC standards are crucial. A fundamental framework for evaluating the mitigation options is provided by the national inventories of sequestration and emissions [1]. The main regional carbon sources and sinks may be better understood with the use of state-wise estimates of emission inventories. Additionally, it aids in comprehending the carbon flow and makes it easier to execute sector-wise mitigation plans at the local level.

Local carbon footprint measurement helps to bring climate policy in line with local growth by comparing emissions from different time periods and by making municipal stakeholders more aware of the links between their activities and climate change [2]. The Employment-Environment Input-Output Analysis (EE-IOA) has been acknowledged for a considerable period as a dependable top-down methodology for establishing a reliable connection between resource utilization or pollution and ultimate demand [3-5]. The enthusiasm for EE-IOA has risen concomitantly with the acceptance of consumption-based emission and resource bookkeeping. Current thinking among policy and decision-makers centers on greenhouse gas (GHG) consumption-based accounting. This method involves attributing all emissions that occur across the supply chain to the people who buy the items in the end. Presenting a number of chances, to round out the territorial-based approach, consumption-based accounting (CBA) takes into consideration all factors that contribute to greenhouse gas emissions from consumption [6-7].

A company's consumption-based greenhouse gas emission inventory is determined by its sales and size. Considering both the inter- and intra-metropolitan variations in per capita income, the carbon footprint of twelve large cities was analyzed. Despite having the greatest per capita earnings of \$546,340 and \$1.94 metric tons, respectively, due to their larger spending habits, New York and Los Angeles had the lowest per capita CF, with 0.70 metric tonnes, respectively, according to the statistics [8]. Our purchasing habits and way of life have been impacted by urbanisation. With the increased energy and carbon efficiency offered by major urban regions, the per capita carbon emissions vary greatly, according to a carbon footprint study of metropolitan America that used a national database spanning the transportation and residential sectors [9]. According to research on the housing market, homes that rely heavily on wood have a higher embodied carbon storage capacity than typical contemporary homes [10]. The current population of India is over 1200 million, with around 8% residing in urban areas, according to the Directorate of Census Operation. Forecasts indicate that this percentage will reach over 40% by the year 2021 [11]. When looking at the world's additional primary energy demand from 2006 to 2030, India and China make up 51% of it, according to WEO [12]. The primary locations for both energy demand and greenhouse gas emissions in these nations are their urban regions. Greater greenhouse gas emissions are found in heavily populated and industrialised areas, according to an inventory of 54 South Asian cities' energy status and carbon emissions, 41 of which are located in India [1]. As the world's population and urbanisation continue to rise, so does the need for energy. Fuel wood, kerosene, electricity, or Liquefied Petroleum Gas (LPG) are all

viable options for cooking and lighting in India. On a monthly basis, city dwellers use about 6.65 kg of fuel, including electricity, kerosene, and LPG. around 22.32 kWh. 0.21 kilogramme, 1.81 kg, and 0.21 kg again. A total of 174 GW of installed capacity for power production was achieved in 2009, up from 16 GW in 1971. The cement and steel sectors have flourished in the post-globalization age, thanks to rising incomes and investments in infrastructure. In 2008–09, cement output reached 181.61 mt, up from 168.31 mt the previous year. The output of crude steel also increases at a rate of 1.23 percent each year. Carbon emissions have increased due to the increased manufacturing of cement and steel, nevertheless, and have surpassed natural sequestration of carbon.

As a nation, India's forests and soils store a lot of carbon. In 2005, trees covered 2.8% of the country's land surface and forests 677.088 km<sup>2</sup>, accounting for 20.6% of the total land area. Alternatively, 2.8% of India's landmass was covered with trees.

Table 1 : Electricity generation emission coefficients

Raw material	CO <sub>2</sub>	CO	Reference
Coal		3.392 g/kWh	[22]
Coal	0.846 t/MWh		[23]
Natural gas	1980 t/Mcum		[24]
Diesel	3.19 t/t		[24]

Table 2 : The total number of road vehicles, the average yearly mileage, and the emission factors in grammes per km.

	Bus	Omni buses	Two wheelers	Light motor vehicles (Passenger)	Cars and jeeps	Taxi	Trucks and lorries	Light motor vehicles (Goods)	Trailers and tractors	Others <sup>a</sup>	Reference
Number	594,059	173,534	51,921,973	2,167,324	8,549,287	901,889	2,372,702	1,375,782	2,372,702	357,569	[85]
AACD <sup>b</sup> (km)	100,000	100,000	6300	33,500	12,600	12,600	57,500	63,000	2100	46,400	[32,33]
CO <sub>2</sub>	515.2	515.2	26.6	60.3	223.6	208.3	515.2	515.2	515.2	343.9	[25]
CO	3.6	3.6	2.2	5.1	1.98	0.9	3.6	5.1	5.1	3.9	[27]
NO <sub>x</sub>	12	12	0.19	1.28	0.2	0.5	6.3	1.3	1.3	3.9	[27]
CH <sub>4</sub>	0.09	0.09	0.2	0.2	0.2	0.01	0.09	0.09	0.09	0.1	[26]
SO <sub>2</sub>	1.4	1.4	0.013	0.03	0.05 <sup>c</sup>	10.3 <sup>d</sup>	1.4	1.4	1.4	1.9	[28]
PM	0.6	0.6	0.05	0.2	0.03	0.07	0.3	0.2	0.2	0.2	[27]
HC	0.9	0.9	1.42	0.14	0.25	0.13	0.87	0.14	0.14	0.5	[27]

<sup>a</sup> Average of above value are used for others.

<sup>b</sup> Annually average covered distance (AACD).

<sup>c</sup> [71].

<sup>d</sup> [22].

Forest soil has the ability to store carbon, therefore more forest cover means more carbon storage. The amount of organic carbon in soil might also be enhanced by better farming techniques.

It would be easier to deploy carbon capture systems with a decentralised inventory of carbon emissions compared to their sequestration potential at disaggregated levels here. To do this, we need to break down the sources and sinks into their respective sectors, and then we may implement mitigation strategies tailored to each area based on the sources we find. Creating a carbon balance inventory for each of India's states is the primary goal of this project. When estimating emissions, many factors are taken into account, including power production, transportation, manufacturing, residential energy use, agriculture, and garbage disposal. Carbon sequestration takes into account biomass from forests, soil from forests, and soil from farms. This is accomplished by collecting data from every sector throughout India, reviewing the results of emission and sink experiments conducted in the country, and using IPCC default emission factors that are particular to India [1].

## 2. Methods

**Factors for emissions by industry:** Information on each state's sector-specific activity was gathered from public sources and the relevant government bodies. Eq. provides the activity level and emission coefficient that may be used to get the total emissions for a certain GHG sector. starting with [1]

Total emissions = [activity level x emission coefficient]

State Source Sectors

**Generating electricity:** Utilizing existing data [9,10], we formulated emission factors tailored to specific regions for coal thermal power plants. Although there are emission characteristics unique to gas and diesel thermal power plants, the following table outlines the region-specific components used in natural gas and diesel combustion. 1.

**Transport:** In Table 2 we can observe the emission factors for road transport by region and vehicle type. According to the current state of automotive technology in India, diesel is utilised as fuel for many types of vehicles, including minibuses, tractors, trucks, lorries, two-wheelers, cars, and jeeps. When it comes to CO, HC, NO, and PM emission coefficients, the majority of buses and minibuses in Delhi run on CNG (Compressed Natural Gas) [3]. The corresponding values for automobiles and jeeps were 0.78, 1.55, 0.92, and 0.02g km<sup>-1</sup>, whereas for buses running on CNG, they were 1.77, 0.88, 2.81, and 0.032g km<sup>-1</sup>, respectively. Table 2 displays the average yearly mileage broken down by vehicle type. According to an alternate reference, buses, minibuses, two-wheelers, light motor vehicles (passengers), cars, jeeps, and taxis cover annual distances of 100,000, 6,300, 33,500, 12,600, and 12,600 kilometers, respectively [32]. Also, it was estimated that trucks and lorries would travel between 25,000 and 90,000 kilometres per year, while trailers and tractors would travel between 63,000 and 21,000 kilometres per year.

**Business sector:** The CO<sub>2</sub> emissions from the cement and steel industry have been calculated using a region-specific emission factor that is based on coal consumption and type (**Table 3**).

**Energy inside the home:** How much and what kind of energy a home uses determines the emissions from that use. Domestic energy in India mostly comes from fuelwood and bio-residues, kerosene, LPG, and power. To prevent the duplicate counting of emissions from power, it is not included here. To determine the emissions from fuelwood and bio-residues, we used region-specific emission factors [34,35]. The CO<sub>2</sub> emissions from kerosene and LPG were calculated using the Net Calorific Value (NCV) [19], and the corresponding emission factors can be seen in **Table 4**.

**Table 3**

Emission factor used in industries.

	CO <sub>2</sub> (t/t)	Reference
Cement industry	0.5	[90,24]
Coking coal combustion (steel sector)	2.05	[24]
Coal combustion	1.76	[24]

**Table 4**

Emission factor used in domestic energy consumption.

	CO	CO <sub>2</sub>	CH <sub>4</sub>	Reference
Fuel-wood	28.50 g/kg	380 g/kg	2.95 g/kg	[34]
Kerosene	62 g/kg			[35]
Kerosene		71.50 t/TJ		[19]
LPG	15 g/kg			[35]
LPG		63 t/TJ		[19]

**Farming:** Circumstances that cause emissions of carbon dioxide include burning agricultural residue, raising cattle, and growing rice. Table 5 displays the quantification of emissions from the agricultural sector, which was done using methods proposed by the IPCC [20]. In 2005/06, the emissions from burning agricultural residue were calculated using crop data, taking into account the standard crop residue ratio and the dry matter percentage [20,38,39,40]. portion that was really burnt, portion that was oxidised [20], factor for emissions of CH<sub>4</sub>, CO [43–45], and factor for emissions of CO<sub>2</sub>.

**Table 5**

Emission coefficient for agricultural residue burning.

Biomass type	CH <sub>4</sub>	CO <sub>2</sub>	CO	Reference
<i>Emission factor (g/kg)</i>				
Agricultural residue	2.70	1515 ± 177	92 ± 84	[44]
Wheat straw	7.37 ± 2.72		156 ± 22	[45]
Rice straw	5.32 ± 3.08		82 ± 20	[45]
Wheat straw	3.55 ± 2.66	1787 ± 35	28 ± 20	[43]
Wheat stubble			21.1 ± 1.9	[89]
Wheat fire			38.20	[89]
Wheat			44.1 ± 7.4	[89]
Wheat			59.00	[89]
Wheat			35.00	[89]
Cereal waste		1400	35.00	[53]
Wheat residue	2.62–8.97	959–1320	61.1–179	[86]
Wheat residue	0.59–2.04	1540–1615	26–64	[87]
Wheat straw	0.41		34.65	[88]
<i>Default emission ratio</i>				
Agricultural residue	0.01		0.06	[20]

**Cultivating rice:** For the 2004–2005 school year, researchers approximated the methane emissions from rice fields. The emission coefficients related to each growing method were averaged out to provide an estimate for rice agriculture.

**Disposal of Municipal solid waste** emissions are proportional to the amount of organic waste generated. On average, 70% of trash makes it to the dump, therefore we may use IPCC recommendations to estimate emissions of CH<sub>4</sub>, the most common greenhouse gas. In 2001, we calculated methane emissions from organic garbage. Estimation also takes into account the following parameters: The components include the portion of biodegradable organic carbon, the percentage of biodegradable organic carbon transformed into landfill gas, the proportion of carbon, the percentage of methane, and the standard values for methane correction established by the IPCC. The oxidation factor and the amount of methane recovered are both taken as zero.

### Conclusions

According to a global analysis of greenhouse gas emissions spanning from 1970 to 2004, carbon dioxide (CO<sub>2</sub>) stands as the most prevalent greenhouse gas. Developed industrialised nations like the United States, Russia, and Japan create much more greenhouse gas emissions per capita than does India. The developing world is home to 80% of humanity and has been the primary polluter since 1751, accounting for around 20% of global emissions. Even the poorest nations, with 800 million inhabitants, have only produced 1% of these emissions [19]. Knowledge about region-wise assessment of GHG emissions and the scope for carbon sequestration is necessary for the implementation of suitable adaptation and mitigation methods at the local level.

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