

A Study on Carbon Footprint

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Abstract

Increasing greenhouse gaseous concentration in the atmosphere is perturbing the environment to cause grievous global warming and associated consequences. Following the rule that only measurable is manageable, mensuration of greenhouse gas intensiveness of different products, bodies, and processes is going on worldwide, expressed as their carbon footprints. The methodologies for carbon footprint calculations are still evolving and it is emerging as an important tool for greenhouse gas management. The concept of carbon foot printing has permeated and is being commercialized in all the areas of life and economy, but there is little coherence in definitions and calculations of carbon footprints among the studies. There are disagreements in the selection of gases, and the order of emissions to be covered in footprint calculations. Standards of greenhouse gas accounting are the common resources

Keyword: Carbon footprint, Direct emissions, emissions, Greenhouse gases

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report has strongly recommended to limit the increase in global temperature below 2°C as compared to preindustrial level (i.e., measured from 1750) to avoid serious ecological and economic threats. Based on NOAA data, the 2017 average global temperature across land and ocean surface areas was 0.84°C (1.51°F) above the twentieth-century average of 13.9°C (57.0°F), making it the third-warmest year on record behind 2016 (warmest) and 2015 (second warmest)[1].

The imbalances caused in natural systems due to warming are already being signaled in the form of extreme weather events and climate change. The mountainous snow cover, permafrost, and glaciers are melting, and Greenland, Antarctic, and Arctic ice packs are experiencing a negative mass balance causing the sea level to rise at a rate of 3 mm year⁻¹ [2-4]. Owing to such complex changes in natural phenomena, it has been projected that 1–2 billion additional people will be under water stress, crop productivity in mid-latitudes will suffer loss, and wildlife and biodiversity will be threatened[2]. On social forefront, developing and poor countries are at immediate and disproportionately high risk of being adversely affected by global warming and thus the “MILLENNIUM development goal” of eradicating poverty may be compromised[5]. “The world is running short of time and option” at social and economic front in view of high risks related with global warming and climate change[6]. Strong and immediate local to international actions are thus needed to stabilize emissions in a justified

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manner. As the understanding of the science and consequences of global warming grew, the concern for preventing disastrous climate change led to a substantive action in the form of endorsement of “Kyoto protocol” in 1997 which requires developed economies or economies in transition listed in its annexure I to reduce their collective emissions of six important greenhouse gases (GHGs) namely carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), set of perfluorocarbons, and hydrofluorocarbons by at least 5.2% as compared to 1990 level during the period 2008–2012[7]. The gases covered under Kyoto protocol are referred collectively as “Kyoto gases”. This protocol, however, has not received equal support from all the nations and some did not ratify it giving reasons that their economies may suffer loss. However, a critical review over impacts of acting or not acting against climate change carried out by Stern[6] led to the conclusion that “the benefits of strong early action considerably outweigh the costs.” It was predicted that not acting immediately will cost at least 5% of global gross domestic product (GDP) loss annually while annual investment equivalent to 1% of global GDP may help in limiting temperature rise below 2°C. Otherwise it would be impossible to revert the changes. Emissions of Kyoto gases need to be cut by 25% below the current level by 2050 so that the growth of countries is not compromised.

2. Greenhouse Gas Sources

Rapid rise in global temperature is due to the “enhanced greenhouse effect” (i.e., the greenhouse effect added to the natural) due to human-induced release of GHGs into the atmosphere. Not all GHGs have equal capacity to cause warming but their strengths depend on radiative forcing it causes and the average time for which that gas molecule stays in the atmosphere. Considering these two together, the average warming it can cause, known as ‘global warming potential’ (GWP), is calculated mathematically and is expressed relative to that of CO₂. Therefore, unit of GWP is carbon dioxide equivalent (CO₂-e).

Important contributors to global warming are Kyoto gases, whose emissions increased by 70% during 1970–2004 [3]. In addition to these six gases, the members of chlorofluorocarbons family bear very high GWP, but since their emissions have been controlled successfully under Montreal protocol, they are no longer a problem. Tropospheric ozone and black carbon have also been found to warm the troposphere. The rates of increment in GHG concentrations are extraordinarily high, far exceeding the natural range as evident from geological and ice core studies[3]. The biggest share of these GHGs comes from fossil fuel combustions in the form of CO₂ (58.6%). Next come CH₄ and N₂O contributing to 14.3% and 7.9%, respectively, to total collective CO₂-e. Major sources of these two gases are the agricultural systems[3].

In order to comply with 2°C target, the atmospheric stock of GHGs needs to be stabilized below 550 ppm in terms of carbon dioxide equivalents, of which 430 ppm has been attained in 2007. Therefore, GHG inventories are going on all over the world and every possible method to control them are being recognized and evaluated. As the climate change issues became prominent on political and corporate agenda, general public, especially in developed countries, started recognizing their responsibility towards acting against global warming. These concerns and media have provided tremendous popularity to quantification of the contribution of various activities to global warming usually represented in terms of “carbon footprint”. However, information available on carbon footprinting beset with uncertainty and inconsistency[8-10]. The objective of the present review is to systematically analyze the relevant available information on global warming, GHG emission, and characteristics, carbon footprinting concepts, calculation of carbon footprints, methodology followed for estimation and uses of this by general public, corporate sector, industries, and governments.

3. Concept of Carbon Footprint

Origin of carbon footprint can be traced back to as a subset of “ecological footprint” proposed by Wackernagel *et al*[11]. Ecological footprint refers to the biologically productive land and sea area required to sustain a given human population expressed as global hectares. According to this concept, carbon footprint refers to the land area required to assimilate the entire CO₂ produced by the mankind during its lifetime. In due course of time as the global warming issue took prominence in the world environmental agenda, use of carbon footprint became common independently, although in a modified form East[12]. The concept of carbon footprinting has been in use since several decades but known differently as life cycle impact category indicator global warming potential[13]. Therefore, the present form of carbon footprint may be viewed as a hybrid, deriving its name from “ecological footprint”, and conceptually being a global warming potential indicator. There are few studies that report carbon footprint in terms of global hectares notwithstanding the modern nexus about it[14]. Besides its widespread favorable public reputation as an indicator of contribution of an entity to the global warming, there are confusions over what it exactly means[10, 13, 15]. It is also remarked that the scientific literature on the subject is scarce and the most studies have been carried out by private organizations and companies predominantly due to their business sense rather than their environmental responsibility[10, 12]. Other terms used associated or

sometimes as a synonym of carbon footprint in the available literature are embodied carbon, carbon content, embedded carbon, carbon flows, virtual carbon, GHG footprint, and climate footprint [10, 15, 16]. There is little uniformity in the definitions of carbon footprint within the available literature and studies [10]. Based on their survey, Wiedmann *et al* [10] defined that the carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. A new term “climate footprint” was proposed as a comprehensive GHG indicator, i.e., if all the GHGs originating from within the boundary are quantified. However, new studies and methods followed for carbon footprint calculation, suggest including other GHGs as well, apart from only CO₂ [17-22]. There is a lack of uniformity over the selection of direct and embodied emissions. Direct emissions are those that are made directly during the progress of a process. As an example, CO₂ released during combustion in a gasoline fired industrial boiler is a direct emission. On the other hand, in electrically heated boiler, no direct emissions will be observed. But if the electricity used in the boiler was generated in a thermal power plant, the amount of CO₂ released in generation and transmission of the units of electricity consumed in the boiler is referred as the embodied or indirect emission. It becomes complex to include all possible emissions and thus most studies report only direct or first order indirect emissions[23-25]. In absence of consistencies among selection of characteristic properties of carbon footprint viz. gases selected, and boundaries drawn for the carbon footprint calculations by different organizations vary significantly. Since carbon footprint is associated with money transactions in form of taxes, carbon offsets, or increase/decrease in consumer choices, consistent carbon footprint calculations are essential to facilitate comparisons. In spite of prevailing differences among the calculations, the CO₂ equivalent (CO₂-e) mass based on 100 years global warming potential has been accepted as reporting unit of carbon footprint. Hammond [26] and Global Footprint Network [27] hold the opinion that “footprints are spatial indicators”. Hence, the term commonly called carbon footprint should precisely be called as “carbon weight” or “carbon mass” [28]. But CO₂-e mass has been promoted as unit of carbon footprint due to convenient calculations and wide acceptance[29]. Therefore, carbon footprint may be defined as, “the quantity of GHGs expressed in terms of CO₂-e, emitted into the atmosphere by an individual, organization, process, product, or event from within a specified boundary”. The set of GHGs and boundaries are defined in accordance with the methodology adopted and the objective of carbon footprinting as discussed later in this review.

4. Importance of Carbon Foot print

Carbon footprint, being a quantitative expression of GHG emissions from an activity helps in emission management and evaluation of mitigation measures[30]. Having quantified the emissions, the important sources of emissions can be identified and areas of emission reductions and increasing efficiencies can be prioritized. This provides the opportunity for environmental efficiencies and cost reductions. Reporting of carbon footprint to the third party or disclosure to the public is needed in response to legislative requirements, or carbon trading or as a part of corporate social responsibility, or for improving the brand’s image[30].

Legislative actions have been taken to quantify and reduce carbon footprint of cities and organizations and it is playing an important role in policy making [16]. USA has made it mandatory to keep register of emissions from firms and companies under ‘Consolidated Appropriations Act, 2008’[31]. EU has also taken lead in formulating legal bindings for reduction in emissions embodied in aviation. California capped the GHG emissions from major industries and put a moratorium on import of non-conventional vehicular fuels unless its carbon footprint is less than that of petroleum-derived fuel[16]. California Global Warming Solution Act, 2006 is aimed at bringing the emissions of California to the level of 1990 by 2020[32]. The UK Government through the Low Carbon Transition Plan, 2009 instigates households to contribute towards building a low carbon future. Most of the organizations and almost all personal carbon footprinting attempts have been observed to head towards reducing the emissions or offsetting the footprints through buying carbon credits, or other control measures. Besides policy matters, carbon footprint has got an enormous importance for business. The corporate world has sensed carbon-constrained economy in near future[33]. Hence a rush to calculate the carbon footprint and to cut down the emissions has begun worldwide so as to take competitive advantage[33]. It is proved by the fact that number of companies participating in CDP increased from 383 in 2008 to 409 in 2009. In a survey conducted by L.E.K. Consulting LLP[34], it was found that 44% consumers preferred to buy the products, which provided the information about their carbon footprints, while 43% were willing to pay more for the products with relatively low carbon footprint. Hence the corporate sector has responded in a big way. With growing awareness regarding climate change, a remarkable concern has grown in individuals over their responsibility of contributing to the emissions of GHGs. This has led to the surge of personal carbon footprinting facilities (consultancies and online calculators) particularly in developed countries[8]. After footprint calculation, they offer to offset the footprint by tree plantation, supporting forestation, and renewable energy resources[35] and for this reason, a dramatic growth in voluntary carbon market has been reported since 1989 [36]. Decrease in fossil-fueled transport systems can be achieved through propensity to walk and use bicycles as a behavioral change in individuals [37].

In addition to its business importance, carbon footprint has been used as an indicator of the impact of lifestyle of a citizen of a country on carbon emissions. The UNDP[5] and Edgar and Peters[38] published country wise per capita carbon footprint, a convenient way to compare contributions of countries, cities, and sectors towards global warming.

5. Conclusion

Carbon footprint has emerged as a strong mode of GHG expression. While earlier studies focused only on CO₂ emissions as the guidelines and suggested inclusion of all the important GHGs in calculation, carbon footprint started becoming synonymous to a comprehensive GHG account, over the life cycle stages of any product or activity. No definition, however, has yet been accepted coherently as is clear from the fact that there are different selection of gases and tiers among studies. However, as carbon footprint reports are increasing in response to legal or business requirements, most of the calculations are following the GHG protocol worldwide. Since it has been extended to cover natural system as well, it becomes essential to deal with the unavoidable emissions. Carbon footprint has been commercialized and is being utilized by organizations to count their carbon and adopt measures to cut down emissions. This business sense has taken carbon consciousness to the households through numerous online calculators and has helped in making the civil society aware of how much their activities are contributing to global warming. Ironically, there is no check on such carbon calculating facilities and they lack coherence and transparency. Since carbon footprinting is associated with money transactions and has been found to influence businesses, legal guidelines are necessary to monitor these calculations. Carbon footprinting must be harnessed as a strong tool to promote GHG emission reductions among businesses, events, and civil society and should be included as indicator of sustainable development.

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