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ENVIRONMENTAL SCIENCE

Carbon Footprinting: A tool for environmental management

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Abstract

The term 'carbon footprint' has become tremendously popular over the last few years and is now widely used in educational institutes, government sector, business and the media. Although the term has been extensively used in the public domain, still there is an apparent lack of appropriate academic definitions of what exactly a 'carbon footprint' is meant to be. Considering the fact of climate change, the term carbon footprint is in strong demand. It is concerned with a less rigorous, consumer oriented, popularised concept of greenhouse gas reductions for the purpose of marketing the benefits of less emission intensive products and services to the public. Numerous approaches have been proposed to provide estimates, ranging from calculators available online to sophisticated life-cycle analysis or input-output-based methods and tools. By the time elapse, there has been growing concern for issues related to climate change by describing interpretation of greenhouse gas measurement and reduction. The purpose of this paper is to define "carbon footprint" and to provide an insight into the terminologies and approaches initiated at national and international platforms.

Highlights

- According to Encyclopedia Britannica, the United States contributes 25 per cent of the world's greenhouse gases.
- Many 'carbon calculators' are available to help people work out the carbon footprints
- Ecological footprint concept is widely used as a resource management
- India's contribution to global carbon credit trading has been estimated at around $1 billion in year 2007.

Keywords: Carbon footprint, ecological footprint, life-cycle analysis, climate change and green house gases

A 'Carbon Footprint' is the measure of the total amount of carbon dioxide (CO_2) or other Greenhouse Gas (GHG) emissions given off by a product, an organization, an individual or even a specific event through energy utilization. It is the annual amount of greenhouse gas emissions, mainly the carbon dioxide, that result from the activities of an individual or a group of people, especially their use of energy, transport and consumption of goods and services. It is measured as the *mass*, in kilograms or tonnes per year, either of carbon dioxide (CO_2) emissions alone, or of the *carbon dioxide equivalent* (CO_2e) or effect of other greenhouse gas emissions. This is sometimes referred to as 'embodied energy'. The calculations included in a footprint may cover travel, heating and cooling and electricity consumption or transportation of day to day items.

According to The United States Environmental Protection Agency (USEPA), "A carbon footprint is the amount of greenhouse gases emitted into the atmosphere each year by human activities in a given time frame". Usually to carry out a carbon footprint study, the calculations are done for the time period of a year.

In other terms, it can be explained as an estimate of the climate change impact of an activity – such as making a particular product, living a lifestyle or running a company. Typically, a carbon footprint is calculated by estimating not only the CO_2 emissions that the activity in question causes, but also any emissions of other greenhouse gases (such as methane or nitrous oxide) and in some cases few other types of climate impacts as well, such as vapour trails from the aeroplanes. For simplicity, all these impacts are added together and expressed as a single number in terms of carbon dioxide equivalent (CO_2e): the amount of CO_2 that would create the same amount of warming. The total amount of greenhouse gases produced directly and indirectly from human activities is usually expressed in equivalent tons of carbon dioxide (CO_2).

The carbon footprint is an *environmental indicator*: a way of measuring impacts on the environment. There are various other environmental indicators that measure different impacts, such as water pollution, air pollution, loss of biodiversity and depletion of mineral resources. This part focuses on only this single measure of CO_2 and other greenhouse gas emissions, but one should be aware that the carbon footprint doesn't measure other impacts, except perhaps indirectly. It is noticeable that carbon footprint is not the only indicator that should be taken into account when assessing the environmental impacts of a product; its appealing recognition in public domain makes carbon footprint a good entry point to increase the environmental consciousness and demonstrate the usefulness of life cycle thinking (Weidema *et al*., 2008).

According to Encyclopedia Britannica, a carbon footprint includes direct emissions, such as from driving a car, as well as whatever emissions are required to consume any goods and or services. Often, a carbon footprint includes the measure of other greenhouse gas emissions as well. The United States, with only 4 per cent of the world's population, contributes 25 per cent of the world's greenhouse gases. The average American produces about 20 tons of carbon dioxide each year. A large carbon footprint has detrimental effects on the environment. Despite the lack of scientific endorsement, the term carbon footprint has quickly become a widely accepted terminology under political and corporate agenda.

Brief history

The concept of carbon footprint took hold at a 1979 U.S. Senate energy committee discussion about the "environmental footprint" of the government operations in Yosemite National Park. Basically, the term originated from the idea of ecological footprint which was formally introduced to the scientific community in the 1990s (Rees, 1992, 1996; Wackernagel and Rees, 1996, 1997; Wackernagel *et al*. 1999a, b). Tom Rawls, chief environmental officer for Green Mountain, is widely credited with the first quoted use of "carbon footprint" in a Seattle Times article, "Carbon Count: Forests Enlisted in Global Warming War," published November 18, 2000. Afterwhile, the term gained wider use through a 2005 British Petroleum advertising campaign. According to the report published by the U.S. Energy Information Administration, carbon dioxide emissions from burning fossil fuels accounted for 82 per cent of the greenhouse gas released in 2006. Wiedmann and Minx (2007) evaluated various definitions of carbon footprint found in gray literature and proposed that carbon footprint should account both direct and indirect emissions stemming from all over the life stages of a product.

Carbon dioxide is the most persistent of the "greenhouse gases," a group of chemical compounds that alter the chemistry of the atmosphere. There is a lack of scientific literature and adequate knowledge on the conceptual definition of a carbon footprint. The carbon footprint offers a way to calculate the contribution to the carbon dioxide emissions that affect our climate by measuring the total amount of carbon production by the consumption of energy. Knowing one's carbon footprint can show areas where the energy consumption could be decreased, in turn; reduce your production of carbon emissions. The idea put forward is that a carbon footprint is what has been left behind as a result of an organisation's activities.

Table 1: Definitions of 'carbon footprint' from the grey literature (Wiedmann and Minx, 2008; Growcom, 2008)

BP (2007)	"The carbon footprint is the amount of carbon dioxide emitted due to your daily activities – from washing a load of laundry to driving a carload of kids to school."
British Sky Broadcasting (Sky) (Patel 2006)	The carbon footprint was calculated by "measuring the CO_2 equivalent emissions from its premises, company-owned vehicles, business travel and waste to landfill." (Patel 2006)
Carbon Trust (2007)	"… a methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding in-use emissions). "… a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product (we [The Carbon Trust] will refer to this as the product's 'carbon footprint')." (CarbonTrust 2007, p.4)
Energetics (2007)	"… the full extent of direct and indirect CO_2 emissions caused by your business activities."
ETAP (2007)	"…the 'Carbon Footprint' is a measure of the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in tonnes of carbon dioxide."
Global Footprint Network (2007)	"The demand on biocapacity required to sequester (through photosynthesis) the carbon dioxide (CO2) emissions from fossil fuel combustion." (GFN 2007; see also text)
Grub & Ellis (2007)	A carbon footprint is a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels. In the case of a business organization, it is the amount ofCO_2 emitted either directly or indirectly as a result of its everyday operations. It also might reflect the fossil energy represented in a product or commodity reaching market."
Parliamentary Office of Science and Technology (POST 2006)	"A 'carbon footprint' is the total amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a process or product. It is expressed as grams of CO_2 equivalent per kilowatt hour of generation (gCO_2eq/kWh), which accounts for the different global warming effects of other greenhouse gases."
Global Footprint Network (2007)	"The carbon footprint therefore measures the demand on biocapacity that results from burning fossil fuels in terms of the amount of forest area required to sequester these CO_2 emissions"
Carbon trust (2008).	"The term carbon footprint is commonly used to describe the total amount of CO_2 and other greenhouse gas (GHG) emissions for which an individual or organisation is responsible. Footprints can also be calculated for events or products"
Wiedmann & Minx (2007)	"The carbon footprint is a measure of the exclusive total amount of CO_2 emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product"
Carbon N Zero (2008)	"A measure of the amount of CO_2 emitted through the combustion of fossil fuels; in the case of an organisation or business, it is the CO_2 emissions due to their everyday operations; in the case of an individual or household, it is the CO_2 emissions due to their daily activities; for a product or service, it includes additional life-cycle CO_2 emissions along the supply chain; for materials, it is a measure of the embodied CO_2 emissions determined through life cycle assessment"
TreeVestors (2008)	"A measure of the amount of CO_2 emitted through the combustion of fossil fuels. A carbon footprint is often expressed as tons [sic] of CO_2 or tons [sic] of carbon emitted, usually on an annual basis"
Triplepundit (2008).	"This term actually refers to the amount of productive land (forest) required to sequester (remove) the equivalent amount of GHGs that a company emits"
MCI (2008)	"The total amount of CO_2 and other greenhouse gases, emitted over the full life cycle of a product or service"
Wright and Williams (2011).	A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO_2e) using the relevant 100-year global warming potential (GWP100).

Significance

The abnormalities in the average surface temperature results in changing weather patterns and increase climatic severity. The U.S. Environmental Protection Agency (USEPA) estimated that the atmospheric concentration of carbon dioxide, the major contributor of carbon footprint, has increased by 36 per cent since 1750. Scientists conclude the majority of this increase is anthropogenic. Therefore, many environmental agencies have developed carbon footprint calculators to measure individual carbon contributions that affect climate change, for example, EPA and other non-profit environmental agencies. Most people are shocked when they see the amount of CO_2 their activities create! If you personally want to contribute to stop global warming, gather your data and calculate your carbon footprint online. The smaller the carbon footprint, the more eco-friendly is the organisation. The estimations of carbon footprints will help us to identify the hotspots of energy consumption, optimise energy efficiency, and identify solutions to neutralise the CO_2 emissions that cannot be reduced by any energy saving measures.

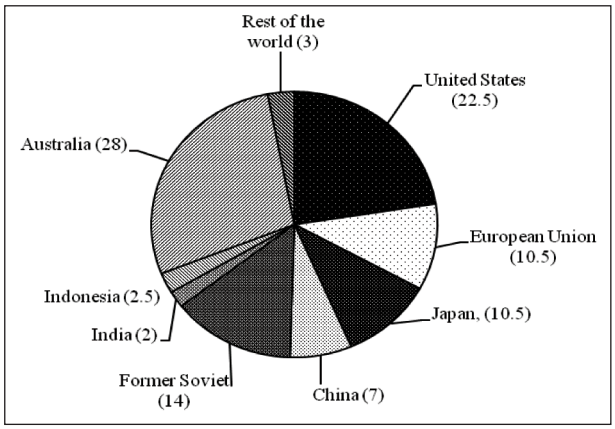

Figure: 1 Carbon Emission % in few important business countries (Birla *et al*. 2012)

Why calculate your carbon footprint?

There are many existing and evolving standards for calculating carbon footprints across the world but in truth no such calculator for footprint estimation is precise. For example, burning a litre of petrol, which releases a known amount of CO_2, there are still uncertainties about the emissions caused by extracting and refining the petrol before it was burnt. For more complicated activities these uncertainties are further multiplied.

The only way to determine if changing your behaviour has a positive impact on the amount of CO_2 you produce is to estimate your current footprint and measure your performance against it over time. Today organisations calculate and report the carbon footprints for their customers as part of their annual reports; but it is important that you also know how much carbon dioxide you are responsible for if you want to offset it. Many a times it seems difficult to decide what emissions they should include when calculating their carbon footprint. The World Resources Institute and World Business Council for Sustainable Development's Greenhouse Gas Protocol classify emissions as follows:

- Scope 1 – (combustion of fuels; most common, also known as the primary carbon footprint). Direct emissions from sources owned or controlled by the company, for example fuel used in company or employee vehicles.
- Scope 2 – (not directly controlled; contributes to 17 per cent of the global GHG emissions). Emissions from the electricity you consume that is generated elsewhere, such as the electricity from coal fired power stations that is used to power lights, computers and other items.
- Scope 3 – (also known as secondary carbon footprint). Other indirect emissions that you cause that are not from emission sources that you own, for example, from your supply chain or from business travel on commercial airlines. Scope I and Scope II emissions must be reported while Scope III emission is optional. Also, when making a corporate-wide inventory, small emission-causing activities are discovered. Hence, producing a full carbon footprint covering all the three types of emissions can be quite a complex task.

Measuring carbon footprints

There are many 'carbon calculators' on the web to help people work out the carbon footprint of their life or individual activities. The data which calculates the carbon footprint needs to be relevant, complete, consistent, transparent, and accurate. The carbon footprint, measured in tonnes, is taken to be a measure of the extent to which all such activities contribute to global warming. Few people express their carbon footprint in kg carbon rather than kg carbon dioxide. The carbon dioxide in kg can

be converted to kg carbon by multiplying with a factor 0.27 (1,000 kg CO_2 equals 270 kg carbon). For long and medium term, the carbon footprint must be reduced to less than 2,000 kg CO_2 per year per person. This is the maximum allowance for a sustainable living.

Numerous approaches are being used for the calculation of the carbon footprint of an organisation. There is a Basic Method (covers direct emissions and emissions from electricity); the process based life cycle assessments or the PALCA Method (bottom-up approach, only on-site, most first-order impacts); the Environmental Input-Output or the EIO Method (top-down approach, provides a picture of all economic activities); and, the Hybrid Method (combines the strength of both methods). ISO 14064 provides detailed guidance for corporate footprint calculations and emissions reporting. Detailed calculations of carbon footprints are provided in the GHG Protocol's Corporate Accounting and Reporting Standard (revised edition); the ISO 14064; and the PAS 2050 standard of the British Standards Institution (BSI). These standards provide unambiguous, verifiable requirements for the quantification, monitoring and verification of greenhouse gases.

Several agencies like EPA, Nature Conservancy and other organizations offer online carbon footprint calculators. The Cool Climate Network at the University of California, Berkley, estimates an average U.S. household carbon footprint at 49 MT of carbon dioxide. While each calculator uses different data, many of them ask for information about your vehicles, public transportation usage, home heating and cooling, household energy use, water consumption, dietary choices and waste management.

There are a number of calculators currently available on the web, example EPAVictoria's personal footprint calculator. The University of Sydney's Centre for Integrated Sustainability Analysis Ecological Footprint Calculator provides a downloadable excel spreadsheet. WWF personal footprint calculator is a great animated footprint calculator and The Australian Greenhouse Calculator. There are undoubtedly many others.

Ecological Footprint

A similar concept commonly talked about is an '*Ecological Footprint'*. William Rees and Mathis Wackernagel from the University of British Columbia used the term "footprint" for the first time to describe the impact of human production or consumption activities was first developed by planners. Further, Wackernagel and Rees (1996) define an "ecological footprint" as an accounting tool used to measure the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area. The Ecological Footprint (Wackernagel *et al*. 2002) can be one of such tools that serve as an indicator for overall pressure mankind poses on the planet's ecological assets.

In other terms, it refers to the amount of nature's resources an individual, a community, or a country consumes in a given year. The overall consumption levels are calculated and translated into the amount of biologically productive land and water area that is required to produce the resources consumed and to assimilate the wastes generated using prevailing technology. Because people use resources from all over the world, and affect faraway places with their pollution, the Footprint is the sum of all resources used wherever they are on the planet. It has been stated that while the term 'carbon footprint' originates in the language of 'ecological footprint', it is a measure of the exclusive total amount of CO_2 emissions that is directly or indirectly caused by an activity or is accumulated over the life stages of a product. Calculations for Ecological Footprints are based on six uses of the planet's bio-productive surface that compete for the Earth's available biologically productive space which include:

- Growing crops for food, animal feed, fibre, oil crops and rubber
- Grazing animals for meat hides, wool and milk
- Harvesting timber for wood fibre and fuel
- Catching fish
- Accommodating infrastructure for housing, transportation and industrial production
- Absorbing carbon dioxide emissions

The widely used environmental indicator *ecological footprint* is a measure of the environmental impact of the population (household, city, nation, etc.) based on the *area of land or sea* theoretically required for the support of their lifestyle for a given period of time. Basically, the ecological footprint measures the area of land and sea required to produce the population's food and accommodate its roads,

buildings, *etc*. as well as the forested area required to absorb the population's CO_2 emissions. So, the ecological footprint measures the carbon footprint component of a population's environmental impact using land area. The ecological footprint concept is still widely used today as a resource management tool (Global Footprint Network, 2007).

Carbon offsetting

Before entering the realm of offsetting, it is important that the carbon footprints are reduced as far as possible. Offsetting carbon emissions is becoming increasingly popular, with both businesses and individuals purchasing offsets for areas where carbon emissions are unavoidable, such as essential flights or car journeys. The concept of renewable energy resources is being taught in educational institutes. The mitigation of carbon footprints through the development of alternative projects, such as solar or wind energy or afforestation, represents one way of reducing a carbon footprint and is often known as Carbon Offsetting.

A forest carbon offset is a financial tool, used by CO_2 polluters, to offset their emissions of greenhouse gases. One carbon offset (or credit) represents one less metric ton of greenhouse gas that otherwise would have been released into the atmosphere. Commercial operations that are increasing atmospheric carbon dioxide can offset their pollution by buying carbon credits from reputable auditor/broker registries.

Lifecycle assessment

The traditional way of estimating a carbon footprint – so-called 'lifecycle assessment' – involves the addition of all the emission pathways regarding their feasibility. Alternatively, 'input-output' analysis approach is used. This approach aims to include the total emissions of a country or region, dividing it into lots of sectors (e.g. toy manufacturing, food growing, freight, etc) and further distributing it to particular activity that each sector accounts for. Those figures can then be used to estimate the footprint of, say, each pound spent on toys.

Environmental impacts related to emission from products or services are best examined using a life cycle based method. One environmental impact is the cumulative amount of greenhouse gases (GHGs) expressed in kilogram CO_2 equivalents released to the atmosphere, represents the carbon footprint of a product or service (Koning *et al*. 2010). Each stage of the life cycle of any product, activity or event is linked to other secondary stages; which may further be linked to others and so on. The assessment process becomes too complex with the expansion of the boundaries covering all the associated steps. Depending on the objective of the assessment as well as on the availability of data, the selection cradle and grave should therefore be done (Pandey *at el*. 2010). A carbon footprint can be seen as a subset of a life cycle assessment (CCA) in which only the global category is studied (SETAC, 2008; Weidema *et al*. 2008).

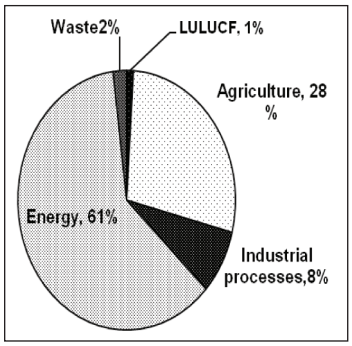

Fig. 2: Emissions by sector, 1994 (based on data from M0EF, 2004)

Indian scenario

Like in many other parts of the world, India, one of the fastest growing economies of the world is under the threat of climate change and its impact. With a 42% of the total Indian population living under the global poverty line, the consequences of climate change particularly in agriculture, which has been a major source of livelihood to many poor people, could worsen the living conditions (Singh, 2012). However there is low awareness as to why it is important to reduce the carbon footprints and how it can affect a country's economy. By virtue of very large population in the country, India is a major emitter of greenhouse gases, ranking fourth globally in overall terms (behind the US, China, and the EU) and contributing around 5.5 % of global emissions (FIIA, 2009). The emissions are also growing rapidly. However, if compared with the most industrialised countries, India's cumulative historical emissions remain relatively low. The per capita emissions of 1.7 tCO_2 (WRI/CAIT, 2009) are very low, even relative to other major developing

economies (the world average is around 5.8 tCO_2 per capita). Recently the announcement of National Action Plan on Climate Change (NAPCC-2008) and the launch of India's first carbon footprint calculator — CARBONyatra.com — are steps supporting towards the national agenda focussing on the need for rapid economic growth as an essential pre-condition to poverty eradication and improved standards of living. According to the NAPCC-2008, India aims to limit its per capita Green House Gas emissions below that of developed countries but still there are contradictions whether it is possible with the economy growing at an annual average growth rate of eight per cent?. Figure 2 shows a sectoral breakdown of emissions for 1994. India's greenhouse gas emissions are estimated to have risen by approximately 50 % between 1994 and 2005. The projected climate change under various scenarios is likely to have implications on food production, water supply, biodiversity and livelihoods. According to the predicted estimations, the area under food grain, for instance fell from 126.18 mha to 122.23 mha during the period from 1975–76 to 2008– 09, the production registered an increase from 121.03 Mt. to 234.47 Mt. during that period (Ahmad *et al*., 2011). The largest bulk of India's emissions come from the energy sector accounting for about 61 % of total CO_2e emissions – of which almost half came from electricity supply, 20 % from industrial fuel combustion and around 11 % from transport. WRI estimates suggest that the overall contribution of the energy sector is rising (around 66 % by 2005). Of the other sectors, *agriculture* accounted for 28 % of total emissions in 1994 (around 22 % in 2005), *industrial process* emissions contributed around 6-8 %, *waste disposal* accounted for 2 per cent (rising to nearly 7 % in 2005), and *land use and land use change* accounted for 1 % (net carbon storage in 2000), (Mishra and Rakshit, 2008).

For the year 2007, the global carbon credit trading was estimated at $5 billion, with India's contribution at around $1 billion. India is one of the countries that have earned 'credits' for emitting less carbon and considered to offer credits to countries that have a deficit. China is also among the one having surplus credit to offer. According to the reports published online, India has generated some 30 million carbon credits and has roughly another 140 million to push into the world market. There is another open market for waste disposal units, plantation companies, chemical plants and municipal corporations that can sell the carbon credits and make money. Carbon, like any other commodity, has begun to be traded on India's Multi Commodity Exchange (MCE). MCX has become first exchange in Asia to trade carbon credits (Birla *et al*. 2012).

Reducing the Carbon Footprint

Carbon footprinting has appeared in the news frequently with the emerging concern towards the climate change. The main way to reduce the carbon footprint is to decrease the energy consumption and minimize the energy an individual waste. For travel, use of public transportation or low-emission vehicles must be favoured. Insulation of houses, use of energy-efficient products and reuse or recycle as much as possible are other ways out. There is possibility to compensate for the effects of carbon footprint through carbon offsetting. Many organisations like The Nature Conservancy and several others provide carbon offset programs that invest donations toward protecting land and planting trees, both proven ways to reduce greenhouse gases.

It is important that people understand the affect that their carbon footprint has on the planet. With the spread of awareness, people want to know how they can reduce their carbon footprint. The day to day activities like shut off lights, air conditioning, and electrical appliances when aren't in a room and use of heat and air conditioning sparingly could serve the purpose. Water conservation by its judicial use is other way out. Other activities include using reusable canvas shopping bags, buying locally grown produce or even better, growing at own garden. Lastly, reconsider your transportation choices. Walking or riding a bike not only reduces your carbon footprint, it brings health benefits.

Chemical fertilizer has a carbon footprint caused by its manufacturing process and transportation but composting breaks existing plant materials down into chemical components producing no carbon dioxide emissions. Using compost rather than chemical fertilizer shrinks the carbon footprint and concentrates carbon in soil. Creating carbon sinks increase fertility as well as eliminating excessive carbon emissions. Composting for the home lawn and garden can create carbon sinks exceeding 20

per cent of the total area but large farms tend to reduce soil carbon content. According to Hogg and Favoino however, even agriculture can rehabilitate carbon sinks by using organic compost to improve soil quality and sequester carbon. Experimental studies have shown that biochar releasing C in the soil could be used as fertilizers. The application of this in various crops can give better idea for fertilizer applicability (Singla and Inubushi, 2013)

Carbon Footprint and the Environment

Our increasing carbon footprint is having profound effects on the environment. Rising temperatures and shifting precipitation patterns are changing the growing patterns of plants and result in indigenous vegetation moving to increasingly cooler climates. Sea levels are rising as the temperature of our planet increases--warmer water occupies more space than cooler water. Rising seas will not only erode shorelines and destroy ecosystems, coastal cities and towns could be displaced by rising seas.

Returning carbon directly to the soil rather than forming carbon dioxide results in a carbon sink rather than a carbon footprint. Carbon is drained back down into the soil and held there in a process called sequestration. In a paper delivered to the European Commission, Enzo Favoino and Dominic Hogg suggested that an increase of 15 per cent carbon sequestration could result in an equal reduction in carbon emissions in one year; the commission also received an estimate suggesting that the establishment of carbon sinks in 20 per cent of agricultural areas could achieve as much as 8.6 per cent of the total European Union objective for carbon emissions.

Carbon Footprint and Wildlife

As vegetation shifts climate because of increasing temperatures and shifting weather patterns, wildlife that depends on it will become threatened because it is unable to keep up with the rate at which the climate is changing. For example, migratory birds arrive at their destination to find that food sources such as plants bloomed too early or not at all. On the other hand, melting Arctic ice destroys hunting ground for polar bears. According to the Nature Conservancy, one quarter of the Earth's species will be headed for extinction in 40 years if climate change increases at its current rate. The Wildlife Conservation Society has calculated its carbon footprint and is taking steps to reduce its greenhouse gas emissions. As a leader in global conservation, WCS aims to lead by taking steps to help New York City reduce its footprint by 30 per cent by 2030 (WCS, 2008). In 2007, WCS launched an effort to ensure its conservation practices at home were truly consistent with its global mission of protecting wildlife and wild places and to position the organization as a leader of New York City's greening plans. To that end, WCS created a Carbon Footprint Project Team to calculate its carbon footprint and then to implement steps to cut back on its emissions. The WCS is poised to be a leader in creating emission reductions through the conservation of tropical forests as part of our work to protect the Earth.

Carbon Footprint and Human Health

The impacts of climate change include warming temperature thereby resulting in increased carbon footprint and affect the biota of the planet. The changes in precipitation, increases in the frequency or intensity of weather events, and rising sea levels threaten our health by affecting the food we eat, the water we drink, the air we breathe, and the weather we experience. The increase in the carbon footprints has the capacity to harm our health causing major risk to women in agricultural work and children. According to the World Health Organization (WHO), climate change is projected to increase the percentage of people in Mali suffering from hunger from 34 per cent to at least 64 per cent after a period of 40 years from now. Malnutrition is causal factor of most deaths in the developing world as a result of the effect of climate change on food crops, such as drought and unexpected rainfall that interferes with the growing season. Drought also causes diarrheal diseases as access to safe water is compromised. Vector-borne diseases such as malaria are increasing as the temperature increase allows malaria causing mosquitoes to survive in countries previously too cool for them. Lastly, increased air pollution has caused an increase in respiratory problems as asthma and allergies have increased.

The Lancet medical journal has had two special editions on this subject which showed that children, the most vulnerable in any community, are already dying in large numbers in poor countries as a

result of a warming world. A WHO assessment of the burden of disease caused by climate change suggested that the modest warming that has occurred since the 1970s was already causing over 140,000 excess deaths annually by the year 2004.

Carbon Footprint, Economic Losses and Depletion of Resources

Increase in the carbon footprints cause the depletion of the resources on large and small scales, either from a country's deforestation activities or increased use of air conditioning. The maximal exploitation of resources results in more GHG spur further climate change. The Environmental Protection Agency (EPA) suggests that consideration of different energy supplies and conservation of current ones will be needed to balance energy demand. Reducing carbon dioxide emissions to maximum and off-setting the remaining emissions by afforestation or supporting alternative energy efforts, will help to reduce the negative effects of carbon footprints.

The threat posed by our increasing carbon footprint on the economy is significant. Climate abnormalities will affect local economies dependent on land and natural resources the most, such as farms that fall victim to lowered crop yields. According to the Nature Conservancy, the economic losses due to our increasing carbon footprint and the resulting climate change has threatened the lobster industry in New England as catches have plummeted. In addition, the ocean/sea ecosystem is also affected by threatening the survival of coral reefs, a $375 billion per year industry. Climate change is considered to affect all four dimensions of food security, namely food availability (i.e., production and trade), access to food, stability of food supplies, and food utilization. Importance of the different dimensions and the overall impact of climate change on food security will differ across regions and over time and, most highly, will depend on the overall socio-economic status that a country has accomplished as the effects of climate change set in (Prajapati *et al.* 2011).

Effects of carbon footprint on greenhouse gas emissions and climate change

Climate change is the ultimate effect of large carbon footprints and has been urged by scientific consensus that we must strive to reduce global greenhouse gas emissions by at least 50 per cent by 2050 to avoid the worst consequences. Greenhouse gases, whether natural or human-produced, contribute to the warming of the planet. According to the reports, carbon dioxide emissions increased by 31 per cent from 1990 to 2005. Further by 2008, the emissions had contributed to a 35 per cent increase in radiative warming, or a shift in Earth's energy balance toward warming, over 1990 levels. The decade from 2000 to 2009 was the warmest decade on record worldwide, according to the U.S. Environmental Protection Agency's (USEPA) Climate Change Indicators Report.

The United Kingdom has been the first country in the world to set itself legally binding 'carbon budgets'. With its introduction in the Climate Change Act 2008, carbon budgets set limits on the total greenhouse gas emissions with a long-term target of an 80% reduction in emissions by 2050 on 1990 levels.

Another sector responsible in this regard is electricity generation and transportation-related activities that account for over half of the 14 per cent increase in greenhouse gas emissions in the United States from 1990 to 2008. The Federal Transit Administration (FTA) estimates that switching to public transportation would allow the average American to reduce his or her carbon footprint by 10 per cent. A reduction in carbon footprints can further be achieved by changing their incandescent bulbs to compact fluorescent lights, preventing the emission of 9 billion pounds of greenhouse gases.

In the data provided by ICLEI, 2009 the carbon emissions in Indian cities are also lower than that compared with the European countries. It should be mentioned that among these cities, apart from Sao Paulo and Rio de Janeiro in Brazil and Shanghai in China, which can be compared to Mumbai, other cities are not comparable directly with Indian cities in terms of their landscape or level of development. As reported, Palo Alto, California, USA, leads the pack with emissions amounting to nearly 12 tonnes per capita, followed by Toronto, Canada (at 9.6 tonnes per capita). Reports present that only seven of the 41 Indian cities studied by ICLEI have per capita emissions greater than Sao Paulo's 1.5 tonnes per capita. The research carried out on the basis of examination of the per capita carbon emissions across metropolitan and non-metropolitan cities, it was found that the average per capita carbon

emissions are higher in the metropolitan cities of India (being 1.19 tonnes per capita as compared to only 0.90 tonnes per capita in the non-metropolitan cities) as was expected, and the national average is 0.93 tonnes per capita (ICLEI, 2009).

Conclusions

Carbon footprints possess the potential of being a good entry point for increasing consumer awareness about the environmental impacts and fostering discussions about the outcome in near future. The "greenhouse gas accounting" is another alternative terminology in this field serving almost the similar purpose. A plethora of definitions are available for carbon footprinting in the public domain but there is a need to establish a clear and unambiguous definition of this term to inform methodological decisions associated with measuring and reporting on greenhouse gas emission. The review of scientific literature, publications and statements from the public and private sector as well as from general media suggests that the term 'carbon footprint' has become widely established in the public domain although very precise calculators are still lacking. There is an urgent need to define the clear methodology of accounting the term "carbon footprint" from different activities carried out in industrial and institutional sector as well as local market.

Several international agreement on emissions reductions such as the Kyoto protocol (United Nations 1998) and international publications such as International Organisation for Standardization (2006) and World Resource Institute and World Business Council for Sustainable Development (2008) as well as national initiatives like NAPCC-2008 provide a valuable resource serving the purpose to aware the public about this concern.

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