

## Evaluation of carbon footprint for contribution to global climate change: a Review

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### ABSTRACT

The concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere has increased rapidly due to human activities, anthropogenic activities and economic growth, resulting in an increase of the atmospheric temperature and causing global warming and climate change. Climate change represents the biggest sustainability challenge. Greenhouse gases are emitted due to use of transport, land clearance activity, production and consumption of the food, use of fuels, manufacturing of goods, buildings and services. Economic growth and urbanization have resulted in activities contributing about 80% of the global GHG emissions and the carbon emitted requires having vigil check. Carbon footprint is an easy tool for monitoring and quantifying carbon emission (GHG emission), as well as checking mitigation programs at different scales. The present study shall focus on the various aspects of carbon footprint like carbon footprint contributors, its effects, carbon assessment methods and mitigation measures.

**Keywords** - Carbon footprint, Carbon management, Climate change, Global warming, Greenhouse gases

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### I. INTRODUCTION

Carbon emission analysis and management and mitigation strategies are key components of sustainability initiative because the Carbon dioxide is the main contributor to the greenhouse effect and can cause problem in the future. The carbon footprint is a tool to manage the greenhouse gas emissions as a reference tool to reduce emissions in the future up to certain level for better sustainability. The term carbon footprint is basically originated from the term "ecological footprint". It is the subset of Life Cycle Assessment (LCA) and ecological footprint. Ecological footprint measures human demand on nature which means the quantity of nature it takes to support people or economy.

Carbon footprint is generally the measure of the total amount of CO<sub>2</sub> and other greenhouse gas emissions that are directly or indirectly caused by human activities and other anthropogenic activities. Human activities like industrial activities, agricultural activities, deforestation, waste disposal and especially, unprecedented use of fossil fuel have been producing increasing amounts of greenhouse gases. Carbon footprint provides the opportunity for environmental efficiencies and cost reductions. Carbon footprint value indicates how much carbon dioxide have been released in to the atmosphere during particular time period due to various human activities. Carbon footprint is comparable to

lifecycle impact assessment and it is also an indicator of global warming potential (GWP) and global sustainability.

Carbon footprint is made of sum of two parts: the primary footprint and the secondary footprint. The primary footprint is the measure of direct emissions of CO<sub>2</sub> from burning of fossil fuels including domestic energy consumption and transportation. The secondary footprint is the measures of the indirect emissions from the whole life-cycle of the products from the manufacturing process of the product to its final disposal. The most significant contributors to the global warming and climate change are the six Kyoto gases. Greenhouse gases that are regulated by the Kyoto Protocol are: Carbon dioxide (CO<sub>2</sub>), Nitrous oxide (N<sub>2</sub>O), Methane (CH<sub>4</sub>), HFC, PFC and SF<sub>6</sub> (IPCC 2007). Among them the largest share of greenhouse gas contributed by the Carbon dioxide (~60%) followed by the CH<sub>4</sub> and N<sub>2</sub>O.

According to IPCC 2007, there is an agreement that the climate is warming and ocean temperature increases due to carbon emission. Human activities, industrialization, economic development and other anthropogenic activities increase the concentration of greenhouse gases in to the atmosphere, which is ultimately resulted in the increased in mean global temperature about 0.74°C. Also, the natural systems like different types of

plants and animals are being affected. However, the calculation of carbon footprint from different sectors is an important tool and providing the total carbon emission of the particular sector at particular time period. The carbon footprint calculation is also the valuable first step towards policy making for better carbon management and better sustainable development. This review paper focuses on the various aspects of carbon footprint like carbon footprint contributors, its effects on environment, assessment methods and mitigation measures.

### 1. Urban and Rural Carbon Footprint

The world's population is now over 50% urban and urban localities are major contributor of national greenhouse gas emissions. According to International Energy Agency report, India is the fourth largest emitter of greenhouse gases and also contributing about 5% of the total global emission. Nowadays, India is experiencing a rapid growth of urbanization, industrialization and economic development which has sweeping climate change because the per capita energy consumption in urban area is about 80% higher than in the other country. Approximately, 50% of the population in India lives in urban areas and serve as a centre of human activities, industrial activities, education, knowledge and political power. As reported in International Energy Agency, urban settlements are responsible for 67% of the total world's energy demand and is expected to expand about 73% by 2030.

In India urban settlements are the main hotspots of anthropogenic and human activities contributing about 80% of the total global greenhouse gas emissions (Jan Minx, 2012). Nowadays, in urban areas, lifestyle studies are interesting research and some mitigation strategies are applied to reduce the emissions about 80% of global total greenhouse gas emissions. Because the lifestyle of the people in urban settlement is directly related to higher carbon emission in urban sectors (Jukka Heinonen, 2011).

Antti Saynajoki suggested that in urban areas, buildings contributing one third ( $1/3^{\text{rd}}$ ) of the total carbon emissions and construction phase emissions are more significant regarding climate change. The main factors responsible for urban carbon footprint are electricity consumption, transportation, water usage, solid waste and food waste generation, usage of fuels, gas consumption, income of the people, lifestyle of the people and cell phone usage (Sankesha P. Bhoyar, 2012).

Rural settlements are also responsible for greenhouse gas emissions. The main factors which are responsible for rural carbon footprint are fuel consumption, open dumpsite, cell phone usage, usage of traditional fuels. Per capita carbon emission is higher in cities than suburban and rural areas due

to higher income level, large housing space, long private transport activity and modern energy services (Jukka Heinonen, 2011). Analysis and assessment of the energy and environmental emissions of household is important tool and correlated with direct and indirect energy requirements of households. (Christopher L. Weber, 2009).

Antti Saynajoki analysed that construction sector consumes 40% of the raw materials and contributes about 40% to 50% of the total greenhouse gas emissions and also energy consumption of buildings in urban settlement is higher than rural areas. Antti Saynajoki analysed that construction phase of residential development project contributing more carbon emission and cement is the major contributor of greenhouse gas emission during construction phase of residential building. Rapid urbanization and urban development are the main factors of carbon emission in urban areas. Wei Huang found that carbon emission from building material production is about 45% of the total greenhouse gas emission, while CO<sub>2</sub> emission from building energy use contributed about 40% to 45% of total emission. Wei Huang also concluded that carbon emissions from building material transport was about 1%.

T. V. Ramachandra compared the carbon footprint of six mega cities of India and found that Chennai emits the highest CO<sub>2</sub> equivalent emissions per GDP among six Indian cities. Urban carbon footprint is the most appropriate methodology to assess the urban sustainability associated with carbon emissions and urban carbon footprint methodology is able to identify the critical economic sectors where policy and decision makers may involve to implement energy efficiency measures to reduce the environmental cost.

### 3. Carbon footprint and measuring methodologies

Evaluation and calculation of carbon footprint serve as an important tool in terms of carbon emissions and reduction of these emissions up to certain level. The carbon footprint calculation also helps to identify the weak areas of high carbon emission that can be eliminated and provide mitigation measures to reduce the emission and to gain carbon credit.

ISO 14064: International standard ISO 14064 provide some guidance for calculating, designing, developing, managing and reporting organization or company level GHG inventories. It includes determination of GHG emission boundaries, quantification of organization's carbon emissions and removals and identification of activities for improving greenhouse gas (GHG) management. ISO 14040 and 14044 for Life Cycle Assessment of products and their impact on

environment during its whole life cycle. International standard ISO 14067 used for carbon footprint calculation of particular product during its whole life cycle from manufacturing process to its final disposal at disposal site. ISO 14067 standard was created based on other international environmental labelling and environmental management standards. This international standard includes basic principles, guidelines for boundaries, quantification of greenhouse gases and communication of carbon emissions (Andriel Evandro Fanner et. al.). The GHG protocol was developed by World Resource Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) and considered the most important and effective tool used for business leaders and governments, providing guidelines for measuring carbon emissions from wide range of categories such as product chains and emissions from different cities. GHG protocol was developed to encourage users to understand, quantify and manage carbon emissions. GHG protocol follow an inclusive, consensus based multi stakeholder processes with participation from businesses, government agencies, non-governmental organizations and institutions around the world.

The PAS 2050 was first methodology developed and used for product carbon footprint. It is the specification for the assessment of the life cycle greenhouse gas emissions of goods and services and it is the first consensus-based and internationally applicable standard on product carbon footprint evaluation. The PAS 2050 includes detailed guidelines for evaluating and calculating the product carbon footprint that has been used as the basis for the development of other standards internationally.

Carbon footprint can be evaluated by other two methodologies namely, bottom-up based on Process Analysis (PA) and top-down considering Environmental Input-Output Analysis (EIO) using Life Cycle Assessment (LCA) method. Process Analysis (PA) is generally bottom-up approach to understand the environmental impacts of individual product from their manufacturing process to the end of its life (cradle to grave). Process Analysis is based on on-site and first order impacts. Environmental Input-Output (EIO) analysis includes top-down approach which is applied in economics and provides majority of economics

#### **4. Greenhouse gas emissions contributes to global climate change**

The Intergovernmental Panel on Climate Change (IPCC) concluded that the climate is warming, atmospheric air and ocean temperature also increases due to carbon emission and sea level rises. Temperature rise resulted in the ice melting,

sea level rise and floods in lower areas. In addition, some areas might get dryer and some may get more moisture. Climate change also affects the biodiversity as a result of changing seasons, affects ocean and coral reefs in particular, endangers the food supply in the world as a result of crop failure.

In India the urban population increases due to rapid urbanization, industrialization and economic development. The urban population in India is predicted to increase about 40% by 2021 and the urban areas are the main hubs of economic growth and higher productivity. Economic growth implies the conversion of semi urban and rural land for urban uses like for residential, commercial and for industrial purpose. Thus, industrialization, economic development and urbanization are the major contributors to carbon emissions in the atmosphere (Kala Seetharam Sridhar). Due to urbanization, the rate of energy consumption for heating and lighting of residential and commercial building increases. The energy consumption in urban area generates about quarter of greenhouse gases globally and transport contributes about 13.5% of the total carbon emission (Mc. Carney, 2009). Among them the net primary impact of carbon emissions in the cities (urban settlements) is due to the usage of private vehicles. Transportation contributes to more greenhouse gas emission in the urban settlements.

The average per capita carbon emission found higher in the metropolitan cities of developing countries like India. The main reason for higher carbon emission in metropolitan cities in India is the presence of a greater number of industries. Therefore, increase in the carbon emission affects the low-income population of urban and rural settlements. Deforestation and greenhouse gas emissions are two major factors of global warming and climate change. The increase level of carbon dioxide and other greenhouse gases have direct impact on the agricultural land, climatic condition and human health. Effects of carbon emission can be classified in to three categories: agricultural impact, effect on sea level and effects on human health.

##### **a. Agricultural impact**

Higher carbon emission affects the growth rate of crops and weeds. This effect of global warming may affect the global precipitation pattern of the crops and soil moisture content. Carbon emissions leads to 9% impact on agricultural land according to Indian Agricultural Research Institute.

##### **b. Effect on sea level**

The rise in atmospheric Carbon dioxide level resulted into global warming and climate change and sea level will also rise. The sea level rises due to thermal expansion of sea water, melting of ice and melting glaciers of Antarctica. The

average sea level will rise about 0.88m by 2100 due to greenhouse gas emissions and climate change.

c. Effects on human health

Rising level of greenhouse gases (GHGs) especially atmospheric carbon dioxide (CO<sub>2</sub>) resulting in the serious health issues like asthma. This may sometimes lead to death. The excessive amount of carbon dioxide aggravates ozone (O<sub>3</sub>) and other pollution levels (Anil C. Ranveer, 2011).

### 5. Need of calculating carbon footprint

The community recognizes the need of calculating their carbon footprint and reduce their carbon emissions to control the effect of climate change and global warming. Many countries, organizations, and individuals are starting to take responsibilities to reduce their greenhouse gas emission and gain carbon credit for better carbon management and sustainable development. Evaluation and calculation of carbon footprint can be a valuable first steps towards the making greenhouse gas emission reduction, green development and mitigating the effect of carbon emission in environment (Stern, N. H., 2007). Once an individual or organization or a particular sector has that number, then they can figure out what steps to take to lower that particular number, either by finding ways to release less greenhouse gases or by doing something that reduces the greenhouse gases released (plantation of trees). Many countries, organizations and individuals are starting to take responsibilities to reduce carbon emissions up to certain level.

Calculation of the carbon footprint is the foremost exercise for most organizations and institutions. The organization's carbon footprint calculation is an effective tool for sustainable development and better carbon management. The organization's carbon footprint calculation quantifies the key emission sources, typically including usage of gas, electricity consumption, human factor, solid waste generation, paper usage, water consumption, use of computers and transportation. Organizations have calculated their carbon footprint for public disclosure which means for marketing purpose, to determine what quantity of carbon emissions they need to offset for them to become carbon neutral.

Evaluating and assessing the carbon footprint is the beginning of the sustainable development and carbon management. So, carbon footprint is very useful exercise for complete environmental management system. Carbon footprint can be a useful tool for city planners and policy makers. Many companies use carbon footprint calculation to assess the environmental impact and sustainability performance of their products and processes. Expressively, carbon footprint evaluation has been utilized to assess such

activities and systems such as tourism, public services and alternative transportation technologies. Many companies use carbon footprint calculation to assess the environmental impact and sustainability performance of their products and processes. Carbon footprint calculation has also been used to assess or evaluate the impact of lifestyle of the citizens.

## II. CONCLUSION

Developing countries like India contribute about 5.3% of the total carbon emissions due to rapid urbanization, industrialization and economic growth. Increasing amount of Carbon dioxide (CO<sub>2</sub>) and poor air quality of major cities in India affecting the climatic condition of the country and the public health. Carbon footprint plays an important role for developing an environmental plan on the greenhouse gas emissions, evaluation, assessment and their reduction for sustainable development and carbon management. The carbon footprint calculation is used to frame regulations to reduce their impact on environment and climate change. The carbon footprint calculation of the particular region would help the city planners and policy makers to in implementing appropriate mitigation measures of carbon emissions.

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