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Carbon Footprint: Concept and Measurement

Introduction:

In the face of the escalating challenge of climate change, global awareness of the environmental impact of human activities is growing rapidly. Among the key indicators that highlight this impact, the carbon footprint emerges as a fundamental metric for understanding the volume of greenhouse gas emissions including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other fluorinated gases resulting from various human activities. This understanding is critical for developing effective strategies to limit global warming to 1.5°C and achieve carbon neutrality, as recommended by the Intergovernmental Panel on Climate Change (IPCC) and the Paris Agreement of 2015.

Over recent years, the term "carbon footprint" has gained widespread use due to its urgent relevance. It is no longer limited to media discussions but has become an integral part of the language of business and governance. Nevertheless, a fundamental question remains: What is the true meaning of the term "carbon footprint"? This is what we aim to clarify below.

1. The Concept of Carbon Footprint:

The term ***"carbon footprint"*** is relatively recent and has evolved from the broader concept of the ***"ecological footprint".*** While the ecological footprint measures the impact of individual or societal consumption on the environment particularly in terms of natural resource use and the Earth's capacity to absorb waste the carbon footprint specifically focuses on measuring greenhouse gas emissions that contribute to climate change. The term "carbon footprint" was first coined in 1992 by William Rees and Mathis Wackernagel, aiming to create a tool to measure the environmental impact of various activities in terms of greenhouse gas emissions and to establish accountability for those emissions and strategies to reduce them(1).

The carbon footprint has been defined in various ways depending on the focus of interest. The primary differences revolve around two main issues: measurement units and scope of assessment(2). **Some of the most important definitions include:**

- The IPCC definition, which adopts the perspective of Wiedmann and Minx (2008), emphasizes the comprehensiveness of emission sources. It defines the carbon footprint as:
- "A measure of the total amount of carbon dioxide (CO_2) emissions that are directly and

indirectly caused by an activity or accumulate over the life stages of a product."[3].

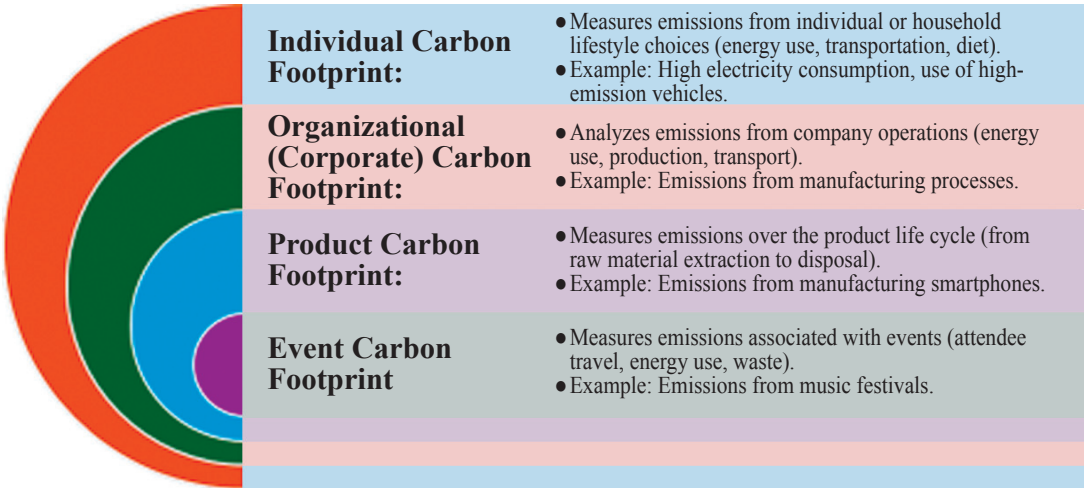
- The Center for Sustainable Systems at the University of Michigan provides a more detailed and comprehensive definition, emphasizing standardized measurement and full life-cycle assessment. It defines the carbon footprint as:
- "The total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event, or product. It is calculated by summing the emissions from every stage of the product's or service's life cycle (*material production, manufacturing, usage, and end-of-life*). During the life cycle, GHGs such as CO_2, CH_4, and N_2O may be emitted. Differences in warming potential are considered through each gas's Global Warming Potential (GWP), resulting in a carbon footprint measured in units of CO_2 equivalents (CO_2e)"[4].

Based on these definitions, we may synthesize a comprehensive definition of the carbon footprint as follows:

A comprehensive metric of the total greenhouse gas emissions including CO_2, CH_4, N_2O, and fluorinated gases resulting from individual and institutional human activities or associated with products, services, or events. These emissions are expressed in units of carbon dioxide equivalent (CO_2e), taking into account the full life cycle of the product or service and all direct and indirect emission sources. The aim is to assess the impact of various activities on climate change and to develop effective strategies to reduce these emissions.

Figure (1) illustrates the main types of carbon footprints:

Figure (1) Types of carbon footprint



2. Measuring the Carbon Footprint:

Methods for measuring the carbon footprint vary depending on the required level of detail and accuracy. Key approaches include[5]:

- Simple calculators for individuals and small organizations:

- These rely on online carbon footprint calculators, using estimated data on electricity consumption, vehicle type and usage, and dietary habits. They are user-friendly but may lack full accuracy.

- Life Cycle Assessment (LCA):

- A comprehensive and accurate method that evaluates emissions across the life cycle of a product or service from raw material extraction to disposal. It requires detailed data and specialized software for modeling emissions and is widely used in industry, though relatively costly and requiring expert knowledge.

- Greenhouse Gas Protocol (GHG Protocol):

- An international standard framework for

accounting and reporting GHG emissions. Emissions are categorized into three main scopes:

A- Scope 1: Direct emissions from sources owned or controlled by the organization.

B- Scope 2: Indirect emissions from the consumption of purchased energy.

C- Scope 3: Other indirect emissions throughout the value chain.

Implementing this protocol requires a high level of expertise(6).

- Input-Output Analysis:

An economic approach that estimates emissions based on economic data (such as spending and production), analyzing the relationships between economic sectors. Emissions are linked to each sector based on industry averages.

3. National and Individual Carbon Footprints:

Differentiating between consumption-based carbon footprints and national emissions inventories is essential for identifying true accountability for greenhouse gas emissions(7):

● National Emissions:

Measure GHG emissions from productive activities occurring within a country's borders. Countries submit periodic reports known as National Communications in accordance with the UN Framework Convention on Climate Change (UNFCCC).

● Consumption-based Carbon Footprint:

Measures GHG emissions linked to the consumption of goods and services, regardless of their place of production. This includes emissions from international transportation and shipping. A country's carbon footprint can increase even as its domestic emissions decline, especially due to high levels of imports highlighting consumer countries' responsibility.

Generally, emissions and carbon footprints vary widely between countries. Developed nations tend to record higher values due to their energy-intensive industries and higher per capita consumption. According to the most recent global

Figure (2) Global Distribution of CO2 Emissions in 2023

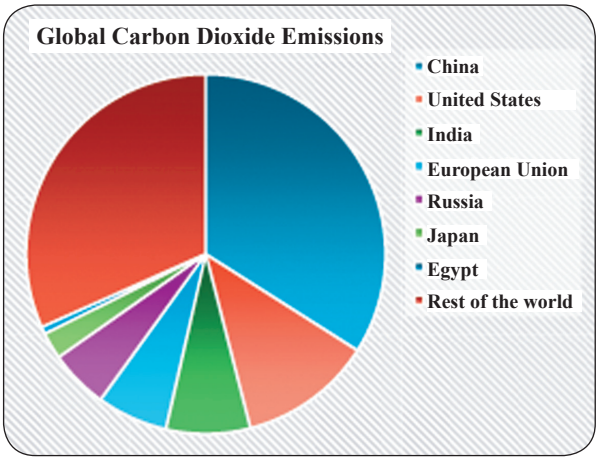
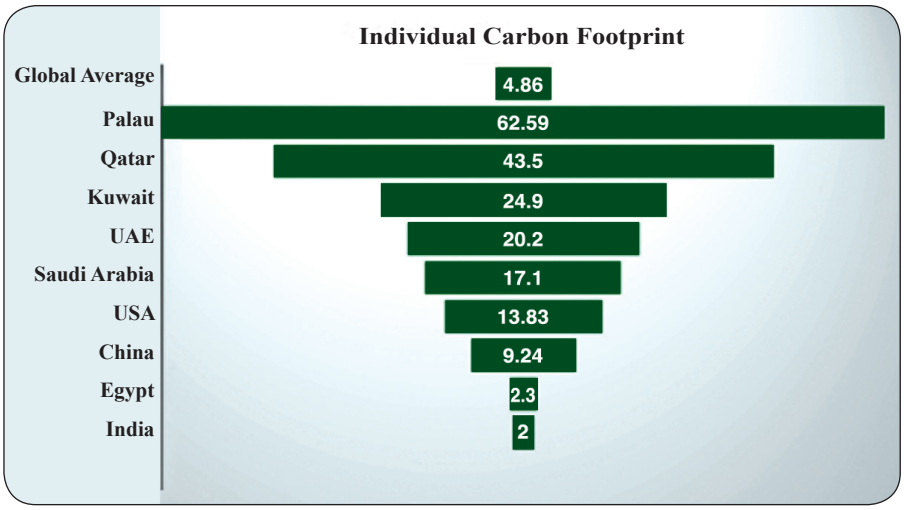


Figure (3) Highest Individual Carbon Footprint Shares in 2023



data from 2023, the top three emitters together account for over half of global emissions:

- China: 33.98% of global CO_2 emissions
- United States: 12%
- India: 7.57%
- Other major contributors include the European Union (6.4%)
- Russia (5.3%)
- Japan (2.42%).
- Egypt accounts for 0.64% of global emissions. (See Figure 2) [8].

At the individual level, Gulf countries top the list due to their high production and consumption of fossil fuels and elevated demand for imported goods. In contrast, Egypt's per capita emissions are below the global average. (See Figure 3).

It is important to note that carbon emission levels are dynamic and continually changing, influenced by critical factors such as advancements in clean energy technologies, improvements in energy efficiency, and shifts in consumption patterns toward sustainability. Government policies also play a central role in promoting the transition to renewable energy, enforcing carbon reduction measures, and encouraging investment in green projects.

Hence, the future trajectory of global emissions will depend heavily on how swiftly these developments are adopted and how effectively ambitious governmental policies respond to the challenges of climate change.

References:

(1) Rees, W, E.& Wackernagel, M, Our Ecological Footprint: Reducing Human Impact on the Earth, 1996, New Society Publishers, Gabriola Island, Canada.

(2) Wright, L. A., Kemp, S., & Williams, I., Carbon Footprinting': Towards a Universally Accepted Definition. 2011, Carbon Management, 2(1), pp. 61–72. https://doi.org/10.4155/cmt.10.39 (20Mar.2025)

(3) Intergovernmental Panel on Climate Change, IPCC, Glossary https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Annex-II.pdf (25Mar.2025)

- Wiedmann, T., & Minx, J., A Definition of 'Carbon Footprint'. In Carbon Footprint and Input-Output Analysis, 2008, Nova Science Publishers, NY, USA, pp. 1–11

(4) Center for Sustainable Systems, University of Michigan, Carbon Footprint Factsheet, 2024, Pub. No. CSS09-05. https://css.umich.edu/publications/factsheets/sustainability-indicators/carbon-footprint-factsheet (17Mar.2025)

(5) International Organization for Standardization (ISO), Carbon Footprint: Measuring and Reducing our Environmental Impact https://www.iso.org/renewable-energy/carbon-footprint (25Mar.2025)

(6) GHG Protocol https://ghgprotocol.org/(22Mar.2025)

(7) Berners-Lee, M., The Carbon Footprint of Everything. 2022, Greystone Books. Canada https://www.perlego.com/book/3234343/the-carbon-footprint-of-everything-pdf / (20Mar.2025)

-Mózner, Z. V., A Consumption-based Approach to Carbon Emission Accounting – Sectoral Differences and Environmental Benefits. 2013, Journal of Cleaner Production, 42, pp.83-95

(8) World Population Review, Carbon Footprint by Country 2025 https://worldpopulationreview.com/country-rankings/carbon-footprint-by-country (2 Apr. 2025)