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Environmental Carbon Footprint : As an Environmental Sustainability Indicator

Dr. Mahima Chaurasia[1] | Dr. Sanjeev Kumar Srivastava[2]

[1]Assistant Professor, Institute of Engineering & Technology, Dr. Rammanohar Lohia Avadh University, Ayodhya, U.P.
[2]Assistant Professor, Department of Environmental Sciences, Dr. Rammanohar Lohia Avadh University, Ayodhya, U.P.

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ABSTRACT

Carbon emissions from anthropogenic activities and their impact on climate change are one of the main challenges for achieving environmental sustainability. Carbon footprint, as an environmental sustainability indicator, has been frequently studied to quantify the environmental performance of a product, individual, company, city, or country, using environmental life-cycle assessment (LCA). Different LCA approaches have been developed to assess the environmental impacts of goods and services throughout their whole life cycle—that is from resource extraction, production, use and disposal—or cradle to grave. These approaches include the bottom-up process-based LCA approach and the top-down input–output-based LCA approach and both have advantages and disadvantages, in terms of system boundaries and detail of production processes. However, we need both approaches to be able to investigate the carbon implications of human activities at different scales, e.g., individual consumption, company operation, regional development. In addition, a win-win or trade-offs analysis between carbon footprint and other environmental indicators (e.g., water footprint, land footprint) may provide important information to decision makers for achieving overall environmental sustainability. Greenhouse gas accountings, commonly referred to with the popular term carbon footprints (CFP), are a widely used metric of climate change impacts and the main focus of many sustainability policies among companies and authorities. However, environmental sustainability concerns not just climate change but also other environmental problems, like chemical pollution or depletion of natural resources, and the focus on CFP brings the risk of problem shifting when reductions in CFP are obtained at the expense of increase in other environmental impacts. But how real is this risk? Here, we model and analyze the life cycle impacts from about 4000 different products, technologies, and services taken from several sectors, including energy generation, transportation, material production, infrastructure, and waste management. By investigating the correlations between the CFP and 13 other impact scores, we show that some environmental impacts, notably those related to emissions of toxic substances, often do not covary with climate change impacts. In such situations, carbon footprint is a poor representative of the environmental burden of products, and environmental management focused exclusively on CFP runs the risk of inadvertently shifting the problem to other environmental impacts when products are optimized to become more "green". These findings call for the use of more broadly encompassing tools to assess and manage environmental sustainability.

KEYWORDS: carbon, environmental, sustainability, footprints, greenhouse, emissions, management, toxic

1. INTRODUCTION

Carbon footprint, amount of carbon dioxide (CO2) emissions associated with all the activities of a person or other entity (e.g., building, corporation, country, etc.). It includes direct emissions, such as those that result from fossil-fuel combustion in manufacturing, heating, and transportation, as well as emissions required to produce the electricity associated with goods and services consumed. In addition, the carbon footprint concept also often includes the emissions of other greenhouse gases, such as methane, nitrous oxide, or chlorofluorocarbons (CFCs). The carbon footprint concept is related to and grew out of the older idea of ecological footprint, a concept invented in the early 1990s by Canadian ecologist William Rees and Swiss-born regional planner Mathis Wackernagel at the University of British Columbia. An ecological footprint is the total area of land required to sustain an activity or population. It includes environmental impacts, such as water use and the amount of land used for food production. In contrast, a carbon footprint is usually expressed as a measure of weight, as in tons of CO2 or CO2 equivalent per year. Carbon footprints are different from a country's reported per capita emissions (for example, those reported under the United Nations Framework Convention on Climate Change). [1,2] Rather than the greenhouse gas emissions associated with production, carbon footprints focus on the greenhouse gas emissions associated with consumption. They include the emissions associated with goods that are imported into a country but are produced elsewhere and generally take into account emissions associated with international transport and shipping, which is not accounted for in standard national inventories. As a result, a country's carbon footprint can increase even as carbon emissions within its borders decrease.

The per capita carbon footprint is highest in the United States. According to the Carbon Dioxide Information Analysis Center and the United Nations Development Programme, in 2004 the average resident of the United States had a per capita carbon footprint of 20.6 metric tons (22.7 short tons) of CO2 equivalent, some five to seven times the global average. Averages vary greatly around the world, with higher footprints generally found in residents of developed countries. For example, that same year France had a per capita carbon footprint of 6.0 metric tons (6.6 short tons), whereas Brazil and Tanzania had carbon footprints of 1.8 metric tons (about 2 short tons) and 0.1 metric ton (0.1 short ton) of CO2 equivalent, respectively.[3,4]

In developed countries, transportation and household energy use make up the largest component of an individual's carbon footprint. For example, approximately 40 percent of total emissions in the United States during the first decade of the 21st century were from those sources. Such emissions are included as part of an individual's "primary" carbon footprint, representing the emissions over which an individual has direct control. The remainder of an individual's carbon footprint is called the "secondary" carbon footprint, representing carbon emissions associated with the consumption of goods and services. The secondary footprint includes carbon emissions emitted by food production. It can be used to account for diets that contain higher proportions of meat, which requires a greater amount of energy and nutrients to produce than vegetables and grains, and foods that have been transported long distances. The manufacturing and transportation of consumer goods are additional contributors to the secondary carbon footprint. For example, the carbon footprint of a bottle of water includes the CO2 or CO2 equivalent emitted during the manufacture of the bottle itself plus the amount emitted during the transportation of the bottle to the consumer.[5,6]

2.DISCUSSION

A variety of different tools exist for calculating the carbon footprints for individuals, businesses, and other organizations. Commonly used methodologies for calculating organizational carbon footprints include the Greenhouse Gas Protocol, from the World Resources Institute and the World Business Council for Sustainable Development, and ISO 14064, a standard developed by the International Organization for Standardization dealing specifically with greenhouse gas emissions. Several organizations, such as the U.S. Environmental Protection Agency, the Nature Conservancy, and British Petroleum, created carbon calculators on the Internet for individuals. Such calculators allow people to compare their own estimated carbon footprints with the national and world averages. Individuals and corporations can take a number of steps to reduce their carbon footprints and thus contribute to global climate mitigation. They

can purchase carbon offsets (broadly stated, an investment in a carbon-reducing activity or technology) to compensate for part or all of their carbon footprint. If they purchase enough to offset their carbon footprint, they become effectively carbon neutral.[7,8] Carbon footprints can be reduced through improving energy efficiency and changing lifestyles and purchasing habits. Switching one's energy and transportation use can have an impact on primary carbon footprints. For example, using public transportation, such as buses and trains, reduces an individual's carbon footprint when compared with driving. Individuals and corporations can reduce their respective carbon footprints by installing energy-efficient lighting, adding insulation in buildings, or using renewable energy sources to generate the electricity they require. For example, electricity generation from wind power produces no direct carbon emissions. Additional lifestyle choices that can lower an individual's secondary carbon footprint include reducing one's consumption of meat and switching one's purchasing habits to products that require fewer carbon emissions to produce and transport.[9,10]

Sustainability, the long-term viability of a community, set of social institutions, or societal practice. In general, sustainability is understood as a form of intergenerational ethics in which the environmental and economic actions taken by present persons do not diminish the opportunities of future persons to enjoy similar levels of wealth, utility, or welfare.The idea of sustainability rose to prominence with the modern environmental movement, which rebuked the unsustainable character of contemporary societies where patterns of resource use, growth, and consumption threatened the integrity of ecosystems and the well-being of future generations. Sustainability is presented as an alternative to short-term, myopic, and wasteful behaviours. It can serve as a standard against which existing institutions are to be judged and as an objective toward which society should move. Sustainability also implies an interrogation of existing modes of social organization to determine the extent to which they encourage destructive practices as well as a conscious effort to transform the status quo so as to promote the development of more-sustainable activities.[11,12]

Sustainability is at the core of concepts such as sustainable yield, sustainable society, and sustainable development. The term sustainable yield refers to the harvest of a specific (self-renewing) natural resource—for example, timber or fish. Such a yield is one that can in principle be maintained indefinitely because it can be supported by the regenerative capacities of the underlying natural system. A sustainable society is one that has learned to live within the boundaries established by ecological limits. It can be maintained as a collective and ongoing entity because practices that imposed excessive burdens upon the environment have been reformed or abolished. Sustainable development is a process of social advancement that accommodates the needs of current and future generations and that successfully integrates economic, social, and environmental considerations in decision making.

3.RESULTS

In contemporary debate, sustainability often serves as a synonym for sustainable development. On other occasions, it is associated more exclusively with environmental constraints or environmental performance, and the expression environmental sustainability is used to emphasize that point. Parallel references can be found to the terms social sustainability, economic sustainability, and cultural sustainability, which allude to threats to long-term well-being in each of those domains. Local sustainability emphasizes the importance of place. Corporate sustainability is another common usage, which relates both to the survivability of the individual corporation and to the contribution that corporations can make to the broader sustainability agenda. Central here is the notion of the so-called triple bottom line—that businesses should pay attention to social performance and environmental performance as well as to financial returns. The notion of corporate sustainability is also connected to debates about reforming corporate governance, encouraging corporate responsibility, and designing alternative (sustainable, green, or ethical) investment vehicles.[13,14]

While numerous practices are cited as threats to sustainability, such as political corruption, social inequality, the arms race, and profligate government expenditures, environmental issues remain at the heart of the discussion. Of course, what is conducive to environmental sustainability remains a matter of intense debate. Approaches range from a moderate "greening" of current social institutions to a radical transformation of the global political and economic order. A gradual

adjustment toward sustainability relies on governmental initiatives to orient production and consumption into less environmentally destructive channels. That implies a reengineering of industrial and agricultural processes, a transformation of land-use practices, and a shift in household consumption. Potentially renewable resources should be managed to conserve their long-term viability; nonrenewable resources should be extracted at rates that allow an ordered transition to alternatives; emission of waste and toxic substances must remain within the assimilative capacities of natural systems; and more-vigorous measures must be taken to preserve species, habitats, and ecosystems. Managing long-term environmental issues such as climate change and the loss of biodiversity is of critical importance to efforts to achieve sustainability.

Governments can deploy an array of policy tools to effect such changes, including regulation, fiscal instruments, negotiated agreements, and informational tools. Yet many problems resist solution because the offending (unsustainable) practices are often linked to deeply entrenched practices and constraints and supported by established definitions of values and interests.[15]

There are also a number of radical takes on sustainability. For some environmentalists, true sustainability is possible only in small-scale communities, where humans can live in close contact with natural processes and rhythms. According to that view, the catastrophic practices of industrial civilization must give way to a different mode of living where humans "walk lightly" on the planet, harmonizing their activities with natural cycles. While other radical environmentalists may accept a high-tech postindustrial civilization, for them too there must be a clear break with existing economic practices and power structures.[16]

4. CONCLUSION

Discussion of sustainability within academia has ranged across many perspectives. Economic analysts have sometimes defined the concept in terms of nondeclining per capita income flows over time, or long-term economic growth, with minimal environmental impacts and debated how to maintain the capital endowments needed to sustain those income flows. Controversy over the substitutability of natural and human-made capital has divided proponents of weak and strong sustainability: the former argue that the two types of capital are largely interchangeable, whereas the latter insist that natural capital is increasingly the scarcest factor of production. In addition, ecosystem services, such as the provision of clean water or crop pollination, are often undervalued aspects of natural capital that should be incorporated into economic discussions of sustainability.[17,18]

Ecologists and systems theorists have tended to approach sustainability in terms of physical interdependencies, energy flows, and population dynamics. They have emphasized the design features that suit social systems for long-term survival, including robustness, resiliency, redundancy, and adaptability. For their part, political analysts have focused on the ideological and normative implications of sustainability, on the character of green political projects, and on the public policy implications.[19,20]

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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