The Carbon Footprint of Buildings: A Review

Samridhi Raghav[#]
[#]Student, Department of Geography, Girls College, Gurugram

Abstract: The carbon emissions associated with the built environment represent the dominant fraction of the total carbon footprint of society. As a result of the intense debate over how to address climate change, Life-Cycle Carbon Emissions Assessment and carbon footprint standards such as the PAS2050, ISO/TS 14067, and the GHG Protocol, are receiving increased attention. However, carbon emission calculations often vary in terms of boundaries, scope, units of greenhouse gas emissions, and methodologies. There is not an internationally accepted method for measuring, reporting, and verifying GHG emissions from existing buildings in a consistent and comparable way. In support of developing a standardized approach, this paper reviews current methodologies for carbon footprint accounting and outlines the inconsistencies of most life-cycle carbon assessments studies. The paper also aims to present the cutting-edge knowledge about emissions resulting from buildings during their life-cycle. The conclusion of this research, after a comprehensive literature review and critical analysis, is that there is a need for a clear, accessible and consistent method to assess the carbon emissions from buildings.

Keywords: Carbon Emissions, Carbon Footprint, Greenhouse Gases

I. INTRODUCTION

The concept of carbon footprint (CF), namely the greenhouse gases expressed in carbon dioxide equivalents, emitted during the life cycle of an examined system, has been known for several decades as an indicator for assessing the impact of human activities to global warming potential [1]. Despite the fact that carbon dioxide is a natural component of air, high concentrations or exposure over a long time period can cause significant problems in human health [2]. CF estimation is helpful for the efficient management of greenhouse gas emissions and the evaluation of measures to reduce them. CF analysis can identify significant sources of emissions and prioritize the areas with the greatest potential for improvement, thereby increasing environmental efficiency and optimizing financial costs of amelioration actions. Several tools for CF calculation are available in current literature [3]. Apart from the widespread use of the term as a contribution factor to global warming and climate change, there are several confusions regarding its definition and its content [4,5]. One of the key arguing points of CF calculation methods is the lack of uniformity in the selection of the boundaries of the study (e.g. the inclusion or not of indirect impacts). Despite the differences among calculations, the equivalent tons of carbon dioxide (t CO2- eq.) have been recognized as the basic functional unit of CF [6].

CF can be valuable for policy formation whereas it can be applied at various scales [4]. Indicatively, CF has been utilized to assess mutually different activities and systems such as tourism [7], public services [8], alternative transportation technologies [9] and knowledge sector [10]. Companies use CF to assess the environmental and sustainability performance of their products and processes [11 – 13].

Historically the amount of CO_2 in the atmosphere hovered just under 300 parts per million (ppm), but it's now approaching 400 ppm. CO_2 is not the most powerful of the greenhouse gases on a per-molecule basis—not by a long shot—but it is by far the most common and most significant of those generated by humans. Various targets have been proposed as acceptable levels of CO_2, most famously 450 ppm, above which the resultant temperature rise would likely cause extreme disruption to Earth's ecological and social systems. Many policy initiatives give lip service to this goal, but current actions are inadequate to reach it.

CO_2 has captured our attention, but it is certainly not the only air-pollutant from building-related activities. Some of the tools described below also quantify emissions of sulphur dioxide (which causes acid rain), smog-generating nitrous oxides, and other pollutants.

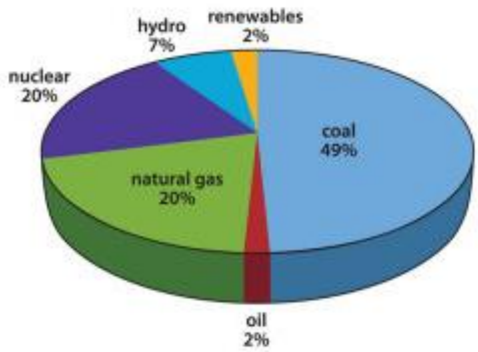

Fig. 1.1: Average Fuel Mix for Generating Electricity

2. OVERALL PROBLEM

Contemporary building has inherited the assumptions and practice models of Modernism, methods of thinking and practice that were developed in the last century, and are based upon historic cultural conditions of the 1940s, 1950s and 1960s. These inherited, and largely unquestioned assumptions of Modernism present us with a large problem when it comes to their construction, maintenance and operation. At best they cater to a fundamental need in the form of shelter, and as a highly capitalized industry, their construction responds to prevailing market forces. But insofar as we have extended their functionality and complexity to provide modern comforts, they are now the largest single contributor to global CO_2 emissions. When all aspects of buildings are considered, some estimate that over half of emissions are related to the building sector.

This is due to a variety of factors. Buildings use 35% of energy in the world and are directly responsible for 35% of global emissions. Two-thirds of global electricity production is for building operations. When including construction and maintenance, it becomes clear that 50–60% of global resources are consumed by buildings while also causing more than 50% of global waste production.

3. CO_2 PROBLEM

The problem of CO2 emissions is atthe core of necessary changes inthe building sector.We agree that the anthropogenic emissions of greenhouse gases are a threat to the future prosperity of our entire race, and the large potential reduction in our sector of buildings must be addressed rapidly and extensively. The extensive compilation of research from thousands of scientists around the world done by the IPCC has demonstrated the importance of limiting the potential anthropogenic temperature rise, and after much negotiation, the international community agreed with the Copenhagen Accord that temperature rise should not exceed two degrees. Out of any single sector, we have one of the largest opportunities to impact CO_2 emissions.

4. MATERIAL PROBLEM

The material problem for buildings takes many forms. As mentioned, the grey energy and emissions must be considered, and the production of building materials requires the use of more high value energy and resources as compared to building operations. There are also environmental problems with the by-products of material used in buildings, and there are limitations on the extraction of resources used for various building components. One must also consider the infrastructure used to support the built environment. There are many technological advances that must be implemented to solve the problems of resource depletion, corrosion, pollution, durability, lifespan, etc. associated with building materials. First of all, new construction should be built more sustainably such that it not only minimizes negative aspects of construction and operations, but that it first maximizes building lifespan, which can be done by removing design aspects that will be rapidly outdated. Also all necessary components with limited lifespans should be designed for reuse or raw-material-recovery. This must be achieved in all aspects by thoroughly breaking down the complexity of the building into its parts, and understanding any trade-offs between integrated systems so that a wholly sustainable solution can be achieved. This can be facilitated by an awareness of the rapidly expanding array of materials available for build structures, enclosures and systems. The past century has seen an explosion of development in material science. This is not just the development of new materials, but also the discovery of many new uses for existing materials. Concrete has been redesigned and reformulated through thousands of iterations and is now three times stronger.

5. SOLUTIONS

Managing and reducing carbon footprints as part of a low carbon strategy, with its inherent cost benefits and revenue opportunities, is increasingly important in building design. Building green is one of the best strategies to temper negative climate change because the technology to make substantial reductions in energy and CO2 emissions already exists.

Reducing a building's carbon footprint reduces its running costs, improves employee morale, raises property values and improves LEED scores. Buildings become environmentally responsible, profitable and healthier places to live and work in. The following tips can help reduce a building's footprint.

1. Start early: At this stage, alternative layouts and materials can be considered and details can be refined to use less material. As the design progresses these opportunities diminish." Part of this early planning involves a life cycle assessment on which carbon foot printing is based. "It is a process of considering all the flows (energy, water, materials, waste) in and out of a system to calculate its environmental impact. The result of a life cycle assessment for a product is a set of life cycle inventory data detailing the environmental impact per unit of the product. This information is becoming increasingly available through environmental product declarations direct from manufacturers. This data can then be combined with the material quantities used in the building to calculate its carbon footprint."
2. HVAC: Since HVAC comprises 40 percent of all carbon emissions, incorporating the most efficient heating, ventilation and air conditioning systems, along with efficient operations and scheduled maintenance of such systems, reduces carbon footprint. Schedule heating and cooling systems to go on during pre-determined hours; let the system run hotter or cooler in off-hours, depending on the season. Most buildings are ventilated with outside air to keep the inside air fresh and odor free. This ventilation runs all of the time, even when it is not needed. This wastes energy because the outside air needs to be heated or cooled. Installing a low-energy humidifier instead of a typical electric steam humidifier will reduce a building's carbon footprint. Also, equipping a building with sensors can measure indoor air quality and determine how much ventilation is needed. This means less electricity and natural gas will be needed for the HVAC system, which lowers energy bills and reduces the building's carbon footprint.
3. Lighting: Use state-of-the-art lighting and optimize day lighting. Lighting accounts for approximately 40 percent of the energy used in a typical commercial building. Solar thermal gain lowers carbon footprints, but too much solar gain in summer causes overheating and increases the need for cooling. Too little solar gain in winter increases the need for heating. Solar control window films can reduce carbon footprints by cutting energy expenditures by up to 30 percent.
4. Recycled content: "Metal building systems are the ideal product for sustainability and green as steel is the most recycled material on the planet. Recycled steel reduces mining waste by 97 percent, air pollution by 86 percent and water pollution by 76 percent. Producing steel through recycling also uses significantly less energy than conventional steelmaking. The typical metal building is manufactured from at least 70 percent recycled steel. "Steel is 100 percent recyclable, sustainable and less is needed for building a frame; therefore it is an excellent framing material to help reduce a building's total carbon footprint."

6. RELATED WORK

Harish Kumar (2018) presented reviews concept of carbon foot printing and assess carbon dioxide emissions and energy consumption for the production of road pavements by means of a literature review. Fenner et al. (2018) reviewed current methodologies for carbon footprint accounting and outlines the inconsistencies of most life-cycle carbon assessments studies. The paper also aims to present the cutting-edge knowledge about emissions resulting from buildings during their life-cycle. The conclusion of this research, after a comprehensive literature review and critical analysis, is that there is a need for a clear, accessible and consistent method to assess the carbon emissions from buildings. The findings in this paper can also support and facilitate the discussion of the meaningful targets required to reduce carbon emissions. Chau et al. (2015) reported that the use of primary or secondary energy is not always explicit in the carbon footprint calculations. Airaksinen (2011)studied a new office building in design phase and offers different alternatives to influence building energy consumption, CO_2 equivalent emissions from embodied energy from building materials and CO_2 equivalent emissions from energy use and how their relationships should be treated. In addition this paper studies how we should weight the primary energy use and the CO_2 equivalent emissions of different design options. The results showed that the reduction of energy use reduces both the primary energy use and CO_2 equivalent emissions. Especially the reduction of electricity use has a high importance for both primary energy use and CO_2 emissions when fossil fuels are used. The lowest CO_2 equivalent emissions were achieved when bio-based, renewable energies or nuclear power was used to supply energy for the office building. Evidently then the share of CO_2 equivalent emissions from the embodied energy of building materials and products became the dominant source of CO_2 equivalent emissions. The lowest primary energy was achieved when bio-based local heating or renewable energies, in addition to district cooling, were used. The highest primary energy was for the nuclear power option. Additionally, some studies have been focusing on particular materials (1998), systems or processes Taborianski et al. (2012), while others have reported comparisons of whole building (Chau C et al. 2015). Furthermore, the life cycle carbon assessment of buildings has been simplified in several studies, such as omitting transportation emissions for light materials and short distances, thus providing only a general picture of GHG emissions Taborianski et al. (2012). Beyond all these differences, each project has its own characteristics, such as climate zone, building type, and local regulations that directly affect the total carbon emissions for each building (Chau C et al. 2015) Therefore, the comparison of GHG emissions is compromised by the lack of a clear and consistent methodology (Onat et al. 2014). In addition, several indirect emissions sources that may represent a significant share of the carbon footprint of buildings, such as the transportation of tenants, are often ignored by most studies.

6. CONCLUSIONS

The consequences of climate change have increased awareness about the need for increased environmental protection in multiple countries across the globe. In the growing green building movement, the building construction sector has become a major target for improvement. While construction still represents a tremendous impact on the environment, this sector has been able to increase its efficiency while reducing impacts by using responsive design and alternative construction methods. Even though the green building movement is constantly providing guidelines for several categories, the main targets still rely on the reduction of harmful impacts created during the fabrication of building materials, the reduction of operational energy for buildings, and the control of carbon emissions associated with building life cycle phases.

Life-Cycle Carbon Assessment of buildings has received increasing interest by researchers, governments, and stakeholders as the consequences of climate change became more perceptible

REFERENCES

1. Harish Kumar (2018), Carbon Footprint of Roads: A Literature Review, International Journal of Engineering Research & Technology, 6(11), 1-3.
2. Andriel EvandroFennera, Charles Joseph Kibert (2018), The carbon footprint of buildings: A review of methodologies and applications, Renewable and Sustainable Energy Reviews, 94, 1142- 1152.
3. Chau C, Leung T, Ng W (2015), A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings, Appl Energy 143, 395–413.
4. Onat N, Kucukvar M, Tatari O (2014), Scope-based carbon footprint analysis of US residential and commercial buildings: an input-output hybrid life cycle assessment approach, Build Environ, 72, 53–62.
5. Taborianski VM, Prado RT (2012), Methodology of CO_2 emission evaluation in the life cycle of office building facades, Environ Impact Assess Rev, 33, 41–7.
6. MiimuAiraksinen, PellervoMatilainen (2011), A Carbon Footprint of an Office Building, Energies, 4, 1197-1210; doi:10.3390/en4081197.
7. Cole RJ (1998), Energy and greenhouse gas emissions associated with the construction of alternative structural systems, Build Environ, 34, 335–48.