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Carbon footprint analysis in a green building

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ABSTRACT

Construction industry is one of the major sectors causing environmental impacts and consequently impacts on the climate. More than one third of global energy-related carbon dioxide (CO_2) is emitted by the construction sector and one of the industries that is largest in terms of the volume of raw materials or natural resources consumed and the volume of construction products manufactured is the Indian construction industry. Energy consumption in the production and procurement of construction materials has the link with GHG emissions and its environmental consequences. Hence, this paper analyzes the carbon emissions caused by the Green building by its electricity consumption (using guidelines of ISO standard and US EPA) during its operational phase from various activities involved in the operation of the building, out of the other carbon emissions from different other energy uses like fuel consumption such as in the form of petrol, diesel for commutation, diesel consumption for generator, LPG consumption for pantry works etc, since electricity plays a major role comparatively. Here, the source building, a Green building in Salem locality with all utilities is considered that could ease the process and arrive at results. The carbon emissions of the electricity is checked so that the options for reducing as well as offsetting can be analyzed and mitigation measures to control those emission can be determined and also the revealing future scope of carbon efficient buildings, which could not only be energy efficient but also could emit less carbon, thereby making it environmentally responsible over the lifetime.

Keywords: Buildings Carbon foot print, Green Buildings assessment, Greenhouse gas, Environment sustainability, carbon emissions mitigation measures

1. INTRODUCTION

Climate change is identified both as a trouble and a challenge. It is unambiguous that the climate and climate systems is impacted by the human activities. Climate has its vital part in the economic development of India and hence many sectors of the economy are climate sensitive. Climate change anthropogenous and hence it's completely engaging the attention of planners, governments, and politicians worldwide. Commonly, approximately 30% of total global GHG emissions are contributed by buildings. GHG reductions in this area would make a significant contribution as an effort in reducing global warming. According to the Intergovernmental Panel on Climate Change (IPCC), reducing energy consumption and building embodied energy, switching to renewable energy, and controlling non-CO_2 emissions, serves as the areas to focus on in reducing emissions from buildings.

Carbon Emissions from Buildings

The buildings and construction sector linked with 36% of final energy use and 39% of energy and process-related carbon dioxide (CO_2) emissions in 2018, out of which 11% resulted from manufacturing construction materials and products (Abouhamad and Abu-Hamd, 2021). Among different human activities that give rise to the most common greenhouse gas – Carbon dioxide, building industry serves as one of the main sources. A universal unison of climate scientists is that there has surely been a hike in the global temperature over the past century. It is widely said that green buildings reduce the carbon footprint. The average certified buildings reduce energy consumption by 32% thus aiding the carbon reduction.

This study has analyzed the carbon footprint of a LEED India Gold rated jewel store in its operational stage. The study has further investigated whether green ratings have significant reduction in Carbon footprint, thereby giving further recommendations for improvement, if any. This work intends to assess the energy use and to collect appropriate data for the base year 2021, to analyze the carbon footprint of the green building and to provide the mitigation measures to for sustainable development.

The World Business Council for Sustainable Development (WBCSB) concluded to inform its representatives to take initiatives related to the Energy Efficiency in Buildings as well as organize a programme in the regard. After acknowledgement in the programme, companies "walk the talk" and send information to the market, stakeholders and the employees. The programme and its associated accomplishment have following 5 guidelines:

1. For the firm's commercial buildings, the criterion has been made and a time-based energy and/or CO_2 cutback goals in accordance with transformative change must be set
2. Company's policy regarding minimum energy performance levels must be published
3. To achieve the energy goals, the organization’s audit program must be explained and followed up along with its establishment schedule.
4. In Corporate Social Responsibility Report or any such report, the energy use details of the building, carbon dioxide emissions etc., must be published in contrast to the annual cutback goals.
5. Through various awareness, R & D, tutoring, etc., the building's energy efficiency can be further enhanced.

WBCSD representatives strongly admitted that the initiatives with an intention to enhance the energy performance in buildings and making interest over the energy-efficient buildings will be more specific in attaining the emissions cutback goals (WBCSD, 2014).

The buildings sector energy intensity has improved in recent years; this has not been enough to offset rising energy demand. Buildings-related CO2 emissions have continued to rise by around 1% per year since 2010, and more than four million deaths each year are attributable to illness from household air pollution. Fortunately, many opportunities exist to make use of the energy-efficient and low-carbon solutions for buildings and construction. These solutions will necessitate greater effort to implement strategic policies and market incentives that change the pace and scale of actions in the global buildings market (United Nations Environment, 2017).

The LEED 2011 for India-New Commercial Construction and Major Renovation (LEED 2011 for India-NC) has set of performance standards for the design and construction phases of commercial and institutional buildings and high-rise residential buildings, thereby certifying them (IGBC, 2011). Out of standards and guidelines available to measure GHG emissions, an offset protocol and independent, voluntary GHG project accounting standard help to measure GHG emission of the organization, event, product, or person is ISO 14064, (2018).

Frequently using methodologies and standard values suggested by the IPCC, the common carbon emissions are estimated at a national level. These national estimates include sector-wise estimations, which are based on detailed sectoral analysis (Asian Development Bank, 2010). It is very essential to calculate the carbon foot prints and it varies day to day life carbon foot printing methodology of EIB projects and also issues directions to EIB staff on to calculate the carbon footprint of the investment projects financed by the EIB (European Investment Bank, 2020).

Global warming if found to be the major issue which results in climatic change and also the various GHGs have different effects on increasing the temperature of the Earth, expressed as Global Warming Potential (in CO_2). In more industries, only CO_2 is of relevance, however there are important exceptions, such as methane and N_2O in the agricultural sector or in high-tech industries (Castro and Beining, 2019). The president and CEO of the WBCSD, in the world economy, buildings are the largest energy consumers, accounting for over one-third of final energy use and approximately 30% of global carbon emissions (Maywald and Riesser, 2016).

Environment change seen unpredicted and impacts high and it is to protect environment & preserve energy: Green Construction Concept. The concept will be an important step for the construction industry for eco-friendly design on energy & environmental regards (Singh, 2018). The Material selection is a key step in product design and typically aims at identifying the most suitable material that meets product performance goals at minimum cost. In recent years research has been driven for developing sustainable solutions at competitive costs (Samani et al., 2015). This work evaluates the sustainability of advanced sandwich-structured composites for novel housing solutions.

The time series of embodied GHG emissions from the building sector for 1997–2011. This data is used to demonstrate that strategies which focus solely on improving operational performance of buildings and the production efficiencies of domestic material producers will be insufficient to meet sector emission reduction targets. Reductions in the order of 80% will require a substantial decline in the use of materials with carbon-intensive supply chains (Giesekam et al., 2014).

The contemporary trends and applications of green building design and the respective impacts on sustainable developments. At a nut shell, the analysis determines that the sustainable energy performance of green buildings has been converted to real-time solution to control the CO_2 emissions and reduce the building sector energy consumption (Ghaffarian-Hoseini et al., 2013) also the selection of construction materials has the major impact in the achievement of the 'Green Buildings' goal and is performed both at an early stage of the design process and at the working plan. The latter feature is so vital specifically as the first one for the attainment of 'greenness' requirements, but building sector professionals of this choice usually lag in materials selection (Franzoni, 2011).

The former investigations have a major role in emphasizing the environmental view of the sustainable building. Various other aspects of sustainability of a green building, particularly the social sustainability is mainly considered. The chances for upcoming studies has been ascertained such as impacts on climate on the efficacy of green building assessment tools, analysis of actual performances of green buildings, future proofing etc., (Zuo and Zhao, 2014), time value of carbon is generally ignored in life cycle energy analysis studies, however in a national emissions reduction regime, when the energy consumption is reduced, can become an important factor.

Applying Net Present Value principles, the impact of embodied and operational energy was analyzed in the context of a future emissions target. In moderate climate, the embodied energy lead to 35% of the upcoming emissions goal of a building, the research says (Karimpour et al., 2014). In worldwide, the need for advancement depends on the non-renewable source which clarifies that the upcoming era will be doubtful except there exists lateral thinking (Ragheba et al., 2016). These complicated topics have no direct clue, mainly taking into account that the sustainability is everyone's target to achieve. Green concepts have advantages over environment, society and economy as well (Huma & Hyder, 2022; Goyal et al., 2019).

The Multi-criteria analyses (MCAs) are generally practiced to determine and verify the sustainability of various renewable energy sources with an intention to give out the support facilitating the decision in selection of apt sustainable choices. MCAs are smart in providing the sustainable results in various dimensions, generally associating a wide range of basis for various forms of data and information (Troldborg et al., 2014).

The buildings and the construction sector have the largest shares of global energy and emissions compared to other sectors, such as industry and transport. The global energy demand from this sector will rise, mainly due to: (i) Improved access to energy in emerging countries, (ii) substantial usage of energy-consuming devices, and (iii) exponential growth of the building sector (Taffese and Abegaz, 2019). The GHG emissions for the entire life cycle and the energy interpretation of the Engineering Pavilion (hereinafter referred to as Building 216) at Curtin University Western Australia. The study determined the popular places where the emission occurs in construction and use of the building 216. Because of this research, the plan for better management of environment is possible. Owed to the existence of BMS, the operational phase of the building gives outs 63% less GHG emissions than the university average (Biswas, 2014).

Hence, the BMS serves in decreasing total embodied energy consumption of the building (i.e., 20% less than the University average). The field of "Architecture" concerned with environmental sustainability and explains different sustainability measures. Environmental sustainability is attributed to build environment design as well as planning and executing the design with nature. Here, the school buildings following sustainable concepts are considered concerning their design aspects and thereby an assessment made about using architecture and its features as an important tool for sustainability education (Tasc, 2015).

2. METHODOLOGY

Materials and methods

The term "sustainability" has been applied extensively to many products and activities in recent years. It is generally considered that there are three distinct sectors in which sustainability can be affected and enhanced.

Environmental sustainability

Economic sustainability and

Social sustainability

In regards to building industry, there is an intense urge for best possible solutions that provide benefits for all of the three sectors. Green Building Rating (GBR) systems help in sustainable design processes by giving out the self-supporting valuation aids, in which strategies used to enhance sustainability of buildings can be calculated according to general sets of rules that involves categories from energy efficiency to water resource. Since building sector accounts one of the major parts of energy use out of the total energy use sectors as quoted in Castro and Beining, (2019), this study plans to consider the building sector energy use and the corresponding carbon emissions. Though there are many ways of energy uses, electricity plays a very major role.

Moreover, there are many analyses on building level carbon emissions in various countries while this paper works on deducting the carbon emissions of the electricity usage of a Green building in a Tier-II city like Salem by using guidelines recommended in ISO 14064 and US Environmental Protection Agency's standard, so that it would pave ways for the future researches in inventing technologies to sort out this. So, here the carbon emissions from the electricity consumption of a Green Building is examined.

Objective of the study

The work focuses to measure the carbon emissions due to the electricity use in the building in its operational phase and how such carbon footprint can be minimized.

Selection of building and Data collection

The project has chosen a three-storey commercial Green building of 21,277 Square feet built up area and a total site area of 15896.04 Square feet. The building has achieved 43 points under LEED INDIA NC 2011 and received certification by July 2012. All these details and the data required for this analysis are collected via questionnaire survey with the facility team and received the database in electronic form.

Energy utilization and carbon footprint analysis

Carbon Footprint Calculations are usually done in Construction (before occupancy), Operation (during occupancy) and End of life-cycle (Demolition period) phases of the building. Here it is done for the operational phase. The calculations are done using various standards and protocols. This involves the following.

Data collection and quantification

The building data (for the base year of 2021) needed for the calculations are obtained prior to the calculation process from the facility team is the Electricity consumption details. The carbon emissions calculations are done using GHG protocol and ISO: 14064-1. Also, the calculations are also done using US EPA's (United State Environmental Protection Agency) Greenhouse Gases Equivalencies Calculator that is available online (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator), to identify variations in emissions. The calculator directly gives the equivalent amount carbon emissions for electricity in Kilowatt-hour (KWh). Also, it provides suggestions for avoiding the net emissions, if unavoidable the ways to offset the same. Out of the Direct scope, Indirect scope & Other Indirect scope, the carbon emissions for electricity consumption comes under Indirect carbon emissions scope.

Indirect Carbon Emissions

In the building, the carbon emissions caused by the consumption of Electricity, that is from power grid and not produced on-site, comes under Scope 2 (There is no power purchased from renewable energy sources and also no on-site power generation such as using Solar panels, Windmills etc.,).

Electricity Consumption

The Electricity consumption of the chosen building for the base year (2021) is given (Table 1).

Table 1 Electricity Consumption of the Building for the Year

Month	Consumption (KWH)
January - February	19633
March – April	27958
May – June	6151
July – August	19385
September - October	30228
November - December	25850
Total	129210

As per ISO 14064, Electricity, mostly from coal-based source emits 0.85 kg of Carbon dioxide (CO_2) per KWh. Carbon dioxide emissions factors from CO_2 emission factor database of Central Electricity Authority (Government of India). (Source: CO_2 emission factor database, version 06, CEA (Government of India), http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm)

Then, Total Carbon emissions from Electricity consumption will be

= 0.85 x 129210 = 109828.5 Kg of CO_2/ year

= 109.828 Tons of CO_2/ year (i.e.) 109.828 Metric Tons CO_2

According to US EPA (United States Environmental Protection Agency), the carbon emissions from gallons of diesel consumed, the emission factor is 7.09×10^{-4} metric tons CO_2/Kilowatt-hour of electricity.

Then, Total Carbon emissions from Electricity consumption will be = $4.33x10^{-}4x129210$

= 55.9 Metric Tons CO_2

Green House Gas Equivalencies Calculator

The Greenhouse Gas Equivalencies calculator permits in transforming emissions or energy data to the corresponding quantity of carbon dioxide (CO_2) emissions from using the quantity given. The calculator aids in transforming conceptual assessment into specific terms that can be identified.

The calculator directly gives the carbon emissions in Metric Tons when the total electricity consumption is entered in Kilo-Watt Hour (KWH). The manual calculation of the quantity of carbon emissions obtained by using formula as per US EPA protocol exactly matches with that of the result obtained from US EPA Green House Gas Equivalencies Calculator that is available online.

The calculator provides the greenhouse gas emissions obtained that is equivalent to the greenhouse gas emissions for the electricity consumption of the green building considered for the study (Table 2).

Table 2 Electricity-based carbon emissions and the other equivalent greenhouse emissions

Carbon emissions for the electricity consumption	In terms of fuel consumption
55.9 Metric Tons of carbon emissions is equivalent to those greenhouse gases obtained from	12 gasoline-powered passenger vehicles driven for one year
	1,38,744 miles driven by an average gasoline-powered passenger vehicle

The calculator provides the Carbon dioxide (CO_2) emissions obtained that are equivalent to the greenhouse gas emissions for the electricity consumption of the green building considered for the study (Table 3).

Table 3 Electricity-based carbon emissions and the other equivalent carbon emissions

Carbon emissions for the electricity consumption	In terms of fuel consumption	In terms of energy consumption
55.9 Metric Tons of carbon emissions is equivalent to those carbon emissions obtained from	6290 gallons of gasoline	7 home's energy use for one year
	5491 gallons of diesel	10.9 home's electricity use for one year
	61, 843 pounds of coal burned	2282 propane cylinders used for home
	0.74 tanker truck's worth of gasoline	0 coal-fired power plants in one year
	0.309 railcar's worth of coal burned	0.0001 natural-gas fired power plants in one year

	129 barrels of oil consumed	67, 99, 278 numbers of smart phones charged

The calculator provides the equivalent greenhouse gas emissions avoided that are equivalent to that of greenhouse gas emissions for the electricity consumption of the green building considered for the study (Table 4).

Table 4 Electricity-based carbon emissions and the equivalents via which it can be avoided

Carbon emissions for the electricity consumption	In terms of waste recycled instead of landfilled	In terms of energy consumption	
55.9 Metric Tons of carbon emissions is equivalent to those greenhouse gas emissions avoided by	19.3 tons of waste	0.015 wind turbines running for a year	2118 incandescent lamps switched to LEDs
	2.8 garbage trucks		
	2419 trash bags		

The calculator provides the carbon sequestered equivalent to that of greenhouse gas emissions for the electricity consumption of the green building considered for the study (Table 5).

Table 5 Electricity-based carbon emissions and the equivalents via which it can be sequestered

Carbon emissions for the electricity consumption	In terms of afforestation
55.9 Metric Tons of carbon emissions is equivalent to carbon sequestered by	924 tree seedlings grown for 10 years
	66.1 acres of US forests in one year
	0.377 acres of US forests preserved from conversion to cropland in one year

This calculator is specifically designed to suit project in US, thereby providing effective alternatives to balance the emissions. If such calculators designed to suit projects in any country or if country-specific calculators are designed in future, it would be efficient in getting ideas in counter parting emissions specifically.

3. CARBON FOOTPRINT ESTIMATION-FINDINGS AND RECOMMENDATIONS OF CARBON FOOTPRINT ANALYSIS

In the operational phase of the building, out of all sources of energy consumption the Electricity usage seems to be higher and hence account for the maximum carbon emissions. As there are continuous booms in the electrical & electronics industry and since the dependency on technologies in day-to-day life is increasing, there exists a huge rely over the electricity. The electricity consumption serves to be of major concern; the carbon emissions from this are hiking gets multiplied. Hence, it's necessary to find ways to reduce as well as to avoid electricity-based carbon emissions from buildings. So, the simple mitigation measures for this are suggested here as follows:

The installation & use of on-site renewable energy such as Solar, wind etc.

Use of greener materials in all processes of the building such as avoiding the materials that increases the temperature of the spaces and so on

Reduction in usage of high-wattage devices like heaters, air-conditioners

Changes in light fixtures with LED ones and other electrical and electronic items etc., serving energy-efficiently, which are new in the market for the time whenever there is any need to change.

The Best solution from the engineering point of view could be the

Development of calculator for determining the carbon emissions such as US EPA's GHG Equivalencies calculator and track the emissions records of any organization, also for individuals even and the features of such a calculator are as follows:-

It must calculate the total carbon emissions (in Metric Tons or Kg of CO_2) based on the ISO 14064 and/or Indian standards or other standards of International treaties/conventions for the carbon emissions determination, for the given amount of Electricity consumption. Also, it can be further helpful in determining the carbon emissions due to various other operations of the building such as

Fuel consumption

LPG consumption

Public transport of the locality and so on
It can mention the CO_2 emissions from other sources that are equivalent to the calculated CO_2 emissions
It should suggest various ways to avoid the emissions that has been calculated
It must provide multiple offsetting methods matching the country's scenario, for the resultant emissions
It can have the track record of day-to-day carbon emissions by any individual or organization and shall provide some score-based system for triggering them to perform well
It shall provide recommendations regarding the up-to-date environmental schemes or any other government (National or regional) schemes that is applicable or that may be helpful for an individual or an organization to achieve their goals in reducing carbon emissions
It must award appreciations if an individual or organization trying their/it's best to downtrend their average carbon emissions, thereby reducing their part of carbon emissions out of the total carbon emissions
It can encourage the voluntary actions of any of them working in an innovative way to reduce their carbon emissions, proving their social responsibility
It shall be user-friendly as much as possible, thereby attracts many users in a short period of time

Many other engineering technologies as well as the technical practices must be found out in future so as to lessen electricity-based carbon emission progressively.

4. CONCLUSION AND RESULT

Electricity usage is one of the high influenced area where it cannot be minimized, it plays a vital role in emission of carbon and the amount of carbon emitted needs to be accounted individually and so that the exact emission per individual building user can be calculated which can be utilized for exact accounting per capita emission and it becomes individual's responsibility to take measures to reduce their part. By accounting carbon emission due to electricity, the high carbon emission buildings can be spotted, and alternate measures can be adopted to reduce and/or offset the same can be analysed with future scope via more detail analysis.

Declarations

The authors hereby acknowledge that this work is completely genuine, does not violate any copyrights and having no conflict of interest. Also, it is assured that the paper does not get published in any of the other journals, technical and/or non-technical.

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Ethical issues

Not applicable.

Informed consent

Not applicable.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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